**Modelling the training strategies for reskilling UK construction workers in the fourth industrial revolution era: A structural equation model approach**

**Abstract**

**Purpose-** The UK construction industry is experiencing a significant skills shortage due to the advancements of the Fourth Industrial Revolution (4IR), leading to a high demand for reskilling. However, there is a lack of effective training frameworks for this purpose. This study aims to develop a framework to serve as a training strategy for reskilling construction professionals in the 4IR era, addressing the existing skills gap in the industry.

**Design/methodology/approach** – This study adopts random sampling in collecting data from stakeholders in the UK construction industry through the aid of a close-ended questionnaire. The data was subjected to principal component analysis (PCA) using SPVSS V24 and confirmatory factor analysis using AMOS Graphics V28 software. The PCA was used to group the training strategies extracted from literature into meaningful constructs which helped inform the development of the conceptual framework. Covariance-based structural equation modelling was then used to validate the framework, with model validation carried out using fit indices such as discriminant validity, SRMR, CFI, NFI, and others.

**Findings**- The model revealed that the key training strategies for reskilling construction workers in the 4IR era are immersive training, experiential learning, and collaborative workforce development. The findings indicate that immersive training, particularly through technologies like Virtual Reality (VR) and Augmented Reality (AR), plays a critical role in equipping workers with both the technical and soft skills required for the future of construction. The study recommends that 4IR-driven technologies should also be used as reskilling tools for construction workers, as this approach would allow them to learn while working.

**Originality/value-** Many studies have advocated for the reskilling of construction workers. However, there is a notable gap in research on the training strategies for effective reskilling of construction workers in the 4IR era. This paper provides a framework for stakeholders to implement effective reskilling strategies, thereby enhancing the industry's capability to thrive in the 4IR era.

**Keywords:** Construction workers; Experiential learning, Fourth Industrial Revolution (4IR), Immersive training; Reskilling;

**Paper type:** Research paper

1. **Introduction**

The construction sector serves as a significant contribution to the United Kingdom's (UK) economic growth and advancement (Osunsanmi et al., 2024a). In a year the UK construction industry holds the potential of contributing approximately £138 billion, representing 9% of the UK's GDP (Goubran, 2019). Abuzeinab et al. (2017) asserted that the UK construction industry is responsible for the country's infrastructure development. Oyedele et al. (2014) asserted that the UK construction industry can be considered one of the fastest-growing sectors, especially when compared to agriculture and manufacturing. Oti-Sarpong (2020) noted that the construction industry is the largest employer in the UK, offering jobs to approximately 30% of the population. According to Yu (2014), the UK construction industry comprises over 280,000 firms, employing more than two million people, which accounts for 10% of the total employment population in the UK. This industry also plays a vital role in employment opportunities and infrastructure development (Goubran, 2019). The above opinions suggest a correlation between national economic growth and the development of the construction industry.

The ability of the UK construction industry to contribute to economic growth is heavily dependent on the skills of its workforce (Maqbool et al., 2024). Likewise, Mohamed et al. (2017) opined that the expertise of construction workers is crucial to the success and development of the construction industry. Skilled laborers are the foundation of construction projects, facilitating the efficient and accurate completion of tasks that guarantee the structural integrity, safety, and quality of buildings and infrastructure (Shojaei et al., 2023, Mackenzie et al., 2000). Windapo (2016) affirmed that globally the construction industry thrives on the skills available at the disposal of its workers. Furthermore, Bowen et al. (2015) emphasized that construction workers' skills are vital resources, as they are essential for integrating other construction resources such as equipment and finance to achieve optimal returns on investment. Rasdorf et al. (2016) also highlighted that the skills possessed by construction workers are key assets for the industry's advancement.

Unfortunately, the UK construction industry advancement is hindered owing to the current skill shortage within the industry (Mohamed et al., 2017). Oti-Sarpong (2020) affirmed that the existing skill shortage is hindering the full contribution of the construction industry to the UK economy. This is because, unlike more advanced sectors, the construction industry heavily relies on labour to achieve productivity in terms of time, cost, and quality (Oti-Sarpong, 2020). Hamid et al. (2011) and Ghosh and Dickey (2024) attributed the shortage of skilled workers in the UK construction industry to the stricter immigration and border controls. McLeod and Milne (2016) affirmed that the UK leaving the EU poses a threat to the skill shortage within the UK construction industry. This aforementioned situation has led to a skill gap which is often referred to as the disparity between the required skills in the construction sector and those currently available. On a global scale, scholars like Adepoju et al. (2022) and Silwal and Safapour (2024) have discovered that there has been a wide skill gap within the construction industry since the rise of the fourth industrial revolution.

The rise of the fourth industrial revolution (4IR) became popular in the manufacturing industry and has been adopted in other industries including the construction industry (Osunsanmi et al., 2018, Oliveira et al., 2022). The core idea of 4IR is that emerging technologies will integrate digital, physical, and biological realms, enabling humans and machines to collaborate and improve efficiency and productivity (Wahab et al., 2021). This revolution ushered in the widespread adoption of cyber-physical systems, which are fundamental to this new era (Alhamoudi and Osunsanmi, 2024). Fatorachian and Kazemi (2021) opined that the adoption of cyber-physical systems means that there would be more machine involvement with traditional construction activities. Osunsanmi et al. (2020) and Siriwardhana and Moehler (2024) call the involvement of autonomous machines with construction activities as construction 4.0 which requires a high level of digitalization and automation of construction activities. Adepoju and Aigbavboa (2021) emphasised that the automation of construction activities creates the need for re-skilling and upskilling construction workers to align with the 4IR era.

