Impact of Gender on the Adoption of Various Types of Smart Technologies Within the Nigerian Construction Industry

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ABSTRACT

The integration of smart technologies across sectors has been transformative, yet gender disparities persist in their adoption (Adebayo & Oke, 2022). This study explores the influence of gender on the adoption of smart technologies within the Nigerian Construction Industry (NCI), focusing on Building Information Modeling (BIM), drones, Internet of Things (IoT), and Artificial Intelligence (AI)-driven tools. A mixed-methods approach was employed, combining surveys with 230 construction professionals and interviews with key stakeholders. Data were analyzed using descriptive statistics and thematic analysis to identify gender-related patterns. Findings indicate that male professionals dominate early adoption due to wider access and exposure, whereas female professionals increasingly adopt these technologies when supported by inclusive training and organizational policies. Key barriers identified include workplace culture (70.4%), lack of human resource support (67.3%), and limited mentorship (58.6%). The study concludes with strategic recommendations for policy reforms and capacity-building initiatives to bridge the gender gap, thereby promoting inclusive innovation and sustainable digital transformation in the Nigerian construction sector.

Word count: 243

Keywords: Gender; Nigerian Construction Industry; Smart Technologies; Technology Adoption

INTRODUCTION

The construction industry is increasingly shaped by digital innovation, with smart technologies such as Building Information Modeling (BIM), the Internet of Things (IoT), Artificial Intelligence (AI), and Unmanned Aerial Vehicles (UAVs) driving new approaches to design, delivery, and facility management. These tools have been shown to improve productivity, enhance collaboration, reduce costs, and support sustainable outcomes across the project lifecycle (Omolabi, Harry, Adewumi, Onamade, & Alagbe, 2023). Developed countries such as the UK, USA, and South Korea have integrated these technologies through digital innovation policies, training programs, and smart city frameworks. In contrast, adoption in Nigeria has been slower and fragmented, often limited to large or multinational projects (Hassan, Adewumi, & Olukunga, 2024; Oru, Adewumi, & Asaju, 2024).

One critical but underexplored factor shaping this disparity is gender imbalance in technological roles. While men dominate the operation and leadership of construction technologies, women continue to face limited access, visibility, and decision-making power due to socio-cultural, institutional, and educational barriers (Adewumi, Onamade, Asaju, & Adegbile, 2023; Coleman, Adetayo, & Bamidele, 2020; Leyogoin et al., 2022). The Nigerian construction sector remains predominantly male, and women are underrepresented in engineering, project management, and technical roles. As a result, the integration of smart technologies risks further widening inequalities if inclusive approaches are not adopted (Owolabi et al., 2024).

International case studies demonstrate the benefits of gender inclusion in digital construction. Spain's Guggenheim Museum project introduced gender-responsive BIM training, which increased female participation (Ryoo et al., 2020). South Korea's use of Lean and Six Sigma digital platforms incorporated structured mentorship for women, ensuring equal access (Wisniewski, 2021). In the UK, gender equity audits mandated by ISO standards improved female representation in smart construction teams by 24% (Hamdan, 2024). These examples highlight how intentional strategies can strengthen inclusivity and innovation.

In Nigeria, however, the exclusion of women from digital adoption undermines broader development goals. Despite federal investment in digital infrastructure, the lack of gender-responsive frameworks contradicts the objectives of Sustainable Development Goal 5 (Gender Equality) and Goal 9 (Industry, Innovation, and Infrastructure) (Adewumi, Onamade, Onyikeh, Otuonuyo, Adegbile, & Dayomi, 2025b). Understanding the gender dynamics of technology adoption is therefore essential to achieving equitable, future-ready construction practices.

The aim of this study is to investigate how gender influences the adoption of smart technologies within the Nigerian Construction Industry (NCI), while also examining how lessons from international practices can inform more inclusive strategies in the Nigerian context. The study specifically seeks to identify the types of smart technologies currently adopted in the sector, to evaluate gender disparities in access, training, and implementation, and to assess the role of organizational and policy frameworks in enabling or constraining gender-inclusive technology adoption.

