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# STATUS QUO OF DIGITALISATION IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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## *ABSTRACT*

*The construction industry faces various issues in completing the project effectively. Numerous studies have found that the construction sector has experienced a rapid and continuous digital transformation to tackle these issues. As a result, to successfully implement Industry 4.0 applications in the Sri Lankan construction industry, it is necessary to identify the status quo of digitalisation in the Sri Lankan construction industry. Therefore, the research aims to analyse the status quo of digitalisation in the Sri Lankan construction industry. The study employs a mixed-method approach consisting of two phases. In phase one, a questionnaire survey was conducted for 50 respondents selected through snowball sampling. The collected data were analysed using SPSS. In phase two, semi-structured interviews were conducted with 11 experts who had knowledge of Industry 4.0 and lean construction, selected through purposive sampling. Data analysis was conducted through code-based content analysis using NVivo 10. The study indicated that the overall level of digitalisation of the construction industry is lower, while BIM (Building Information Modelling), 3D printing, and Drones/Unmanned Aerial Vehicles (UAV) are the most often implemented applications. Research has made significant contributions to knowledge in identifying issues in the current construction industry in Sri Lanka and the level of implementations of Industry 4.0 applications in the construction industry to measure digital disruption in the industry. Accordingly, the research provides a path to investigate the barriers to implementing these industry 4.0 applications and strategies to eliminate those barriers to raise the construction sector's overall digitalization level.*

***Keywords:*** *Construction industry; Digitalisation; Industry 4.0; Issues; Sri Lanka.*

## 1. INTRODUCTION

Construction output represents half of the gross capital and 3 to 8% of the Gross Domestic Product (GDP) in most countries (Alaloul et al., 2021; Berk & Biçen, 2018; Chiang et al., 2015; Saka & Adegbembo, 2022). Therefore, failure to utilise innovative productive plans and lack of collaboration will lead to collapse and under-developing of the construction sector, which will reduce the GDP in the national economy and the need for

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adequate infrastructure for the economy as well (Alaloul et al., 2021). Thus, proper construction management should be followed in every construction project to eliminate such consequences. According to Erdogan et al. (2019), the two most important factors influencing the construction sector are technology and construction management. Although the construction industry is achieving rapid progress while gradually expanding, there are still some problems in the construction management and sustainable delivery of the project (Fu, 2019). There are communication problems and uncertainties in the process with an increasing number of disciplines (Biçer et al., 2020). Furthermore, a study conducted by Pakhale and Pal (2020) showed that the traditional approach usually fails to execute projects on time and within budget in the construction industry. As discussed by Tzortzopoulos et al. (2020), The findings of a few researchers further discussed endemic management issues in design management, client decision-making, and construction management (Koskela, 2000; Talebi et al., 2016). Poor construction management has also been identified throughout the past as one of the main barriers to the development of the construction industry (Gamil & Abdul Rahman, 2020; Odeh & Battaineh, 2002; Potts & Ankrah, 2008; Walker, 2015). Many researchers have highlighted the causes of problems in the construction sector. Among them, poor construction projects, taking into account costs and planning, are one of the common causes (Erdogan et al., 2019). Besides design and execution issues, budget limitations (Chin-Keng & Shahdan, 2015), contractual scheduling constraints (Liu et al., 2020), quality requirements (Wawak et al., 2020), safety and environmental concerns (H. Guo et al., 2017), issues with material logistics, sustainability rating system requirements, and stakeholder dissatisfaction with project delays are also can be taken into account as causes (Alothaimeen & Arditi, 2019). In recent decades, the construction industry has undergone a gradual and accelerated digital transformation to address these issues.

Digitization, automation, and integration provide opportunities for productivity improvement as well as design and construction quality. Certainly, the construction industry is becoming more digitalised, as it is difficult to imagine the modern construction sector without the use of specific information technology, and the importance of these technologies is growing every day (Nataliia & Oleksii, 2019). Level of implementation of Industry 4.0 applications in the Sri Lankan construction industry. Although the implementation of the digitalising construction industry has been discussed in many research. However, there is a lack of research on the level of implementation of Industry 4.0 applications in the Sri Lankan construction industry. Therefore, the research aims to investigate the status quo of digitalisation in the Sri Lankan construction industry. Further, the objective can be obtained through the current level of implementation of Industry 4.0 applications in the Sri Lankan construction industry. First, a review of the literature on issues in the construction industry and the benefits of Industry 4.0 for the construction industry. The methodology used is explained in the following section. Thereafter, the findings of the research on issues in the construction industry, the current digitalization level, and knowledge of Industry 4.0 applications in the Sri Lankan construction industry.

