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READINESS TO IMPLEMENT CONSTRUCTION 4.0 APPLICATIONS IN BUILDING CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

The Construction industry is a vital indicator of the country's economic progress and development. Technological advancements play an essential role across various sectors, and their integration boosts both productivity and efficiency. Industry 4.0, a global concept, focuses on digitalising industries through cutting-edge technologies. Construction 4.0, as an application of Industry 4.0, seeks to enhance construction projects' efficiency, effectiveness and profitability. While many countries have begun to adopt Construction 4.0 applications, studies show that the practical use of these technologies is significantly lower than their theoretical potential. This research investigates the readiness of the Sri Lankan building construction industry to implement Construction 4.0 technologies, with a specific focus on assessing the digital literacy of professionals in the sector. A qualitative approach was used, involving interviews with five experts, including academics and industry professionals, to evaluate the current level of digital literacy & awareness. This study followed four main objectives. The research was conducted in two phases: a thorough literature review and semi-structured interviews with five experts using snowball sampling. Data was analysed through coding techniques using NVivo 14 software. The findings revealed that while some technologies are being adopted in Sri Lanka's construction projects, their use remains limited. BIM is the most widely adopted technology, while IoT, VR, AI, big data and cloud computing are only partially implemented. Technologies such as robotics, cobots, digital twins, AR,3D printing, and machine learning are scarcely used. Additionally, the study explored barriers to implementing construction 4.0 applications & strategies to overcome them.

Keywords: *Building construction; Construction 4.0; Implementation; Industry 4.0; Sri Lanka.*

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1. INTRODUCTION

1.1 CONTEXT AND BACKGROUND

The construction industry is one of the major industries playing a pivotal role in fostering economic growth & contributing significantly to the overall global economy. It holds paramount significance and has the potential to impact transportation education & healthcare through the creation of essential infrastructure (Adepoju & Aigbavboa, 2021). According to Perera et al. (2023), construction output represents half of the gross capital and constitutes a range of 3 to 8% of the GDP (Gross Domestic Product) in most countries. Industry 4.0 or the fourth Industrial Revolution has become one of the most discussed subjects among researchers, academicians, and professionals around the world. It represents a new way of organising industrial resources and processes, making them more responsive to an ever-changing environment (Lemstra & de Mesquita, 2023). I4.0 (Industry 4.0) has applications in many sectors like construction, healthcare, agriculture, wood, food, and education. Consequently, Agriculture 4.0, Construction 4.0, Health 4.0, Smart Material 4.0, Smart Operator 4.0, and many more were introduced to improve the efficiency, productivity, and profitability of their industries (Rana & Rathore, 2023). As per (Forcael et al., 2020), the concept of Construction 4.0 is derived from the broader framework of Industry 4.0, often referred to as the "Fourth Industrial Revolution." This emerging paradigm has become prominent in recent years for its transformative impact on major industries, particularly in design and production, shaping the future of efficiency and advancement in the manufacturing sector. However, (van der Heijden, 2023), explained that the construction industry has been slow to adopt new technologies and is often seen as a laggard in innovation. The present research on Construction 4.0 encounters substantial challenges in terms of methodology. Moreover, the existing studies are largely comprised of conceptual studies rather than practical applications, which may create a misleading impression that the Construction 4.0 phenomenon is widely accepted and understood. Therefore, there is an opportunity to revolutionise the sector through the adoption of digitalisation and automation in the field of construction, prioritising practical applications.

1.2 RESEARCH PROBLEM

Despite global interest in Construction 4.0, literature reviews indicate a significant gap between theory and practical implementation in many countries (van der Heijden, 2023). It highlights the need for a thorough investigation into how nations are ready to adopt and maximise the benefits of Construction 4.0 applications in their construction projects. Closing this knowledge gap is essential for the successful integration of advanced principles into the global construction industry. As a major component of the Sri Lankan construction sector, building construction can achieve greater efficiency and profitability through the integration of Construction 4.0 technologies. Through an examination of the current awareness and utilisation of Construction 4.0 applications in building construction projects in Sri Lanka, the research assumes that insights into the industry's current neglect can be obtained, providing a glimpse into its future direction.

