J. Res. Technol. Eng. 5 (4), 2024, 93-102

Journal Of Research Technology & Engineering
www.jrte.org

Technological Infrastructure for Remote Construction Works in Western Province of Sri Lanka

*M.D.D. Gunawardana, Devaki Bandaranayake

Faculty of Technology, University of Sri Jayewardenepura
*devakibandaranayake@gmail.com

Received:20 Aug 2024; Revised:25 Aug 2024; Accepted: 30 Sep 2024; Available online: 10 Oct 2024

Abstract—This study investigates the technological infrastructure required for remote construction projects in the Western Province of Sri Lanka, focusing on key areas such as transportation, communication, project management, monitoring and control, and safety and security. A mixed-methods approach was employed to collect data from 42 participants through questionnaires and semi-structured interviews and 20 peoples were identified as who have experience on remote construction activities. The reflexive thematic analysis method, supported by NVivo software, was used to identify the key themes; patterns and themes within the data. Key findings for each infrastructure show that transportation technologies, such as GPS trackers, significantly improve logistics and site navigation. Communication tools like mobile phones and video conferencing enhance real-time coordination, though connectivity issues remain a challenge. Project management technologies, including Primavera and MS Project, are widely adopted, contributing to better scheduling and planning efficiency. Monitoring and control systems, such as drones and IoT devices, are emerging technologies, but their adoption is limited due to high costs and technical issues. Safety and security infrastructures, primarily CCTV and surveillance systems, are effective but face challenges related to power outages and maintenance. The study concludes that while foundational technologies like mobile networks and basic digital tools are widely utilized, there are significant gaps in advanced technology adoption, particularly in AI and IoT. Addressing these gaps through targeted training and investment will be crucial for improving the efficiency, safety, and sustainability of remote construction projects in the region.

Index Terms—Remote construction, Transportation, Communication, Project Management, Monitoring and Control, Safety and Security, Western province in Sri Lanka,

1 INTRODUCTION

1.1 Overview

The Western Province of Sri Lanka, which includes major cities like Colombo, faces specific challenges including a shortage of skilled workers, rising costs, and a lack of technological infrastructure. Remote construction work involves various aspects, including project management, communication, data sharing, and remote monitoring, which require a robust technological ecosystem. Urbanization in developing countries has rapidly increased the development of large linear infrastructure projects such as road-ways, railways, tunnels and pipelines [1]. One of the distinctive features of such projects is that they usually involve a sequence of tasks which are repetitive in each unit or location for the length of project [2]. This results in a complex scheduling network with a large number of tasks which are difficult to monitor and control [3]. As the social and technological environments and trends are changing, so does the way of working. Today workers at different organizations have more freedom and flexibility than ever to work from anywhere else than the “traditional” office. What we mean with traditional office is an office where people mainly work on their computers, but still are together in the same place. It is mainly about those working on the computer on their own, such as banking workers, insurance company workers and workers with different administrative responsibilities in the organization. What people want to achieve is a cheaper, faster, and greener way of working. Remote work is one of the flexibilities and is defined as “performing work at a location other than one’s primary office” [4]. Remote construction projects exist in many regions throughout the world such as the Sahara Desert, Antarctic regions, the Arabian Peninsula desert, the Australian desert, the Empty Quarter etc. The dilemma in managing remote projects is highlighted by [5]. These authors have pointed out that remoteness thus the loose control is major cause of the management problems. They suggested possible causes such as the lack of human resources, infrastructure and experience of managing these remote projects. In the Kingdom of Saudi Arabia, remote construction sites have unique problems [6]. In this project, existing technological infrastructure in the Western Province is evaluated including digital tools, and hardware/software capabilities. Identify primary technological patterns, challenges, benefits and disadvantages faced by construction projects in the Western Province when implementing remote work practices.

1.2 Aim and objectives

Assess and analyse the utilization of technical infrastructure in the Western Province to enable effective and secure remote construction techniques, supporting regional economic growth and sustainable development.

i. Investigate the current state of remote construction work in the construction industry.
ii. Evaluate the existing technological infrastructure in the Western Province, including digital tools, and hardware/software capabilities.
iii. Identify primary technological patterns, challenges, benefits and disadvantages faced by construction projects in the Western Province when implementing remote work practices.

