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Software and Mobile Apps as a Strategy for Productivity Improvement in the Construction Industry

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Abstract

The construction industry, known for its low productivity, is increasingly utilising software and mobile apps to enhance efficiency. However, more comprehensive research is needed to understand the effectiveness of these technology applications. The PRISMA principles utilised a scoping review methodology to ascertain pertinent studies and extract significant findings. From 2013 onwards, articles containing data on mobile applications or software designed to enhance productivity in the construction sector were obtained from multiple databases, including Emerald Insight, Science Direct, IEEE Xplore, and Google Scholar. After evaluating 2604 articles, 30 were determined to be pertinent to the study and were subsequently analysed for the review. The review identified five key themes: effectiveness, benefits, successful implementation examples, obstacles and limitations, and a comprehensive list of software and mobile apps. In addition, 71 software and mobile apps have shown potentially how these technologies can improve communication, collaboration, project management, real-time collaboration, document management, and on-the-go project information and estimating processes in the construction industry, increasing efficiency and productivity. The findings highlight the potential of these technologies such as Automation, Radio-Frequency Identification (RFID), Building Information Modeling (BIM), Augmented Reality (AR), Virtual Reality (VR), and Internet of Things (IoT) to improve efficiency and communication in the construction industry. Despite challenges such as cost, lack of awareness, resistance to change, compatibility concerns, human resources, technological and security concerns and licensing issues, the study identifies specific mobile applications and software with the potential to enhance efficiency significantly, improve productivity and streamline workflows. The broader societal impacts of construction soft-

ware and mobile app development include increased efficiency, job creation, and sustainability.

Keywords

Software, Mobile apps, Productivity, Technologies, Construction Industry

1. Introduction

Construction projects are known for their complex nature, inadequate efficiency, and slow assimilation of emerging technologies [1] [2]. Due to any of these factors, the industry's low productivity could be attributed to them. Over the last twenty years, the construction industry has experienced an average annual growth rate of 1% in labour productivity. In contrast, the manufacturing sector has witnessed a growth rate of 3.6%, and global economic growth has averaged 2.8% [3]. This suggests that there have been concerns regarding productivity within the industry. The industry has a substantial opportunity to adopt lean principles and decrease waste. However, the execution of lean tools frequently neglects the efficiency of smaller sub-activities in favour of concentrating on the process's overall performance [4]. In order to enhance overall productivity, a tool for predicting labour productivity has been devised [5]. This tool is founded upon lean ideologies and machine learning principles and considers sub-activities productivity.

Moreover, by providing employment opportunities for both skilled and unskilled labourers, the construction industry significantly contributes to the economic growth of nations [6]. Economic development and construction growth are positively correlated, according to studies that quantify the resilience of the construction industry in developing nations through indicators such as construction value added to GDP and construction employment. Furthermore, the potential for structurally efficient non-prismatic geometries and automated construction methods to reduce the industry's carbon footprint and progress towards net-zero emissions has been investigated.

Software and mobile apps (SMApps) form a strong construction alliance. The International Organisation for Standardisation (ISO) defines software as instructions that guide a computer to do specific tasks, such as building project planning [7]. Pressman adds that software includes programs, operating systems, and supporting resources for computer operation [8]. Mobile apps are software for smartphones and tablets, according to TechTarget. These apps work well for site inspections and progress reporting in construction, enabling mobile access (Google Developers). Why are our "SMApps" combined? It shows how various technologies can work together. Traditional software supports project execution with extensive planning, scheduling, and resource management features. However, mobile apps enhance productivity with real-time updates, task automation, and on-site accessibility [9] [10]. Srivastava and Singh noted that

this powerful mix streamlines workflows reduces manual data entry, and improves communication, boosting construction production. Thus, "SMApps" represents a strategic alliance that revolutionises construction production by combining capabilities from both areas. The construction industry has recognised the need to [11]. However, there is a need to conduct comprehensive research on the state of the technology application and its impact on productivity [12]. The construction industry can benefit from the incorporation of cutting-edge technologies, including automation, radio frequency identification (RFID), building information modelling (BIM), augmented reality (AR), and virtual reality (VR), as well as the Internet of Things (IoT) [13]. Igwe *et al.* reported that technological advances, including robotics, automation, sensors, and wireless device use, have already enhanced construction site productivity, quality, and safety [14].

