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BIM to BIMI Building Information Model Implementation

[1] **Serge T. Chua Jr.**, [2]**Carmela C. Quizana**
[1] Technological University of the Philippines, [2] Polytechnic University of the Philippines,

Abstract- The paper discusses the emerging technology of BIM or Building Information Modelling at the threshold of its implementation. The acronym "BIMI" represents Building Information Modelling Implementation, with the appendage of "I" for implementation, as the focus of this research.

The evolving identity of BIM as a Building "Intelligent" Modelling technology from an information-filled one, has impacted its adoption & implementation, the expected gains, and performance outcomes as an end-all validation of the decision to integrate the technology to projects of the built environment. Indecisions and lulls, "glass half-full" knowledge and assessment-based identification of project-cycle and phase entry levels have been found to contribute to the indecision.

Sequentially, five (5) key and focus technology areas, namely, policy, strategy, transfer, R & D, and forecasting assessment analyze the issues and concerns on BIMI. Policy formulation requires a thorough understanding of the people, processes, competencies, goals of management at all levels before finalization. This understanding is not limited to the fixed workplace but the AEC project and their specific project life cycles. At this point, any strategy for adoption, implementation, or integration will require training and transfer of the technology/competencies continually to ensure the competitive advantage and positioning measured by performance indicators, outcomes & goals.

The evolving nature of BIM technology, globally and industry-wide, has increased concentrations in research and development, for data sharing and ownership, cloud storage and access, servers, script-based applications, and plug-ins, simulation and AR, manufacture, interoperability, and standardization to name a few. These are linked directly with forecasting of future technologies' development that is exponentially increased with the IoT, IoE, and 4th IR elements.

Keywords- BIM, BIM Implementation, Performance Indicators, Technology, Technology Transfer, Barriers

Introduction

For well over three decades, BIM or Building Information Modelling has become an essential tool in the AEC industry. Its usage ranges from standalone structure to multi-structure collaborations, from built-environment external and internal design to tract and site developments involving landscape designers and environment-related experts. Process efficiency, lean and green design and construction, and team-based approach in the overall project life cycle, from inception to building, project and facility realization and usage has set BIM as a cornerstone of the AEC industry and practices. [1] [2]. This inarguable fact of BIM integration is not without its challenges. The advent and emerging technologies, Cloud, AI, AR, Robotics, Chain Block, to name a few present a new set of challenges, and conversely, opportunities. This study aims to provide and understand the needs for a base map, and the possible but realistic routes for the AEC professional, towards the adoption, transition, and methods for the AEC professional, in the disciplines of architecture and engineering. A fringe product to this is the delineation between these disciplines in the context of professional practice areas articulated by the team-based approach of BIM.

I.Materials And Methodology

The gathering of data and research materials was accomplished by the use of search engines. Hits returned from search engines and browsers such as Google Scholar, Science Direct, Researchgate, Elsevier, and Academia were filtered based on their relevancy and relation. Due to the nature and purpose of the research (stated in the Executive Summary), repetition and reuse of previous literature gathered were avoided wherever possible.

The filtering resulted to (31) research literature containing discussions across various geographic locations, such as the United States, Australia, Hong Kong, Iceland, United Kingdom, Oman, and other EU & Middle East countries.

The literature review was undertaken on thirteen (13) journal publications, three (3) book chapters, eight (8) conference papers, four (4) annual reports, and three (3) webpage articles.

II.Research And Discussions

1. Technology Policy

Typically, a technology policy sets the conditions for information technology. The basic considerations revolve around the technology's usage, its security, and continuity, the training required & responsibilities to be defined [3]. Similarly, once an organization decides on the adoption and implementation of BIM, formulation of a technology policy for the stated purpose. Identifying which stage of a project and the corresponding level of development or (LoD) needed is essential in defining the policy features. A simplified list for a BIM technology policy enumerates the 3P's as follows; 1) People, 2) Processes, and 3) Policy. Resistance and unwillingness to accept the inevitability of change by people or personnel, [4] [5] and a reclined culture of *"if it ain't broke, don't fix it"*, entrenched deeply in the CAD workflows is the most common obstacle to attempts for adoption. How people work, interact with in-house teams or a "design support solutions" provider is the predicate of technological change initiation. [6] [7]

Figure 1 The 3P's of BIM

Processes' concern transitioning from a culture of a traditional schema to a new one. A schema in BIM can be simply defined as "what is to be modeled and how it is modeled". Despite awareness of BIM by AEC professionals, struggles on BIM implementation exists. The challenge presented is how to unwire and rewire how the AEC professionals are already wired. Confidence and comfort levels can prevail and favor old and proven processes over new technological processes.

