Breaking the concrete wall: The untapped potential of technology to increase the participation of women in the construction industry

*Aba Essanowa Afful[1], Cynthia Wang[2], Riza Yosia Sunindijo[3], Portia Atswei Tetteh[4], and Samuel Frimpong[5]

[1,5]Postgraduate researcher, University of New South Wales, Kensington, Sydney, Australia
[2,3] A/Prof, University of New South Wales, Kensington, Sydney, Australia
[4]Postgraduate researcher, Western Sydney University, Kingswood, Sydney, Australia
Corresponding author's E-mail: aba.afful@unsw.edu.au

Abstract

Research on gender disparities in the construction industry has traditionally overlooked the role of technology in empowering women. This study aims to fill this gap by setting two key objectives: firstly, to outline the job roles of women in construction and their associated challenges, and secondly, to pinpoint areas where technology can address the challenges to increase female participation within those job roles. Through a systematic literature review and a task-based taxonomy, the study identifies two primary job roles for women: on-site roles encompassing tradeswomen and on-site professionals/managers, and off-site roles comprising managers/CEOs, administrative/clerical staff, and office professionals. To address the second objective, the study identifies 29 construction 4.0 technologies from existing literature, presenting them within a framework that categorises these technologies into digital layers, digital tools, and physical layers. By doing so, the research highlights specific technologies that could alleviate the challenges faced by women in both on-site and off-site job roles. Practical implications of this research lie in its potential to inform future interventions aimed at narrowing gender disparities in the construction industry. By identifying specific technologies that can facilitate women's participation and advancement in the field, policymakers, industry stakeholders, and organisations can develop targeted strategies to enhance inclusivity and diversity within the sector. Theoretical implications of this study extend to the broader discourse on gender, technology, and employment. By shedding light on the synergies between technology adoption and gender equity in a traditionally male-dominated industry, this research contributes to theoretical frameworks exploring the intersection of gender, technology, and labour market dynamics. Moreover, it underscores the importance of considering gender perspectives in technology design and implementation to foster more inclusive work environments across industries.

Keywords: gender diversity, women in construction, empowerment, technology, construction 4.0.

1. INTRODUCTION

Industry 4.0, characterised by intelligent machines, digital technologies, sensor systems, and smart materials, has significantly automated processes within the construction sector. The benefit of intelligent technologies in the construction industry is felt in increased efficiency and productivity and holds the potential for empowering women and fostering greater gender diversity within the sector. Nevertheless, scholarly literature examining the adoption of Industry 4.0 technologies within the construction industry acknowledges a tendency for the sector to lag in embracing emerging technologies (Tahmasebinia et al., 2020). The reasons for delving into the relationship between construction 4.0 technologies and women in construction (WIC) are three-fold. First, the gradual adoption of technology within the construction industry is revolutionising traditional practices and birthing new job roles that have yet to be fully explored. Based on a task-oriented approach (Morsh, 1964), it is possible to categorise the job roles of women into three broad categories; (1) ***on-site*** workers that engage in hands-on tasks encompassing physical labour alongside supervisory, monitoring and onsite management, (2) ***off-site*** professionals primarily operating in administrative, planning, design, and coordination roles, focusing on tasks conducted away from the physical construction site, and strategic planning and management, (3) ***the fluid role*** characterised as adaptable and encompassing both on-site and off-site responsibilities. Second, reviews on construction 4.0 have concluded that the technologies are not fully adopted in the construction industry (Statsenko et al.,

2023). Third, attempts at focused reviews into the issues of WIC have largely ignored the role of technology as a solution to the challenges raised. Manesh et al. (2020) for instance, reviewed the literature on ethnic minorities in construction and civil engineering education. Yet while technological interventions could have been proposed as part of the retention and recruitment strategies, this aspect was ignored. Given the gaps in the existing literature presented, this study seeks to answer the research question: *How can construction technologies increase the participation of women in the construction industry?* Therefore, this study aims to explore from a literature review, how construction technologies can increase the participation of WIC.