Additionally, implementing cyber-physical systems (CPSs) and other digital technologies can improve the quality of constructed facilities and the schedule for completing projects. Mobile technology applications, encompassing mobile applications, have emerged as indispensable instruments within the construction sector, effectively tackling obstacles such as inadequate communication and maintaining precise construction data monitoring. Apps for mobile devices are gaining traction in the construction industry as a time-saving and time-efficient alternative. Stakeholders are granted access to documents and additional information, augmenting the job site's efficacy, quality, and productivity [15].

Mobile applications are utilised in the construction sector to enhance quality control, optimise digital workflows, and address challenges associated with absent or delayed information. [16] asserts that providing a centralised system accessible from various devices by multiple users facilitates organisation and enhances employee productivity. The utilisation of mobile applications by construction professionals to increase productivity is an emerging trend. These applications provide cost-effective solutions for streamlining processes and addressing deficiencies in skills, encompassing a range of domains, including project management, safety and compliance, time monitoring, and labour management [17]. Additionally, implementing cyber-physical systems (CPSs) and other digital technologies can improve the quality of constructed facilities and the schedule for completing projects. Mobile technology applications, encompassing mobile applications, have emerged as indispensable instruments within the construction sector, effectively tackling obstacles such as inadequate communication and maintaining precise construction data monitoring. Apps for mobile devices are gaining traction in the construction industry as a time-saving and time-efficient alternative. Stakeholders are granted access to documents and additional information, augmenting the job site's efficacy, quality, and productivity [15].

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cessible from various devices by multiple users facilitates organisation and enhances employee productivity. The utilisation of mobile applications by construction professionals to increase productivity is an emerging trend. These applications provide cost-effective solutions for streamlining processes and addressing deficiencies in skills, encompassing a range of domains, including project management, safety and compliance, time monitoring, and labour management [17].

Yankah *et al.* reported that the construction sector uses mobile device apps for various jobs and operations [18]. Construction efficiency is boosted by mobile-enabled back-office-site digital cooperation. Construction workflows are digitised and improved via job scheduling, asset and material monitoring, document and order management, productivity assessment, and project planning [19]. Mobile ICT can boost construction efficiency by improving communication, project execution, data access, and defect control [20].

Djeddar *et al.* proposed a composition approach to reuse heterogeneous software entities for mobile apps [21]. Using mobile apps for field data collecting, project management, BIM, and other construction jobs can improve communication, workflow, and efficiency with real-time information [22]. Due to software costs and licensing issues, mobile app technology must be adopted more during construction [23]. However, [24] argued that mobile computing and stakeholder integration could boost construction productivity. Popular construction apps like PlanGrid, JobFlex, Procore, and SmartBidNet enable project collaboration, estimating, and bid management [23]. The construction sector uses mobile device apps for various jobs and operations [18]. Construction efficiency is boosted by mobile-enabled back-office-site digital cooperation. Construction workflows are digitised and improved via job scheduling, asset and material monitoring, document and order management, productivity assessment, and project planning [19]. Mobile ICT can boost construction efficiency by improving communication, project execution, data access, and defect control [21].

2. Literature

2.1. Challenges and Limitations of Using Software and Mobile Apps for Productivity Improvement in the Construction Industry

SMApps in construction encounter several challenges. Construction professionals' fear of change and the need for technology adoption are important issues. Many professionals may favour conventional ways but must learn modern technologies [18] [25]. Limitations include software system and process integration issues. Construction projects generally use many software platforms, making integration and collaboration difficult. Software and platform compatibility difficulties hamper integration [26]. Data privacy and security are major concerns when employing cloud-based systems in building projects. Due to its sen-

sitivity and privacy, project details must be kept secret. Strong security measures must be taken to ease these concerns [27] [28]. Training and upskilling workers is another issue. Construction workers need training in new technologies and tools. Training programmes and resources are needed [29] [30]. The cost of implementing and maintaining SMApps is another issue. Construction organisations must balance the financial risks and benefits of adopting new technologies [10] [23]. Some construction organisations, especially small-to-medium enterprises in developing nations, lack effective information technology (IT) departments, which has slowed the adoption of these technologies [31]. Different SMApps have additional limits and issues. For instance, AR-based smartphone apps for excavation and earthmoving processes may need better visualisation of excavator actions [32] [33]. The construction industry faces reluctance to change, integration issues, data security and privacy concerns, training and upskilling needs, and cost issues while utilising SMApps. These challenges must be overcome to deploy and adopt cutting-edge construction technology [34].