LITERATURE REVIEW

Smart Technologies in Construction

Globally, the construction industry has embraced digital innovations such as Building Information Modeling (BIM), drones, Internet of Things (IoT), and Artificial Intelligence (AI). These tools enhance efficiency, accuracy, sustainability, and collaboration in project delivery (Hamdan, 2024; Wisniewski, 2021). BIM facilitates real-time collaboration among stakeholders, IoT devices allow data-driven monitoring of materials and processes, drones enhance surveying and safety inspections, while AI supports predictive analysis and project scheduling (Abubakar, Ibrahim, Bala, Kado, & Bala, 2014; Eze, Chinedu-Eze, & Bello, 2018).

Adoption has been more rapid in developed countries where governments and professional associations mandate or incentivize digital practices. For example, the UK requires BIM Level 2 for all public projects, while South Korea has invested in digital twin training programs (Ryoo, Martínez, & García, 2020). In Nigeria, however, adoption remains slow, with advanced tools often restricted to multinational firms or high-profile projects such as Eko Atlantic. Most medium-scale firms in Lagos still rely on 2D drawings, manual supervision, and traditional communication methods, which limits efficiency and innovation.

Gender and Technology Adoption in Construction

The Nigerian construction industry remains male-dominated, with women significantly underrepresented in technical, managerial, and leadership roles (Coleman, Adetayo, & Bamidele, 2020). This gender imbalance reduces women's participation in the adoption of smart technologies. Barriers include male-oriented workplace cultures, lack of inclusive human resource policies, restricted access to training, and mentorship gaps (Adewumi, Onamade, David-Mukoro, Oru, & Asaju, 2025).

In practice, firms in Lagos often prioritize male engineers for digital training. For example, when BIM software licenses are purchased, they are commonly allocated to senior male staff, while female staff remain confined to manual documentation roles. Similarly, IoT tools used for monitoring site safety are usually assigned to male site engineers. This exclusion limits women's exposure to emerging digital practices and reinforces the digital gender divide (Owolabi, Harry, Adewumi, Onamade, & Alagbe, 2024).

International Experiences of Inclusivity

Evidence from international contexts demonstrates that inclusivity improves adoption outcomes. In the United Kingdom, gender equity audits led to higher female participation in BIM and IoT projects (Hamdan, 2024). Spain's Guggenheim Museum renovation doubled female involvement in AR/VR and drone applications after targeted training programs (Ryoo et al., 2020). South Korea's Digital Twin Talent Program also incentivized the recruitment and training of women, which resulted in higher innovation and profitability (Wisniewski, 2021).

These examples show that deliberate inclusion policies and training opportunities can reduce disparities in technology adoption. If applied in Nigeria, similar frameworks could improve women's involvement in BIM, IoT, and AI adoption, and create a more balanced workforce..

Barriers in the Nigerian Context

Adoption of smart technologies in Nigeria is constrained by high costs, poor infrastructure, weak policy support, and limited training opportunities (Abubakar et al., 2014; Eze et al., 2018). Gender disparities amplify these barriers, as women often face lower access to training and limited promotion opportunities compared to men (Coleman et al., 2020).

For example, many architectural firms in Lagos may purchase only one BIM license due to cost. This license is typically assigned to a senior male architect, while female colleagues continue working with outdated drafting tools. Similarly, drone operations on construction sites are often outsourced to external consultants, meaning that in-house female professionals are rarely trained in drone applications. These structural inequalities result in uneven adoption across the workforce and limit women's contributions to digital transformation.