2. METHODOLOGY

This research is based on a literature review, and the methodology was structured into three integral components: (1) the reason behind using a systematic literature review (SLR) process, (2) the search strategy employed, and (3) the coding constructs employed in the content analysis phase to unveil emergent themes from the body of literature. In fields like the construction industry where literature is often fragmented and lacking coherence, SLRs are valuable. Next, a preliminary exploration of key concepts using Google Scholar provided the authors with a general understanding of the topic. This was a crucial step that aided in developing a list of keywords and the creation of the search string to conduct the literature search. Our preliminary search revealed that before 2000, very few articles explicitly mentioned the technology in use. Thus, it was necessary to limit the search from 2000 to the present. Two databases, Web of Science (WoS) and Scopus, were used for the literature search given that these databases are well attested for, and considered highly reliable by other authors who have conducted SLRs. The planning stage was then succeeded by the conduct of the SLR. Briner and Denyer (2012) propose a 5-step process for conducting SLRs encompassing (1) protocol development, (2) identification of relevant articles, (3) screening and selection of articles, (4) knowledge gathering and analysis, and (5) reporting of the process, findings and knowledge. To ensure comprehensive coverage and avoid biases in literature reviews, the structure of a search string is crucial. To address this, the COCoPoP framework was adopted. COCoPoP, which stands for Concept, Other Terms, Population, and Problem, provides a structured approach for constructing search strings in SLRs, aiming to optimise the search process and maximise effectiveness. The search was conducted on 6 March 2024 in Scopus and WoS concurrently and the search string was formulated as follows.
Concept: "construction 4.0", "technolog construction", "construction technolog*"*
Other Terms: "digital construction", "automat in construction",*
Context: "construct industry", "build*industry*"*
Population: "construction manage", "AEC"*
Problem: "buil environment"*
The PRISMA flow diagram (Figure 1) is included to improve the quality and transparency of the SLR and to detail the article refinement process.

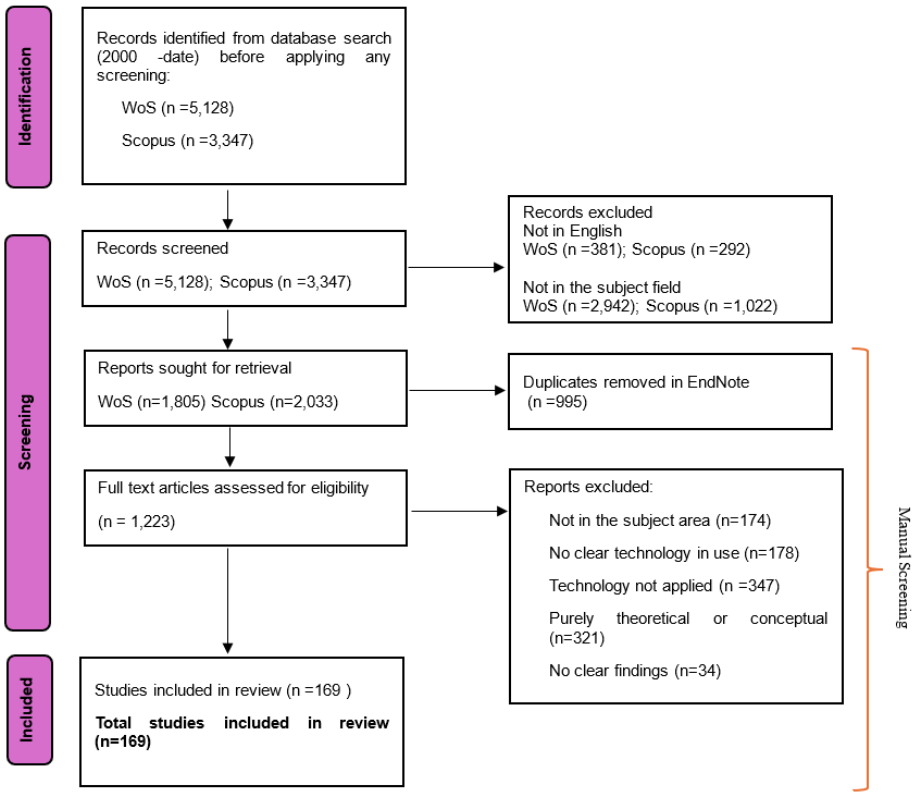

Figure 1 PRISMA Flow Chart

3. RESULTS – BODY OF LITERATURE

Table 1 Summary of Literature Body

Built Environment Field	**Frequency**
Building Construction	142 papers
Road Construction	17 papers
Civil Engineering	10 papers
Technologies	
Building Information Modelling (BIM)	63 mentions
Virtual/Augmented/Mixed Reality (AR/AR/MR)	37 mentions
Smart Robots	26 mentions
Sensors	17 mentions
3D modelling	14 mentions
Artificial Intelligence (AI)	12 mentions
Job Role Categories	
On-site	55 mentions
Fluid	47 mentions
Off-site	72 mentions