A most familiar scenario is a side-by-side monitor' or display configuration of two or more open windows of a word processing, spreadsheet, CAD, and BIM software, where the professional switches from one display to the other to correlate and update data. This practice requires data recreation and waste across the project's lifecycle. Awareness of BIM's potential, features, and the required LoD would eliminate the redundant and iterative processes.

In all, a company's technology policy, general or BIM-specific, may be the biggest obstacle. An antiquated and existing policy is an example. This ultimately trumps any positive reception and readiness of people to the BIM adoption.

The quantity, quality, and freedom of data shared, the ensuing and continued collaboration by the people, processes, and policy, are markers of a successful BIM implementation.

Typically, confidentiality and data privacy clauses built-in contracts breed liability and legal concerns. BIM implementation should therefore be wary of potential litigation, data ownership, and associated proprietary issues and risk-sharing. [8] This condition sets in stone the need to embrace the need for data collaboration, that results to design solutions while protecting the firms and companies. [6]

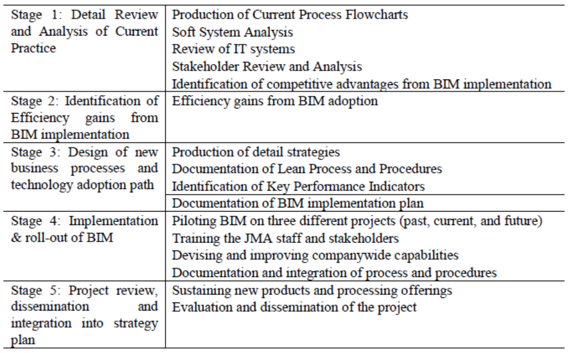
Information filters such as color-coding defining information to be of either an incomplete, provisional or final quality are used to protect data. At the project onset and agreed (ToR) Terms of Reference on the upon definitions, processes, policies, and parameters for risk reduction and BIM workflow streamlining. [6]

2. Technology Strategy

In its online article, "*Revizto*" outlines three (3) basic steps in developing a BIM strategy. These are *1) Assessment, 2) Goals and Planning, and Advancement and Implementation*. [6]

Assessments conducted in the manner of interviews are linked to the goals, after which strategic planning with milestone advancements set launching the implementation of BIM.

The partnership between the University of Salford and the architectural office of John McCall Architect (JMA) is one example of this technology strategy. A five-stage approach for JMA's BIM implementation was used by the University *(Coates, SP, Arayici, Y, Koskel a, et al)* included the following: 1) Current Practice Analysis and Detail Review, 2) BIM Implementation Efficiency Gains' Identification, 3) new business process design and technology adoption path, 4) BIM implementation & roll-out, Project review, dissemination and strategy plan integration. [9]



Stage 1: Detail Review and Analysis of Current Practice	Production of Current Process Flowcharts Soft System Analysis Review of IT systems Stakeholder Review and Analysis Identification of competitive advantages from BIM implementation
Stage 2: Identification of Efficiency gains from BIM implementation	Efficiency gains from BIM adoption
Stage 3: Design of new business processes and technology adoption path	Production of detail strategies Documentation of Lean Process and Procedures Identification of Key Performance Indicators
	Documentation of BIM implementation plan
Stage 4: Implementation & roll-out of BIM	Piloting BIM on three different projects (past, current, and future) Training the JMA staff and stakeholders Devising and improving companywide capabilities Documentation and integration of process and procedures
Stage 5: Project review, dissemination and integration into strategy plan	Sustaining new products and processing offerings Evaluation and dissemination of the project

Figure 2 Five-stage Design Practice Assessment

Each of the stages not only covered the people, processes, and policy factors in BIM adoption and implementation, it provided potential and expected efficiency gains linked to office and project needs, requirements, and areas for improvements.