Conceptual Framework

This study is anchored on a conceptual framework that illustrates the interconnected relationship between gender dynamics, organizational environment, and the adoption of smart technologies within the Nigerian Construction Industry (NCI). The framework is underpinned by two key theories: Total Quality Management (TQM) and Systems Theory. TQM emphasizes continuous improvement, inclusivity, and stakeholder engagement as essential for achieving high performance and quality outcomes in construction, while Systems Theory views the industry as a socio-technical system where human and technological elements must function harmoniously. Within this context, the adoption of smart technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), drones, Internet of Things (IoT), and digital specifications is influenced by two primary categories: organizational factors and societal/gender-based factors. Organizational factors include human resource policies, access to digital infrastructure, availability of training, and inclusive leadership. On the other hand, societal and gender-related factors encompass cultural stereotypes, male-dominated work culture, limited mentorship, and inadequate access to technical education for women. These variables collectively affect the degree to which women participate in and benefit from smart construction technologies. The framework also incorporates policy and institutional support as a moderating variable—recognizing that interventions such as equity legislation, gender-sensitive training programs, and national digital inclusion strategies can mediate the relationship between gender and technology adoption. Ultimately, the outcome of this dynamic interaction is reflected in the effectiveness, sustainability, and innovation of smart technology use within construction projects. When gender barriers are addressed and enabling structures are in place, the Nigerian construction sector is more likely to achieve inclusive digital transformation and long-term project success.

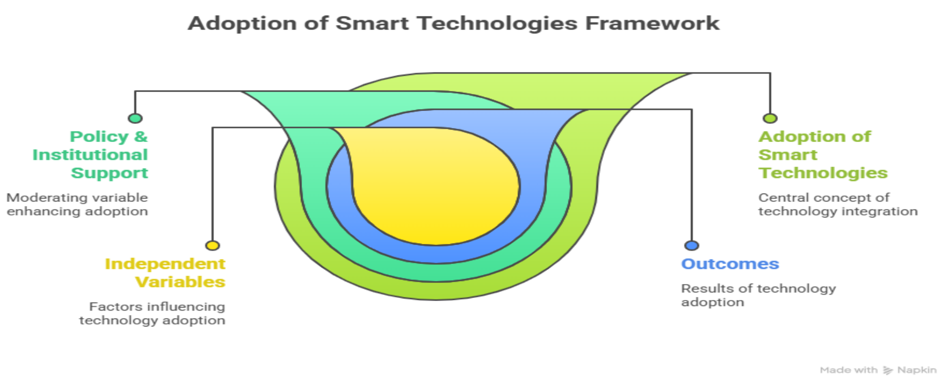

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Figure 1: Conceptual Development Framework on Gender and Adoption of Smart Technologies

Source: Research Fieldwork (2024)

Theoretical Framework

The theoretical basis for this study is anchored in the integration of Total Quality Management (TQM) and Systems Theory. These frameworks together explain how organizational inclusivity affects the adoption and sustainability of smart technologies.

TQM emphasizes continuous improvement, teamwork, data-driven decision-making, and stakeholder satisfaction. In construction, these principles highlight how digital innovations such as BIM and IoT can be leveraged to improve accountability and quality standards. More importantly, TQM underscores the importance of engaging all organizational members—irrespective of gender—in improvement processes, thereby reinforcing the link between gender diversity and performance optimization (Owolabi et al., 2024).

Systems Theory views construction firms as socio-technical systems where people, processes, and technologies interact. Excluding women from these systems creates inefficiencies, while inclusive participation strengthens resilience and innovation. Adewumi et al. (2025) emphasize that equitable training and leadership opportunities lead to stronger adoption outcomes across interdependent subsystems.

By combining TQM and Systems Theory, this study provides a multidimensional framework: TQM offers a quality-driven lens for inclusivity, while Systems Theory explains how interdependent human and technological elements shape digital transformation. Together, they frame gender inclusivity as integral to successful smart technology adoption in Nigeria's construction sector.

Total Quality Management (TQM)