 Chookaew and Howimanporn (2022) stated that reskilling involves acquiring entirely new skills while upskilling focuses on enhancing existing skills to improve one's current situation. To meet the requirements of the Fourth Industrial Revolution (4IR), a substantial number of construction workers will need both reskilling and upskilling, necessitating improvements in the educational system (Atiku and Boateng, 2020). Li (2022) emphasized the importance of reskilling for construction workers to effectively use the innovative technologies emerging in the 4IR era. Similarly, Shojaei et al. (2023) highlighted that upskilling is vital for construction workers to adapt to the changing job landscape brought about by the 4IR. Adepoju and Aigbavboa (2021) warned that construction workers who fail to upgrade their skills to match the advancements and digitalization of the 4IR era risk facing unemployment in the future.

Towards reducing the risk of construction workers’ unemployment in the 4IR era numerous research has been conducted focused on their skilling and re-skilling. Li (2022) conducted a study focused on identifying the skills needed by construction workers in the 4IR era. Wahab et al. (2021) conducted research identifying the reskilling requirements for logistics and supply chains. Chakma and Chaijinda (2020) and Sohimi et al. (2019) highlighted the importance for firms to develop a reskilling plan for their workforce. Muchiri (2022) focused on the benefits emanating from reskilling and upskilling workers within an organisation. Studies that focus exclusively on the construction industry (Siriwardhana and Moehler, 2024, Souza and Debs, 2023, Adepoju et al., 2022, Adepoju and Aigbavboa, 2021, Silwal and Safapour, 2024) identified the skills needed for construction workers to function effectively in the 4IR era. It can be deduced from the aforementioned studies that the direction of research regarding the reskilling of construction professionals can be broken into two directions. The first direction is focused on identifying the skills needed for construction professionals in the 4IR era. The second direction is aimed at revealing the benefit of reskilling construction workers in the 4IR era.

Despite all the studies identifying the skills needed for construction workers, the industry still experiences a skill gap in the 4IR era. The situation is severe in the UK owing to the advancement of technologies driven by the 4IR. This study attributes the problem to the absence of a teaching or training strategy framework aimed at providing the blueprint for re-skilling construction workers. Earlier on Aliu et al. (2023) and Caires and Almeida (2005) affirmed that the training strategy adopted by an instructor or teacher has an impact on the learning outcomes. Unfortunately, there is a gap in practice and research for an effective framework utilised as a training strategy for reskilling construction professionals. Thus, this study is aimed at developing a framework to be adopted as a training strategy for reskilling construction professionals in the 4IR era. The objectives of the study will include appraising the components for developing the framework. The second objective is focused on validating the framework using a structural equation model to assess the impact of the training strategy on developing 4IR-ready construction skills. The findings emanating from this study would contribute to practice and research through the provision of an effective training strategy capable of providing construction workers with the skills needed to function effectively in the 4IR era.

**2. Skill gap among construction workers in the UK**

The construction sector is a significant contributor to the UK's economic growth through employment and infrastructure provision (Osunsanmi et al., 2024a). The successful contribution of the construction sector is heavily dependent on skilled labour to complete and manage construction projects (Abdel‐Wahab et al., 2008). Unfortunately, recent research highlights that substantial skill shortages are hindering the sector's contribution to economic growth (Kotera et al., 2020, Maqbool et al., 2024). The skill shortage has led to a huge skill gap which refers to the difference between the skills that employers need and the skills that the workforce possesses (Siriwardhana and Moehler, 2024). Mohamed et al. (2017) opined that owing to the sector's dependence on workers the skill gap affects client requirements concerning project cost, time, and quality. The review of (Ejohwomu et al., 2006, Chan and Dainty, 2007) revealed that there are different factors responsible for the skill gap in the UK. Chan and Dainty (2007) identified the departure of the UK from the EU as a significant factor responsible for the skill gap. The departure complicates the recruitment and retention of skilled workers from the European Union, who comprise 6.70% (142,502) of the total workforce in the UK's construction sector (Mohamed et al., 2017). This looming threat of reduced labour mobility, combined with a severe shortage of skilled native-born workers, is already impacting the productivity of the UK construction industry (McLeod and Milne, 2016).

 Malik et al. (2019) opined that the UK construction industry witnessed a sharp decline in productivity post-Brexit. Ghosh and Dickey (2024) and Mohamed et al. (2017) attributed the decline of the construction industry’s productivity to the skill gap post-Brexit. Ejohwomu et al. (2006) avowed that skills gaps like masons, quantity surveying and engineers were difficult to fill during this period. Furthermore Green (2016) affirmed that the UK's withdrawal from the European Union led to a severe skill gap for both skilled and unskilled workers in the construction sector. The skill gap was exacerbated by limited access to offshore skilled labour amidst historically unstable economic conditions and shifting labour demands (Fitzpatrick and Pawson, 2016). Chan and Dainty (2007) related the skill gap in the UK construction industry to the disconnection between policy decisions aimed at improving construction skills and the actual impact these decisions are having on skills provision.

