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A-EYE Tech: Framework to Evaluate an AI Construction Visibility Platform

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ABSTRACT: The authors present the early stages of an Irish government-funded project, A-EYE. This disruptive technology seeks to create a construction visualisation platform that enables measurable productivity advantages through passive data capture and real-time delivery of mission-critical information in an accessible form. The authors outline how they will utilise data captured during construction site operations using camera and sensor equipment to monitor construction resources and processes. Moreover, the positive impact of easy access to visualised data on collaboration between construction stakeholders is discussed. Extensive user-experience research data will be captured after deploying the technology on live projects to create interactive dashboards that can co-exist with 4D BIM data leading to improved workflow and productivity on construction job sites. A-EYE promises an integrated and connected system bringing real-time reality capture and automated scheduling into a singular real-time data source.

1. Introduction

Kaplan and Haenlein (2019) defined artificial intelligence (AI) as a system's ability to accurately collect, interpret, and learn from external data to achieve specific goals and tasks through flexible adaptation. The advent of AI has radically transformed most economic activities in modern societies, such as manufacturing, retail, and telecommunications (Abioye et al., 2021).

Advances in AI technology such as machine learning, computer vision, and robotics have leveraged business endeavours to increase profitability, sustainability, efficiency, safety, and security (Puntoni et al., 2021). However, the construction industry remains one of the least digitised industries, which obstructs momentum to address the myriad of challenges facing construction firms (e.g., cost and time overruns, low productivity, health and safety issues, staff shortages, and the Covid-19 pandemic) (Abioye et al., 2021).

Resistance to change of dated operational practices by construction firms has often exacerbated the complexity of managing projects and hindered the efficiency of the execution process (Young et al., 2021). A report published by McKinsey & Company worldwide management consultancy, concluded that the construction industry is ripe for technological disruption since large projects are regularly completed by up to 80 per cent over budget and fall by 20 per cent behind schedule (Agarwal et al., 2016).

This paper investigates the potential utilisation of the A-EYE disruptive technology to address construction firms' persistent productivity, sustainability, communication, and safety challenges. Driven by AI, the A-EYE construction visualisation platform seeks to leverage the execution process through passive data capture and real-time delivery of mission-critical information in accessible forms to facilitate productivity measurement, process monitoring, and team-wide collaboration.

The authors initially describe the project's background and present state of the art, focusing on the technology's evolution process, multiple functions and potential advantages to construction firms and clients. Moreover, they present a framework for process analysis to evaluate the performance of the A-EYE solution on construction sites. Finally, the paper proceeds to explain the adopted methodological approach and conclusion. Currently, there is no data capture or analysis presented in this paper.

2. Literature Review

2.1 Background

Modern construction sites are rich in data emerging from various sources, including people, computers, machinery, and sensors (Huang et al., 2021). Nevertheless, the vast volumes of data generated in projects' planning, design, construction, operation, and maintenance phases remain underutilised due to the modest intensity of innovation in the construction industry (Yu and Tsai, 2021).

The scope of traditional information systems in construction management is often limited to recording basic information related to project design, schedules, costs, and resources (Martinez-Rojas et al., 2016). Nevertheless, their ability to organise, analyse and exploit abundant data from daily communications, camera recordings and sensor readings remains limited.

Harnessing these large volumes of data through digital transformation leads to in-depth insights and better construction management decisions (Hwang et al., 2021; Yu and Tsai, 2021). However, the reluctance of construction firms to embrace change in pursuit of digital transformation has been linked to the large productivity gap between the construction industry and other industries (Young et al., 2021).

2.2 Construction Industry Challenges

Besides sustainability and communication, modest productivity remains one of the fundamental challenges obstructing the growth and prosperity of the construction sector. Productivity is the output produced by a unit of study as a proportion of the inputs required for production (OECD, 2001). Construction outputs are measured by the value and quantity of elements/projects produced to a specific defined quality and standard. On the other side, inputs include an array of resources required for project completion (e.g., time, manual labour, managerial staff, finance, plant, technologies, materials, energy, etc. (Loosemore, 2014).