It was found that the highest cited job role category was the off-site job role category comprising professions such as architects, quantity surveyors, civil/structural engineers, and urban planners among others. The second highest was the on-site job role category comprising professions such as tradespersons, site managers and contractors among others. The least cited were fluid job roles comprising facility managers, contract managers/administrators and project managers among others. This finding indicates a significant shift within the construction industry away from traditionally defined on-site and off-site job roles and towards more flexible fluid job roles. A mind map (Figure 2)

was thus developed to reveal the relationships existing between the technologies, the tasks performed in the industry (their application) and the job roles. The detailed discussions are presented in the next section.

4. DISCUSSION

In the mind map, technologies are positioned centrally, with their applications to tasks and professions on either side. Arrows indicate the flow from technologies to tasks and specific job roles. The authors recognise that technologies, in essence, are tools utilised to enhance and/or enable tasks and operations within the construction industry.

The off-site construction industry encompasses a range of professional positions, including office and administrative roles such as office managers, CEOs, and trainers, as well as specialized positions like civil/structural engineers, bid managers, architects/designers, quantity surveyors, and urban designers. Key job tasks in these roles typically revolve around submission management, decision support, design management, progress monitoring, collaboration management, training and education, risk assessment and management, and city planning. For women in these professions, specific challenges include limited career advancement opportunities, difficulties in maintaining work-life balance, gender bias and discrimination, and restricted access to professional networks. Technologies like Building Information Modeling (BIM), mobile applications, common data environments, data mining, 3D/4D modeling, digital twins, cloud computing, virtual/augmented reality, and the Internet of Things (IoT) have played a crucial role in mitigating these challenges and enhancing women's participation in the construction industry. While both women and men can benefit from these technologies, the benefits for women can play more important roles in their career development, which will increase women's competitiveness over men. A good example is, remote monitoring of the construction site provides convenience for both women and men, however for women has carer responsibility and can only work from home, this technology enabled them to take site management roles.