 Maqbool et al. (2024) reported that the skill provisions among UK construction workers declined after the rise of technology adoption within the construction industry. Wusu et al. (2024) and Almatari et al. (2024) reported that the rise of technologies like machine learning and artificial intelligence (AI) further contributed to the skill gap within the industry. This is because machine learning and AI change the performance dynamics among construction workers (Almatari et al., 2024). Mansuri and Patel (2022) discovered that construction workers adopting AI for visual inspection perform better and faster than conventional inspection methods. The performance experienced from the adoption of AI further widens the skill gap among those who use the traditional method (Silwal and Safapour, 2024). George et al. (2021) asserted that the wide skill gap is responsible for high construction costs within the UK construction industry. Similarly, Mackenzie et al. (2000) avowed that the skill gap is responsible for the labour crisis experienced in the construction industry. Oti-Sarpong (2020) discovered that the labour crisis has led to construction firms engaging in the practice of poaching highly skilled workers from one another. This trend has resulted in higher construction costs, which in turn causes significant fluctuations in construction output. Maqbool et al. (2024) revealed that poaching is focused on technologically savvy workers who possess an understanding of the technologies driven by the fourth industrial revolution. Thus, to mitigate the skills gap in the UK construction sector, especially in the era of the fourth industrial revolution, it is essential to identify the skills needed in the current era.

*2.1 Essential Construction Skills in the 4ir era*

The fourth industrial revolution (4IR) also known as Industry 4.0 originated from the manufacturing industry aimed at ensuring autonomous manufacturing of goods (Almatari et al., 2024). Lekan et al. (2021) reported that Industry 4.0 enhanced the seamless automation of the manufacturing sector through the incorporation of embedded sensors in product components. The application and research of 4IR in the construction industry could be traced to the works of (Osunsanmi et al., 2022b, Osunsanmi et al., 2018, Adepoju et al., 2022). Its application for the construction industry is often referred to as construction 4.0 which marks the advent of the cyber-physical system for construction activities (Silwal and Safapour, 2024). The adoption of 4IR principles and technologies has recorded numerous advantages for the construction industry ranging from sustainable housing delivery (Alhamoudi and Osunsanmi, 2024), supply chain resilience(Osunsanmi et al., 2022b), sustainability (Lekan et al., 2021) and many others. Thus, it can be implied that the application of 4IR technologies poses numerous advantages for the construction industry.

Unfortunately, the construction industry has not fully tapped into the advantages provided by the technologies driven by the 4IR (Adepoju et al., 2022). Silwal and Safapour (2024) related the failure of the full adoption of 4IR technologies for the construction industry to the huge skill gap within the industry. Also, Siriwardhana and Moehler (2024) indicated that the efficient utilization of the 4IR technologies requires the reskilling of construction workers. This is because the application of the 4IR began the advancement of modern technology which requires new skills, particularly digital skills (Adami et al., 2021). Aside from digital skills Oliveira et al. (2022) argued that 4IR applications also require improved teamwork, critical thinking, communication, and leadership abilities. Consequently, skills in this era are categorized into two main types: hard and soft skills (Adepoju et al., 2022, Li, 2022). Hard skills encompass computer programming, information processing, software design and knowledge, smart construction site management, simulation tools, and virtualization. In contrast, soft skills include teamwork, critical thinking, communication, and leadership.

Insert Table 1 here

Table 1 presents the essential skill and their importance for construction stakeholders in the 4IR era. A critical analysis of the table it can be deduced that the skills can be divided into technical and soft skills. Technical skills which are also often referred to as hard skills require a form of formal training to acquire (Loveder, 2017). Whereas, soft skills are often acquired through an informal training activity (Mackenzie et al., 2000, Adepoju et al., 2022). Goel et al. (2024) affirmed that soft and hard skills are intertwined as an individual cannot function effectively without the other. For instance, Shojaei et al. (2023) and Rosario and Reyes (2022) argued that emotional intelligence and agile project management (soft skills) are needed to effectively implement technical skills like BIM, blockchain and others. It can be deduced from the literature (Wahab et al., 2021, Chan and Dainty, 2007, Germain, 2020) that the major problem is establishing a strategy to effectively re-skill construction stakeholders in acquiring both soft and hard skills. Likewise, Li (2022) affirmed that there is a need to establish a strategy for re-skilling due to the frequent change of skills needed in the 4IR era.

***2.2 Training strategies for reskilling construction stakeholders***

Abbasnejad et al. (2024) opined that strategy encompasses the developmental plan adopted by an organization to overcome its challenges and adapt to changes in the environment. Feng et al. (2024) and Parameswaran and Ranadewa (2024) opined that the concept of strategy can be traced to the military conflict management schemes which believe that the war outcome is dependent on a nation with an effective strategy. This is because effective strategies are crafted to navigate unforeseen obstacles (Teece et al., 2020). Baylis et al. (2022) gave a pragmatic definition of strategy and described it as making plans and decisions that enable an organization or sector to achieve long-term goals and address potential challenges that could hinder productivity. On the other hand, Tien (2020) avowed that the term strategy is closely linked with innovation, achievement, ambition, determination, and inspirational leadership. This study identifies strategies as the group of processes and activities responsible for re-skilling and upskilling construction stakeholders in the 4IR era. The re-skilling strategy proposed in this study was done following the recommendations of (Abbasnejad et al., 2024, Feng et al., 2024) regarding the key component of an effective strategy. Feng et al. (2024) believes that the first step in picking an effective strategy is the identification of the problem. In this study, the major problem is the skill gap within the construction industry coupled with the frequent change in skills required by construction stakeholders in the 4IR era.