The most prevalent construction productivity measure is labour productivity which quantifies the value added per labour hour (Loosemore, 2014; Moohialdin et al., 2020). However, labour productivity is a partial measure that does not account for other production factors and subsequently does not provide a holistic picture of on-site construction productivity. Total Productivity Factor (TPF) aimed to resolve this dichotomy by bundling diverse productivity factors (e.g., labour and capital) as well as variables influencing on-site productivity (e.g., management practices and communication). Nevertheless, gathering data related to these diverse factors and variables mandates advanced AI-driven technology for passive data capture and comprehensive visibility of construction sites.

In an Irish context, productivity measurement remains limited to traditional labour productivity measures due to the complexity of gathering data from dispersed construction sites. It has been reported that there was little growth in labour productivity between 2000 and 2016 (Government of Ireland, 2019). Likewise, labour productivity in the Irish construction sector was found to be 24% below the Euro Area average (Government of Ireland, 2019).

An official report published by the Irish government estimated that the lag between productivity growth in the broader local market and the construction industry was worth €3.1 billion during the same period (Government of Ireland, 2019). Moreover, multiple studies ascertained that the productivity gap is a global challenge to the building sector (Assaad and El-Adaway, 2021; Tam et al., 2021; Dixit and Saurabh; 2019).

Delays and cost overruns that plague the construction industry were reasoned by inadequate planning and execution practices (Adam et al., 2017). Construction managers and practitioners lack on-site progress visibility due to the absence of timely and reliable information and robust productivity measures. The advent of AI technologies represents a considerable opportunity to address the prevalent productivity challenge threatening the survival of modern construction businesses. AI-driven solutions, such as A-EYE, can accurately gather passive real-time data relating to the diverse factors of on-site productivity to monitor the construction process, identify irregularities, and measure the actual rates of partial/overall productivity. Data exploitation through digitised solutions can improve collaboration and construction process integration in pursuit of increasing productivity (Assaad et al., 2020).

Given the scale of the industry, even a slight increase in overall productivity would have significant economic and societal benefits (Dixit and Saurabh, 2019). Raised productivity will likely result in higher efficiency in using materials to face persistent sustainability challenges (Awad et al., 2021). The construction industry is one of the most significant contributors to global warming and adverse climate change. The industry produces 36 per cent of all greenhouse gas emissions and is responsible for 40 per cent of overall energy consumption across the EU (European Commission, 2020). Poor sustainability is closely related to inadequate project visibility and delayed responses to emerging events (Zhong and Wang, 2019).

A survey conducted by a construction software company revealed that 59 per cent of construction managers receive incomplete information about work progress, and 65 per cent miss change-order opportunities due to the hefty reliance on manual methods for data collection and analysis (Slowey, 2018). The absence of contractors' enthusiasm to realise the digital potential leads to excessive waste due to supply chain disruptions and unnecessary rework.

The management process of construction projects requires sufficient resilience and collaboration to cope with uncertainties, unexpected events, and disputes between stakeholders (Elnaz et al., 2021). Nevertheless, developing effective communication between stakeholders has often been considered a primary challenge to the success of construction projects. The communication challenge has been reasoned by the absence of an efficient, comprehensive, and reliable platform to exchange timely and accurate information between stakeholders (Forcada et al., 2017).

Communication between project partners through numerical data has proven insufficient in creating a constructive and transparent dialogue between stakeholders (Woodward et al., 2010). Numerical data may not provide a comprehensive picture of a project's performance. Likewise, it remains highly vulnerable to manipulation (Olanrewaju et al., 2017). Hence, adopting a real-time image capture and sharing system can leverage collaboration, reduce uncertainty, and eradicate numerous causes of disputes.

2.3 State of the Art

The A-EYE technology is developed to help address the productivity, sustainability, and communication challenges facing construction firms in the current complex business environment. This disruptive innovation aims to create a construction visualisation platform that enables measurable productivity advantages through passive data capture and real-time delivery of mission-critical information in an accessible form. A-EYE seeks to provide easy access to visualised data and documented proof of events in pursuit of efficient team-wide collaboration on construction sites.

The following figure displays the intended application of the A-EYE visualisation platform to monitor and track labour and machinery on construction sites. A-EYE's control tower, supported by high-resolution cameras and tracking sensors, is uniquely positioned to provide complete project visibility and enables the most transparent, visual communication between stakeholders.