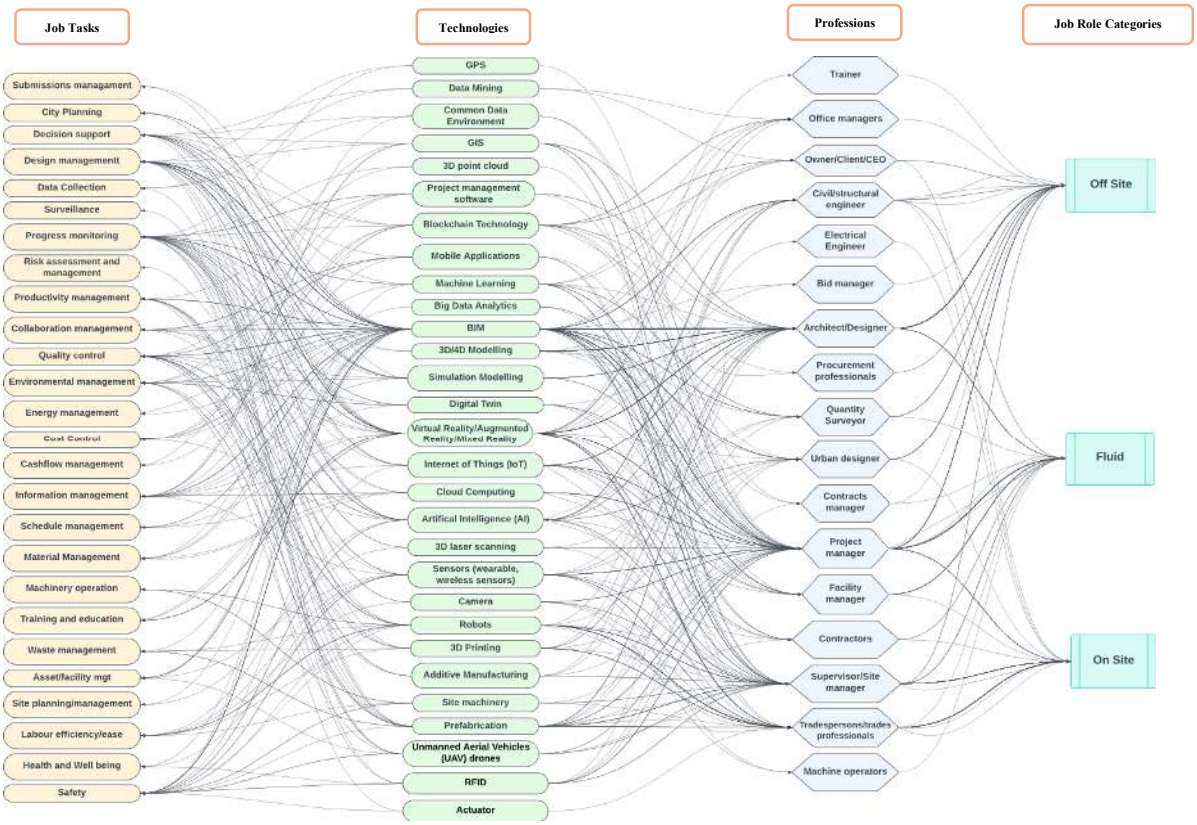

Figure 2 Mind Map of job roles, tasks and technology applications in the construction industry

Despite the prominence of technologies like BIM in facilitating comprehensive design and construction project management, allowing for better collaboration and communication among team members, overlooked technologies such as data mining and blockchain hold significant potential in reducing gender bias in the industry (Xiang and Hou, 2023). For instance, data mining can identify and rectify inequities in pay and workload distribution that disproportionately affect women, while blockchain can enhance transparency and fairness in performance evaluations and promotions. In fluid job roles, such as project management, construction 4.0 advancements enable remote monitoring and management, reducing the need for on-site presence and allowing professionals, including women, to balance work and family responsibilities more effectively (Agyekum et al., 2022). The literature concurs that the integration of technologies like BIM, Digital Twin, Cloud computing, Big Data Analytics, IoT, cameras, RFID, and sensors, enhances remote progress monitoring, cashflow management, and resource management, alleviating some of the challenges associated with traditional on-site project management. Where women had to be physically present on all construction sites to physically monitor progress and report on resource use and management, technologies have become an enabling tool to aid in work-life balance. Advancements such as digital twins, BIM and drones now allow comprehensive control of construction projects remotely. Digital twins offer real-time insights into performance and maintenance needs, while BIM facilitates detailed project management and collaboration from any location. However, on-site roles such as tradespersons, machine operators, contractors, and site managers remain less explored female professions in the literature due to their physically demanding nature. Women often face barriers related to physical strength requirements, safety concerns, and gender bias. Technologies like robotics can mitigate these barriers by facilitating the lifting and handling of materials, making these roles more accessible to women. By utilising robotics, construction sites can address the physical strength limitations that often deter women from participating in these roles. Safety and labour efficiency in on-site tasks have received significant attention, with technology serving as an enabling tool, particularly for women in the construction industry. While Building Information Modeling (BIM) has been extensively explored in off-site and fluid applications, its potential in on-site tasks remains under-utilised and warrants greater focus. For instance, BIM can be a powerful tool for ensuring site safety as revealed by Zhu et al. (2023). In addition to BIM, Virtual Reality (VR) can be employed to reduce injuries during the training of female labourers and tradespersons. Furthermore, wearable sensors have emerged as a vital technology for monitoring the safety and well-being of on-site workers. As Çınar (2019) revealed, women on construction sites often feel pressured to match up to their male counterparts. The use of wearable sensors can be particularly beneficial in such scenarios, as they can provide objective data on the physical strain and health conditions, thereby promoting a safer and more supportive work environment for women (Wang et al., 2022). Moreover, robotics have increasingly gained acceptance in the construction industry as a solution to physically demanding tasks on-site. While men may find it easier to lift heavy materials, this has been a significant barrier to the entry of women into the industry. By utilising robotics, construction sites can facilitate the lifting and handling of materials, mitigating the physical strength limitations that often deter women from participating in these roles. Despite the promising applications, much of the research on robotics in construction remains in the testing phase, with many robotic technologies still conceptual or purely experimental and not ready for commercialised use in the industry (Ali et al., 2022). Against this backdrop, this study proposes that highlighting the potential of robotics to increase women's participation in construction could drive further research and development in the field of robotics. Overall, while significant advancements have been made in off-site roles, more focus should be given to how technologies can increase the participation of women on-site to mitigate challenges such as discrimination, unsafe work environments, lack of training opportunities, and gender bias. Emphasising the potential of technologies to create a more inclusive and equitable construction industry is crucial for enhancing women's participation across all roles.