After identifying the problem (skill gap) Parameswaran and Ranadewa (2024) recommend that the second step in developing a strategy is the review of past policies or practices to establish a suitable strategy. The literature of see (Shojaei et al., 2023, Rosario and Reyes, 2022, Ishar et al., 2020, Gledson et al., 2016, Goel et al., 2024) has established numerous strategies for training workers. Unfortunately, some of them were not developed for construction stakeholders. Also, the few (Gledson et al., 2016, Shojaei et al., 2023) studies which focused on establishing strategies for training construction workers only focused on a particular activity. For instance, Shojaei et al. (2023) recommended a growing together strategy for reskilling construction professionals on the use of BIM. The strategy emphasises the need for construction firms to have an in-house approach to training and developing their employees' skills.

Insert Table 2 here

Table 2 presents the re-skilling strategies adopted by construction firms and organizations. Gledson et al. (2016) and Rosario and Reyes (2022) opined that construction companies can adopt a multifaceted approach to reskilling their professionals. This can include internal training programs, where the organization provides in-house skill development opportunities for their employees. Additionally, the growing together approach, which involves collaborative learning between the company and its workers, can be an effective strategy (Shojaei et al., 2023). Research has shown the potential of incorporating advanced technologies, such as virtual reality (VR), into training programs. A study by Adami et al. (2021) and Wang et al. (2018) demonstrated the effectiveness of using both VR-based and in-person methods to train construction workers on operating a demolition robot. Goel et al. (2024) recommended the use of artificial intelligence (AI) as a teaching assistant for adult education. Another form of reskilling strategies adopted by organizations includes gamification (using games to re-skill workers), workshops, Hackathons and mentorship programs (Vapiwala and Pandita, 2022, Chookaew and Howimanporn, 2022, Ajayi and Udeh, 2024). Vapiwala and Pandita (2022) revealed that gamification is a powerful tool for enhancing the upskilling and reskilling of workers which involves the creation of game-based learning activities to help professionals develop critical thinking and problem-solving abilities. Hackathons are developed by creating competitive and reward-based nature games that worker motivation and foster a culture of continuous improvement within the organization (Granados and Pareja-Eastaway, 2019).

**3 Research Methods**

The construction industry in the United Kingdom (UK) plays a vital role in the economy by developing infrastructure and creating employment opportunities for the nation's workforce (Osunsanmi et al., 2024a). Maqbool et al. (2024) emphasized that the skills of construction professionals are essential for the industry's success and growth. Skilled labourers are fundamental to construction projects, ensuring the efficient and accurate execution of tasks that uphold the structural integrity, safety, and quality of buildings and infrastructure (Ejohwomu et al., 2006, George et al., 2021). Unfortunately, the progress of the UK construction sector is currently impeded by a significant skill shortage (Mohamed et al., 2017). The shortage has been linked to various factors, with the rise of the Fourth Industrial Revolution (4IR) being particularly influential (Silwal and Safapour, 2024). Adepoju et al. (2022) indicated that integrating 4IR technologies into the construction industry necessitates re-skilling and upskilling workers to meet the demands of this new era. Although studies (Silwal and Safapour, 2024, Souza and Debs, 2023, Wahab et al., 2021) have identified the skills required for construction stakeholders in the 4IR era, a significant skill gap remains due to the lack of a comprehensive model or framework for re-skilling strategies. Therefore, this study aims to develop a framework revealing the training strategies for re-skilling for construction stakeholders in the 4IR era.

The research study began by extensively reviewing existing literature to identify the training strategies for reskilling and the skills needed by construction professionals in the 4IR era. These factors were then used to develop the questionnaire that was distributed to the study participants. The respondents, comprising construction stakeholders and professionals within the UK were selected using a random sampling method. This sampling method is known to offer several advantages, such as enabling the calculation of sampling errors, facilitating the selection of credible respondents, and allowing for the generalization of the findings to the broader population (Abdullahi et al., 2022, Dieronitou, 2014). The random sampling technique employed in this study helps to ensure the reliability and validity of the data collected. By randomly selecting participants from the target population, the researchers can minimize the potential for bias and increase the representativeness of the sample (Noor et al., 2022). The bias was eliminated through careful definition of the entire population and preventing external factors from influencing the selection process. This, in turn, enhances the ability to draw meaningful conclusions and extrapolate the results to the wider construction industry. The use of this well-established sampling approach aligns with the study's objective to gain a comprehensive understanding of the training strategies needed for reskilling construction stakeholders.

Through using Cochran's formula 215 respondents were randomly selected ensuring a 90% confidence level and a 0.5% margin of error. The sample was drawn from a list of registered construction firms in Scotland, United Kingdom. The population size was validated by comparing it with the findings of similar studies conducted in the UK (Osunsanmi et al., 2024a, Maqbool et al., 2024). Out of the 215 selected participants, 194 completed the questionnaire accurately, and their responses were thoroughly analyzed. The data collection was carried out using Google Forms over several weeks, from March to mid-April 2024. To assess the reliability of the collected data, the researchers calculated Cronbach's Alpha, which resulted in a value of 0.862, exceeding the acceptable threshold of 0.70 as recommended by (Bujang et al., 2018). This high Cronbach's Alpha score suggests that the researchers have followed robust methodological practices to ensure the validity and reliability of the data collected for this study.