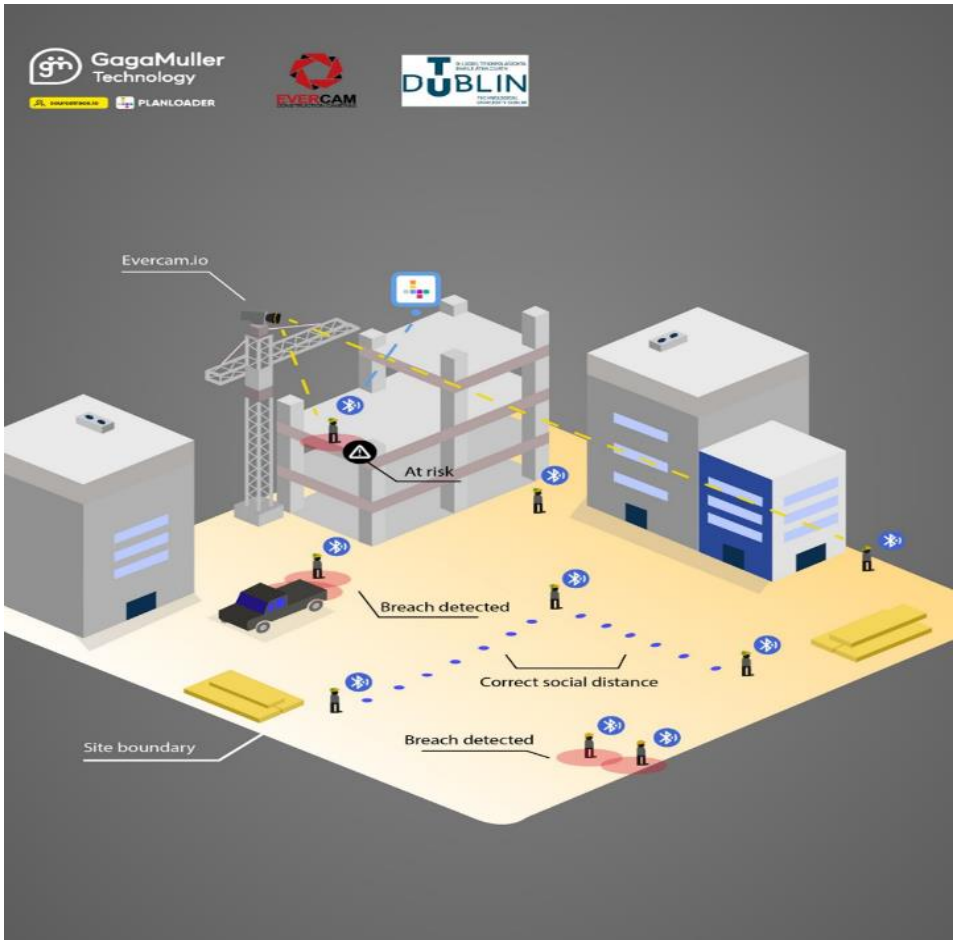

Figure 1: Illustration of A-EYE Technology Demonstration

The intelligent construction environment will be supported in the cloud with desktop and hand-held device interfaces. Most existing data organising, project scheduling, and reality capture technologies operate individually and mandate human intervention to connect these systems through manual data input. A-EYE's point of differentiation lies in the automated integration of reality capture and scheduling processes on construction sites.

This disruptive technology is established by integrating a couple of innovative solutions developed by two worldwide construction technology firms. The first firm designed the visualisation system to overlook entire construction sites and passively extract data, images, and videos through cameras and sensors. Captured data automatically feeds into the advanced construction planning platform, developed by the second firm to achieve valuable productivity and sustainability advantages through passive real-time tracking of project resources and monitoring of project progress.