These allowed JMA to adopt a sound strategy based on current practice detailed review and analysis that included current practice process mapping, soft system, stakeholder review and analysis, and BIM implementation competitive advantages identification. [6] [9]

The strategy resulted in a clear delineation between and enlistment of five (5) short and (4) medium-term gains. All gains were equally weighted to ensure an objective assessment. This supported and founded the necessity for eventual BIM adoption.

Performance Indicators. Performance indicators are used as measures of success and performance metrics. In the case of the AEC industry/s. The terms common to this industry include construction industry indicators (CIIs), key performance indicators (KPIs), and project success criteria (PSC) have been used interchangeably to Construction project performance indicators (CPPIs). [1]

An understanding of organizational inputs, outputs, and the outcomes desired is needed for the Performance Indicator (PI) derivation. These, in turn, are linked to top-level goals (Gerber & Rice, 2009). [9]

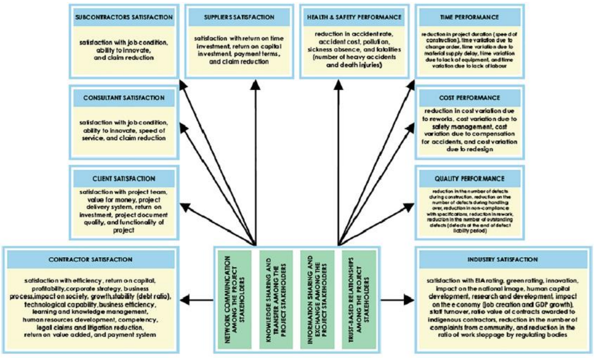
Therefore, the inputs, outputs, and outcomes closely linked to the goals are precursory to the development of the PI's. Conduction and collation of all results of brainstorming & interview sessions, both internally and externally (stakeholders) culminating in the accomplished PI form should be followed by an evaluation and assessment. [9]

In construction, a project's performance is measured by the project management system's PIs. CPPIs, in turn, measure the effectiveness of the project stakeholders.

Integration efficiency and tools'/platforms' collaboration is multiplied by BIM incorporation or what is now referred to as BIM-PIs.

Significant levels of transfer and sharing of knowledge, efficient network communication, and the fostering of relationships based on trust between and among the project stakeholders. [9] [1]

Construction Project Delivery Systems. Evaluation of BIM-based projects Construction Project Delivery Systems (CPDS) must take the BIM-PIs and CPPIs dimensions into equal consideration. This provides a comprehensive evaluation system of project delivery to measure and validate the expected gains from BIM, directly or indirectly. CPDS additive effects are expected to be manifested indirectly by the direct effects of BIM in the project. [1]



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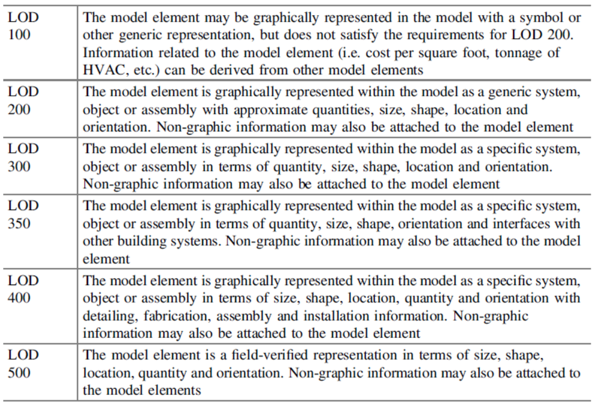
igure 3   BIM-integrated CPPIs

Performance Outcomes. Performance outcomes, be these owner-related or contractor-related, are final validations of project performance. It must be mentioned that better performance may be expected based on project cost values. Cost, changes, and rework performance categories achieve better performance outcomes for higher project cost values The larger the project the greater use of performance-enhancing practices. [10]. While contractor-related performance outcomes vary primarily due to the project contract inclusion of design that would require D/IT systems.

