Technologique: A Global Journal on Technological Developments and Scientific Innovations
2025, Vol. 4, No.1, 84 – 91 | ISSN Online: 3028-1415 | ISSN Print: 3028-1407
DOI: https://doi.org/10.62718/vmca.tech-gjtdsi.4.1.SC-0525-017

Assessment of Barriers, Trends, and Sources of Growth on 4D BIM Technology Implementation for Building Construction Project Planning and Scheduling in the Philippines

Article History:
Received: 17 May 2025
Accepted: 19 June 2025
Published: 27 June 2025

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Abstract

Caused by human activity and extreme weather occurrences, climate change is a major worldwide concern. About 40% of the world's energy consumption comes from the building and construction industry, which also has a substantial impact on environmental sustainability through resource depletion and carbon emissions. To address these impacts, sustainable building practices – enabled by technologies like Building Information Modeling (BIM) – are vital. 4D BIM, which integrates time-based data into construction planning, supports Sustainable Development Goals, such as SDG 11, 12, and 13, by enhancing resource efficiency, reducing waste, and promoting climate-resilient development. Given the hazards caused by climate change, 4D BIM can assist in the construction of climate-resilient infrastructure and help the Philippines meet the Sustainable Development Goals of the UN by 2030. However, little knowledge, expensive prices, and opposition to new ideas limit its adoption. Responding to these situations, this study aims to explore these barriers, trends, and sources of growth to strengthen the Philippines' role in sustainable building and global climate action. This study examines the skills, demographics, and technological use barriers that influence the adoption of 4D BIM in the Philippines. Most of the respondents are women, between 31 and 40 years old, and frequently hold senior project management positions. According to the findings, despite a lack of practical experience, adoption is accelerated by competition and technology, but major obstacles include lack of digital skills, high costs, and aversion to change. Views about growth or financial obstacles were not significantly influenced by gender, indicating that hiring should prioritize experience and talent over demographics. This study suggests focused training, inclusive hiring, and investigating financial incentives to promote broader use of digital technology in the industry to support 4D BIM and assist in achieving the Philippines' sustainable construction goals.

Keywords: Building Information Modeling (BIM); barriers; trends; sources of growth; building construction; project planning; project scheduling

INTRODUCTION

One of the most urgent issues of the twenty-first century is climate change, which is caused by human activities. Heatwaves, droughts, and flooding are just a few of its widespread effects that necessitate immediate international response. International collaboration and a shift in behavior are necessary for effective mitigation techniques, such as waste management, energy efficiency, and renewable energy (Behsoodi et al., 2024). As a result, global efforts to promote sustainable development have stepped up, pushing businesses to use eco-friendly procedures (Zhuang et al., 2021). This change is mostly affecting the infrastructure and construction industries. These sectors account for around 40% of the world's energy use, and they also greatly increase carbon emissions and resource depletion, which exacerbates environmental problems (Mi & Deng, 2024). The sector has a significant impact on society and the environment, despite being essential to economic growth and quality of life (Grover & Chhabra, 2024). Sustainable building methods that lessen damage to the environment and boost resource efficiency are therefore becoming more and more important. Sustainability is the long-term viability of

systems and is frequently associated with sustainable development. To address global issues like poverty, inequality, and climate change, the United Nations established the 2030 Agenda for Sustainable Development in 2015, which contains 17 Sustainable Development Goals (SDGs) (Aslam, 2023). The advancement of sustainability in buildings is mostly dependent on technological advances. Throughout the construction lifecycle, Building Information Modeling (BIM) improves project management, fosters collaboration, and lowers errors (Boton et al., 2020). The most advantageous of these advancements is 4D BIM, a sophisticated type that incorporates time-related data into project planning. Scheduling, waste reduction, and resource allocation can all be enhanced by modeling time in conjunction with spatial data (Agostinelli et al., 2019).