1.3 RESEARCH AIM AND OBJECTIVES

The research aims to assess the level of digital literacy and awareness among professionals in the building construction projects of Sri Lanka to implement

Construction 4.0 applications effectively. To achieve the above aim, the following objectives were pursued; [1] Study the concept of Industry 4.0 and Construction 4.0, explore their key technologies, and evaluate the significant benefits they bring to contemporary industrial and construction practices, [2] Check the awareness and digital literacy among professionals in building construction projects in Sri Lanka regarding implementing Construction 4.0 applications, [3] Investigate barriers to implementing Construction 4.0 for building projects in Sri Lanka and [4] Explore strategies to overcome challenges in integrating Construction 4.0 technologies into building construction projects in Sri Lanka.

2. LITERATURE REVIEW

2.1 THE NOTION OF I4.0 AND ITS IMPORTANCE

I4.0 has gained global attention as a key driver of the next generation of industrial development. It represents the fourth Industrial Revolution, bringing advanced technologies to transform industries. The Industrial Revolution began in Britain in the late 1700s and early 1800s, marking a period of significant innovation. The First Industrial Revolution was initiated by the introduction of steam power, which played a vital role in driving industrialisation and quickly expanded to regions across the globe, including the United States (Islam et al., 2022). The Second Industrial Revolution (1900) introduced the internal combustion engine, enabling rapid industrial growth through oil and electricity-powered mass production. The Third Industrial Revolution (1960) integrated electronics and information technology, leading to production automation. These advancements significantly improved industrial efficiency and technological progress (M. Xu et al., 2018). Industry 4.0, also known as the Fourth Industrial Revolution or 4IR, is characterised by the integration of networking, Cyber Physical Systems (CPS), and the Internet of Things (IoT), creating a dynamic and intelligent working environment. This amalgamation of technologies contributes to the enhancement of workplace efficiency and intelligence (Islam et al., 2022). The concept of I4.0 was published by the German government in 2003.

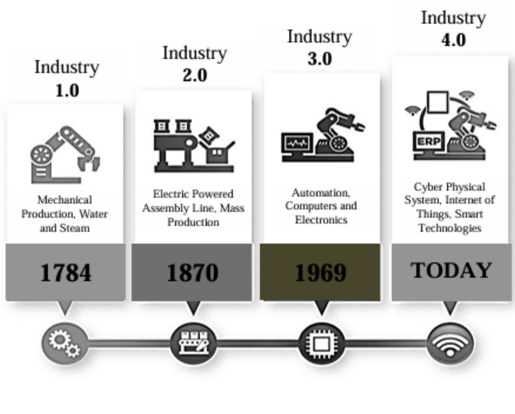

Figure 1: Industrial revolution

Nine primary pillars define the Fourth Industrial Revolution, considered key elements of I4.0. These pillars outline the new technology manufacturers use to enhance all production processes (Singh et al., 2023). I4.0 encompasses IoT, Cloud computing, Cybersecurity, System integration, big data & analytics, Smart manufacturing, AI (Artificial intelligence), CPS, and Blockchain. I4.0 is crucial in enhancing industrialisation, informatisation, and digitalisation in global business operations and the economy. It aims to improve efficiency, competence, and competitiveness significantly, as evidenced by the research conducted by L. Xu et al. (2018).