Levels of Development. The concept that a project's life cycle requires a clear definition and delineation of uses of BIM formulated the level of development (LoD) for its maximized and optimized beneficial use.



LOD 100	The model element may be graphically represented in the model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the model element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other model elements
LOD 200	The model element is graphically represented within the model as a generic system, object or assembly with approximate quantities, size, shape, location and orientation. Non-graphic information may also be attached to the model element
LOD 300	The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, location and orientation. Non-graphic information may also be attached to the model element
LOD 350	The model element is graphically represented within the model as a specific system, object or assembly in terms of quantity, size, shape, orientation and interfaces with other building systems. Non-graphic information may also be attached to the model element
LOD 400	The model element is graphically represented within the model as a specific system, object or assembly in terms of size, shape, location, quantity and orientation with detailing, fabrication, assembly and installation information. Non-graphic information may also be attached to the model element
LOD 500	The model element is a field-verified representation in terms of size, shape, location, quantity and orientation. Non-graphic information may also be attached to the model elements

Table 1 BIM Levels of Development

Simply put, the LoD describes the BIM model's detailed level of development. Originally developed by the (BIM Forum 2013), the 6 development levels are set against the phases of the project life cycle and the AEC professionals and project actors. (see Fig. 4)

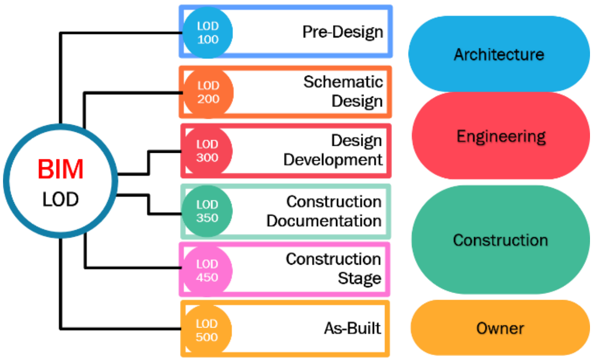


Figure 4 Levels of Development of BIM in the Project Cycle

3. Technology Transfer

Education. Before the turn of the millennial century, formal education has already recognized the importance and need for curriculum insertions for Design/Information Technology (D/IT) [9] [10] subjects. Although direly needed [11], these curriculum accommodations were at least a decade behind the advancement and development of AEC industry needs with the use of 3D CAD modeling applications for the D/IT subjects.

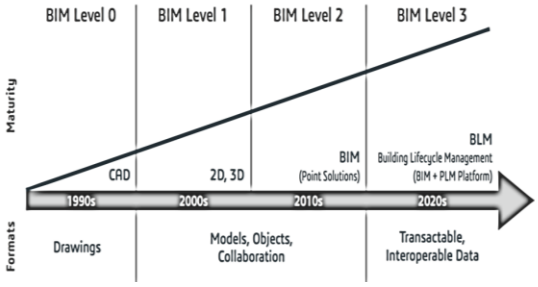


Figure 5 The BIM Timeline

Academia had little or practically no awareness of the emerging BIM Technology, [4]. and justifiably so, due to the technology's infancy described as just a "3D model with information"

A research study conducted by Dean (2007) on BIM as a need for education in the southeast United States, showed that 70% of the industry participants surveyed were either using or considering the use of BIM, while 75% regard BIM skills as an advantage for employment candidates. A study by (Woo 2006) in turn, pushed for the re-configuration of a BIM-integrated academic program to prepare the graduates for successful careers in the AEC industry. [8] [12]

Learning Spectrum. According to the U.S. Department of Education, BIM technologies, workflows and protocols are essential parts of the Learning Spectrum. This also includes all subject matter with the AEC disciplines and their roles. From this, BIM competencies for the various industry practitioners and students to learn and attain. [13]

Figure 6 Collaborative BIM Education Framework Part A v1.1

Knowledge Transfer Partnerships. Memoranda of understanding (MoU/MoA) and partnership agreements have been traditional tools to formalize knowledge and technology transfer ventures in the adoption of BIM. An exhaustive yet holistic tool in the technology transfer of BIM is the "Knowledge Transfer Partnership or the KTP. This partnership which has been widely used in the United Kingdom, since the new millennium, does not limit itself to the structured training BIM sessions, but goes beyond degree assessments of successful BIM implementation. [5]