In the Philippines, where climate-related risks are rising, 4D BIM has the potential to support the development of more resilient and sustainable infrastructure. It facilitates strategic planning and decision-making, enhancing project outcomes while lowering environmental impact. Despite these benefits, adoption is nevertheless constrained by issues including high implementation costs, a lack of digital skills, a lack of awareness, and change aversion. Promoting the adoption of 4D BIM requires an understanding of these barriers. With an emphasis on worker skills, demographic trends, and technological barriers and sources of growth, this study investigates the factors impacting its implementation in the Philippine construction industry. The results are intended to help guide plans that promote the industry's digital transition and further the general objective of sustainable development.

Theoretical Framework. Key theories of technology adoption, innovation, and sustainability where, all of which are in line with the Sustainable Development Goals (SDGs) of the UN for 2030, are incorporated into the theoretical framework for evaluating the obstacles, patterns, and growth drivers for the deployment of 4D BIM in the Philippines. To understand how construction professionals in the Philippines might view the advantages of 4D BIM in improving project efficiency and cutting costs, it is essential to apply the Technology Acceptance Model (TAM), which holds that perceived usefulness and ease of use are crucial factors for technology adoption. Venkatesh and Bala (2008) created the technology acceptance model version 3, or TAM3, which is the most recent version of TAM. It incorporates the PEOU determinants and TAM2, which are heavily highlighted (Canavari et al., 2021). The study is further supported by the Diffusion of Innovations (DOI) Theory, which explains how 4D BIM can proliferate throughout the Philippine construction industry. It focuses on elements like perceived benefit and compatibility, which support resilient and sustainable urban development and are in line with SDG-11 (Sustainable Cities and Communities). Furthermore, by increasing resource efficiency, reducing waste, and encouraging energy-efficient construction practices, 4D BIM can support SDG-12 (Responsible Consumption and Production) which will help the construction industry align with the sustainability goals.

Conceptual Framework. Figure 1 shows the research paradigm of the study. The input box is to identify barriers to 4D BIM Technology Implementation for Building Construction Project Planning and Scheduling in the Philippines. Also, information is taken from research and related literatures.

The procedure in obtaining the anticipated output using the descriptive research approach is shown in the process box. Data is acquired from relevant BIM literatures. The information was gathered through a survey to profile and understand the experiences of the target respondents. Questionnaires were administered and all the data were evaluated. Further shown in Figure 1 is the illustration on how the feedback loop transitions from the input box to the output, indicating that the study is a continuous process. If new methods are developed, they can be integrated into the system and process to produce the outputs, which will serve as the foundation for enhancing the study in question.

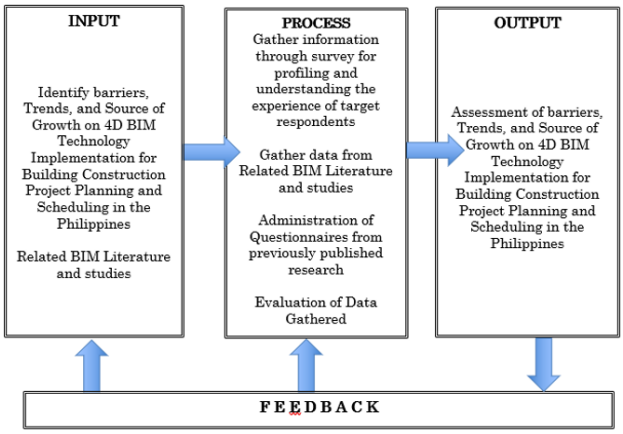

Figure 1
Research Paradigm

Scope and Limitations. The study is only limited in assessing the barriers, trends, and sources of growth in building information technology (BIM) for project planning and scheduling in the Philippines. Respondents included were those who held various roles and had previous experiences, as well as currently working in a construction site in the National Capital Region. The researcher only used a questionnaire as instrument in gathering inputs from construction experts, such as architects, engineers, contractors, and subcontractors.

LITERATURES

Barriers to BIM adoption and use in developing countries. Building Information Modeling (BIM) holds a significant promise for improving efficiency and collaboration in the construction industry. However, its widespread adoption, particularly in developing countries, is hindered by a range of barriers. These challenges can be broadly categorized into technical, financial, and organizational or policy-related obstacles.