2 Literature Review

2.1 Remote Construction

Remote construction describes building projects executed in places that are geographically isolated or hard to reach. Many challenges in such a project management, logistics, and execution more complicated, requiring specific methodologies and technology. Construction remote sites mainly have limited accessibility, which complicates the transportation of materials and equipment and often results in increased costs and hence elongated project timelines. Factors such as severe weather, lack of power, and local infrastructure further raise the stakes [7]. Hachem-Vermette and Yadav, 2023 [7] has further stated that, utilities such as water, electricity, and internet that are taken for granted on urban construction sites might not even be available at all on remote sites. Moreover, remoteness can imply scarce availability of skilled labour, which in turn can have a negative impact on the development and quality of construction projects. Issues such as human resources, production and cost management, infrastructure and communication have been identified as key issues in remote construction projects.

2.2 Global Trends in Technological Infrastructure for Construction

Infrastructure in the construction industry refers to the basic physical and organizational structures and facilities needed for the operation of a country, city, or area, that is, the services and facilities necessary for the economy to function. This generally applies to constructing roads, bridges, tunnels, the provision of water, sewers, electrical grids, telecommunications, etc. The problems associated with remote construction have been easily mitigated using several technologies. Among them are GIS (Geographical Information Systems) and GPS (Global Positioning Systems). They really help in site selection and at the drawing board of the construction process, as the project managers make crucial decisions of the project based on the geographical data provided. Another category of technology that has greatly enhanced remote construction is Building Information Modelling technology. BIM enables architects, engineers, and construction practitioners to work more productively on a project at all levels of development, starting with an idea, then designing, building, and finally during operation and maintenance [8]. BIM technology enhances project visualization, ensures accuracy in the construction process, and improves communication among stakeholders by providing a common platform for the sharing of information [9]. Moreover, remote monitoring systems improve project monitoring and control, allowing project managers to track progress, monitor equipment performance, and ensure safety compliance in real-time, even at remote locations [10]. Choi et al., 2023 [11] has stated that drones and unmanned aerial vehicles used for in construction works for aerial surveys, site inspections and data collection in remote areas, providing valuable insights, improving decision-making and improving project planning and management. Sophisticated technologies such as Virtual Reality (VR) and Augmented Reality (AR) are also being used in developed countries for virtual site visits, remote training sessions, and interactive project simulations, enabling stakeholders to visualize and experience construction projects remotely, collaborative processes, and decisions [12]. Using cloud-based project management platforms provides real-time access to project data, documents, and schedules from anywhere, enabling seamless collaboration, information sharing, and project monitoring among teams dispersed in remote locations [13].

2 METHODOLOGY

2.1 Study Area

The research is based in the Western Province of Sri Lanka, which is the economic and administrative capital city of the country, Colombo, along with other major urban centres like Gampaha and Kalutara. The dynamic nature of the construction industry in this region provides a strong context for examining the integration and impact of advanced technologies. Under this research, participants were drawn from different categories of construction projects, including residential, commercial, industrial and large-scale infrastructure, to be able to understand the technological needs and challenges peculiar to the respective scopes of construction work.

2.2 Data Collection

In this research, a mixed-methods approach was employed for data collection, primarily using questionnaires and semi-structured interviews. The questionnaire was administered through both face-to-face and interviews, capturing responses based on the information provided by participants. Data collected included both quantitative and qualitative aspects. A total of 42 participants contributed to the study, with

20 of them specifically involved in remote construction projects.

For the qualitative phase, semi-structured interviews were conducted with key stakeholders, such as project managers, site supervisors, and engineers. Each interview lasted between 30 to 60 minutes and focused on collecting demographic data as well as insights into critical aspects of technological infrastructure related to remote construction activities. These interviews provided in-depth perspectives on the challenges and opportunities of adopting technology in the field, as well as practical experiences with specific technologies used on construction sites.