KTP projects' overall expected benefits to academia 1) business-relevant development of teaching and research material, 2) real-life applied knowledge and expertise 3) new research themes and undergraduate and postgraduate projects' identification in the United Kingdom (www.ktponline.org.uk/), that include opportunities in higher education for teaching and research purposes. [14] [13]

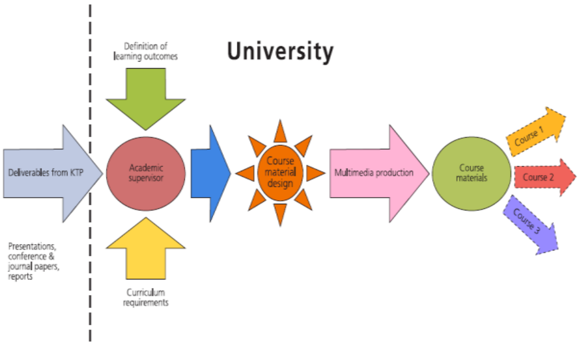


Figure 5 Process Of Course Material Development from KTPs

KTP’s ultimate goal is to contextually position firms with value-add offerings, to place the same in their specific sector’s high-end knowledge-based terrain. [9] [14]

The socio-cultural environmental aspect was an integral part of the project undertaken by the University of Salford with John McCall Architects. [9] The context change, reinforces the value of the 3P’s presented by Trivedi [6] in his shortlist for policy formulation. [9] [14]

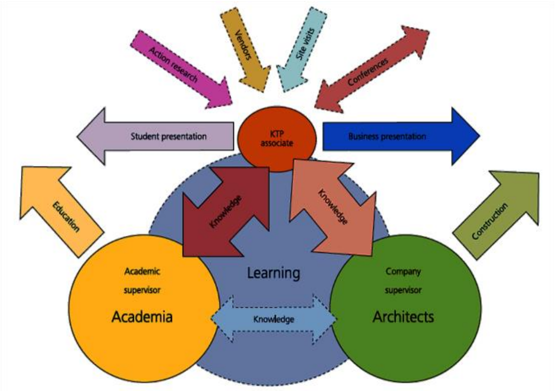
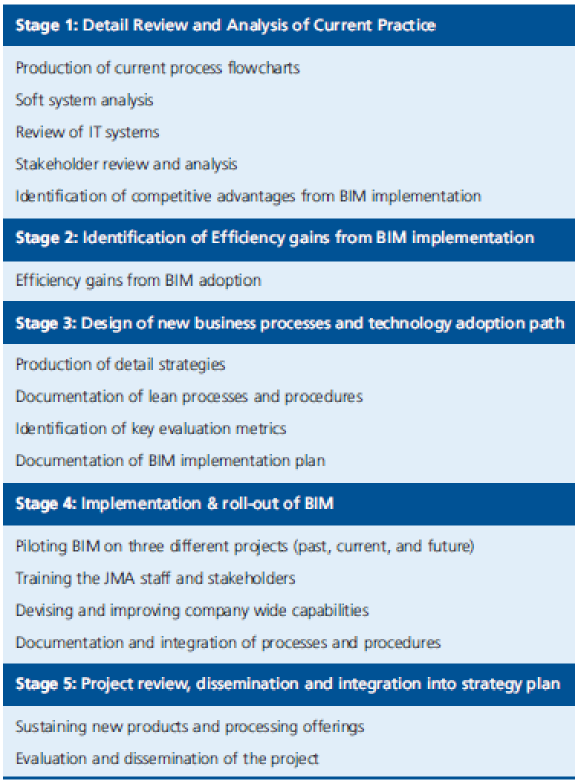


Figure 6 KTP knowledge and technology transfer schema

The overall impact of the KTP most felt by the firm is the levels-based process improvement. Elimination of risk calculation, design misinterpretation, stakeholders' communication, and interoperability, unencumbered and available data/ documents sharing, and control comprise the impact.