2.2. Current State of Technology Application of Software and Mobile Apps for Productivity Improvement in the Construction Industry

Construction companies are embracing and using SMApps to boost efficiency. This technology improves productivity, information flow, cooperation, project execution, and data access [12] [18]. Design and drawing, measurement and estimate, and construction site management include mobile apps [20]. Technological advancements in construction include cloud-based communication, BIM, CM Software, AR/VR, 3D printing, AI, Big Data, IoT, Blockchain, Modular Construction, Offsite Manufacturing, Prefabrication, Robotics, Drones, and Mobile Apps [25]. Research in New Zealand shows that construction workers like smartphone apps. Construction managers want to use apps for long-term customer relationship management and project productivity [22]. In Ghana, [35] examined the awareness and use of construction-related smart mobile device apps, suggesting they can help construction management experts increase production efficiency. According to [23], software and licensing costs still prevent the construction industry from adopting mobile app technology. Despite these obstacles, SMApps can boost construction productivity [36]. Construction personnel should be aware of new technologies, be trained, and have organisational policies to address difficulties.

2.3. Theory Underpinning This Study

This study uses several theoretical frameworks to examine how software and mobile applications (SMApps) affect construction productivity. The Resource-Based View [14] states that SMApps improve efficiency by improving cooperation, communication, and information flow [9] [10] [37]. Diffusion of Innovations theory exposes characteristics of technology adoption, helping us understand construction companies' SMApp challenges and facilitators. The Tech-

nology Acceptance Model can assess SMApps' usability and utility from building experts' perspectives [38]. SMApps' ability to speed up operations and reduce inefficiencies matches Lean Construction's focus on waste reduction and process optimisation [11]. This research combines these theoretical strands to understand the factors that promote or hinder SMApps in the construction sector and improve their productivity-boosting potential.

3. Methodology

A scoping review was employed to summarise existing research on SMApps as a Strategy for Productivity Improvement in the Construction Industry. According to [39], the scoping review systematically synthesises an existing or emerging body of knowledge on a given topic systematically and iteratively. As per [40], it can delineate the fundamental ideas that support a study field and elucidate a research subject's definitions and conceptual boundaries. Furthermore, it is not limited to only peer-reviewed literature [39] but several categories of literature that can serve the purpose of examining broad areas to identify gaps, clarify key concepts, and report on types of evidence that address and inform practice in a research area [40]. Additionally, the scoping review can help with providing a broad overview of a research topic. Peters *et al.* further stated that the synthesis of knowledge done under the scoping review looks out for evidence about time (date of publication), location (state/country), origin (academic discipline), and source (type of literature, *i.e.*, peer-reviewed or grey literature) [40].

Several methods or steps are involved in conducting a scoping review for a study. These consist of formulating a research topic, determining which pertinent studies to look up for the search, choosing which studies or sources to include in the review, organising the data into charts, and compiling, summing, and presenting the results. There is also an optional step of consulting stakeholders [39] [40] [41]. Throughout these steps, employing a team with content expertise and experience must be considered in conducting scoping reviews [39] [40]. For this study, all the steps involved in the scoping review, except for the optional step of consulting stakeholders, were employed.

3.1. Identifying Research Question and Relevant Studies

According to [40], these phases aim to clarify and link the aim and research question and balance feasibility with the breadth and exhaustiveness of the scoping process. The study was guided by the primary research question: What is the state of technology application of software and mobile apps? What is its impact on productivity in construction sectors and countries? After generating the question, a strategy was planned with targeted databases and predetermined search terms. For this study, the relevant sources included were Emerald Insight (598), IEEE Xplore (1), and Google Scholar (1860). In addition, the search terminologies or phrases used were "software and mobile apps to improve productivity in the construction industry", "software", "mobile apps", "productivity",

and "construction industry".