2.3 Data Analysis and Visualization Methods

To accomplish the research objectives, a reflexive thematic analysis approach was adopted to analyse the qualitative data obtained from interviewing 20 participants out of 42. According to Braun and Clarke's approach to reflexive thematic analysis is an easily accessible and theoretically flexible interpretative approach to the analysis of qualitative data, which will facilitate the identification and analysis of patterns or specific themes in a given data set [14]. In this study the researcher relied on NVivo 14 a well-established qualitative data analysis tool to conduct the reflexive thematic analysis. Microsoft Excel and NVivo software were used to properly analyse and represent the quantitative and qualitative data obtained through the questionnaire. The data were analyzed based on five key categories of technological infrastructure used in construction projects: transportation, communication, project management, monitoring and control, and safety and security.

3 Results and Discussion

3.1 Demographic data of the Participants

The Results and Discussion section of this thesis presents the findings from the 20 interviews out of 42 conducted with professionals involved in construction projects in the Western Province of Sri Lanka. Because 22 students did not have experience in remote construction works. The Fig. 1. illustrate the distribution of professional roles among the study participants, categorized into seven roles: Project Manager, Site Engineer, Planning Engineer, Assistant Engineer, Technical Officer, Project Engineer, and Construction Manager. The largest segment, comprising 40.0% of the participants, are Site Engineers, indicating a significant representation of professionals involved in on-site project execution. The age distribution of participants in the study, categorized into three age groups: 20-30 years, 30-40 years, and above 40 years. According to Fig. 2. The largest segment of participants, representing 65.0% of the total sample, falls within the 30-40-year age group. Participants above 40 years constitute 30.0% of the sample, making them the second largest group. The smallest group, comprising only 5.0% of the participants, consists of individuals aged 20-30 years. The Fig. 3. depicts the gender distribution of the participants in the study and the figure reveals a significant gender imbalance, with 95.0% of the participants being male and only 5.0% being female. The Fig. 4. describes the work experience distribution of the study participants, divided into five categories: 0-5 years, 5-10 years, 10-15 years, 15-20 years, and above 20 years. The largest segment of participants, representing 40.0% of the total, has 10-15 years of work experience, indicating a substantial portion of midcareer professionals.