2.2 CONSTRUCTION 4.0 AND ITS POTENTIAL BENEFITS TO CONSTRUCTION

The construction industry is a major source of employment in numerous countries and is vital to their economic growth. It is important to highlight that the construction sector represents around 13% of the world's GDP (Karmakar & Delhi, 2021). Construction projects face numerous challenges in timely and budget-compliant delivery. According to Perera et al. (2023), the traditional approach often fails to execute projects within the expected time & budget in the construction industry. Furthermore, their study revealed that the adoption of Construction 4.0 technologies remains relatively low in Sri Lanka. The findings suggest the potential to guide future research aimed at the effective implementation of Industry 4.0 applications within the country's construction sector. Meanwhile, many researchers have identified various issues plaguing the sector. Notably, inadequate consideration of costs and planning in construction projects is a common problem. Additionally, design and execution flaws, budget constraints, contractual scheduling issues, stringent quality requirements, safety and environmental concerns, material logistics problems, sustainability rating system mandates, and stakeholder dissatisfaction due to project delays are significant contributing factors. Authors Mansour et al. (2023) demonstrated that the term Construction 4.0 has recently been utilised by researchers to signify the incorporation of I4.0 technologies into the construction sector. The application of the I4.0 concept can be utilised to address the previously mentioned issues in construction. The study conducted by Forcael et al. (2020), explained that the concept of Construction 4.0 did not emerge independently but was derived from the broader theoretical framework of Industry 4.0. As the concept is relatively new, there is currently no universally accepted definition for it. Instead, several scholars have emphasised the need for a flexible and holistic definition, referring to this fourth industrial revolution as “shift in the manufacturing logic towards an increasingly decentralized, self-regulating approach of value creation, enabled by concepts and technologies such as CPS, IoT, Internet of Services (IoS), cloud computing, or additive manufacturing and smart factories” (Forcael et al., 2020). Moreover, they pointed out that these advancements have also positively impacted the construction sector, giving rise to the term Construction 4.0, which has become increasingly prominent in recent years. This concept is fundamentally driven by construction companies' realisation of the industry's digital shift and is built upon four main pillars: digital data, automation, connectivity, and access to digital technologies (Forcael et al., 2020). Integrating these advanced technologies into the sector can significantly improve efficiency and productivity, helping to resolve common problems and enhance project delivery. However, van der Heijden (2023) argued that the construction industry has hesitated to adopt new technologies and is often viewed as trailing behind in innovation. This hesitance is partly attributed to the industry's complexity, involving multiple stakeholders, intricate supply chains, and large-scale projects with substantial risks. Nonetheless, the rise of Construction 4.0, marking the extensive integration of digitalisation and automation in construction, presents a significant opportunity to revolutionise the sector. The term "Construction 4.0" was introduced in 2016 by the consultancy firm Roland Berger GMBH in their report titled

"Digitisation in the Construction Industry: Building Europe's Road to 'Construction 4.0'. The report highlighted several crucial technologies that could revolutionise the construction industry, such as BIM, IoT, sensors, robotics, and augmented reality. These technologies promise increased efficiency, cost reduction, and improved collaboration and communication among stakeholders in the construction sector (van der Heijden, 2023).

2.3 KEY TECHNOLOGIES INTEGRATED WITH CONSTRUCTION 4.0

2.3.1 BIM

BIM digitally represents a construction project, allowing collaborative design, construction, and operation throughout its lifecycle. BIM goes beyond traditional 2D drawings by integrating 3D models enriched with data. It enables collaborative digital communication and prompts the construction industry to enhance effectiveness and efficiency through data utilisation (van der Heijden, 2023).

2.3.2 IoT

IoT technology significantly improves construction processes, productivity, and safety by collecting and exchanging real-time data. This is evident in construction site management, where IoT devices like servers, computers, tablets, phones, and embedded sensors in equipment generate valuable data. This data is instrumental in optimising operations, enhancing resource management efficiency, and implementing energy-efficient strategies in buildings, such as monitoring energy usage, occupancy, and environmental conditions (van der Heijden, 2023).