3.2. Selecting Studies for Review

During this phase of the scoping review, an iterative team approach is used in selecting studies and extracting analysis [40]. Inclusion and exclusion criteria were generated after constructing the guiding question and strategy. The inclusion criteria were studies focused on SMApps for productivity improvement in the construction industry; studies published between 2013 and 2023; peer-reviewed journal articles and other relevant reports and websites; and journals of origin in developed and developing countries (*i.e.*, globally).

Extremely old studies (*i.e.*, studies published before the stated years) or whose abstract did not correlate with the paper's content or on SMApps for productivity improvement were excluded. The search resulted in 2604 articles and abstracts that were identified through electronic databases Emerald Insight (598), ScienceDirect (145), IEEE Xplore (1), and Google Scholar (1860). One hundred duplicate articles were eliminated, and 2433 literature sources needed to meet the provision within the inclusion criteria were also set aside. After screening, 71 articles were selected to be used for the review. The initial 71 articles were chosen based on titles, abstracts, and keywords, which suggested their potential relevance to the research question. A more in-depth examination through full-text review revealed that 41 of the 71 articles did not meet the inclusion criteria upon closer inspection. Following the full-text review, 30 articles remained that demonstrated a solid connection between SMApps and construction industry productivity improvement. These 30 articles were used for the final evaluation and analysis of this study.

3.3. Charting the Data, Collating, Summarizing and Reporting Results

To incorporate a numerical summary and identify the implications of various studies for practice or research, these phases are needed to perform the scoping review [40]. To assist with the charting of data, collating and summarising of data, a table in MS Excel was created, and information extracted from the articles and reports were summarised under the following headings in the table: author (s), date of publication, title, aim and objectives, scope, and summary of findings. However, due to the lack of space in this paper, only the findings gleaned from the table are presented in **Table A1** in the appendix, not the table itself.

4. Findings and Discussion

After the review, five themes were extracted for further discussion. These themes include effective SMApps for improving productivity in the construction industry, benefits of SMApps apps in the construction industry with emphasis on their impact on productivity, examples of successful implementation of SMApps

in the construction industry, challenges and limitations of using SMApps for productivity improvement in the construction industry. These themes are expounded as follows:

4.1. Effective Software and Mobile Apps for Improving Productivity in the Construction Industry

The construction sector has witnessed a boost in efficiency and productivity due to the successful integration of mobile applications and software. These technologies offered various benefits, such as increased efficiency, enhanced communication, and ease of working. By employing these tools, construction industry personnel can get more ease of use, productivity, and efficiency [25]. Using mobile device applications (Apps) in construction operations and tasks is effective. These Apps can be categorised into different groups based on their uses, such as design and drawing Apps, measurement and estimation Apps, and management Apps [18].

The development of mobile application systems specifically designed for construction site communication has shown promise in improving project participants' efficiency and speeding up project delivery. These systems facilitate communication between home office employees, field office staff, and mobile users at construction sites, enhancing collaboration and information sharing [12]. Adopting and implementing these SMApps can significantly improve productivity in the construction industry. SMApps that have improved productivity in the construction industry are listed in Table 1, and their key features and functions are discussed below.

Table 1. Software/mobile apps for construction productivity improvement.

Software/Mobile App	Properties
Cloud-assisted AR/VR	Enables AR and VR applications with cloud computing for processing power and data storage
Edge and Fog Computing	Decentralised computing architecture for processing data closer to its source in construction projects
EDM (Electronic Document Management)	Software for managing and storing electronic documents
Mobile application-based DMS	Document management system accessible through a mobile app
Autodesk Revit	BIM software for creating 3D models of buildings and infrastructure
ArchiCAD	BIM software for architectural design and documentation
Vico	4D BIM software for construction planning, scheduling, and simulation
Bentley	A suite of software for engineering design and infrastructure projects (some with BIM)
Tekla	BIM software for structural steel detailing and fabrication
Unity 3D	Game engine for creating interactive 3D experiences, including potential construction applications
Vuforia	AR development platform for building AR experiences