# 2. LITERATURE REVIEW

## 2.1 ISSUES IN THE CONSTRUCTION INDUSTRY

Most economies place a high value on the construction industry. It influences and is influenced by the GDP of any nation (Debelo & Weldegebriel, 2022; Erdogan et al., 2019; Hughes & Thorpe, 2014). According to the reports, the efficiency and productivity of the construction industry have been one of the major considerations among countries over the past 40 years (Teicholz, 2013) and was caused by several challenges, as well as needs to be improved in efficiency and productivity (Prabhu & Nagarajan, 2013). The scale of construction projects is expanding due to the growing human requirements, and construction projects are becoming more challenging in tandem with technological advancements (Biçer et al., 2020). Hence, addressing the issues within the industry is a highly concerning topic worldwide. As many researchers identify, there are common issues in construction such as poor execution of construction projects (Erdogan et al., 2019), budget limitations (Chin-Keng & Shahdan, 2015), contractual scheduling constraints (Liu et al., 2020), quality requirements (Wawak et al., 2020), safety and environmental concerns (Guo et al., 2017), issues with material logistics, sustainability rating system requirements, and stakeholder dissatisfaction with project delays (Alothaimeen & Arditi, 2019), poor communication (Makulsawatudom et al., 2004; Thorpe, 2003), poor site conditions, and poor site layout (Lim & Alum, 1995; Makulsawatudom et al., 2004). Adekunle et al. (2021) highlighted that technological growth offers solutions to the aforementioned problems, in the construction sector.

## 2.2 INDUSTRY 4.0

Industry 4.0 can be stated as the fourth industrial revolution which can deliver more intelligent processes in the manufacturing industry as well as in the construction arena (Zhou et al., 2015). Through this development, major problems such as lack of interoperability & automation, information transparency, and technical assistance can be addressed. BIM, drones, robotics, 3D printing, and virtual and augmented reality are some of the applications utilized to assist construction projects (Zhou et al., 2015). Building information modelling (BIM) is a digital representation of a building's geometric and non-geometric data that is used to make decisions on a facility throughout its existence (Guerriero et al., 2018; Hasan & Rasheed, 2019; Leite et al., 2011). One of the technical tools utilized by the construction business is virtual reality (VR), which allows a person to explore and interact with a three-dimensional, computer-generated environment. Augmented reality (AR) uses the same concept as virtual reality (VR), but instead of interacting in a non-existent environment (digital reality), AR uses the current environment while including virtual aspects to appear as though both are there at the same time (Dunleavy & Dede, 2013). 3D printing is a type of additive manufacturing that creates objects layer by layer. There are several forms of 3D printing, including those that use thermoplastic or polymeric materials (Chong et al., 2018) or the process known as contour crafting (Khoshnevis, 2004; Khoshnevis et al., 2006). Drones, also known as Unmanned Aerial Vehicles (UAV), have long been studied for their potential application in construction (Irizarry et al., 2012; Siebert & Teizer, 2014). Given that construction and maintenance projects frequently span large areas that can be more comprehensively and easily scanned from the air by drones, the use of drones in conjunction with 3D models and BIM systems for visual progress monitoring, site survey, safety, and quality analysis

appear promising. Therefore, there are lots of benefits that can be gained through digitalisation via Industry 4.0 in the construction industry.