5. CONCLUSION

In conclusion, this study underscores the significant potential of these technologies to increase women's participation in the construction industry. Understanding the intersection of technology and

female participation within the industry could offer valuable insights for shaping future policies, educational programs, and organisational practices. In off-site roles, these technologies enhance transparency, rectify pay inequities, optimize tasks, and offer immersive training and flexible remote work options. For fluid roles such as facility and project management, BIM, sensors, drones, and cameras facilitate remote monitoring and management, overcoming traditional barriers to women's entry and progression in the industry. In on-site roles, safety concerns are mitigated through VR training, which allows women to engage in real-life simulations without physical risk. Additionally, the reliance on physical strength is reduced with the use of smart robots, although further research is needed to improve and commercialise these technologies on job sites. As the industry continues to embrace technology, it has the potential to become more inclusive and diverse, further empowering women and challenging traditional gender norms in the field.

The limitations of this study align with those commonly found in systematic literature reviews, such as the risk of selection bias and incomplete coverage of relevant studies. These limitations do not nullify the results or make them redundant but rather underscore the importance of consulting with field experts to ensure comprehensive and valid findings.

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7. REFERENCES

Agyekum, K., Amos-Abanyie, S., Kumah, V. M. A., Kukah, A. S. K. andSalgin, B. 2022. Obstacles to the career progression of professional female project managers (pfpms) in the ghanaian construction industry. *Engineering, Construction and Architectural Management,* 31**,** 200-226.

Ali, M. H., Kuralbay, Y., Aitmaganbet, A. andKamal, M. 2022. Design of a 6-dof robot manipulator for 3d printed construction. *Materials Today: Proceedings,* 49**,** 1462-1468.

Çınar, S. 2019. Construction labour, subcontracting and masculinity: "Construction is a man's job". *Construction Management and Economics,* 38**,** 275-290.

Manesh, S. N., Choi, J. O. andShrestha, P. Critical literature review on the diversity and inclusion of women and ethnic minorities in construction and civil engineering industry and education. Construction Research Congress 2020, 2020. American Society of Civil Engineers Reston, VA, 175-184.

Statsenko, L., Samaraweera, A., Bakhshi, J. andChileshe, N. 2023. Construction 4.0 technologies and applications: A systematic literature review of trends and potential areas for development. *Construction Innovation,* 23**,** 961-993.

Tahmasebinia, F., ME Sepasgozar, S., Shirowzhan, S., Niemela, M., Tripp, A., Nagabhyrava, S., Mansuri, k. k., Zuheen andAlonso-Marroquin, F. 2020. Criteria development for sustainable construction manufacturing in construction industry 4.0: Theoretical and laboratory investigations. *Construction Innovation,* 20**,** 379-400.

Wang, X., Veeramani, D. andZhu, Z. 2022. Wearable sensors-based hand gesture recognition for human–robot collaboration in construction. *IEEE Sensors Journal,* 23**,** 495-505.

Xiang, L. andHou, R. 2023. Research on innovation management of enterprise supply chain digital platform based on blockchain technology. *Sustainability,* 15**,** 10198.

Zhu, A., Dai, T., Xu, G., Pauwels, P., De Vries, B. andFang, M. 2023. Deep reinforcement learning for real-time assembly planning in robot-based prefabricated construction. *IEEE Transactions on Automation Science and Engineering,* 20**,** 1515-1526.