A-EYE disruptive technology aims to construct an integrated and connected platform that combines advanced visualisation and planning systems into a singular real-time data source (see Table 1):

Challenge	Description
Real-time scheduling and resources control	Adopting A-EYE technology on construction sites can help monitor the numerous concurrent activities and track labour and plant. Real-time monitoring and tracking have proven effective in detecting irregularities, automated amending schedules, and cutting down various kinds of waste (Assaad et al., 2020; Zhong and Wang, 2019).
Real-time Building Information Model (BIM)	The update of construction designs requires manual intervention as conditions change on the ground. However, integrating real-time data with a project's BIM model allows an automated model update to reduce buildings' initial and lifecycle costs (Tanaka, 2021; Khalili, 2021; Wills and Diaz, 2017).
Budgets and billing	One of A-EYE's key advantages is matching the billing process with actual progress on site. The technology's ability to detect materials' delivery time, quantities, and equipment up-time can transparently resolve supplier disputes and cut unnecessary costs.
Safety monitoring	Analysing video footage using A-EYE technology can provide real-time alerts in the event of safety violations. Signals can be delivered in case of equipment operating procedures violations and personal protective equipment is not used on site. Advanced on-site visualisation assists in preventing safety hazards due to labour faults or exposure to heavy machinery (Bhagwat et al., 2021; Dai et al., 2021; Wang et al., 2021).
Performance Analytics and Estimation	One of the A-EYE's main objectives is to develop robust construction productivity measures using real-time and visual data. Measured productivity will include partial productivity (e.g., labour and machinery) and overall productivity of the construction process. Developing reliable productivity measurements in construction are vital for creating an accurate industry benchmark and improving future decision-making (Turner et al., 2021).

Table 1: A-EYE Technology Applications

3. A-EYE Process Analysis Framework

3.1 Technology Evaluation

The technical evaluation of A-EYE mandates piloting the technology on-site to research the productivity and sustainability benefits of deploying this disruptive solution. The collaborative research plan includes gathering quantitative data to measure the impact of A-EYE on construction productivity when compared to established productivity benchmarks. Likewise, fieldwork will capture user experience data to gauge the A-EYE application's usability, functionality, performance, and risks.

User experience research will gather comprehensive feedback from construction practitioners involved in the pilot phase through semi-structured interviews and focus group sessions. The technical team responsible for the technology development aims to deliver incremental improvements to arrive at an optimal product fit during the piloting phase. Therefore, the Delphi technique will be deployed at a final stage to reach a regarding the A-EYE final product design.

A qualified team of researchers will conduct user-experience research in the School of Surveying and Construction Innovation, Technological University (TU) Dublin. The research-performing organisation aims to publish rigour and reliable results that are representative, reproducible, and valid for the broad spectrum of construction end-users.

Figure 2 represents the framework that guides the collaborative research fieldwork to analyse, evaluate, and develop the A-EYE technology. The planned research will incorporate gathering data on the micro, meso, and macro levels of the construction society in Ireland. Likewise, it will involve professionals from technology developing companies to measure the extent of correlation between the A-EYE application and prevalent industry challenges. Similarly, socio-ecological challenges to the technology implementation in practice will be identified to leverage A-EYE's risk management plan and support its future commercialisation.