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Documentation of lean processes and procedures
Identification of key evaluation metrics
Documentation of BIM implementation plan
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Training the JMA staff and stakeholders
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Sustaining new products and processing offerings
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Table2 BIM implementation approach for JMA’s design practice

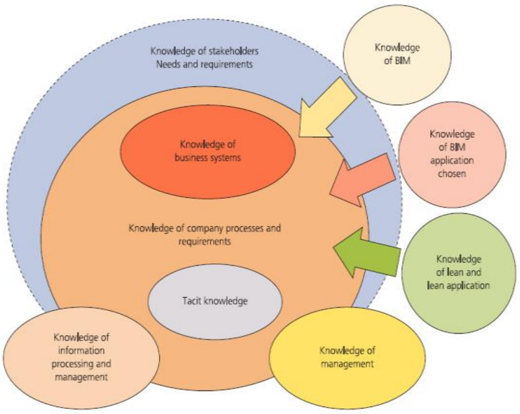

Figure 7 Knowledge and requirements needed for the successful conduct of the KTP

Learning Penalty. A term in assessments refers to "learning curve", and denotes a negative impact especially in construction projects where BIM adoption, implementation, and integration proceeded without the needed technology transfer events and BIM maturity mapping. [10] This penalty is linked to the BIM LoDs and maturity/dimensions. *(See Fig. 9)*

Continuing Professional Development. BIM education and knowledge transfer to professional association memberships play a major role in BIM promotion within both academia and industry. Certificate courses, workshops, and accredited Continuing Professional Development (CPD) programs provide access to the BIM professional on advances, trends, and updates. [13]

4. Technology Research and Development

A decade into the current millennium, *Underwood and Isikdag's* collaboration [15], "The Handbook of Research on Building Information Modelling and Construction Informatics: Concepts and Technologies", identified the possible and potential areas of BIM research and development. [16]

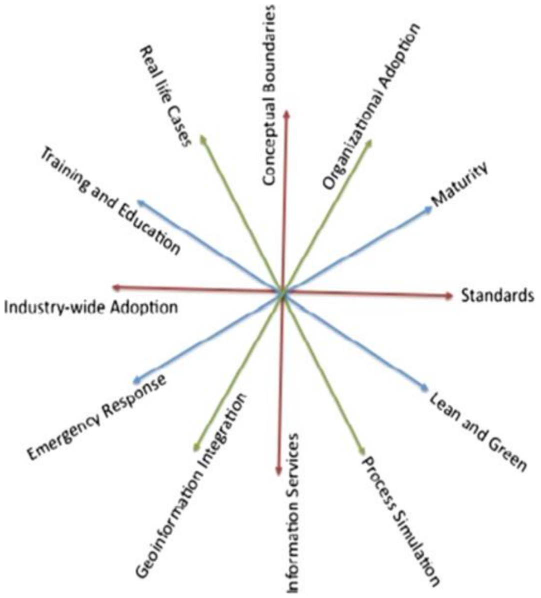

Figure 8 BIM Research Compass (Underwood & Isikdag)

Enumerated below are twelve areas of BIM research and development, cross-linked and related derived from the diametric relationships illustrated in the figure (*see Fig. 7*).

1. Conceptual Boundaries / Information Services
2. Organizational Adoption / Geoinformation Integration
3. Maturity/Emergency Response
4. Standards /Industry-wide Adoption
5. Training and Education/Lean and Green
6. Process Simulation/Real Life Cities

The aspects within which these cross-linkages fall are Information Model-Related, Organizational, Domain-Specific, Project Management, and Integration and Interoperability.

Conceptual Boundaries / Information Services. Methods and languages for reasoning-based and algorithm approaches are research focus areas that result in the interoperability of BIM applications. Research and development in the areas further enhance the interoperability of data exchanges formulated from BIM schema standards. [16] [15]

Adoption. Cultural changes [6] [17] from CAD to BIM presented the greatest challenge due to the philosophical difference in data management. The occurrence of BIM adoption is related to the phase of the project life cycle, such as Pre-design, Schematic, Design development and the other illustrated in Figure 9 as and the necessary LoD for that phase *(see Fig. 4 Levels of Development of BIM).*

Maturity. Maturity levels in the BIM area usually associate with the skill set a BIM professional, engineer, or manager possesses. Although non-related to the geometric quality of BIM, unlike in CAD, the maturity levels are denoted as dimensions or the 7Ds. *(see Fig. 10 BIM Maturity Levels).*

Real-life Cases. Increasingly, BIM methods have been applied on 3D models virtually "created" and shared in real-life project settings. Experiential, qualitative, and quantitative assessments improve future model development and project management.