This study adopted a survey instrument instead of interviews or case studies because a survey will enable this study to reach a larger number of participants in a shorter period (Osunsanmi et al., 2022a). Creswell and Hirose (2019) opined that the adoption of surveys facilitates the collection of quantitative data, which can be statistically analyzed to identify correlations, and patterns, providing a more objective basis for conclusions. The adoption of a survey also provides the opportunity for this study to validate the framework emanating from this study. The study’s survey questionnaire was structured into three sections. The first section collected respondents’ personal information, including their educational background, profession, affiliation, and work experience. Analysis revealed that all respondents were educated, and with diverse qualifications. A majority (64%) held a BSc/BTech degree, 28% had a master’s degree, and 8% possessed a PhD. Over half (56%) were construction project managers, making their responses highly relevant to the study’s goals. The remaining respondents included quantity surveyors, builders and architects. The majority of the respondents in this study, 72%, are affiliated with the Royal Institution of Chartered Surveyors (RICS), a prominent professional organization that regulates, monitors, and provides training for construction stakeholders in the United Kingdom. Given RICS's influential role in the industry, the input from these respondents is considered particularly valuable for this study. In addition to the RICS-affiliated respondents, the sample also includes participants who are members of other professional bodies, such as the Chartered Institute of Building (CIOB) and the Engineering Construction Industry Association. The diverse affiliations of the respondents help to ensure that the study captures a comprehensive range of perspectives from various construction industry stakeholders.

The second section of the questionnaire assessed respondents' agreement with the training strategies for re-skilling construction stakeholders in the 4IR era. The final section focused on the skills needed to function in the 4IR era. A structural equation modelling (SEM) approach was employed for this purpose. According to Nasrabadi and Hataminejad (2019), SEM originated from the medical field to study the complex relationships of bones. However, a review of existing literature shows that the application of SEM has since expanded beyond science to other areas such as manufacturing, agriculture, education, and construction project management. Recent studies by Aliu and Aigbavboa (2020) and Osunsanmi et al. (2024a) have applied SEM to explore complex relationships within the real estate industry.

Insert Figure 1 here.

The research methodology framework is presented in Figure 1 and it presents the steps embarked upon in this study for conducting the SEM. After conducting a systematic review of the literature to identify the training strategies needed to re-skill construction stakeholders. The next step entails breaking them down into meaningful constructs. Exploratory Factor Analysis (EFA) with varimax rotation was utilized to pinpoint these constructs, as recommended by Jolliffe and Cadima (2016) for creating meaningful constructs from correlated variables. The EFA was performed using the Statistical Package for the Social Sciences (SPSS V26). Prior to analysis, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett’s test of sphericity were employed to validate the data. The EFA results were then used to develop a structural equation model. The Covariance-Based Structural Equation Modeling (CB-SEM) approach was selected, as it is well-suited for social science research, non-experimental studies, and mitigating excessive multicollinearity, according to (Osunsanmi et al., 2024b). The next step as shown in Figure 1 entails conducting a confirmatory factor analysis (CFA) to validate the accuracy of the variables within each construct. This analysis was performed using Amos Graphics version 29, along with tests for discriminant validity, composite reliability (CR), and average variance explained (AVE). AMOS was used because it is designed for CB-SEM, which is ideal for theory testing and confirming hypotheses about the relationships between variables. Also, AMOS was chosen over PLS-SEM because the latter is suitable for predicting the explained variance of the dependent variables (Jolliffe and Cadima, 2016). The CFA followed the guidelines of Hair et al. (2017) and Lowry and Gaskin (2014) who recommend that variable loadings within a component should be 0.70 or higher for the best-fit model. Discriminant validity was assessed using the Fornell-Larcker criterion, with CR values between 0.70 and 0.95, and AVE exceeding 0.5. A bootstrapping function on Amos was used to validate the hypothesis concerning the effectiveness of the training strategies on the skills acquired by construction stakeholders in the 4IR era.

**4 Results and Discussion**

*4.1 Training strategies for construction stakeholders in the 4IR era*

The results and discussions emanating from the exploratory factor analysis regarding the training strategies for construction stakeholders in the 4IR era were presented in this section. Principal Component Analysis (PCA) was used to categorise the training strategies into meaningful constructs (components). The method (PCA) used in this study is grounded in past studies (Osunsanmi et al., 2024b, Aliu et al., 2023) that have adopted EFA to develop meaningful constructs from variables extracted from literature. In this study, nineteen (19) variables related to the training strategies for construction stakeholders were extracted from the literature.

The extracted variables were subjected to a varimax rotation method to ensure a better separation among the variables into a meaningful dimension. Prior to conducting the rotation a test was conducted to determine the data's suitability for PCA. To determine the data's suitability for PCA, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were used. The KMO value was 0.747, exceeding the recommended threshold of 0.5 as suggested by (Aliu et al., 2023). Bartlett's test of sphericity was significant at both 99% and 95% confidence levels, yielding a chi-square value of 4276.160 with 2492 degrees of freedom. This confirms the data's suitability for PCA, in line with recommendations from Ong and Puteh (2017) and Aliu et al. (2023).