2.3.3 Robots, Cobots, and Automation

In Construction 4.0, integrating robots, collaborative robots (cobots), and automation emerges as a pivotal factor in enhancing construction productivity. These technologies play a crucial role by efficiently managing repetitive tasks and addressing both time-consuming and physically demanding aspects of construction work (van der Heijden, 2023).

2.3.4 Digital Twinning and Extended Reality (XR)

Digital twinning is the process of creating a virtual representation of a physical object, system, or process by integrating data from sources such as sensors, BIM, and IoT devices. This creates a real-time digital duplicate that faithfully mirrors the physical entity. The use of digital twins in construction involves simulating processes to allow stakeholders to anticipate and address issues like clashes or inefficiencies before they arise in the physical environment. The integration of XR, including VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality), are commonly employed to support digital twinning initiatives (van der Heijden, 2023).

2.3.5 3D Printing and Additive Manufacturing (AM)

In Construction 4.0, 3D printing and AM emerge as pivotal technologies that bring significant value by revolutionising traditional construction methods. These technologies enable precise and efficient fabrication of complex architectural structures. The key benefits encompass design freedom, allowing for intricate customisation, cost reduction, enhanced sustainability through optimised material usage, and considerable time savings in the construction process. According to van der Heijden (2023), 3D printing and AM allow for the creation of intricate geometries and complex shapes that are challenging or impossible to achieve with conventional construction methods.

2.3.6 AI, Big Data, Machine Learning (ML), and Analytics

In Construction 4.0, AI, Big Data, ML, and analytics are transformative technologies that reshape traditional construction processes. Their impact is evident in data-driven decision-making, improved project management, increased productivity, and optimised resource allocation. These technologies play a crucial role in efficient resource management by analysing historical data and real-time information, leading to optimized allocation of resources such as labour, equipment, and materials (van der Heijden, 2023).

2.3.7 Cloud Computing and Blockchain

Cloud computing and blockchain are integral to Construction 4.0, ushering in a revolution in the construction industry. Cloud computing empowers the industry by providing scalable and flexible computing resources, storage, and services. Blockchain is a digital record-keeping system that securely stores information in a chain of blocks. Each block contains data and is linked to the previous one, making it difficult to alter past records. Its role in Construction 4.0 is crucial for enhancing communication and collaboration among stakeholders and facilitating the efficient management, analysis, and sharing of extensive project data (van der Heijden, 2023).

Siriwardhana and Moehler (2023), Construction 4.0 offers benefits like cost and time savings, performance improvements, and better collaboration. It has the potential to transform the industry and support development goals. However, adoption remains slow due to skill-related challenges. Recognising its potential, governments worldwide promote Construction 4.0, following Germany’s lead in implementing I4.0 across sectors. Moreover, they pointed out that Many countries, including Australia, China, the UK, the USA, and Malaysia, have strategic plans for Construction 4.0, but a gap exists between theory and practice. Further research is needed to assess readiness and maximise benefits. Closing this gap is vital for global adoption, with Sri Lanka's construction sector being a key economic contributor. Ranasinghe (2022), highlighted that the construction sector is flourishing in Sri Lanka. The impact of the construction industry on society, both socially and economically, is considerable and cannot be overlooked due to its substantial contributions. Integrating digital technologies into the construction industry is crucial for revolutionising the sector by enhancing efficiency, productivity, profitability, and overall sustainability (Wang & Guo, 2022). The study highlights the need for Sri Lankan practitioners, professionals, and academics to understand Construction 4.0 and its enabling technologies. While Construction 4.0 can enhance efficiency, productivity, and sustainability in the construction industry, its effective adoption depends on professionals' digital literacy and awareness. However, findings reveal a knowledge gap, with professionals demonstrating uneven familiarity with Construction 4.0 concepts. Although some are aware of digital technologies, the broader understanding of Construction 4.0 remains low. A thorough assessment of digital literacy levels is essential to bridge this gap and support successful implementation.