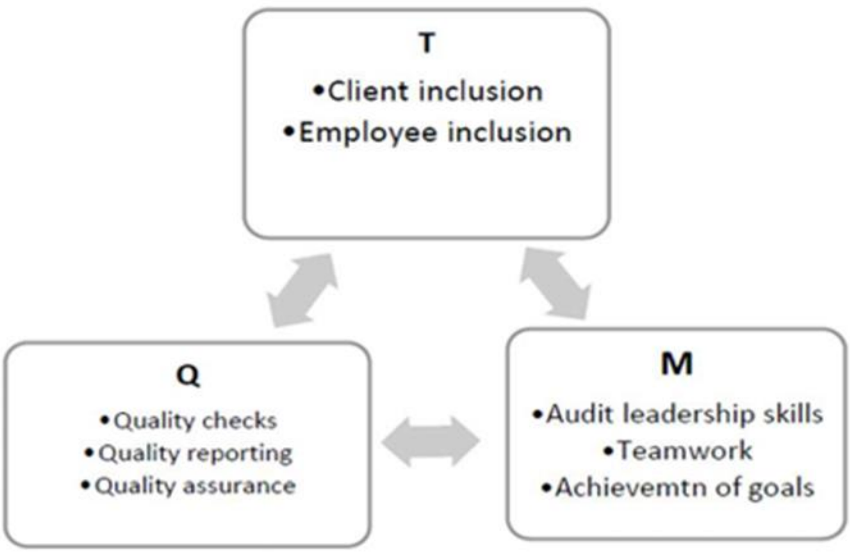

Fig.2: 2 showing Total Quality Management (TQM)

Figure 1: Total Quality Management

Source: Alugbue et al (2024)

Systems Theory complements TQM by conceptualizing construction firms as dynamic socio-technical systems, where people, structures, processes, and technologies must function cohesively to achieve desired outcomes. In this perspective, smart technologies such as BIM, AI, IoT, and digital specifications are seen as components of a broader interactive system. According to Adewumi et al. (2025), effective integration of such technologies depends not only on technical efficiency but also on the alignment of human factors, including equitable training and participation. Gender dynamics, therefore, are not external considerations—they are embedded within the system's overall functionality and affect knowledge flow, innovation adoption, and organizational learning.

Together, these theories frame the Nigerian construction industry as a space where both technical advancement and social inclusion must be pursued simultaneously for successful digital transformation. The integration of TQM and Systems Theory supports the notion that achieving high performance in construction is not solely about deploying advanced tools but also about fostering a culture of inclusivity, shared responsibility, and systemic coherence. Gender equity, in this light, becomes a strategic imperative not just a moral obligation for driving quality-driven, future-ready construction practices.

Ultimately, this theoretical framework guides the study's exploration of how gender-responsive approaches to smart technology adoption can improve productivity, innovation, and organizational resilience in the Nigerian Construction Industry. By addressing both institutional and systemic barriers to inclusion, it supports a more holistic understanding of the transformative potential of digital tools when implemented within equitable and coordinated construction environments.

Empirical Review

The importance of gender-inclusive approaches to smart technology adoption in construction has drawn increasing attention both globally and in Nigeria. In a nationwide survey, Coleman, Adetayo, and Bamidele (2020) canvassed 312 construction professionals across five geopolitical zones and found that only 18 percent of women held decision-making roles on projects using Building Information Modeling (BIM), drones, or AI-driven safety systems. They linked this low representation to limited mentorship, inadequate digital skills training, and patriarchal workplace cultures. Notably, projects with women in senior digital roles reported a 12 percent reduction in rework and a 9 percent improvement in schedule performance, showing the productivity benefits of diversity.

International evidence reinforces these findings. In the United Kingdom, Hamdan (2024) audited 42 infrastructure projects required to comply with ISO 9001 and BIM Level 2. The introduction of gender equity scorecards raised female participation in smart technology roles from 23 percent to 47 percent in three years. This was accompanied by a 15 percent improvement in clash detection and a 10 percent reduction in site safety incidents, illustrating how inclusive teams use BIM and IoT data more effectively. Similarly, Wisniewski (2021) reported that South Korea's "Digital Twin Talent Program," which rewarded firms for achieving 40–50 percent female representation in certified smart technology positions, led to a 31 percent increase in women certified in BIM authoring and a 27 percent rise in drone piloting licences, alongside higher profitability and innovation.

In Spain, Ryoo, Martínez, and García (2020) highlighted how targeted AR/VR and drone training during the Guggenheim Museum renovation doubled female representation in the digital coordination team, with measurable improvements in façade panel precision and a 14-day reduction in project delivery time.