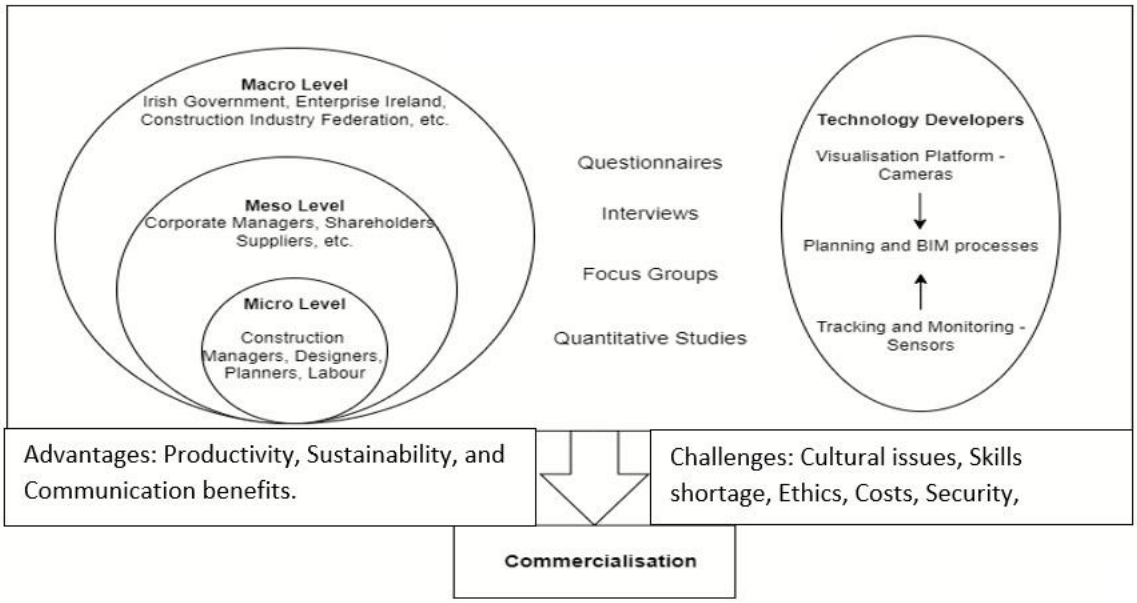

Figure 2: A-EYE Evaluation Framework

3.2 A-EYE Road Map

The collaborative research project aims to analyse, evaluate, and develop disruptive A-EYE technology seeking to address the prevalent productivity, sustainability, and communication challenges in the global construction industry. A-EYE research project is divided into six work packages implemented over three years. The figure below depicts the project work packages.

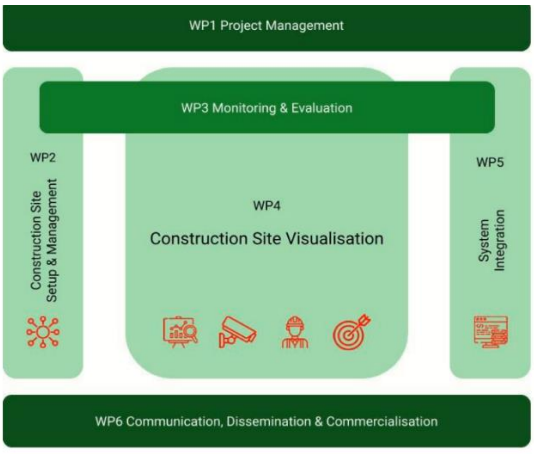

Figure 3: A-EYE Project Work Packages

The first work package, project management, is responsible for guiding the entire project in its administrative, financial, and organisational aspects, including the management of risk and research ethics. Likewise, it includes establishing the project's steering committee and project advisory board. Eventually, it outlines the reporting process to the funding authority, Enterprise Ireland.

The second package is primarily concerned with the design and implementation of the pilot phase in line with the project objectives. The purpose of the third work package is to monitor and evaluate the impact of the A-EYE technology using a framework incorporating pre-defined key performance indicators. The work package to follow will focus on assessing the findings of the piloting phase to adjust A-EYE's AI engines and tools (e.g., cameras and sensors) to achieve the project goals.

Work package five will create a joint A-EYE ecosystem to ensure the successful integration of A-EYE various applications into a single platform. Likewise, it is responsible for producing a final Application Programming Interface (API) version. The final work package aims to design a coherent communication strategy to disseminate results to the broad construction academics and practitioners community. Also, it is in charge of standardising A-EYE with the Irish Standards Authority and procuring necessary ethical clearances.

The adopted research methodology is grounded in the conceptual framework presented in figure 3 to analyse the AI-driven solution. It includes multiple research strategies to gather quantitative and qualitative data to

evaluate the performance of A-EYE's application in the construction practice.

The developed framework bridges the gap between the prevalent construction industry challenges and the proposed disruptive solution. It focused on the tripod of productivity, sustainability, and communication challenges facing construction firms in Ireland. Moreover, it illuminates the various applications of A-EYE to tackle these persistent challenges by using visualised data and documented proof of events to enable smooth time-wide collaboration, monitor and track factors of production, and cut process wastes.

3.3 Ethical Challenges

The TU Dublin ethics and integrity committee had several concerns about A-EYE technology application in practice. These concerns were primarily related to the ethical implications of using the A-EYE monitoring platform to track individuals on construction sites. The research team responded to clarify that the technology developing firms and the research performing organisation are committed to meeting and upholding the requirements set out within the EU General Data Protection Regulation (GDPR) concerning the protection of the privacy of individuals.

Several procedures are implemented to maintain individuals' privacy on the construction site, including signage, data storage and retention policy, data access request, camera field of view and video editing policy. Likewise, it has been confirmed that tracking individuals do not form part of the planned research (GDPR, 2022).