3. METHODOLOGY

3.1 RESEARCH PARADIGM

The first research objective was achieved through a comprehensive review of existing literature. A qualitative research methodology was adopted to address objectives [2], [3], and [4]. This approach provided a deeper insight into professionals' awareness and digital literacy, as well as the specific challenges and obstacles they encounter in implementing Construction 4.0. The rich, context-specific data obtained was crucial for examining the complexities of adopting advanced technologies in building construction projects in Sri Lanka. Semi-structured interviews were chosen as the data collection method for these objectives, as they enabled the gathering of detailed, firsthand insights from professionals directly engaged in building construction projects. This approach allowed for open-ended questioning, encouraging participants to share their experiences, perceptions, and opinions on their awareness, digital proficiency, and the challenges associated with implementing Construction 4.0. Additionally, it facilitated an in-depth exploration of both personal and organisational barriers, as well as potential strategies to overcome these challenges.

3.2 POPULATION, SAMPLING FRAME, SAMPLING TECHNIQUE AND SAMPLE SIZE

As Construction 4.0 is a relatively new concept, the study targeted professionals within Sri Lanka's building construction sector, such as civil engineers, project managers, quantity surveyors, architects, and academics, who possess knowledge of Construction 4.0. Given the limited availability of such experts, a snowball sampling technique was employed to recruit participants. This approach aligns with the study's qualitative and exploratory nature, and all data collection and analysis were completed within a constrained four-month timeframe.

4. DATA COLLECTION AND ANALYSIS

This study employed semi-structured interviews to investigate various dimensions of construction 4.0 technologies implemented in building construction projects across Sri Lanka, ensuring that essential topics were thoroughly explored. These interviews featured open-ended questions designed to capture participants' knowledge, experiences, challenges, and perspectives on strategies related to Construction 4.0. Thematic analysis was used to interpret the collected data. Table 1 provides a summary of each participant's position, academic qualifications, and professional background.

Table 1: Demographic profile of participants

Participant's ID	Position	Highest academic qualification achieved	Years of experience
P1	Senior Lecturer	Doctor of Philosophy	More than 10 years
P2	PHD Scholar	Bachelor of Science	2-3 years
P3	Consultant Quantity Surveyor	Bachelor of Science	More than 5 years

Participant's ID	Position	Highest academic qualification achieved	Years of experience
P4	Civil Engineer	Advanced Diploma in Civil Engineering & Advanced Diploma in Supply Chain Management	More than 15 years
P5	Chartered Architect	Bachelor of Architecture	5-10 years

4.1 CURRENT USE OF MODERN TECHNOLOGIES IN SRI LANKAN BUILDING CONSTRUCTION PROJECTS

According to the participants' responses, the Sri Lankan building construction industry is gradually adopting modern technologies, though the overall level of technological integration remains relatively low compared to global standards. BIM is gaining traction, with four out of five participants recognising its value in improving collaboration, efficiency, and project management. AutoCAD and Revit are used for drafting and 3D modelling, though limited references to these tools suggest that traditional methods are still prevalent. Quantity Surveyors are beginning to utilise digital tools like COSTX, Planswift, and Cubicost for accurate quantity take-offs and BOQ (Bill of Quantities) preparation, though manual methods remain common. Primavera, mentioned by an experienced civil engineer (P4), is used for project scheduling and resource management in large projects. Modular construction, noted by P2, is still in its infancy, with adoption hindered by high initial costs, technical barriers, and resistance to change. IoT is being explored in the pre-construction and construction phases, but its implementation is minimal. Similarly, ERP (Enterprise Resource Planning) systems are used by some larger or more progressive companies for data and resource management. While architects have begun using 3D printing for design visualization, its broader application remains rare. Overall, the findings indicate that although technologies like BIM, Revit, and Primavera are gaining traction, more advanced solutions such as modular construction, IoT, ERP, and 3D printing are still underutilised, reflecting the industry's slow pace of technological transformation.