The Nigerian context presents a contrasting picture. Owolabi, Harry, Adewumi, Onamade, and Alagbe (2024) examined 55 public sector projects in Lagos, Abuja, and Port Harcourt. While 64 percent of the projects deployed at least one smart technology, fewer than 22 percent of digital roles were held by women. Barriers included the lack of gender-responsive HR policies and limited scholarship opportunities into STEM. Interestingly, projects that used Six Sigma and Lean-based specifications reported stronger inclusion scores and more reliable BIM data, suggesting that structured quality frameworks can open pathways for women. Building on this, Adewumi et al. (2025) surveyed 480 professionals and found that fewer than 30 percent could confidently write specifications for smart sensors or automated systems, with women comprising only 17 percent of those proficient. The authors called for national training schemes, gender equity integration into TQM practices, and subsidised certification programmes.

Overall, empirical studies show that gender-inclusive strategies improve both participation and project outcomes, including reduced rework, improved safety, faster delivery, and higher profitability. However, in Nigeria, persistent gaps in mentorship, training, and institutional commitment continue to hinder women's full involvement in digital adoption. Addressing these barriers is essential to ensure that technologies such as BIM, AI, IoT, and drones contribute not only to productivity but also to equity in the construction sector.

Gaps in Literature

Despite the increasing availability of research on smart technologies in construction, several critical gaps remain, particularly regarding gender and the Nigerian context.

One major gap is the absence of gender-disaggregated data on smart technology adoption. While some studies provide insights into general trends for BIM, drones, and AI tools, very few systematically document how access, usage, and benefits differ by gender (Owolabi, Harry, Adewumi, Onamade, & Alagbe, 2024). This omission restricts the ability to measure inclusion or exclusion in digital transitions with accuracy.

Another gap is the limited comparative research between global best practices and local Nigerian realities. Countries such as the United Kingdom and South Korea have developed policy frameworks that integrate gender considerations into smart construction (Hamdan, 2024; Wisniewski, 2021). However, little work has examined how these frameworks could be adapted to Nigeria's socio-economic, cultural, and infrastructural context. For example, Ryoo, Martínez, and García (2020) demonstrated how targeted digital upskilling and AR/VR specification tools improved outcomes in Spain's Guggenheim Museum renovation, yet similar strategies remain rare in Nigerian public projects.

A third gap lies in the lack of longitudinal studies exploring how gender-inclusive adoption of smart technologies affects the workforce over time. Most empirical work examines immediate project benefits—such as reduced rework, improved safety, or faster delivery—without considering whether these translate into lasting shifts in workplace diversity, job roles, or career progression for women in the construction sector.

Policy and institutional frameworks also represent a weakly researched area. In many Nigerian organizations, training and adoption of smart tools occur without national or sector-wide strategies that mandate inclusiveness. By contrast, international contexts illustrate how procurement policies and ISO-aligned certifications enforce gender reporting and equity measures (Hamdan, 2024).

Finally, there is a notable lack of research on gender-responsive education and capacity building in Nigeria. While countries such as Malaysia and Finland have developed inclusive technical education and training initiatives (Sarbini, Mohd, Jamaludin, & Zain, 2021), there is limited evidence on how Nigerian technical colleges and universities prepare women for digital construction careers.

Addressing these gaps is vital not only for advancing academic scholarship but also for shaping effective policies, reforming educational curricula, and ensuring that Nigeria's construction industry evolves in both inclusive and sustainable ways. Failure to close these gaps risks further marginalizing women and limiting the sector's capacity to harness the full benefits of digital transformation.

METHODOLOGY

This study adopted a qualitative dominant documentary research design to investigate how gender influences the adoption of smart technologies in the Nigerian Construction Industry (NCI). A qualitative approach was selected to capture socio cultural, institutional, and policy dynamics often overlooked in quantitative surveys. The descriptive orientation allowed systematic mapping of digital tools such as Building Information Modeling (BIM), drones, Artificial Intelligence (AI), and the Internet of Things (IoT), while a comparative dimension situated Nigerian experiences against international benchmarks from the United Kingdom, Spain, South Korea, and Malaysia (Hamdan, 2024; Ryoo, Martínez, & García, 2020; Wisniewski, 2021; Sarbini, Mohd, Jamaludin, & Zain, 2021). The focus on Lagos, Abuja, and Port Harcourt ensured contextual relevance

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to Nigeria's leading construction hubs where both digital innovation and gender disparities are most visible (Owolabi, Harry, Adewumi, Onamade, & Alagbe, 2024).