## 2.3 BENEFITS OF DIGITALISATION

Digitalization offers numerous opportunities for the advancement of the AEC business. For example, digital solutions facilitate data-driven decision-making through visualizations and simulations (World Economic Forum, 2016). Digitalization also lay the groundwork for collaborative value creation through new types of interaction, improved information exchange, and stakeholder openness (Schober & Hoff, 2016). According to (Bock, 2015), construction automation technology, such as robots, is gradually ingrained in buildings and building components. However, digitalization poses dangers to the AEC industry's future. Start-ups with digital innovations can threaten existing AEC industries, resulting in lower revenue for current players (Christensen, 2016). Over the last five years, more than 80 start-ups based on digital technologies have emerged and begun to operate in the AEC industry in Finland (Lehtinen et al., 2017). Social media, cloud computing, sensors, big data, and wireless networks are no longer buzzwords in technology. They have the potential to disrupt traditional enterprises (Porter & Heppelmann, 2014). In the media, commerce, and music sectors, incumbents have been subjected to enormous forces generated by new business models based on digital technology and data. Uber, Airbnb, and the App Store are all instances of platform-based digital services (Gawer, 2014). The conservative AEC industry has begun to feel the effects of digitalisation. BIM and other similar systems, as well as wireless sensors and data analytics, have the potential to revolutionize infrastructure construction and maintenance (World Economic Forum, 2016). Decision makers in the AEC have highlighted concerns about which digital technologies, important trends, and uncertainties will have an impact on the industry (Jacobsson et al., 2017; Linderoth, 2017). A recent study by Schober and Hoff (2016) found that decision-makers in the AEC are uncertain about realizing the benefits of digitization. In other words, business leaders are grappling with how to manage the transition from traditional construction practises to digitalized construction supply chains. Table 1 presents the benefits of digitalization for the construction industry identified throughout the existing literature.

*Table 1: Benefits of industry 4.0 for the construction industry*

| Benefit | Descriptions | Reference |
|---|---|---|
| Cost savings | Labour expenses are reduced when labour-intensive operations are mechanized, such as through the use of robotics or automated workflows. Furthermore, integrating embedded sensors to automate the tracking of equipment and materials might help to cut material costs. | [1], [2], [3], [4] |
| Time savings | Innovative manufacturing technologies and concepts such as prefabrication and additive manufacturing allow structures to be built in a matter of days, much faster than traditional construction processes. | [5], [6], [7] |
| On-time and on-budget delivery | Historically, completing building projects on time and under budget has proven to be a difficult task. BIM can help to reduce project delivery time and keep projects on budget. | [8], [9] |
| Improving quality | The use of BIM and other simulation technologies has been suggested to improve building quality since errors can be eliminated in the early stages by replicating the entire construction process. Furthermore, based on previous data, Big Data analytics can assist project managers in making more effective and well-informed decisions. | [10], [11] |

| | | |
|---|---|---|
| Improving collaboration and communication | Because each construction project involves a large number of project participants, cloud- and BIM-based platforms or social media apps can effectively boost collaboration and communication even beyond corporate borders. | [12], [13] |
| Improving customer relationship | Construction companies can provide project owners with more insights into the features and design of a building before it is created by combining simulation technologies such as Augmented Reality, Virtual Reality, and Mixed Reality with mobile devices or wearable computers. Customers can thus be included in the design process for better building customization. | [14] |
| Enhancing safety | The abundance of literature on safety management demonstrates that safety is one of the most critical issues in construction. The construction industry is well known for its high rate of work injuries and accidents due to its hazardous work environment. As a result, many different approaches are presented by researchers and practitioners to improve construction safety, such as virtual safety training, using risk maps to avoid work accidents, or using wearable technologies such as Smart Glasses or Smart Helmets. | [15]. [16], [17] |
| Improving the image of the industry | The construction industry is notorious for its tough working conditions and poor level of digitalization. As a result, it has a terrible employer image and frequently struggles to attract talented people to its team. The entire industry's digital revolution can help to boost its image. | [18] |
| Improving sustainability | The building and construction industry contributes significantly to $CO_2$ emissions due to high energy consumption and trash generation during the construction process. Several ways have been offered to address these environmental issues, such as minimizing project emissions through strategic project management or using BIM to create design alternatives. | [19], [20], [21], [22] |