Technical barriers are among the most frequently cited limitations to BIM adoption. Across multiple contexts, a shortage of skilled professionals and inadequate training infrastructure significantly impede implementation. For example, in Ethiopia, the lack of trained BIM professionals, limited access to integrated design tools, and insufficient training opportunities were identified as major barriers (Alemayehu et al., 2022). Similarly, in Pakistan and Nigeria, both technical limitations and a lack of practical experience among users have slowed BIM adoption (Akdag & Maqsood, 2019; Babatunde et al., 2020). In China, the absence of localized BIM tools, national standards, and academic research has further limited its effective use, especially in the prefabrication sector (Tan et al., 2019). Additionally, interoperability challenges and uncertainty about where and how to begin implementation remain common, especially among small firms unfamiliar with the technology.

Financial barriers also play a central role in slowing BIM adoption. High initial costs—encompassing software, hardware, and training—are a consistent concern across developing economies. In Nigeria, for instance, the top five deterrents included the cost of acquiring BIM tools and the expense of training personnel (Babatunde et al., 2020). These concerns are echoed in Pakistan and China, where limited financial capacity among firms, particularly small and medium-sized enterprises, restricts their ability to invest in BIM infrastructure (Akdag & Maqsood, 2019; Wu et al., 2021). Even in countries with increasing digital awareness, the financial burden of transitioning to BIM remains a substantial obstacle.

Organizational and policy-related barriers are equally critical and often interlinked with the above challenges. Many studies highlight resistance to change within firms and a lack of top management support as key factors impeding adoption. In South Africa, poor organizational planning and reluctance to change existing workflows were identified as major hurdles (Olugboyega & Windapo, 2022). Similarly, in the UAE, resistance to new work processes and weak executive backing have slowed adoption efforts (Omar & Dulaimi, 2023). A recurring theme in many regions, including Algeria and Hong Kong, is that BIM implementation suffers in the absence of supportive policy frameworks and government leadership (Tehami & Seddiki, 2023; Chan et al., 2019). In Ethiopia and Egypt, lack of national standards, poor government support, and unclear implementation strategies were also

cited as significant limitations (Belay et al., 2021; Marzouk et al., 2022). Countries in the MENA region, including Lebanon, Syria, and Jordan, face similar challenges due to insufficient regulatory requirements and a lack of coordinated national strategies (El Hajj et al., 2023).

Despite these challenges, some cross-cutting patterns are evident. Resistance to change—whether due to traditional work practices, uncertainty, or lack of training—is one of the most universally acknowledged barriers. The need for strong government support and well-defined policies is another consistent theme, as is the importance of accessible, high-quality BIM education and training programs. While financial constraints remain a significant concern, particularly in low- and middle-income countries, studies suggest that overcoming organizational inertia and investing in capacity-building are equally critical to advancing BIM adoption.

Exploring technology acceptance model with system characteristics to investigate sustainable building information modeling adoption in the architecture, engineering, and construction industry: The case of the Philippines. The study by Mata et al. (2024) offers valuable insights into the strategic deployment of BIM in the Architecture, Engineering, and Construction (AEC) industry, particularly in developing countries such as the Philippines. A key finding emphasizes the importance of software performance and compatibility in fostering broader acceptance among professionals. Prioritizing user-centric designs such as incorporating feedback systems, contextual help, and intuitive interfaces—can enhance usability and adoption. Organizational support, including accessible training and ease of use, significantly influences technology adoption behavior. Moreover, understanding the industry's demographic composition, especially its growing base of younger professionals—highlights the need to tailor adoption strategies toward this tech-savvy group. Leveraging their digital fluency can maximize the impact of BIM investments and improve project delivery processes.

The study presents three major contributions. First, it finds a strong relationship between perceived usefulness (PU) and perceived ease of use (PEU), underscoring the importance of usability in BIM tools, especially in regions where adoption is still emerging. Addressing these issues through user-focused design and training initiatives is critical. Second, PU plays a key role in shaping positive attitudes toward BIM, directly influencing adoption intent. This suggests that implementation strategies must align with organizational capacity and promote favorable perceptions. Third, the findings advocate for a strategic focus on BIM software quality and compatibility, user experience, and institutional support to drive effective adoption. In sum, successful BIM deployment in the AEC requires an integrated approach: prioritizing usability, ensuring software compatibility, providing strong organizational support, and engaging younger professionals. These measures will strengthen adoption efforts and help maintain competitiveness in the evolving construction landscape.