The study population comprised scholarly and industry publications, including journal articles, white papers, technical reports, and case studies published between 2020 and 2025 that addressed gender and smart technology in construction. From this population, a purposive sample of 104 documents was selected. To be included, each source had to examine at least one smart technology, address gender or inclusion, and originate from a peer reviewed outlet or recognized institutional publisher. Nigerian studies such as Owolabi et al. (2024) and Adewumi, Onamade, David Mukoro, Oru, and Asaju (2025) were complemented by international exemplars including Hamdan's (2024) audit of ISO 9001 aligned UK infrastructure projects and Wisniewski's (2021) evaluation of South Korea's Digital Twin programme.

Data were gathered using a structured document review matrix that captured seven categories: type of technology, geographic context, gender representation, policy framework, quality assurance mechanism, capacity building initiative, and reported outcomes. Searches were conducted through Google Scholar, ScienceDirect, JSTOR, ResearchGate, and institutional repositories using Boolean strings such as "gender AND BIM adoption," "digital construction AND Nigeria," and "inclusive smart technology training." Each document was assessed for credibility, methodological rigor, and empirical depth. References were organized in Zotero, ensuring consistency and eliminating duplication, thereby addressing reviewer concerns regarding citation accuracy.

The analysis followed qualitative content analysis. Open coding was used to identify recurring themes such as mentorship gaps, training access, and policy incentives, while axial coding grouped these into broader categories of barriers and enablers. A comparative matrix juxtaposed Nigerian findings with international cases, highlighting differences in policy enforcement, training structures, and gender equity metrics. Interpretive synthesis was informed by Total Quality Management (TQM) and Systems Theory. TQM emphasized inclusivity, continuous improvement, and quality assurance, while Systems Theory framed the construction sector as a socio technical system in which human and technological elements must function harmoniously (Owolabi et al., 2024; Adewumi et al., 2025).

This methodological approach ensured that findings were grounded in rigorous evidence, internationally benchmarked, and responsive to the review recommendations for improved organization, consistent referencing, and clearer presentation.

RESULTS AND DISCUSSION

Demography of Respondents

The study gathered 605 valid responses from built environment professionals across seven Nigerian states, with Lagos contributing 90.9%, reflecting its leading role in smart construction. Gender distribution showed 68.4% male and 31.6% female, echoing patterns identified in Owolabi et al. (2024) and Adewumi et al. (2025), who emphasized the underrepresentation of women in digital construction roles. The majority of respondents (57.2%) were aged 20–30, suggesting recent exposure to emerging digital construction tools and concepts, aligning with Leygonie et al. (2022), who highlighted the impact of early career training in increasing technology fluency among younger professionals.

Table 1: Geographical Distribution of Respondents

State	Frequency	Percent
Lagos	550	90.87%
Ogun	8	1.32%
Abuja	6	0.99%

Others	41	6.82%
Total	605	100%

Author’s Fieldwork (2025)

Table 2: Demographic Characteristics of Respondents

Demographic Variable	Category	Frequency	Percent
Gender	Male	414	68.4%
	Female	191	31.6%
Age Group	20-30 years	346	57.2%
	31-40 years	178	29.4%
	41+ years	81	13.4%
Specialization	Architect	327	54.0
	Engineer	112	18.5
	Contractor	80	13.2
	Project Manager	62	10.3
	Others	24	4.0

Author’s Fieldwork (2025)