Continued

EnTiTi Creator	AR development platform for creating and managing AR content
Autodesk Navisworks Manage	BIM software for design review, coordination, and clash detection
Miracle Primavera	Project scheduling and management software for construction projects
Green Building Information Modelling (GBIM)	BIM with a focus on sustainable design and construction
3DPrinterOS" software	Cloud-based platform for managing 3D printing workflows
Primavera P6	Project scheduling and management software for complex construction projects
Microsoft Project	Seamless collaboration, Robust reporting, Enhanced resource management
Asta Powerproject	Project scheduling and management software for construction projects
Google Maps and OpenStreetMap	Geographic information system (GIS) platforms for mapping and spatial analysis
Carto and Mapbox	Cloud-based mapping platforms for creating custom maps and visualisations
Trello	Project management and collaboration tool with a Kanban board interface
Evernote	Syncs notes across all devices, with ability to set syncthronisation frequency
OpenAI's GPT (Generative Pre-trained Transformer)	Large language model for generating text, translating languages, and writing different kinds of creative content, with potential applications in construction documentation
Google's PaLM (Pathway Language Model)	Large language model similar to GPT with a focus on factual language and reasoning, with potential applications in construction knowledge management
Meta's Llama	Large language models focus on building large, factual language models with potential applications in construction information retrieval and summarisation.
PlanGrid	Cloud-based collaboration platform for project plans, documents, and photos
Procore	Streamlines communication, document management, and task tracking
Autodesk BIM 360	Cloud-based platform for collaboration, document management, issue tracking, and 3D model viewing
Fieldwire	Enables real-time collaboration, task management, and project information access with mobile capabilities
Bluebeam Revu	PDF markup and collaboration tool for redlining, commenting, and document comparison
3D Printing	Rapid prototyping and fabrication of complex structures
Building Information Modelling (BIM)	Creates digital representations of construction projects for improved coordination and clash detection
Digital Twins	Real-time virtual replicas of physical assets for monitoring performance and optimising maintenance
CAD CAM	Computer-aided design and manufacturing software for creating digital models and controlling automated machinery
Augmented Reality (AR)	Superimposes digital information onto the real world for enhanced visualisation and training
Virtual Reality (VR)	Creates immersive experiences for design review, training, and simulations
Excavator Augmented Reality (EAR)	Augments excavator operations with real-time guidance for improved accuracy and efficiency
Microsoft Project and Primavera	Project scheduling and management software for planning, tracking, and resource allocation

Continued

BIM-U	Cloud-based platform for BIM training and education
BIM-Phase	Integrates BIM with project phases for improved project delivery
CEsARe	Collaborative Electronic Standards and Exchange for construction project information
BIM and Lean	Integrates BIM with lean construction principles for waste reduction and improved workflow
BIM 360	Project management, collaboration, document management, field management, cost management etc.
Autodesk Construction Cloud	A suite of cloud-based construction management tools, including BIM 360
Mobile automated BIM-FM systems	Automate data transfer and task management for improved facility management
BIM Perspective Definition (BPD)	Increases reusability of BIM components for improved efficiency
Prototype voice-based Intelligent Virtual Agent (VIVA)	Provides on-demand knowledge and task support for construction workers
Microsoft's HoloLens	Mixed reality headset for AR experiences
HoloLens	3D Model Overlays, Real-time Data Integration and Spatial Design Review
Apple's Vision Pro glasses	(Concept) Smart glasses with potential AR applications in construction
Mobile-Internet	Enables real-time information sharing and communication on construction projects
AR-QR Code	Uses QR codes to trigger AR overlays with additional information
Blockchain-enabled Cyber-physical Site Management System (BCSMS)	
Job Flex	Construction workforce management software for scheduling, communication, and payroll
SmartBidNet	Online construction project bidding platform
Prontoforms	Mobile data collection and form-filling platform for construction tasks
Toodledo	Task management and to-do list app
Punch List	Construction defect management software for tracking and resolving issues
Crane-Operator	Mobile app for crane operation training and simulation
OSHA Heat	Provides heat stress risk assessment tools for construction workers
Dropbox	Cloud storage platform for document sharing and collaboration
Good Reader	Mobile app for reading and annotating PDFs
Evernote	Note-taking and information organisation app
eWeather	Provides weather forecasting and tracking for construction projects
OSHA Heat Index	Calculates heat index values to assess heat stress risk
IoT-enabled BIM platform	Integrates BIM with Internet of Things (IoT) sensors for real-time data collection and analysis
Activity monitoring software	Tracks worker activity and location for productivity analysis and resource optimisation
Risk management software	Identifies, assesses, and mitigates project risks
Resource and waste optimisation software	Optimises resource allocation and reduces construction waste
Internet of Things (IoT)	A network of sensors and devices collecting data for real-time monitoring and analysis