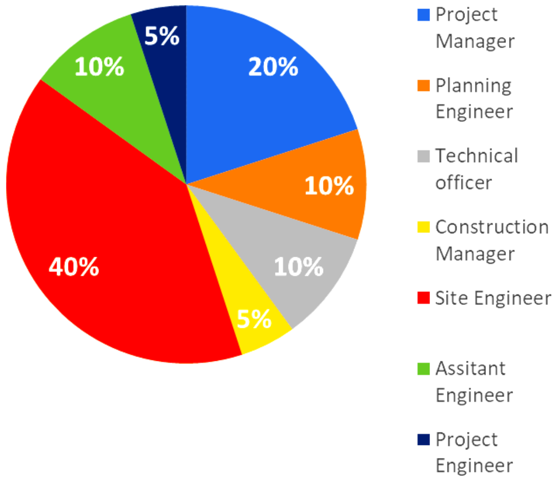

Fig. 1. Participant's Demographics-Professional Role

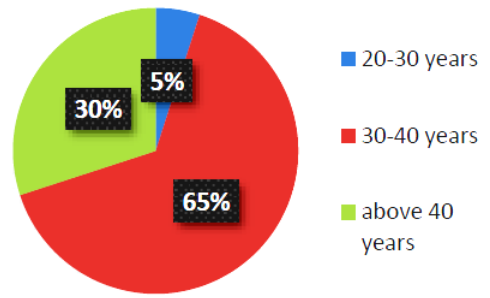

Fig. 2. Participant's Demographics-Age distribution

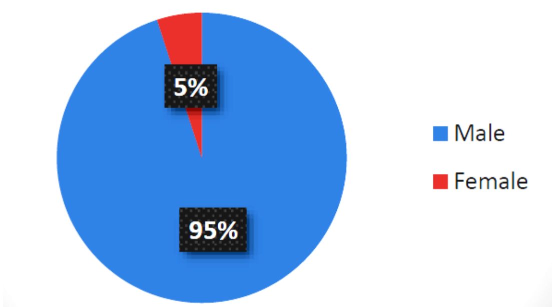

Fig. 3. Participant's demographics- Gender Distribution

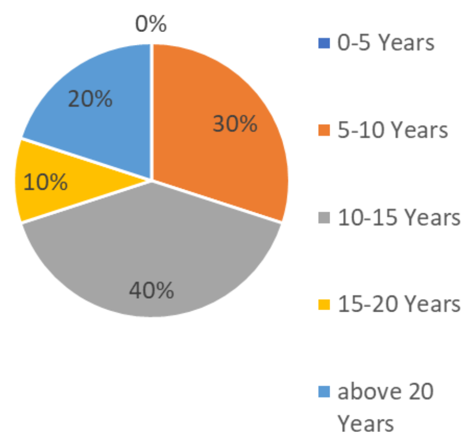

Fig. 4. Participant's demographics- Work Experience

3.2 Relationship with remote construction

Remote construction is a newly emerging concept in the construction industry. Therefore, one of the objectives of this research is to investigate the current state of working remotely within the construction industry. Fig. 5. shows the distribution of experience in the remote construction field among the 42 participants. The data reveals that 48% of the participants have experience in remote construction, while the remaining 52% do not. This nearly even split highlights a diverse range of backgrounds among the participants, indicating that almost half of the respondents bring relevant expertise to the table, whereas the other half might be new to this field or possess experience in traditional construction settings. Further analysis was done for the professionals who already have industry experience. The knowledge about technological infrastructure of industry professionals was assessed based on 20 professionals. Fig. 6. depicts the participants' knowledge about technological infrastructures in the construction field, divided into three categories: Low, Medium, and High. The chart reveals that a significant majority, 80.0% of participants, rate their knowledge at a medium level, indicating a moderate understanding of technological infrastructures. The remaining 20.0% of participants assess their knowledge as Low, with no participants rating their knowledge as High. This distribution suggests that while most participants have a basic to intermediate grasp of technological infrastructures, there is a noticeable gap in advanced expertise. The absence of participants with high-level knowledge highlights a potential area for improvement in the training and education of remote construction professionals. Fig. 7. Illustrates, the distribution of responses regarding whether participants' organizations have an expert team to handle technological infrastructures in remote construction projects. According to the chart, 60.0% of participants reported that their organizations do not have such a team, while 40.0% confirmed the presence of an expert team. This data highlights a significant gap in the availability of specialized technological expertise within the construction field. Many organizations lacking an expert team suggest potential challenges in effectively managing and implementing technological infrastructures, which could impact project efficiency and success. Conversely, 40.0% of organizations with dedicated expert teams are likely better equipped to navigate technological complexities, ensuring smoother operations and possibly gaining a competitive edge. The analysis of the presence of a training program for introducing new technology in remote construction projects reveals a positive outcome, as all survey participants reported having received such training. Fig. 8 illustrate that 100% of participants reported having a training program in place for new technology, indicating unanimous adoption of structured training initiatives.