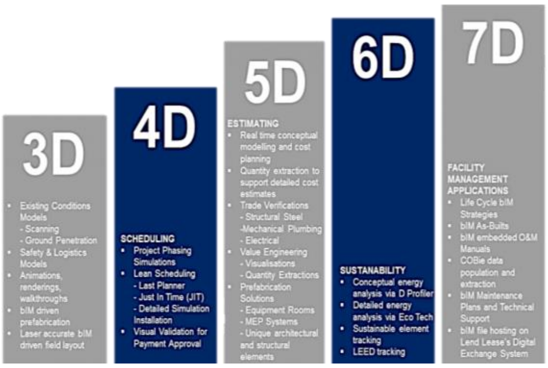

Figure 11 BIM Maturity Levels (7D)

The lull between the adoption and implementation will reveal these levels. An organization's maturity in the technological, methodological, and process areas determine its competitive advantage/disadvantage. [16] [18]

Industry-wide Adoption. Present conditions and future expectations of a firm contribute to its competitive position in the industry affecting BIM adoption in target disciplines or for the entire set. The 3P's of BIM [6] remain to be the main factors for industry-wide adoption decisions. [16]

The development of the Industry Foundation Class (IFCs), allowed software-independent work on models due to its vendor-neutrality. [19]

Lean Construction and Green BIM. The headway made by BIM into green and lean design and construction are anchored on BIM's informative and intelligent design models, project database and management, as well as its simulation capabilities for solar and comfort analysis, structural design analysis among others. [20] [11]

Building and Geo-information Integration. Geo-positioning and its generated information have allowed the BIM model to detach from the digital model and move to a virtually realistic one. Whole cities are modeled and run through simulations for geophysical settings, energy efficiency, calamity, and population growth effects, in the BIM model called “twin” cities.

Project Management Aspects. Similarly, clash detection simulation on BIM models allows stakeholders to mitigate and minimize cost due to design oversights, value engineers, quantity surveys, and project management monitoring.

Building Information Services (BIS). Web-based and cloud services have enabled and enhanced data storage, interoperability issues, data sharing, and project collaboration across the internet through the use of BIM servers.

5. Technology Forecasting and Assessment

From an information-rich 3D modeler that was strategized and based on information management, BIM has evolved into an indispensable construction management method. The evolution rate has accelerated with the 4th IR technological developments and the vastness of BIM’s use and applications across the industries. [12] [15]

Beyond the traditionally off-site and on-site AEC activities, BIM has opened up the avenues for total project collaboration upon project inception and long after completion. Built-in algorithmic and reason-based applications have made BIM evolve further with Dynamo, Python and similar simulation languages have boosted the technology’s efficiency, allowing the user to do away with iterative modeling and data management.

Two dimensions that can be identified with BIM 2.0 are the everchanging role of information models critically dependent on shared data and sources, and BIM’s emergent role as a “de facto” construction management method. In 2013, AECOM, the world's trusted infrastructure consulting firm, predicted that BIM’s market growth would hit 6.5 billion dollars by 2020. [19]

The integration of Artificial Intelligent with BIM, and design explorations through the use of design options and generative design allow for design exploration. [6] [7] BIM-based cloud collaboration and modular construction and prefabrication will continue to drive the demand for BIM and its technological research and development. [21] [22]

Despite the decline in 2020, due to the pandemic-induced economic recession worldwide, a CAGR (Compound Annual Growth Rate) of 9-11% (2019-2025). BIM sales forecasts will reach the nine-billion dollar mark by the year 2025, experiencing AEC software demands are the main segment of the forecast presented in the July 2021 *“Building Information Modeling Market Report: Trends, Forecast, and Competitive Analysis”* report due to appreciable benefits, like application’s interoperability, easy visualization, and cost-effectiveness. [21]