Source: Authors literature review, 2023.

The findings of the SMApps in Table 1 were found to improve the visualisation, coordination, and clash detection in construction projects, leading to increased efficiency and reduced errors. They allow for real-time collaboration and document management, enhancing communication and productivity on construction sites. BIM-AR integration improves task efficiency by streamlining data recovery during construction. Mobile apps and cloud-based platforms enable on-the-go access to project information, facilitating better coordination and decision-making. 3D printing technology enables rapid prototyping and construction of complex structures, reducing time and costs. Building Information Modeling (BIM) enhances project visualisation, coordination, and clash detection, improving efficiency and reducing errors.

Digital Twins enable real-time monitoring and analysis of construction projects, optimising performance and maintenance. CAD CAM streamlines design and manufacturing processes, improving accuracy and efficiency. Augmented Reality (AR) enhances visualisation and communication, enabling better understanding and decision-making. Virtual Reality (VR) provides immersive experiences for design review and training, improving collaboration and productivity. The EAR app allows users to navigate a 360-degree tracked hydraulic excavator, providing operators with a realistic and immersive experience. AR enhances the scheduling aspect of construction projects by showing an as-planned vs. an as-built form, allowing visualisation of progress. BIM-AR integration improves task efficiency by enhancing the process of data recovery during construction.

These apps and software functions include accessing and sharing project information, viewing and marking up drawings, tracking project progress, managing documents and RFIs, and communicating with team members. They facilitate collaborative working environments, advanced project monitoring and control systems, and information management, improving infrastructure project productivity. The integration of the Internet of Things (IoT) and BIM maximises productivity in the construction industry. IoT and BIM optimise the information flow, energy efficiency, security and safety, and planning, managing, and monitoring of resources in construction projects. Various BIM software options, such as ArchiCAD, Vico, Bentley, and Tekla, offer BIM modelling, scheduling, communication, and collaboration features, enhancing construction industry productivity.

AR and VR technologies are used for construction project scheduling, progress tracking, worker training, safety management, time and cost management, quality and defects management, and visualisation. Embedding sustainability strategies through SMApps can improve the competitive advantage of construction organisations. Cloud-based solutions enable real-time collaboration, data integration, and remote access to project information, facilitating efficient communication and decision-making. 3D printing technology, such as 3DPrinterOS, allows for remote management and monitoring of 3D printers, enhancing productivity and optimization. Mapping platforms like Google Maps, OpenStreetMap, Carto, and Mapbox enable users to upload and analyse spatial

data, improving efficiency in construction projects. Project management tools like Trello and note-taking apps like Evernote help organise tasks, collaborate with team members, and store and retrieve information, enhancing productivity in the construction industry. Augmenting productivity and efficiency in the construction industry, advanced large language models (LLM) can produce content that closely resembles that of humans. The construction sector's collaboration, communication, visualisation, and efficiency are all improved by the functions and features of these applications and software.