Synthesis of Related Literature and Studies. This study examined the barriers, trends, and source of growth associated with the implementation of 4D Building Information Modeling (BIM) in the Philippine construction industry, with a particular focus on the roles of gender and age. The findings highlight how these demographic factors influence 4D BIM adoption and its alignment with the United Nations Sustainable Development Goals (SDGs) for 2030.

Key barriers identified include the high cost of technology, a shortage of skilled professionals, and resistance to digital innovation. However, the study reveals a generational shift, with younger professionals – particularly those in their 20s and 30s – showing greater openness to adopting 4D BIM, signaling a trend toward digital transformation in construction management.

Notably, the study underscores the significant role of women in driving 4D BIM adoption. Despite the male-dominated nature of the construction and technology sectors, female

professionals demonstrated strong adaptability and leadership in implementing BIM processes. A gender-inclusive perspective is essential to understanding how diversity can facilitate smoother transitions to digital tools and foster innovation within the industry.

The increasing use of 4D BIM in large-scale infrastructure projects reflects a growing trend in the Philippines. Companies reported improved scheduling, coordination, and resource management, leading to more efficient project outcomes. Government support and targeted training initiatives were also identified as key enablers, helping to build the digital skills needed for successful implementation.

Additionally, 4D BIM contributes to environmental sustainability by optimizing resource use and reducing waste, directly supporting SDGs related to sustainable cities, infrastructure (SDG 9), and climate action. By addressing existing barriers and actively engaging diverse age and gender groups, the Philippines can accelerate the adoption of 4D BIM and advance its broader sustainable development goals. This inclusive and forward-thinking approach not only enhances construction efficiency but also promotes equity and innovation in the sector.

METHODS

Using purposive sampling to select respondents with at least three years of experience, aged 21 to 70, the study focused on professionals in the building construction industry in the Philippines. A self-administered questionnaire with three sections—respondent profile, evaluation of digital software for planning and scheduling, and organizational trends—was used for data collection. The questionnaire, which comprised of close-ended questions, was approved by a construction company. Data was then tabulated and analyzed using descriptive statistics, with findings presented as frequencies and percentages. Descriptive statistics and inferential techniques were used in this study to evaluate and compile the information gathered from participants. The results were shown as percentages (%), which were computed by dividing the number of responses by the total and then multiplying the result by 100, and frequencies (f), which indicated the number of responses.

One-Way Analysis of Variance (ANOVA) at a 0.05 level of significance and independent sample t-tests were employed in the study to assess the research hypotheses. After the data was tabulated and analyzed, the results were interpreted, enabling the researcher to make broad inferences and offer relevant suggestions.

RESULTS

The study surveyed 84 professionals from various organizations in the building construction industry (Table 1), with the majority aged 31 to 40 (55.95%) years old and predominantly female (73.81%). Most were employed by General Contractors (41.67%), and senior-level professionals made up the largest group (41.67%). In terms of experience, most had 5 to 10 years in project management (55.95%) and 5 to 10 years in planning/scheduling (41.67%). Majority were involved in large or mega projects.

Regarding barriers to technology adoption, respondents identified digital skills gaps, high costs, and budget limitations as significant obstacles. Trends such as changing technologies and growing competition were seen as impactful, and new technologies were identified as a key source of growth. No significant differences in assessments were found between gender or age groups on most barriers, trends, or growth sources, though some statistical significance was noted in specific areas such as technology costs and certain trends like changing technologies and flexible work arrangements based on age.

All of the computed p-values from the study's collected data that are higher than 0.05 are not statistically significant according to the t-test. However, all the computed p-values from the study's collected data that fall below 0.05 are considered statistically significant.