Table 3 presents the results of the rotated component matrix analysis, showcasing the loadings and dimensions of the variables identified through the literature review. Prior to this analysis, the Kaiser criterion was applied to determine the number of components to extract from the variables. This criterion, as suggested by Ong and Puteh (2017) identifies components with eigenvalues greater than 1 as significant. The analysis revealed that only three components met this criterion, leading to their selection for the rotated component analysis using the varimax method. Table 3 outlines the loadings of each variable within the three components, along with their corresponding variance. The variables within each component are arranged in descending order based on their loadings. The components were named based on the variables with the highest loadings, following the approach recommended by Ong and Puteh (2017), Aliu et al. (2023) and Osunsanmi et al. (2024b). This naming convention emphasizes the variables with the strongest influence within each component, providing a clear interpretation of the underlying factors identified through the analysis.

Insert Table 3 here

**Component 1: Immersive training**

The initial construct (component) identified through exploratory factor analysis accounts for a variance of 33.4%, indicating that it explains 33% of the variations in the training strategies for re-skilling construction stakeholders in the 4IR era. This component consists of six variables, with the most prominent being simulation-based learning, followed by adopting virtual reality, gamification, workshops, adopting AI, hackathons and traditional educational systems. Table 3 shows that these variables are closely related, with loadings ranging from 0.872 to 0.520. As suggested by Aliu et al. (2023), the naming of a component should reflect the variables with the highest loadings. Accordingly, this component was labelled "Immersive training" based on its constituent variables.

This study describes an immersive training strategy as a reskilling experience that aims to fully engage construction stakeholders through the creation of a realistic and interactive environment. Adami et al. (2021) also discovered that adopting immersive technologies like virtual reality for training professionals provides the opportunity for extending the training beyond traditional classroom settings or online courses to create a more engaging and impactful learning experience. The use of virtual reality is a growing trend within the construction industry in the 4IR era. Studies such as see (Wang et al., 2018, Ahmed, 2018) have used virtual reality to provide immersive training for professionals within the construction industry. However, immersive training extends beyond virtual reality as it also includes the use of games (gamification) (Vapiwala and Pandita, 2022) workshops(Ahmed, 2018) and hackathons (Oliveira et al., 2022) for reskilling professionals.

**Component 2: Experiential learning**

 The second component, as illustrated in Table 3, accounts for 24.4% of the variance in the training strategies for re-skilling construction stakeholders in the 4IR era. This component encompasses six variables, with the strongest loadings associated with project-based learning, onsite training, mentorship programs, industry-led training programs, incorporating case studies, quality circles and in-house. The variables are closely related with loadings ranging from 0.781 to 0.510. Given the significant influence of variables with high loadings such as project-based learning = 0.854 and onsite training = 0.784, this component was labelled "Experiential learning." This study describes a training strategy for reskilling construction stakeholders which requires learning by doing as experiential learning.

 Vass and Kiss (2022) discovered that project-based learning provides the opportunity for students to have a hands-on approach to industry problems. Also, Assaad et al. (2022) emphasized that onsite training provides construction professionals with the needed expertise to tackle trending industry problems. Alhamoudi and Osunsanmi (2024) opined that stakeholders require sufficient expertise in adopting the technologies driven by the 4IR for sustainable housing delivery. Thus, this makes experiential learning a crucial training strategy for reskilling construction stakeholders in the 4IR era. Another crucial form for acquiring experiential learning is through the establishment of mentorship programs (Germain, 2020, Asadu and Onyegiri, 2011). Asadu and Onyegiri (2011) believe that mentorship programs provide the opportunity for mentees to leverage the experience of their mentors for upskilling and reskilling.

**Component 3: Collaborative Workforce Development**

The third component, identified through the varimax rotation method, explains 12.4% of the variance in training strategies for re-skilling and up-skilling construction stakeholders in the 4IR era as shown in Table 3. This indicates that the third component contributes significantly to the overall understanding of these training strategies. This component comprises five variables with the topmost being industry and academic collaboration to create a training strategy. Other variables in order of hierarchy are graduate apprenticeships, growing together, accredited certificate programs and tailored training programmes. The variables are closely related with loadings ranging from 0.764 to 0.547. Based on the prominence of these variables, this component was labelled "Collaborative workforce development" highlighting the importance of a collaboration between the industry and academic community for re-skilling construction stakeholders.

 Shojaei et al. (2023) emphasised that a collaborative form of reskilling is crucial for growing the skills of construction workers. The scholar recommended the concept of growing together which includes a collaborative arrangement amongst construction firms for reskilling regarding the adoption of BIM. On the other hand, Markowitsch and Hefler (2019) and Loveder (2017) made a case for graduate apprenticeships as a tool for a collaborative workforce development training strategy. Loveder (2017) discovered that graduate apprenticeships can significantly enhance the skills of construction workers by combining academic learning with practical and on-the-job experience. This leads to a synergy or collaboration between industry and academic learning activities. Markowitsch and Hefler (2019) affirmed that graduate apprenticeship can take numerous form which includes specialised training, integrated training and professional development. Whatever the form adopted graduate apprenticeship ensures a collaborative workforce development which is essential for re-skilling construction professionals in the 4IR era.

*4.2 Impact of training strategies on developing 4IR-ready construction skills*

 The second research objective aimed to investigate the impact of reskilling training strategies on the skills needed by construction stakeholders in the 4IR era. To achieve this, structural equation modelling (SEM) was employed, as depicted in Figure 2. Prior exploratory factor analysis identified three primary training strategies for reskilling construction stakeholders in the 4IR era which are: immersive training, experiential learning and collaborative workforce development. Figure 2 presents a conceptual framework that posits a significant relationship between these training strategies and the skills needed by construction stakeholders in the 4IR era. Following established SEM procedures (Mustafa et al., 2020, Afthanorhan et al., 2014), the initial step involved conducting a confirmatory factor analysis using AMOS software.