4. Conclusion

A-EYE disruptive technology is a breakthrough in the field of digital construction. The visualisation platform aims to address the persistent productivity, sustainability, and communication challenges adversely impacting the performance of construction firms. Likewise, the potential benefits of A-EYE can support the Irish government in accomplishing its strategic plans focused on achieving sustainability targets, improving the national infrastructure stock, and addressing the housing crisis. A-EYE technology integrates advanced camera/sensor hardware and software solutions to capture passive real-time data for delivering mission-critical information through desktop and hand-held devices. It is uniquely positioned to become this much-needed control tower for construction firms aiming to achieve measurable productivity advantages.

A-EYE's point of differentiation lies in the automated integration of reality-capture and scheduling processes on construction sites that combines the advanced visualisation and planning systems into a singular real-time data source. The technology's unique monitoring and tracking capabilities also facilitate performance analytics, safety monitoring, and billing processes.

In compliance with the requirements of the funding authority, Enterprise Ireland, a framework was developed to support the planned collaborative research aiming to gauge the performance of A-EYE technology in construction sites. Quantitative and qualitative research will measure the perceived productivity and sustainability benefits and evaluate the technology's usability, functionality, and risks. Achieving valid and reliable results is a crucial priority for the project's team to support disseminating and exploiting A-EYE technology in construction practice.

5. References

Abioye et al. (2021). Artificial Intelligence in the Construction Industry: A Review of Present Status, Opportunities and Future Challenges. *Journal of Building Engineering*, 44, pp. 1-13.

Adam, A., Josephson, P. & Lindahl, G. (2017). Aggregation of Factors Causing Cost Overruns and Time Delays in Large Public Construction Projects: Trends and Implications. *Engineering, Construction and Architectural Management*, 24(3), pp. 393-406.

Agarwal, R., Chandrasekaran, S. & Sridhar, M. (2016). *Imagining Construction's Digital Future*. Mckinsey. [Online] Available at: https://www.mckinsey.com/business-functions/operations/our-insights/imagining-constructions-digital-future [Accessed 12 April, 2022].

Assaad, R. et al. (2020). Predicting Project Performance in the Construction Industry, *Journal of Construction Engineering and Management*, 146(5), pp. 1-22.

Assaad, R. & El-Adaway, I. (2021). Impact of Dynamic Workforce and Workplace Variables on the Productivity of the Construction Industry: New Gross Construction Productivity Indicator. *Journal of Management in Engineering*, 37(1), pp. 1-15.

Awad, T., Guardiola, J. & Fraíz, D. (2021). Sustainable Construction: Improving Productivity through Lean Construction. *Sustainability*, 13.

Bhagwat, K., Kumar, P. & Delhi, V. (2021). Usability of Visualization Platform-based Safety Training and Assessment Modules for Engineering Students and Construction