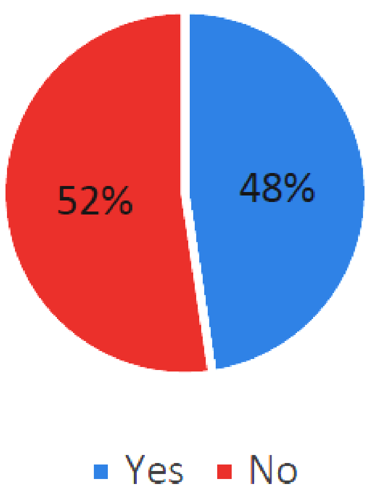

Fig. 5. Remote construction-experience in remote construction field

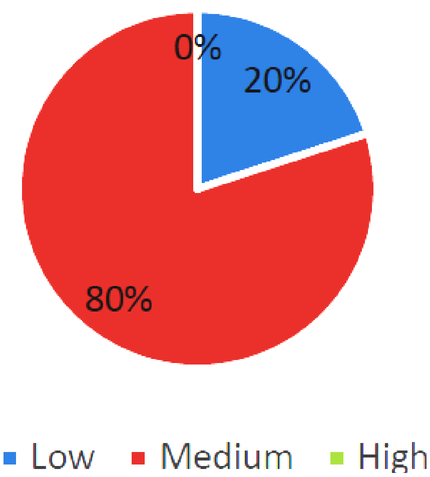

Fig. 6. Remote construction-knowledge about technological infrastructures

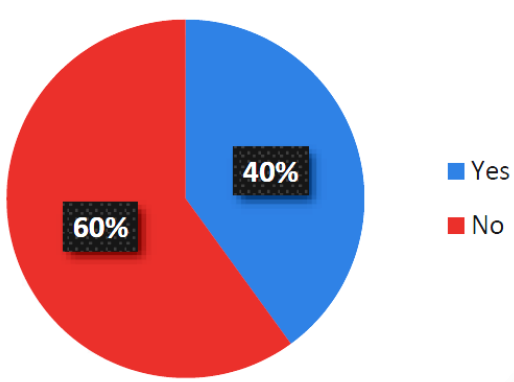

Fig .7. Remote construction-expertise team to deal with technological infrastructures

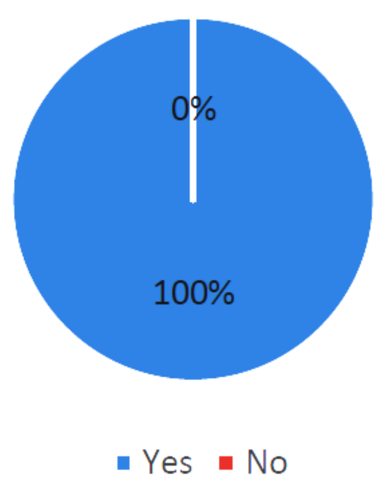

Fig. 8. Remote construction- training program to introducing a new technology

3.3 Analysis of Qualitative Data

The data are analyzed by 5 patterns of the technological infrastructures used in construction works. Such as Transportation, Communication, Project management, Monitoring and controlling, and Safety and security to check the current statues of Benefits, Effective Technologies, Emerging Technologies, Limitations, Methods of usage, and Usage Percentage of the particular infrastructure as themes. After familiarizing the data, the researcher proceeded to the second step of reflexive thematic analysis, which is generating codes and themes. The report represented the different codes and how they came together to form themes that answered the research questions posed in the study.

3.3.1 Analysis of Transportation

The data obtained from NVivo and analyzed thematically provides insights into various aspects of remote construction projects, particularly focusing on transportation technologies. The benefits associated with transportation technologies in remote construction are frequently cited, for example, mentions reflecting the perceived advantages of these technologies, such as improved accuracy, reliability, location track, Improved logistic process etc. Technologies that have been identified as effective in the field are mentioned, although less frequently. GPS Tracker is a common effective technology mentioned in the interviews, suggesting its widespread use and effectiveness in location tracking and security. The discussion of emerging technologies indicates awareness of ongoing advancements technologies like GPS Trackers and Camera-Video tracking are mentioned, pointing to new tools being integrated into remote construction practices. The limitations and challenges faced in remote construction projects are crucial for understanding the areas needing improvement. Common limitations mentioned include network problems, cost, and maintenance issues, which can hinder the effectiveness of technological solutions. The methods employed in utilizing transportation technologies are also highlighted. Interviews mention specific methods such as using GPS-Redimix trucks emphasizing practical approaches to technology use. The data also provides insights into the percentage of technology usage of transportation in projects. Usage percentages vary, with mentions of 10% and 20%, indicating the extent to which these technologies are integrated into transportation field in the construction operations.