Insert Figure 2 here

*4.2.1 Confirmatory factor analysis*

Building upon the exploratory factor analysis (EFA) that identified key training strategies for reskilling construction stakeholders in the 4IR era, a confirmatory factor analysis (CFA) was conducted using AMOS software with the outcome presented in Figure 3. The CFA aimed to validate the alignment of the measured constructs with their theoretical definitions. AMOS was selected for its ability to assess the goodness of fit between the collected data and the proposed model. The model development process adhered to established guidelines by Oke and Ogunsemi (2016) and Mustafa et al. (2020), which recommend variable loadings exceeding 0.6 and an average variance explained greater than 0.5.

Insert Table 4 here

Table 4 presents the results of the confirmatory factor analysis, outlining the loadings for each variable within the identified constructs, along with composite reliability (CR) and average variance extracted (AVE). To achieve optimal model fit, the analysis was iteratively refined, leading to the removal of certain variables from each construct. For instance, variables related to experiential learning (EL5, EL6 and EL7) were excluded due to loadings below the recommended threshold of 0.6. Conversely, variables such as EL1(Project-based learning), EL2 (Onsite training), EL3 (Mentorship programs), and EL4 (industry-led training programs) were retained as they represent key factors for determining experiential learning. Other variables that did not meet the threshold were also eliminated for other constructs (immersive training, collaborative workforce development and construction skills in the 4IR era). The CFA confirmed that the training strategies would ensure that construction stakeholders acquire the necessary skills to function effectively in the 4IR era. The skills include CS1(proficiency in BIM software), CS7 (Emotional intelligence), CS8(Cybersecurity), CS9(Agile project management principles), CS10 (Advanced materials), CS11(Extended reality) and CS13(Blockchain management).

Insert Table 5 here

Table 5 presents the results of the discriminant validity analysis, which was conducted to ensure that the measures accurately reflect the distinct nature of each construct. Discriminant validity was assessed using the Fornell-Larcker criterion. According to established guidelines (Lowry and Gaskin, 2014), discriminant validity is confirmed when the highest correlation for each construct along the diagonal is greater than all other correlations in the table. Additionally, it is considered valid if the square root of the Average Variance Extracted (AVE) for each construct exceeds the inter-construct correlations (Hair et al., 2017). In Table 5, the highest correlation for each construct is highlighted in bold. A careful examination of Table 5 reveals that these bolded correlations are higher than the other correlations, indicating that the variables used to measure the four constructs in this study are both adequate and discriminately valid.

Insert Figure 3 here

To evaluate the structural model, various fit indices were examined, following established guidelines (Lowry and Gaskin, 2014, Oke and Ogunsemi, 2016, Osunsanmi et al., 2024b). These indices include the standardized root mean square residual (SRMR), comparative fit index (CFI), Tucker-Lewis index (TLI), and others, as presented in Table 6. The table also outlines the recommended thresholds for each fit index to determine the model's validity. A review of Table 6 indicates that all fit indices fall within the suggested thresholds. According to established criteria (Oke and Ogunsemi, 2016, Hair et al., 2017), the SRMR should range between 0.05 and 0.07. The SRMR value in Table 6 suggests that the model is appropriate for identifying the impact of training strategies for developing 4IR-ready construction skills. Further validation was conducted by examining other fit indices, including TLI, CFI, RMSEA, NFI, and IFI. As shown in Table 6, the values from these indices confirm the structural validity of the model.

Insert Table 6 here

*4.2.2 Hypothesis testing*

This section examines the structural relationships within the model to test the hypotheses proposed in this study. The study hypothesized that training strategies such as experiential learning, immersive training and collaborative workforce development would enhance the skills needed for construction professionals to function effectively in the 4IR era. Figure 4 visually depicts the hypotheses tested in this study. As indicated in AMOS software (Mustafa et al., 2020) arrows represent path coefficients between two constructs, illustrating their relationships. The construct that the arrows point to is known as the endogenous, explained, or dependent variable. Therefore, Figure 4 suggests that the dependent variable is construction skills in the 4IR era, while the independent variables are the three training strategies: experiential learning, collaborative workforce development and immersive training.

 Insert Figure 4 here.

Figure 4 presents the standardized path coefficients for each construct, with their corresponding estimates detailed in Table 7. Based on these findings, it can be concluded that the training strategies for reskilling construction stakeholders have a significant positive impact on their skills acquisition as indicated by a critical ratio (CR) value exceeding 1.96. Amongst the training strategies, immersive training has the highest impact on reskilling construction stakeholders in the 4IR era. Immersive training in this study is described as a reskilling experience that aims to fully engage construction stakeholders through the creation of a realistic and interactive environment. The adoption of virtual reality is the predominant form of immersive training strategy used for reskilling construction stakeholders (Wang et al., 2018, Ahmed, 2018).