[1] (Barro-Torres et al., 2012), [2] (Bello et al., 2021), [3] (Bruemmer, 2016), [4] (Valente et al., 2019), [5] (Baynes & Steele, 2015), [6] (McGraw Hill Construction, 2011), [7] (Valente et al., 2019), [8] (Jones, 2014), [9] (Teisserenc & Sepasgozar, 2021), [10] (Allison, 2015), [11] (McMalcolm, 2015), [12] (Groves-Delphos, 2014), [13] (Merschbrock & Munkvold, 2015), [14] (Jones, 2014), [15] (Chun et al., 2012), [16] (H. L. Guo et al., 2013), [17] (Vahdatikhaki & Hammad, 2015), [18] (Slowey, 2015), [19] (Chou & Yeh, 2015), [20] (Davies et al., 2014), [21] (Tang et al., 2013), [22] (Yuan & Wang, 2014)

Table 1 summarises various benefits that can be achieved using innovative technologies and concepts in the construction industry. These benefits include cost and time savings, on-time and on-budget delivery, improved quality, collaboration, customer relationships, safety, industry image, and sustainability. The descriptions of each benefit are supported by references to relevant research studies. In general, Table 1 provides a concise and informative overview of how the construction industry can leverage technology to improve various aspects of its operations and results.

## 2.4 TECHNOLOGIES AND APPLICATIONS USED IN DIGITALIZED CONSTRUCTION INDUSTRY

Among numerous technologies that are trending, the followings are the most discussed Industry 4.0 applications in the construction industry (El Jazzar et al., 2021). Although several technologies are emerging in the construction industry, Virtual Reality (VR) and Augmented Reality (AR), BIM, robotics, AI (Artificial Intelligence), 3D printing, IoT, and drones or UAVs can be identified as the most commonly employed (El Jazzar et al., 2021). Major problems such as lack of interoperability & automation, information transparency, and technical assistance can be addressed through Industry 4.0 (Zhou et al., 2015). Furthermore, the author stated that mostly BIM and related technologies rectify these issues while enhancing communication and collaboration. Moreover, the latest

technologies, such as drones, robotics, 3D printing, and virtual and augmented reality, are also assisted during construction projects and improve information transparency. Even though the applications are advantageous to the industry, the level of implementation has to be properly identified before proceeding further (Sony & Naik, 2019). The gap in properly identifying the level of implementation level has been addressed through this paper to find the readiness of Industry 4.0 in the construction industry (Mansour et al., 2023). According to that, there is a need to determine the current state of digitalization in the Sri Lankan construction industry to successfully adopt Industry 4.0 applications in the Sri Lankan construction sector.

## 3. RESEARCH METHODOLOGY

This research was carried out using a mixed research approach to analyse the status quo of digitalisation in the Sri Lankan construction industry. Therefore, a comprehensive literature review was conducted to review the issues in the construction industry and the benefits of digitalization. Mixed-method research is a kind of investigation that involves gathering both quantitative and qualitative data, combining the two types of data, and employing distinct designs that may include philosophical assumptions and theoretical frameworks. The key assumption of this type of investigation is that combining qualitative and quantitative data offers additional knowledge beyond what quantitative or qualitative data alone can provide (Creswell, 2014). The benefits of using this specific strategy are the ability to look at the quantitative and qualitative data to reflect the perspectives of participants, provide methodological adaptability, and gather rich, comprehensive data (Johnson & Onwuegbuzie, 2004). Thus, it is important to select the best method to carry out comprehensive research. Considering the merits and demerits of the research approaches, both the qualitative and quantitative approaches were selected. Accordingly, a mixed approach was adopted to achieve the research aim.

The data was collected in two phases. Phase one: questionnaire survey carried out among the construction industry professionals. Consequently, Phase Two: semi-structured interviews with industry experts were conducted to identify the status quo of digitalization in the Sri Lankan construction industry. The methodology employed for sampling in this dissertation involved the utilization of two distinct techniques. Firstly, the snowball sampling method was utilized to gather responses for the questionnaire and was analysed using descriptive analysis. This method involves the use of referrals by participants to recruit additional individuals who meet the study criteria. The survey was carried out via Google® Forms among 50 industry professionals who are working in the Sri Lankan construction industry and are aware of the industry 4.0 applications/technologies and digitalization in the construction industry. 50 number of participant sample size was chosen as statistically at least there should be 30 participants (Aithal & Aithal, 2020). Second, eleven expert interviews were conducted using the purposive sampling technique, a subjective sampling method that involves selecting individuals based on their expertise and relevance to the research topic, and data was analysed using code-based content analysis using NVivo 10. The number of experts was restricted to 11 as the data saturation was there with repetitive information (Fusch & Ness, 2015).