Professionals, Journal of Civil Engineering Education, 147(2), pp. 4-20.
Breitfuss, D., Sibenik, G. & Sreckovic, M. (2021). Digital Traceability for Planning Processes. ECPPM – European Conference on Product and Process Modelling 2020-2021; Moscow, pp. 15-17.
Dai, F., Olorunfemi, A., Peng W., Cao, D. & Luo, X. (2021). Can Mixed Reality Enhance Safety Communication on Construction Sites? An Industry Perspective. Safety Science, 133.
Dixit, S. & Saurabh, K. (2019). Impact of Construction Productivity Attributes Over Construction Project Performance in Indian Construction Projects. Periodica Polytechnica. Architecture; Budapest, 50(1), pp. 89-96.
Elnaz, S., Sharareh, K. & Shirin, K. (2021). Analysis of Effective Project-based Communication Components within Primary Stakeholders in Construction Industry. Built Environment Project and Asset Management, 11(2), pp. 157-173.
European Commission (2020). Energy Efficiency in Buildings. European Commission Governing Body. [Online] Available at: https://ec.europa.eu/info/sites/default/files/energy_climate_change_environment/events/documents/in_focus_energy_efficiency_in_buildings_en.pdf [Accessed 13 April, 2022].
Forcada, N., Serrat, C., Rodriguez, S. & Bortolini, R. (2017). Communication Key Performance Indicators for Selecting Construction Project Bidders. Journal of Management in Engineering, 33(6).
Government of Ireland (2019). Project Ireland 2040: Build Construction Sector Prospects 2019. Government of Ireland. [Online] Available at: https://assets.gov.ie/6659/3312cd28edf04f4c83666ac76b534c45.pdf [Accessed 15 April, 2022].
GDPR (2022). General Data Protection Regulation. [Online] Available at: https://gdpr-info.eu/ [Accessed 16 April, 2022].
Huang Y. et al. (2021). Research Status and Challenges of Data-Driven Construction Project Management in the Big Data Context. Advances in Civil Engineering, 2021.
Kaplan, M. & Haenlein, M. (2019). Siri, Siri, in my Hand: Who's the Fairest in the Land? On the Interpretations, Illustrations, and Implications of Artificial Intelligence. Business Horizons, 62(1), pp. 15-25.
Khalili, A. (2021). An XML-based Approach for Geo-semantic Data Exchange from BIM to VR Applications, Automation in Construction, 121 (1).
Loosemore, M. (2014). Improving construction productivity: a subcontractor's perspective. Engineering, Construction and Architectural Management, 21(3), pp. 245-260.
Martinez-Rojas, M., Marin, N. & Vila, M. (2016). The Role of Information Technologies to Address Data Handling in Construction Project Management. Journal of Computing in Civil Engineering, 30(4).
Moohialdin, A., Lamari, F., Miska, M. & Trigunarsyah, B. (2020). Construction worker productivity in hot and humid weather conditions: A review of measurement methods at task, crew and project levels. Engineering, Construction, and Architectural Management, 27(1), pp. 83-108.
OECD (2001), Measuring Productivity OECD Manual, Measurement of Aggregate and Industry Level Productivity Growth, Organisation for Economic Cooperation and Development, Paris.
Olanrewaju, A., Tan, S. & Kwan, L. (2017). Roles of Communication on Performance of the Construction Sector. Procedia Engineering, 196, pp. 763-770.
Puntoni, S., Reczek, R., Giesler, M. & Botti, S. (2021). Consumers and Artificial Intelligence: An Experiential Perspective. Journal of Marketing. 85(1), pp. 131-151.
Slowey, K. (2018). Contractors still Manually Collect Data despite Risks, Costs. Construction Dive. [Online] Available at: https://www.constructiondive.com/news/contractors-still-manually-collect-data-despite-risks-costs/523020/ [Accessed 13 April, 2022].
Tam, N., Toan, N., Hai, D., & Quy, N. (2021). Critical Factors Affecting Construction Labor Productivity: A Comparison between Perceptions of Project Managers and Contractors. Operations, Information & Technology, 8(1), pp. 1-17.
Tanaka, Y. et al. (2021). Time-delayed Collective Flow Diffusion Models for Inferring Latent People Flow from Aggregated Data at Limited Locations. Artificial Intelligence, 292(1), pp. 1-15.
Turner, C., Stergioulas, L. & Griffin, D. (2021), Utilising Industry 4.0 on the Construction Site: Challenges and Opportunities. IEEE Transactions on Industrial Informatics, 17(2).
Wang, X., Liu, J. & Peng, H., (2021), Motion Planning and Control for Overhead Cranes, Intelligent Systems, Control and Automation: Science and Engineering, 97, pp. 145-164.
Wills, N. & Diaz, J. (2017). Integration of Real-Time data in BIM enables FM processes. WIT Transactions on the Built Environment, 169, pp. 127-133.
Woodward, C. et al. (2010). Mixed Reality for Mobile Construction Site Visualization and Communication. 10th International Conference on Construction Applications of Virtual Reality; Miyagi, pp. 35 – 44.
Young, D., Panthi, K. & Noor, O. (2021). Challenges Involved in Adopting BIM on the Construction Jobsite. EPiC Series in Built Environment, 2, pp. 302-310.
Yu, M. & Tsai, M. (2021). ACS: Construction Data Auto-Correction System - Taiwan Public Construction Data Example. Sustainability, 13(1), pp. 362.
Zhong, W. & Wang, P. (2019). Visual Simulation for Optimisation and Application in Tunnel Schedule Engineering. International Conference on Construction and Real Estate Management, pp. 199-203.