4.2 IMPLEMENTATION OF KEY CONSTRUCTION 4.0 TECHNOLOGIES IN THE SRI LANKAN BUILDING CONSTRUCTION SECTOR

Construction 4.0 incorporates several key enabling technologies such as BIM, IoT, Robotics, Cobots, Digital Twinning, ER, 3D Printing, AI, Big Data, Machine Learning, and Cloud Computing. This research primarily examines the extent to which these technologies are being utilised in building construction projects and aims to determine the level of implementation of Construction 4.0 technologies in Sri Lanka. Participants provided their insights based on their professional experience. The following findings will present the implementation level of each technology within the Sri Lankan context. The following findings will present the implementation level of each technology within the Sri Lankan context.

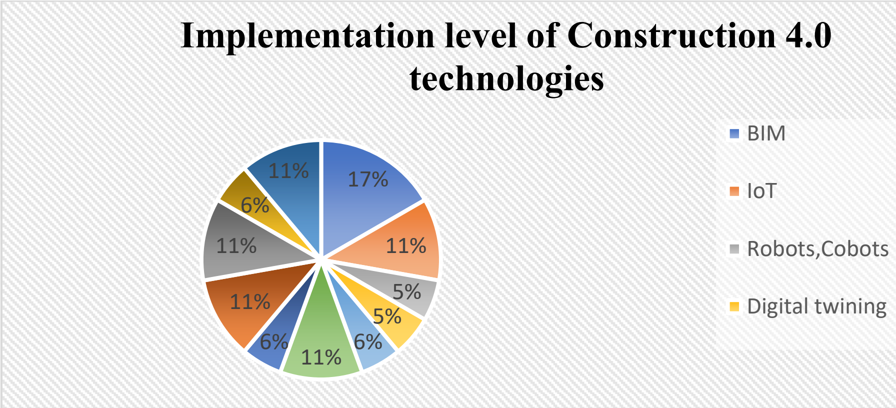

Figure 2: Visual representation of the implementation level of Construction 4.0 technologies

The study revealed that BIM is the most widely implemented Construction 4.0 technology in Sri Lanka's building sector, with all participants confirming its use, and P1 specifically mentioning its robust implementation. IoT integration is progressing well, with architects using digital devices like tablets and mobile phones for on-site efficiency, as noted by P3, P1, P2, P4, and P5 emphasized its growing adoption across the industry. However, advanced technologies like robots, cobots, and digital twinning remain unimplemented, with P2, P4, and P5 pointing out their absence. VR is being tested and partially used, as confirmed by P1, P2, and P5, while AR and 3D printing have minimal to no adoption, with P1, P3, P4, and P5 highlighting their lack of implementation, and P2 stating 3D printing is at a minimal level. AI applications are limited, mostly in design and documentation, with P1 noting its use, P3 indicating its limited application to the design phase, and P5 observing its role in ensuring accuracy during documentation but not in construction. Machine learning is rarely used, as mentioned by P3 and P4. Big data analytics show mixed implementation levels, with P3 and P4 reporting no use, while P2 noted its use and P1 mentioned partial implementation. Cloud computing is widely adopted across most projects, supporting e-tendering and document sharing through platforms like Google Drive, as confirmed by all participants, with P2 highlighting its role in e-tendering and P4 mentioning Google Drive for managing and sharing documents.

4.3 DIGITAL LITERACY LEVEL OF PROFESSIONALS IN SRI LANKA'S BUILDING CONSTRUCTION SECTOR FOR CONSTRUCTION 4.0 IMPLEMENTATION

Participants expressed two main viewpoints regarding digital literacy among professionals. One perspective is that digital literacy is very low, while the other suggests that it is at a reasonable level, not low. The findings highlight that digital literacy among Sri Lankan construction professionals remains low, especially in the government sector, and this poses a key barrier to adopting Construction 4.0 technologies. While some awareness exists, particularly among younger professionals and recent graduates, practical implementation and hands-on experience are minimal. P1 and P3 noted that only a few financially capable companies are integrating modern technologies, while the majority lack the necessary infrastructure and resources. P4 and P5 emphasized generational differences, with younger professionals being more tech-aware but lacking opportunities to apply their knowledge. Overall, digital literacy among professionals is estimated at 40-50%, with the country lagging behind global standards. Enhanced awareness, resources, and practical application are essential for the broader adoption of Construction 4.0 in Sri Lanka.