# 4. RESEARCH FINDINGS AND ANALYSIS

## 4.1 ISSUES IN THE CURRENT CONSTRUCTION INDUSTRY

Construction projects often face various challenges that can impact their success. To overcome these challenges, it is crucial to identify and prioritize the issues that are most likely to occur during a project's lifecycle. **Error! Reference source not found.** presents a list of common issues in construction projects gathered through phase I: questionnaire survey, along with their RII, and ranks based on those RII scores. The RII scores reflect the level of importance assigned to each issue.

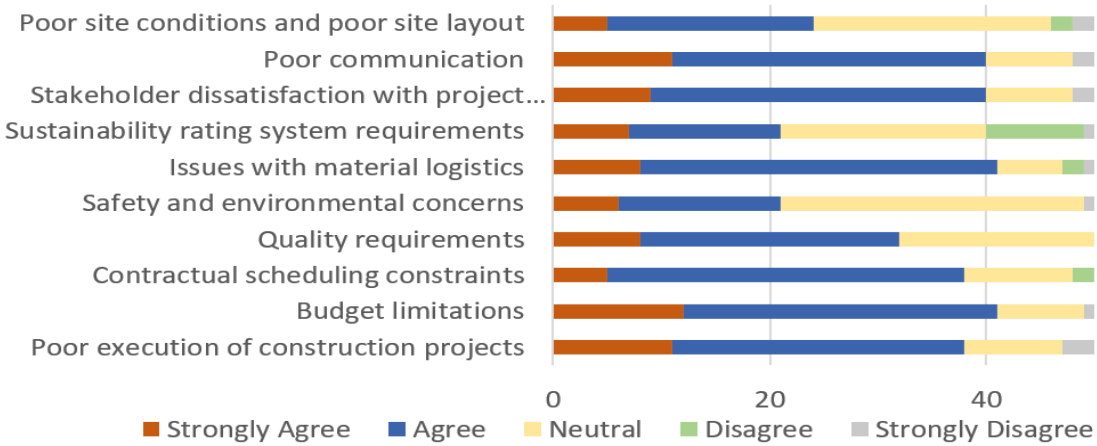



*Figure 1: Issues in the current construction industry*

According to the questionnaire survey, 'Budget limitations' was marked as the most critical issue in the current construction industry, gaining relative importance of 80%. Furthermore, 'poor communication', 'problems with material logistics', and "Stakeholder dissatisfaction with project delays' were also ranked higher in the issues. As all the issues have more than 60% RII value, it can be identified that all the issues as described in the literature review exists in the real-world scenario. The 60% RII value is taken as the benchmark and the issues that have less than that value cannot be taken as applicable for the Sri Lankan construction industry. The RII scores represent the level of importance assigned to each issue by a group of stakeholders, such as project managers, contractors, and clients. At the top of the list are "Budget limitations" with an RII of 0.80, indicating that it is the most important issue identified by the stakeholders. This is followed closely by "Poor communication" (RII = 0.79) and "Issues with material logistics" (RII = 0.78). These three issues are all related to project management and coordination, suggesting that effective planning and communication are critical for successful construction projects. Other important issues identified include "Stakeholder dissatisfaction with project delays" and "Poor execution of construction projects", which both received an RII of 0.78, as well as "Contractual scheduling constraints" (RII = 0.76) and "Quality requirements" (RII = 0.76).

In addition to that, issues in the construction industry were validated through phase II: expert interview. Accordingly, in Section 02 of the interview guideline, the respondents were asked to give their opinion on current issues in the construction industry in Sri Lanka. Among all the issues mentioned, the limited use of digitalized applications and technology has been identified by most as a prominent issue in the construction industry.

Other than that, financing and cash flow issues, less skill and competency level of labourers, and import restrictions are also highlighted by more than two respondents.