3.3.2 Analysis of Communication

The analysis of the data obtained from NVivo, focusing on communication within remote construction projects provides a comprehensive understanding of the role and impact of communication technologies in the field. The benefits of communication technologies are frequently highlighted across interviews. Common benefits include improved accuracy, speed, real-time updates, and validity, and ability to monitor repeatedly. Technologies deemed effective are frequently mentioned, with mobile phones and tools like Google Drive and email being prominent. There is awareness of emerging technologies that enhance communication capabilities. Examples include the latest technological trends and video conferencing tools, indicating a shift towards more advanced communication methods. Several limitations and challenges are identified, impacting the effectiveness of communication technologies. Common issues include network and connectivity problems. Various methods are employed to facilitate communication, reflecting a mix of traditional and modern approaches. Examples include the use of walkie-talkies, mobile phone networks, and internet access. The extent of technological usage in communication is also detailed, providing insights into adoption rates. Usage percentages range from 50% to 60%, indicating moderate to high integration of communication technologies in project operations.

3.3.3 Analysis of Project Management

The thematic analysis on project management provides valuable insights into the tools and strategies used in project management and their effectiveness. Various tools are frequently mentioned, reflecting their importance in managing remote construction projects. Common tools include Primavera, MS Project, and ERP Systems. The benefits of using these project management tools are highlighted across the interviews. These benefits include data accuracy, improved scheduling, better planning, and timesaving. Technologies identified as effective in project management are frequently noted. Primavera and MS Project are consistently mentioned across interviews as effective tools for managing projects. Awareness of emerging technologies in project management is evident. Examples include AI-based project management software and developed project management software, indicating ongoing advancements in this field. Several limitations are discussed, highlighting the challenges faced in project management. Common limitations include software development issues, network failures, and cost. The extent of usage of these project management tools is also provided, giving insights into their adoption rates, Usage percentages are high, ranging from 80% to 90%, indicating a significant reliance on these tools for project management.

3.3.4 Analysis of Monitoring and controlling

The data obtained from NVivo, focusing on monitoring and controlling remote construction projects, has been analyzed thematically for aforementioned themes. This analysis provides valuable insights into the tools and strategies used for monitoring and controlling construction projects and their effectiveness as represented in appendix 5. Various tools are frequently mentioned, reflecting their importance in managing remote construction projects. Common tools include mobile apps and project management software. The benefits of using these monitoring and control tools are highlighted across the interviews. These benefits include time saving, real-time data access, and improved accuracy. Technologies identified as effective in monitoring and control are frequently noted. Software is consistently mentioned across interviews as effective tools for monitoring projects. Awareness of emerging technologies in monitoring and control is evident. Examples include IoT devices, cameras, and drones, indicating ongoing advancements in this field. Several limitations are discussed, highlighting the challenges faced in monitoring and controlling projects. Common limitations include technical issues, high costs, and maintenance problems. The use of various sensors and tools for monitoring is also highlighted. Examples include cameras and reinforcement covering checking tools, which are used to ensure accuracy and efficiency in monitoring. The extent of usage of these monitoring and control tools is also provided, giving insights into their adoption rates. Usage percentages vary, ranging from 10% to 70%, indicating different levels of reliance on these tools for project management.

3.3.5 Analysis of Safety and security

The data set provided, titled "Safety and Security," encompasses various aspects of technological infrastructures utilized in remote construction projects, specifically focusing on safety and security measures. The data reveals that while current technologies such as CCTV cameras are widely used and considered effective. The benefits of these technologies include continuous monitoring, easy hazard detection, and enhanced security through real-time surveillance. Limitations identified include issues such as power cuts, high costs of implementation, and occasional technical failures that might hinder their effectiveness. The data includes information on how extensively these technologies are used on remote construction sites. For example, CCTV cameras might have a usage percentage indicating how prevalent they are compared to other safety measures. Emerging technologies that could benefit remote construction projects are discussed. For instance, advancements in drone technology for surveillance and the use of IoT devices for real-time monitoring, barrier gates with pass cards, are highlighted.