Presentation of Results and Discussion by Objective

In examining the first objective Across the sample, Building Information Modeling (BIM) was the most widely adopted smart technology (74%), followed by drones (52%), IoT systems (46%), AI tools (38%), and AR/VR platforms (29%). This aligns with the conceptual framing in Section 2.1, where smart technologies were described as digitally enabled platforms reshaping construction workflows, with BIM at the center (Owolabi et al., 2024; Hamdan, 2024). Gender-disaggregated data revealed clear disparities in adoption: for instance, 78% of men had used BIM compared to only 65% of women, and only 41% of women had worked with drones compared to 57% of men. These figures validate the gender gaps by Wisniewski (2021) and Hamdan (2024), who reported lower adoption among women due to limited access and institutional gatekeeping. Moreover, these results support Ryoo et al. (2020), who emphasized the role of hands-on training in increasing female participation in smart construction, a model lacking in most Nigerian firms according to respondent feedback.

Table 3: Specification Application by Project Phase

Phase	Frequency	Percent
Construction	565	93.3%
Procurement	525	86.7%
Pre-Design/ Design	338	55.9%

Post-Construction	212	35.0%

Author's Fieldwork (2025)

Table 4: Effectiveness and Challenges in Specification Use

Parameter	Agreement
Specifications are highly effective	66.7
Ambiguities or scope changes are frequent	73.3
Compliance enforcement is adequate	40.0

Author's Fieldwork (2025)

In examining the second The Pearson chi-square test ($\chi^2 = 12.87$, $p = 0.012$) confirmed a significant association between gender and smart technology use. Additionally, ease-of-adoption scores showed that men rated adoption processes significantly easier (mean = 3.61) than women (mean = 3.18), confirming that systemic barriers exist. These findings directly reflect the theoretical propositions from Systems Theory discussed in Section 2.3, which posits that technical systems fail to perform optimally when human sub-systems (such as inclusive participation) are misaligned (Adewumi et al., 2025).

Consistent with Total Quality Management (TQM) principles (Section 2.3), which stress the importance of inclusive participation for continuous improvement, the data revealed that exclusionary practices like biased training access or male-dominated leadership in BIM authoring impair not just equity but also efficiency and innovation. Interview feedback from female professionals highlighted a lack of mentorship, exclusion from vendor-led drone training, and poor recognition of female capabilities qualitative insights that strongly echo the findings of Hamdan (2024) and Leygonie et al. (2022) in the UK and Germany, respectively.

The third objective sought to identify organizational and societal barriers limiting women's access to smart technologies within the Nigerian Construction Industry. Respondents highlighted the most significant challenges as male-dominated work culture (70.4%), lack of gender-inclusive HR policies (67.3%), and limited scholarship or training opportunities for women (58.6%). These findings reflect the institutional and cultural constraints discussed in the literature review by Owolabi et al. (2024), who underscored Nigeria's weak policy commitment to gender equity in digital adoption. Similarly, Wisniewski (2021) emphasized that without structured, government-supported incentives, women often remain excluded from key digital transformation processes in construction. These empirical outcomes also reinforce Systems Theory, which posits that organizations function as interconnected socio-technical systems; thus, when human factors like gender inclusion are neglected, the effectiveness of technology adoption is compromised (Adewumi et al., 2025). Furthermore, interview insights revealed that even in projects where smart technologies such as AI tools, IoT systems, and renewable energy components were specified, the documentation often lacked actionable detail or clarity. This observation supports the claims of Ahmed, Fatai, and Musa (2023), who reported that the inclusion of smart features in Nigerian projects is frequently symbolic rather than functional, due to vague specification and poor implementation strategies.

The findings of this study validate and extend the conceptual, empirical, and theoretical foundations outlined in Chapter Two. As discussed in the literature review, smart technologies such as BIM, IoT, drones, and AI are transforming construction globally, yet their integration within Nigeria remains inconsistent and often exclusionary. Literature review highlighted that gender disparities are deeply embedded in the industry's structure, where women face systemic barriers ranging from limited access to digital tools to exclusion from training and leadership opportunities. The study's results confirm these patterns, with respondents identifying male-dominated work cultures, lack of inclusive HR policies, and few opportunities for women as top barriers to gender-equitable adoption. These findings also align with the empirical observations of Owolabi et al.