## 4.2 LEVEL OF IMPLEMENTATION OF INDUSTRY 4.0 APPLICATIONS IN THE SRI LANKAN CONSTRUCTION INDUSTRY.

The list of 5 Industry 4.0 applications/technologies in the construction industry extracted from the literature review were rated for the implementation level in Sri Lanka by the respondents through phase I: a questionnaire survey. Those applications with their Relative Importance and ranks are tabulated in Table. The most implemented Industry 4.0 applications are respectively BIM, 3D printing, and Drones/UAVs. Since all applications have equal or less than 61% of the RII value, the implementation level of all the applications is considerably low.

*Table 2: Level of implementation of Industry 4.0 applications in the Sri Lankan construction industry*

| **Application/Technology** | **Scale percentage (%)** | | | | | **RII** | **Rank** |
|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | | |
| BIM | 3 | 14 | 17 | 9 | 7 | 0.61 | 1 |
| VR and AR | 21 | 12 | 11 | 4 | 2 | 0.42 | 5 |
| Robotics | 33 | 8 | 5 | 2 | 2 | 0.33 | 7 |
| 3D Printing | 12 | 12 | 14 | 9 | 3 | 0.52 | 2 |
| AI | 31 | 10 | 2 | 6 | 1 | 0.34 | 6 |
| Drones or UAV | 7 | 15 | 22 | 5 | 1 | 0.51 | 3 |
| IoT Solutions | 12 | 17 | 15 | 4 | 2 | 0.47 | 4 |
| [1] Very poor, [2] Poor, [3] Moderate, [4] Good, [5] Very good | | | | | | | |

According to Table 2, BIM is the mostly implemented technology, with an RII of 0.61 and a rank of 1. This is followed by 3D Printing with an RII of 0.52 and a rank of 2, and Drones or UAVs with an RII of 0.51 and a rank of 3. On the other hand, Robotics has the lowest RII value of 0.33 and a rank of 7, indicating that it is considered to be the least implemented technology among the surveyed group. Table 2 provides useful insight into the perceived implementation of different technologies in the construction industry.

Near the middle of the vortex, the effect of digital disruption is greater for anyone working in that sector. In other words, those sectors are highly digitalised. According to previous research the position of the construction industry in the vortex is far away from the eye (Keast, 2016). According to that, the level of digitization of the construction sector was further examined and validated during phase II: expert interviews. All the respondents said the construction industry in Sri Lanka has been digitalized in a percentage between 5%-50%. **Error! Reference source not found.** illustrates the level of digitalization of the construction industry according to respondents' views by positioning each respondent’s views in a vortex model.

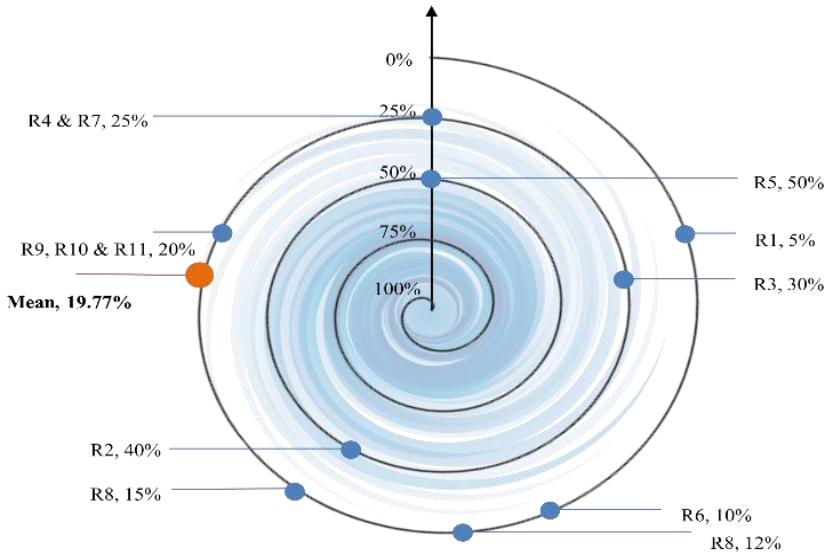



*Figure 2: Level of digitalisation of the construction industry according to respondents' view*