4 CONCLUSIONS

The research on "Technological Infrastructure for Remote Construction Work in the Western Province of Sri Lanka" reveals a complex but promising landscape. The Western Province, with its urban centres like Colombo, is a dynamic region that faces both opportunities and challenges in integrating advanced technological infrastructures in construction projects. This study has identified the current state of technological adoption, the benefits realized, and the barriers faced, while also proposing strategies for improvement. The current technological infrastructure in the Western Province of Sri Lanka for remote construction work is found to be moderately developed. Essential technologies such as mobile networks, internet connectivity, and basic digital tools are in place, but there are significant gaps in advanced technological adoption, such as AI, IoT, and advanced project management tools. The study identified several critical challenges in the implementation and maintenance of technological infrastructure. These include budget constraints, environmental factors, logistical issues, and limited access to skilled personnel. Power and communication issues, as well as data security and privacy concerns, also pose significant challenges. The presence of training programs to introduce new technologies is a positive step. However, there is a significant gap in advanced expertise among professionals, which affects the effective deployment and management of these technologies. It is crucial to address this gap to ensure that construction professionals are well-equipped to utilize modern technological tools and systems effectively. Technologies currently employed, such as mobile networks and video conferencing tools, have been effective in improving communication and project management. However, their full potential is not being realized due to the challenges mentioned. There is a clear indication that more advanced new technologies could further enhance efficiency and project outcomes. The potential for adopting advanced technologies is significant. These technologies can provide predictive maintenance, real-time monitoring, and enhanced project management capabilities, leading to better efficiency, safety, and sustainability in remote construction projects. In summary, the research highlights the importance of continuous improvement and investment in technological infrastructure for remote construction in the Western Province of Sri Lanka. By addressing the existing challenges and leveraging the benefits of advanced technologies, the construction industry can achieve greater efficiency, sustainability, and competitiveness.

REFERENCES

[1] Lawrence, P., Renaud, B. and Wadhva, K. ‘National Urbanization Policy in Developing Countries.’, The Economic Journal, 94(375), p. 690, 1984.

[2] J.D. Lutz, A. Hijazi, Planning repetitive construction: current practice, Constr. Manag. Econ. 11 (2) 99–110, 1993

[3] Arditi, D., Sikangwan, P. and Tokdemir, O.B. ‘Scheduling system for high rise building construction’, Construction Management and Economics, 20(4), pp. 353–364, 2022

[4] Perry, Sara & Rubino, Cristina & Hunter, Emily. (2018). Stress in remote work: two studies testing the Demand-Control-Person model. European Journal of Work and Organizational Psychology. 27. 1-17. 10.1080/1359432X.2018.1487402, 2018

[5] Kestle, L. and London, K. ‘Towards the development of a conceptual design management model for remote sites’, IGLC 2002: proceedings: 10th Conference of the International Group for Lean Construction, pp. 1–14, 2022

[6] Sidawi, B. and Al-Sudairi, A.A. 'The use of advanced computer-based management systems by large Saudi companies for managing remote construction projects', Procedia Engineering, 77, pp. 161–169, 2014

[7] Hachem-Vermette, C. and Yadav, S. 'Impact of Power Interruption on Buildings and Neighborhoods and Potential Technical and Design Adaptation Methods', Sustainability (Switzerland) , 15(21), pp. 1–26, 2023

[8] Azhar, S., Khalfan, M. and Maqsood, T. 'Building information modeling (BIM): Now and beyond', Australasian Journal of Construction Economics and Building, 12(4), pp. 15–28, 2012

[9] Mccoy, A.P. and Yeganeh, A. 'An Overview of Emerging Construction Technologies', NAIOP Research Foundation, (March), pp. 1–45, 2021

[10] Makhathini, N., Musonda, I. and Onososen, A. 'Utilisation of Remote Monitoring Systems in Construction Project Management', Lecture Notes in Civil Engineering, 245, pp. 93–100, 2023

[11] Choi, H.W. et al. 'An Overview of Drone Applications in the Construction Industry', Drones, 7(8), 2023

[12] Sowunmi, O.S. et al. 'An Investigation of Visualization Technologies for Remote Work in the Architecture, Engineering, and Construction Industry', Construction Research Congress 2022: Computer Applications, Automation, and Data Analytics - Selected Papers from Construction Research Congress 2022, 2-B(March), pp. 361–370, 2022

[13] Smith, R. and Clarno, B. (2012) 'Construction challenges in Kabul', Military Engineer, 104(676), pp. 55–56, 2012

[14] Byrne, D. A worked example of Braun and Clarke's approach to reflexive thematic analysis. Qual Quant 56, 1391–1412, 2022