4.4 CHALLENGES TO IMPLEMENT CONSTRUCTION 4.0 TECHNOLOGIES IN THE SRI LANKAN BUILDING SECTOR

Table 2: Challenges to implement Construction 4.0 technologies in Sri Lanka

Challenges	Overview	References
The labour force is not ready to implement these technologies	P1 mentioned that the industry is not yet prepared to adopt these technologies P2 explained that the workforce is not prepared to adopt these technologies, and their skill level for implementing them is quite low. Additionally, the skilled labour force in Sri Lanka is declining	P1, P2
The government doesn't support to implement of Construction 4.0 technologies	P1 noted that professionals lack adequate support from the government. P2 explained that because the majority of projects are managed by the government, it has not taken any steps to promote or implement Construction 4.0 technologies. Additionally, the government has not established any regulations in this area. P4 noted that most construction projects in Sri Lanka are government driven. participant also pointed out that the government is not aware of the new technologies being adopted in other countries	P1, P2, P4
Implementation cost is high	P1 mentioned that organizations need to invest a significant amount of money for implementation purposes P2 explained that construction firms in Sri Lanka, aside from high-level contractor companies, lack the necessary capital and infrastructure to implement these technologies in the local context. P3 pointed out that when working with modern technologies, professionals need to use certain advanced software. However, purchasing this software can be challenging for professionals due to its potentially high cost. P5 highlighted that implementing Construction 4.0 applications requires a significant financial investment.	P1, P2, P3, P5
Resistance to change	Professionals and labourers are resistant to change and hesitant to adopt or embrace modern technologies	P2
Researchers don't have the proper forum to present their findings	Many academics research how to transform the sector using digital technologies. However, they lack a sufficient platform to present their findings and share them with professionals	P1

Challenges	Overview	References
Professionals need to switch to new software or technology for construction projects, but they require time to learn these tools	Professionals need to switch to new software or technology for construction projects, but they require time to learn these tools while managing their current workload. P5 mentioned that many professionals do not have enough time to adopt new software and continue to rely on older systems.	P5
Knowledge gap of the professionals	P1 highlighted that the lack of knowledge and digital literacy among professionals is a major barrier to progress. P5 mentioned that there is a knowledge gap, with only few professionals understanding how to utilize Construction 4.0 technologies within the industry.	P1, P5
Lack of resources	P3 stated that the lack of resources makes it difficult for professionals to adopt these technologies. They need to purchase software, which can be a challenge due to the high costs involved. P4 also noted that many professionals cannot afford the cost of the software, making it a significant challenge for them. P5 also mentioned that the high cost of software poses challenges for utilizing modern tools within the industry.	P3, P4, P5
Lack of foreign investment	P3 explained that professionals are not engaging with foreign clients. For example, if a client is from Germany and expects the project to be executed using their technologies, the professionals must utilize and implement these technologies to complete the project. P4 shared a similar perspective to P3, highlighting that there is a lack of foreign investors in Sri Lanka's construction projects. The other two job roles (Consultant & Contractor) are contingent on the client's needs, and if the client prefers to utilise modern technologies for their project, professionals are obligated to follow those requirements	P3, P4
Lack of experts in the industry	Professionals in the Sri Lankan context lack sufficient expertise to seek advice, as indicated by Participant P1. P2 identified a challenge in implementing Construction 4.0 applications, nothing that even though there is awareness of Construction 4.0, practical implementation is low. Additionally, it is difficult to find professionals in the industry with experience using this technology or who have been involved in projects utilizing Construction 4.0 in Sri Lanka. P3 also noted that there are only a few experts in Sri Lanka who are knowledgeable about implementing these technologies in projects	P1, P2, P3