According to the data, the geometric mean value of the given percentages is 19.77%. Therefore, the level of overall responses proves that the digitalisation of the construction industry in Sri Lanka is almost below 20% compared to other industries. R4 specifically said that 'when *considering textile, manufactories industries, they are now mostly automated. For example, the Rhino roofing sheets factory is also highly automated. They use highly digitalised machines. Therefore, compared to other industries, the construction industry has only 25% digitalisation in Sri Lanka. China is very far ahead of Sri Lanka*.". R4 also stated that now some companies are taking action to digitalise the industry by implementing ERP systems, BIM, and others. In other developed countries like China, they use highly automated technologies in the construction industry like counting labourers when they entering to the site through sensors fixed in their helmets. Some construction companies in Sri Lanka also tried to implement those but due to the country's problems, all such efforts have been stopped. R9 stated: "*I think according to the research, the construction industry is the lowest digitalised industry in the world. In the Sri Lankan industry, it is not digitalised at all. We don't use advanced software for take-off and pricing, and we don't use modular building, 3D printing, VR, AR, or digital twin, we don't use those currently in Sri Lanka. I can rate very lower level*." R11 argued that currently, the Sri Lankan construction industry is experiencing technologies like BIM and IoT. Other than that, the industry is using various software for project management and BOQ preparation. Therefore, currently, the door for digitalization is open in the Sri Lankan construction industry.

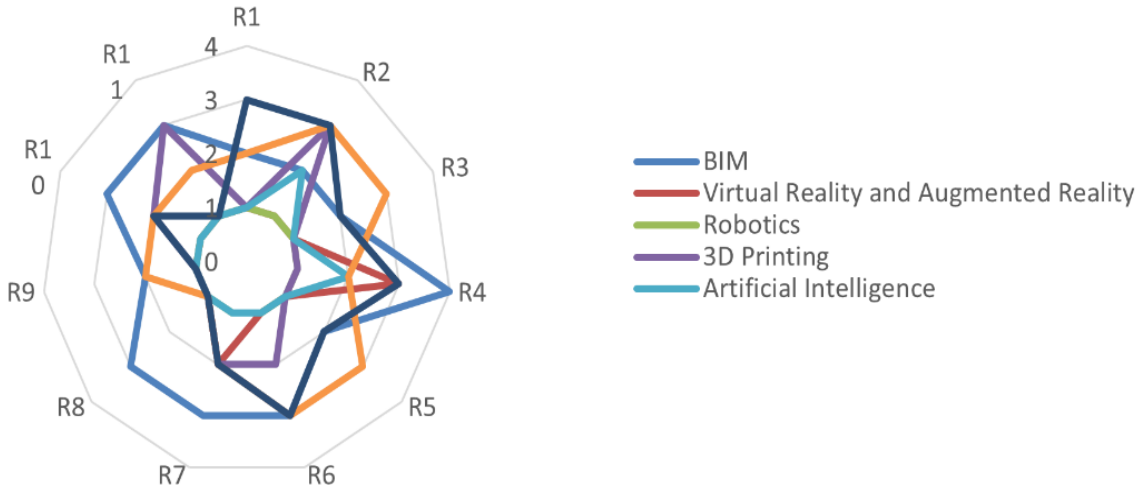
## 4.3 KNOWLEDGE OF INDUSTRY 4.0 APPLICATIONS

As Industry 4.0 technologies continue to transform the construction industry, it is important to understand the level of knowledge and awareness that industry professionals have of these technologies. BIM, VR and AR, drones, robotics, and other advanced technologies are revolutionizing the way that construction projects are designed, planned, and executed. To explore the degree of knowledge and awareness of industry professionals about these technologies, this research conducted interviews with a group of experts in the construction industry. The interviews aimed to measure the level of knowledge of each respondent regarding various Industry 4.0 applications and to map the

results in a graphical figure that provides insights into the current state of knowledge in the industry. Almost all the respondents except one have sufficient knowledge of BIM. Other than that, many of them also had the knowledge and understanding of VR & AR, 3D printing, and drones. But only 2 respondents have heard of robotics in the construction industry. All respondents have participated in at least one seminar/workshop related to any type of Industry 4.0 technologies. But many of them mentioned that they used self-learning methods to gain knowledge about many types of Industry 4.0 technologies.

### 4.4 IMPLEMENTATION LEVEL OF EACH INDUSTRY 4.0 APPLICATION

In the interview, the experts were asked to rank the implementation level of each Industry 4.0 application. **Error! Reference source not found.** graphically demonstrates the




results.