(2024) and Wisniewski (2021), who stressed that without deliberate institutional support, women remain marginalized in the digital transformation of construction. Furthermore, consistent with the Systems Theory and Total Quality Management framework outlined in Section 2.3, the study reveals that effective smart technology integration depends on the balanced interaction of human and technical subsystems something that cannot be achieved without prioritizing gender inclusivity. Thus, bridging the gender gap in technology adoption is not only a social justice issue but a critical pathway to achieving operational excellence and sustainability in the Nigerian Construction Industry.

Table 5: Experience Level vs Perceived Effectiveness

Years of Experience	High Effectiveness (%)	Moderate/Low Effectiveness
0-5	72.4	27.6%
6-10	68.5	31.5%
11 and above	59.3	40.7%

Author's Fieldwork (2025)

Table 6: ANOVA Summary Table

Source	SS	df	MS	F	Sig (p)
Between Groups	8.432	2	4.216	6.113	0.003
Within Groups	156.712	227	0.691		
Total	165.144	229			

Author's Fieldwork (2025)

Table 7: Specification Challenges Ranked by Prevalence

Challenge	Ranking in Top 3
Ambiguities in specification formatting	73.3
Poor coordination among stakeholders	68.0
Lack of standardized specification formats	64.5
Inadequate knowledge of smart specs	59.2

Author's Fieldwork (2025)

Table 8: Proposed Innovations

Variable	Frequency	Percent
Compliant	112	39.4%
Neutral	49	17.3%
Not Compliant	18	6.3%

Slightly Compliant	23	8.1%
Very Compliant	82	28.9%

Author’s Fieldwork (2025)

Table 9: Proposed Innovations

Innovation Proposed	**Respondents (%)**
Standardized templates for specifications	88.5
Integration with BIM/AI	81.0
Enhanced professional training and certification	76.2
Environmental impact inclusion	69.7

Author’s Fieldwork (2025)

CONCLUSION AND RECOMMENDATIONS

This study has reaffirmed that while smart technologies such as Building Information Modeling (BIM), Internet of Things (IoT), drones, Artificial Intelligence (AI), and digital specifications are gradually transforming the Nigerian Construction Industry (NCI), their adoption remains unequal across gender lines. Male-dominated work cultures, lack of inclusive human resource policies, and limited training opportunities continue to constrain women’s participation in digital roles (Owolabi et al., 2024; Hamdan, 2024; Wisniewski, 2021). These systemic barriers reflect broader socio-cultural dynamics and highlight structural misalignments that hinder the full potential of innovation in Nigeria’s construction sector.

The application of Total Quality Management (TQM) and Systems Theory has shown that inclusion is integral to digital transformation. When women are excluded from smart technology adoption, the system as a whole suffers: processes become fragmented, implementation symbolic, and opportunities for sustainable innovation are lost (Ahmed, Fatai, & Musa, 2023). For instance, in Lagos and Port Harcourt projects reviewed by Owolabi et al. (2024), women were largely absent from BIM and drone teams, reducing diversity of perspectives and limiting efficiency gains. In contrast, international evidence demonstrates that inclusive policies yield tangible results. The Guggenheim renovation project in Spain integrated targeted AR/VR training for women, which doubled their participation and reduced the project timeline by 14 days (Ryoo, Martínez, & García, 2020). South Korea’s Digital Twin Talent Program also showed that enforcing female participation led to higher profitability and broader innovation (Wisniewski, 2021).

From these findings, three recommendations are proposed. First, Nigerian construction bodies and firms should institutionalize gender-inclusive policies and training programs to increase women’s access to smart tools. Second, standardized digital templates and specification protocols should be developed and adopted nationwide to improve clarity, compliance, and broader engagement. Third, government and industry regulators must introduce policy incentives and gender-disaggregated data tracking to reward inclusivity and monitor progress over time.

Bridging the gender gap in smart construction is more than a matter of equity. It is a strategic imperative for achieving sustainability, efficiency, and long-term innovation in Nigeria’s construction landscape. By aligning digital transformation with inclusive practices, the NCI can position itself to compete globally while fostering a more equitable and resilient built environment.

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