Market trends and forecasts are based on offering, product life cycle, end-use industry, and region [21]

Offering	Project Life Cycle	End-Use Industry	Region
▪ Software ▪ Architectural Design ▪ Sustainability ▪ Structure ▪ MEP ▪ Construction ▪ Facility Management Services	▪ Preconstruction ▪ Construction ▪ Operations	▪ Residential and Commercial Buildings ▪ Industrial ▪ Civil Infrastructure ▪ Oil & Gas ▪ Utilities ▪ Others.	▪ N. America ▪ U.S.A. ▪ Canada ▪ Mexico ▪ Europe ▪ Germany ▪ United Kingdom ▪ Italy ▪ Asia Pacific ▪ China

▪ Software Support, and Maintenance ▪ Project Management, and Support			▪ Japan ▪ India ▪ The Rest of the World

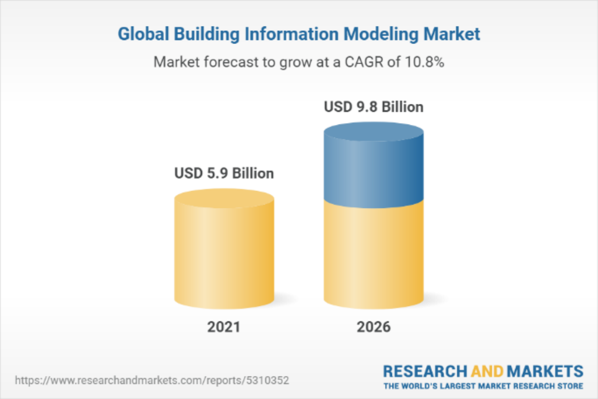

Figure 12 Global Building Information Modelling Market

North America tops the forecast in large part because of its wide adoption of BIM in residential and infrastructure planning, design and construction projects, and government support for capital facilities projects. *[21]*

III.Findings

A conscientious and detailed assessment of 3Ps of BIM is a *sine qua non* for BIM's implementation and integration with the model, to optimize and maximize the data-sharing and reason-based features of the technology. A better and objective understanding of the people, processes, tools, project, and organizational goals can identify the areas, timing, acceptance and resistance, capital investments, training, and knowledge transfer, among others, can and should be aligned with the firm's overall goals.

It may be said though that because of the technology's vast applications in the AEC industry, and more recently in the fabrication and manufacturing industry, that any unknowledgeable attempt may result in BIM integration being more complicated than complex. It is also this vast quality that seems to encourage overlaps in the different design disciplines and the project construction management team. Where knowledge is power in the 4th Industrial Revolution, it is not too far-fetched to say that data is currency.

A polarized distortion on the ownership and data proprietary rights and issues may either encourage data sharing or accesses being denied, which would negate the positive impacts of BIM collaboration. Litigation probabilities may ultimately be discouraged by prevailing patent, copyright, and intellectual property as well as civil statutes.

A daunting observation looms with the accelerated pace of technological advances, research and development, AI, robotics, Cloud and other technologies cascaded by the events, the Internet of Things/Everything (IoT) and (IoE), a scenario where the man may be replaced by machine or at least a role reduction.

BIM standardization and interoperability will play key roles in mitigating the potential displacements. Goals' alignment is more socio-politically and economically motivated with possible major consideration to professional regulation and standards of potential stakeholder countries.

Market forecast for BIM appears encouraging and yet regional presence, dominated by early users from the developed economies outweigh the Asian regions sans Asia-Pacific, China, Japan & India. A trend that hopefully may be offset with the supply and demand effects on competitive pricing.

A potential paradigm shift may be expected resulting from the attained competencies of higher education that egg out current industry actors. This shift would necessitate an acceleration in BIM adoption to prevent any displacement of the people, the first of BIM's 3Ps. The conundrum of CPD (state-mandated) and local cultures, further exacerbates the potentials of BIM integration that may result in products of higher education with BIM competencies to stray into illegal practice of the profession.

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