4.5 STRATEGIES TO OVERCOME CHALLENGES IN INTEGRATING CONSTRUCTION 4.0 TECHNOLOGIES INTO BUILDING CONSTRUCTION PROJECTS

Considering all the participants' responses, it is evident that the readiness level of professionals and the sector to implement Construction 4.0 is quite low. Participant P4 pointed out that the Sri Lankan construction industry hasn't even fully embraced Construction 3.0 yet. Therefore, significant efforts are needed to promote Construction 4.0, to maximise its potential and enhance the efficiency, effectiveness, and profitability of building construction projects in Sri Lanka. Each participant has provided their recommendations on how to encourage the adoption of Construction 4.0 applications within the industry, and these suggestions will be detailed in the following section. To promote the adoption of modern construction technologies, raising awareness among financially capable individuals through case studies that demonstrate cost savings is essential. CIDA (Construction Industry Development Authority) should take the lead by organising training programs, CPD (Continuous Professional Development) sessions, and bringing in international experts to enhance digital literacy among industry professionals. For instance, countries like Germany, Singapore, and Japan, which are leaders in smart construction, could provide valuable benchmarks, while short-term training programs in digital construction management or BIM could greatly benefit local professionals. Software companies should be encouraged to provide their packages at more affordable prices, making advanced tools more accessible. The government and CIDA must support R&D (Research and Development) by introducing new regulations and encouraging student and professional research projects. Universities should update their curricula to include modern construction technologies, ensuring graduates are well prepared for industry demands. Additionally, professionals must engage in international projects, developing the necessary skills to meet global standards. The government can further accelerate adoption by offering tax incentives and financial support to companies implementing technologies like modular construction. Clients should also be educated on the benefits of modern technologies in improving project efficiency. Moreover, industry professionals and workers need to shift their traditional mindsets and embrace innovation. To gain valuable insights, companies can organise study tours to countries successfully implementing these technologies, allowing professionals to learn from global leaders.

5. METHODOLOGICAL LIMITATIONS

Given that only five participants were involved in this study, the sample size may not sufficiently reflect the broader population's levels of digital literacy and readiness. To gain a more comprehensive understanding, a larger sample, typically around 25 participants or more, would be more appropriate. Data was collected through a virtual platform, with each session lasting approximately 15 to 20 minutes. Furthermore, the study was limited to a qualitative approach due to time constraints and did not incorporate a mixed methods design.

6. CONCLUSION AND RECOMMENDATIONS

The study reveals that while the Sri Lankan building construction industry has begun to embrace modern technologies, the overall adoption of Construction 4.0 is low. Technologies like BIM, AutoCAD, Revit, Primavera, and cloud-based tools are gaining traction, particularly among larger or more progressive firms. However, more advanced innovations such as IoT, ERP systems, modular construction, AI, machine learning, AR/VR, and 3D printing remain underutilised due to a combination of structural, financial, and educational barriers. A key obstacle is the low level of digital literacy among professionals, particularly in the government sector and among older generations. The readiness of the workforce to adopt Construction 4.0 technologies is low, and the industry has yet to fully transition from Construction 3.0. Challenges such as high implementation costs, lack of government support, resistance to change, limited R&D infrastructure, and a shortage of skilled professionals further hinder progress. Despite these challenges, there is growing awareness, especially among younger professionals, and recognition of the potential benefits these technologies offer. Encouragingly, several participants suggested actionable strategies for fostering wider adoption, including targeted training, curriculum updates, cost reduction for digital tools, and international collaboration. Future studies can be carried out to investigate the impact of governmental policies, incentives, and regulations on either promoting or limiting the adoption of digital technologies in the construction sector.

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