Table 1
Demographic profile of respondents

Category	Details / Findings
Sample Size	84 professionals
Age Distribution	Majority aged 31–40 (55.95%)
Gender Distribution	Predominantly female (73.81%)
Organization Type	Most worked for General Contractors (41.67%)
Professional Level	Senior-level professionals (41.67%)
Experience in Project Management	5–10 years (55.95%)
Experience in Planning/Scheduling	5–10 years (41.67%)
Project Type Involvement	Majority involved in large or mega projects
Top Barriers to Technology Adoption	- Digital skills gap- High technology costs- Budget limitations
Key Trends Identified	- Changing technologies- Growing competition
Main Growth Sources	- Emerging technologies- Market demand
Gender-Based Differences	No significant differences in perceptions across gender
Age-Based Differences	Minor statistical significance in: - Perceived technology costs- Trends like changing tech & flexible work arrangements

DISCUSSION

This study emphasizes the value of gender diversity and digital proficiency by showing that female professionals between the ages of 31 and 40 are essential in the Philippine construction industry's adoption of 4D BIM. By empowering this important group, a focus on inclusive hiring and targeted upskilling advances SDG-4 (Quality Education) and SDG-5 (Gender Equality). The necessity for specialist training is highlighted by the fact that senior-level professionals make up most of the workforce but frequently lack BIM experience. Reducing this skills gap promotes innovation through improved workforce capacities, which is in line with SDG-9 (Industry, Innovation, and Infrastructure). Key barriers such as lack of digital skills, high costs, and financial limitations are typical of developing countries. To support small and medium-sized enterprises (SMEs) and encourage broader adoption, government incentives, subsidies, and public-private partnerships are essential. This will help to advance SDG-8 (Decent Work and Economic Growth) and SDG-13 (Climate Action) using sustainable construction practices. While age and gender had no effect on most of the barriers, age-group disparities in financial attitudes and technological openness point to the need for customized engagement tactics. Supporting seasoned employees while utilizing the digital fluency of younger professionals guarantees inclusive and successful adoption, hence advancing SDG-10 (Reduced Inequalities). In summary, this study supports a multi-pronged approach to 4D BIM adoption – combining skills development, inclusive workforce strategies, and supportive government policies. By addressing identified barriers and leveraging the strengths of a diverse workforce, the Philippines can accelerate progress toward its national infrastructure goals and contribute meaningfully to the "UN's 2030 Sustainable Development Agenda."

Acknowledgement. First and foremost, I would like to thank God Almighty for the abundant blessings, guidance, and strength He has showered upon me in completing this research. I am deeply grateful for the opportunity He gave me to meet the remarkable people who have supported and encouraged me throughout this journey.

I would like to express my sincere gratitude to my research adviser, Engr. Paul Michael Guntalilib. Your unwavering guidance, expertise, and patience have been invaluable throughout this research. It has been a privilege to work under your mentorship.

My heartfelt thanks also go to Engr. Joseph Raniel Bianes, Dr. Philip Ermita, Ar. Reynaldo Ventura, and Dr. Guillermo Bernabe for their insightful comments, suggestions, and constructive criticism that helped refine my work. I am equally thankful to Ms. Joselinda Golpeo for her generous time and assistance in addressing my questions and providing support throughout this research process.

To my loving wife, Zenaida, I am forever grateful for your unyielding love, encouragement, and belief in me. You have been my pillar of strength, supporting me emotionally, spiritually, and

financially. Your unwavering faith in my abilities has kept me going, especially when I felt like giving up.

To my wonderful kids, Samantha, Simon, Sophia, and Seb, you have been my source of inspiration. Your joyfulness and boundless energy have lifted my spirits and kept me focused on completing this journey. You are the reason I persevered, and I am forever thankful for that.

To my parents, Papa Amy and Mama Cecille, thank you for your endless love, sacrifices, and constant support. Your presence has been my foundation, and your belief in me has given me the courage to push forward.

To my Siblings, Aicel and John Ray, I appreciate your love, encouragement, and comfort. Knowing I have you by my side has been a great source of peace throughout this journey.

Finally, thank you to my colleagues and friends for your continuous support and motivation. Your presence in my life has made this journey more meaningful.

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