*Figure 3: Implementation level of each Industry 4.0 application*

When analysing the responses of the experts, same as the questionnaire survey, BIM was identified as the technology most widely implemented in the construction industry. Next, respectively, Drones or UAVs, IoT solutions, and 3D Printing can be ranked at the implementation level. According to their views, robotics and AI are the least implemented applications in the industry.

## 5. DISCUSSION

When focusing on the issues in the construction industry, research findings validate that budget limitations (Chin-Keng & Shahdan, 2015) was the most critical issue found in the industry. Other than that, issues which are found in literature such as poor communication (Makulsawatudom et al., 2004; Thorpe, 2003), stakeholder dissatisfaction with project delays (Alothaimeen & Arditi, 2019), and issues with material logistics were also accepted by the respondents. Not limited to that, expert interviews revealed that there were issues due to less digitalisation, less skill level of labourers, financing and cashflow issues, import restrictions, and so on. As discussed by Guo et al. (2017), the existence of safety and environmental concerns was again revalidated by experts in interviews.

When comparing the results of both questionnaire and expert interviews, among all the major Industry 4.0 applications which were identified by El Jazzar et al. (2021), BIM was

identified as the technology most widely implemented in the construction industry with an RII of 0.61 in the questionnaire survey results. Drones or UAVs, IoT solutions, and 3D printing were also at higher implementation levels. The findings of both the questionnaire and the expert interview show that robotics and IoT were less implemented technologies in the industry. As a result of expert interviews, the overall level of digitalisation of the construction industry was less than 20%. The results of the interviews conducted with construction industry professionals provide valuable insight into the level of knowledge and awareness of Industry 4.0 technologies. While almost all respondents had sufficient knowledge of BIM, there was a significant knowledge gap in robotics. This highlights the need for more awareness and education about these advanced technologies in the industry. It is encouraging to note that many of the respondents had knowledge and understanding of VR & AR, 3D printing, and drones. This suggests that these technologies are gaining wider acceptance and adoption in the construction industry. Furthermore, the fact that all respondents had participated in at least one seminar/workshop related to any type of Industry 4.0 technologies indicates that industry professionals are actively seeking out opportunities to learn and stay up-to-date with the latest developments in the field. However, the finding that many of the respondents used self-learning methods to gain knowledge about Industry 4.0 technologies also highlights the need for more accessible and user-friendly educational resources. Overall, the insights gained from this research can inform the development of targeted educational programmes and initiatives aimed at improving knowledge and awareness of Industry 4.0 technologies in the construction industry.

## 6. CONCLUSIONS

The research's aim was met by conducting a systematic literature review and conducting a questionnaire survey and expert interviews of construction industry professionals. The digitalisation of the construction industry is based on the status of Industry 4.0 technologies/applications in the industry. Through the literature review, several industry 4.0 applications have been identified which are considerably used in the industry, such as BIM, VR & AR, 3D Printing, robotics, AI, Drones, and UAV and IoT solutions. The survey data indicated that the overall implementation and usage levels of these applications were lower in Sri Lanka compared to other countries. Among the selected applications, BIM was found to be the most commonly used one in the industry. Subsequently, the expert responses were analysed and BIM was identified as the technology most widely used in the construction sector, similar to the questionnaire survey. Subsequently, 3D Printing Drones or UAV and IoT solutions can be prioritized in terms of implementation. Furthermore, among them, Robotics and AI are the least implemented applications in the construction sector. However, it is important to note that these findings are limited to the context of Sri Lanka and may differ in other countries. This study recommends that industrial practitioners determine the level of implementation of Industry 4.0 applications in the Sri Lankan construction industry to effectively implement Industry 4.0 applications in the Sri Lankan construction industry and overcome the various issues in the construction industry. The findings will also pave the way for further research on the successful implementation of Industry 4.0 applications in the Sri Lankan construction industry. The results of this research will allow construction practitioners to investigate solutions to problems in the Sri Lankan construction industry. Further research is required to understand the factors that may be

hindering the adoption of these technologies in Sri Lanka and to explore ways to increase their implementation and usage in the construction industry.

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