Insert Table 7 here

Figure 4 reveals that adopting an experiential learning training strategy accounts for 24% of reskilling construction stakeholders in the 4IR era. This implies that strategies such as project-based learning, onsite training, mentorship programs and industry-led training programs have a 24% probability of reskilling construction stakeholders in acquiring the skills needed to function effectively in the 4IR era. Whereas collaborative workforce development training has a 16% chance of enhancing the construction skills in the 4IR era. Past studies like Loveder (2017), Markowitsch and Hefler (2019) and Shojaei et al. (2023) have adopted a form of collaborative workforce development for reskilling construction stakeholders. The model confirmed that the training strategies discovered in this study would enable construction stakeholders to acquire soft and hard skills simultaneously. Adepoju and Aigbavboa (2021) and Maqbool et al. (2024) discovered that hard and soft skills are needed by construction stakeholders to function effectively in the 4IR era.

**5. Implication of the Model to Practice, Society, and Research**

The model developed in this study offers enormous implications and contributions for both research, society and practice, for addressing the skills gap in the UK construction industry exacerbated by the Fourth Industrial Revolution (4IR). Amongst the implications of the model to practice is the call for a paradigm shift in training construction workers. The model recommends that the training and skill acquisition of construction workers should go beyond rote memorization. Instead, the skill acquisition for construction workers should be structured in a pattern that supports practical and experiential learning. Towards achieving this the model proposed the incorporation of immersive training techniques, such as VR and AR, that align with contemporary educational trends which prioritize engagement, and interactive learning experiences.

The model recommends that the practice of reskilling construction workers should prioritize experiential learning, to ensure that training is grounded in practical, real-world applications. This approach not only enhances the relevance of the training but also facilitates the immediate transfer of skills to job tasks, addressing the urgent need for a workforce that can adapt quickly to new technologies. Finally, the model contributes to practice by emphasizing collaborative workforce development, highlighting the necessity of partnerships among construction firms, educational institutions, and government agencies. This collaborative approach can lead to tailored training programs that meet the specific needs of the industry, fostering a more effective and cohesive training ecosystem. Based on the model’s contribution to practice it influences society through informing policies on vocational training and employment.

The model contributes to research by filling the gaps that exist in past models such as ADDIE, Kirkpatrick and the European mainboard model of reskilling **(Muruganantham, 2015, Nadiyah and Faaizah, 2015, Cahapay, 2021). The ADDIE model provides a structured framework for instructional design, focusing on analysis, design, development, implementation, and evaluation. While it is effective in creating systematic training programs, it may not emphasize the integration of technology and collaborative development as strongly as the model from this study. On the other hand,** the Kirkpatrick Model focuses on evaluating training effectiveness across multiple levels, it does not inherently provide a framework for designing training strategies.

**6. Conclusion and Recommendation**

The UK construction industry stands at a pivotal juncture as it confronts the profound implications of the Fourth Industrial Revolution (4IR). The rapid pace of technological advancement from automation and artificial intelligence to advanced materials and digital tools has rendered traditional skills increasingly obsolete. Consequently, the critical skills shortage that plagues the sector is a clarion call for immediate and strategic action to reskill the workforce. The urgent need for reskilling in the UK construction industry amid the 4IR presents a challenge for stakeholders within the construction industry. The challenge emanates from the absence of a framework for an effective framework to be utilised as a training strategy for reskilling construction professionals.

This study developed the training strategy framework, grounded in a structural equation model approach. The framework offers a beacon of hope in bridging the skills gap that threatens to stifle the industry's growth and competitiveness. By employing a structural equation model, this study has not only identified the significant skills gap but has also developed a robust framework that underscores the essential components of successful training strategies. The findings reveal that immersive training, experiential learning, and collaborative workforce development are the three blocks of this framework, each playing a vital role in equipping workers for the demands of a rapidly evolving industry.

By incorporating the three blocks, the training framework will provide a well-rounded and effective reskilling training strategy. The implementation of the framework will ensure that construction professionals actively engage with the re-skilling content, gain practical experience, and develop their collaborative abilities, ultimately leading to a more skilled and adaptable workforce. The framework calls for a holistic approach towards reskilling which ensures that training programs produce skilled construction professionals who can contribute meaningfully to their fields.

Despite the holistic approach of the reskilling framework, its long-term success hinges on the commitment and involvement of various stakeholders. For instance, policymakers play a crucial role in creating an enabling environment that supports the implementation of these training strategies. Also, educational institutions can better prepare construction students for the realities of the workforce by integrating emerging technologies and industry practices into their curricula. Lastly, Industry leaders, too, must take an active role in cultivating a culture of continuous learning within their organizations. This involves not only investing in ongoing training and professional development for existing employees but also fostering an environment where learning is valued and encouraged.

Finally, the model contributed to practices as it stipulated that the reskilling of construction workers in the 4IR era should be done in a way that workers learn by experiment and practice. Regardless of the contribution of the model emanating from this study to practice and research, it has its limitations which is recommended as an area of further research. For instance, the model developed in this study could utilize Kirkpatrick's evaluation levels to assess the impact of its training strategies, thereby ensuring continuous improvement and alignment with industry needs. Also, the future of construction depends not just on technical skills but on how well workers can adapt, think critically, and communicate effectively. Thus, it is recommended that a framework should be developed for training construction workers to adopt the soft skills needed to perform in the 4IR era. A further study can also be conducted to ascertain the role of human resources in continuous professional among construction workers in the development of the latest technological advancements, ensuring that their skills remain relevant in a rapidly evolving industry.

Informed Consent Statement

The informed consent of the respondents who participated in the study was acquired before the distribution of the survey questionnaire. The study was also approved by the Ethics Committee of Edinburgh Napier University.

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