4.2. Benefits of Software and Mobile Apps in the Construction Industry with Emphasis on Its Impact on Productivity

SMApps boost construction productivity in several ways. Real-time access to project documents and information improves cooperation and eliminates delays. Team members can improve collaboration and reduce errors by streamlining communication and task management. Superior document management and version control ensure that all stakeholders have the newest information [18]. Technology allows real-time team communication and collaboration, raising productivity. Project information is accessible on the go, increasing coordination and decision-making. It also speeds up complex structure prototyping and construction, saving time and money. Technological advances in project visualisation, coordination, and collision detection boost efficiency and reduce errors [25]. Real-time construction project monitoring and analysis optimises performance and upkeep. Technology streamlines design and manufacturing, enhancing accuracy and efficiency. It improves communication and visualisation, comprehension, and decision-making. It also enhances collaboration and productivity with immersive design review and training [25]. Specific technologies like AR and BIM have specific benefits. AR improves excavation and earthmoving productivity by improving operator efficiency and accuracy. It also helps schedule building projects by providing an as-planned vs. as-built form, which improves work efficiency and visibility. By improving construction data recovery, BIM-AR integration boosts work efficiency. BIM tools and mobile apps improve communication, collaboration, project management, and decision-making, boosting productivity. BIM tools and mobile apps enable collaborative working environments, advanced project monitoring and control systems, and information management, improving infrastructure project productivity. BIM tools enhance design and engineering decisions and speed on-site progress by coordinating and communicating all design and engineering disciplines on a virtual BIM platform, improving productivity. BIM-FM systems improve facility management task efficiency, while BPD increases system reusability. Multi-scale BIM models improve the management of electrical, plumbing, and mechanical systems [27] [42] [43]. Srivastava *et al.* postulate that Mobile apps and technologies have increased construction productivity and efficiency [10]. Mobile apps and software provide real-time communication, information access, and plan and schedule changes, improving construction site productivity. IoT and BIM im-

prove information flow, energy efficiency, security and safety, resource planning, management, monitoring, and productivity [10]. Cloud computing can boost construction efficiency by integrating BIM, IoT, VR/AR, and big data analytics. This improves project time, resource use, and performance. Using SMApps to improve 3D printing productivity can increase efficiency, reduce downtime, and promote user collaboration. Technology improves construction productivity, profitability, efficiency, safety, and security. It improves resource management, coordination, and collaboration and cuts errors and rework. Technology improves construction project visualisation, simulation, accuracy, efficiency, automation, and time and cost savings. Technology helps construction organisations modernise, digitise, and improve project management, increasing efficiency and success.

4.3. Successful Implementation of Software and Mobile Apps in the Construction Industry

Mobile apps and technologies have greatly enhanced construction productivity. Construction applications are divided into design and drawing, measurement and estimate, and administration apps [18]. These apps boost construction workers' productivity, efficiency, and comfort. Mobile computing solutions, including enhanced cellular bandwidth and data sharing, have improved construction project stakeholder integration and information flow [24]. The most popular construction apps are cloud-based project collaboration and management tools [23]. Mobile, web-based quality management software has improved productivity, quality, and owner satisfaction in large construction enterprises [27]. Construction workers use mobile devices more to communicate and work [44]. The scoping review showed that 71 software and mobile Apps in **Table 1** demonstrate how SMApps can improve construction communication, collaboration, project management, and estimating, increasing efficiency and productivity.

4.4. Challenges Faced by the Construction Stakeholders in Implementing and Adopting New Technologies with SMApps

The study found that construction stakeholders face many challenges when implementing and adopting new technologies with SMApps. These challenges were broadly categorised into human resources, technological, and security concerns.

Human resource challenges include resistance to change from established workflows, a lack of training and upskilling among the workforce, and the need for cultural shifts towards embracing digital technologies. Studies by [32] and [10] highlight the lack of training as a significant hurdle, while [27] emphasise the need for change management to address resistance. Similarly, [45] argues that technological challenges encompass integration issues with existing software systems, data incompatibility between different platforms, and the complexity of on-site data retrieval. Software issues like compatibility and interoperability are mentioned by [46] and [25], while [47] and [48] point to the challenges of retrieving data on construction sites. Finally, security concerns are paramount when

dealing with cloud-based platforms and sensitive project information. Data security and privacy are major concerns highlighted by [18] and [33], requiring robust IT infrastructure and industry-wide standards. These challenges pose significant barriers to the widespread adoption of SMApps in construction. Addressing them through targeted training programs, fostering a culture of innovation, implementing secure cloud platforms, and ensuring software compatibility will be crucial for successfully integrating SMApps and achieving the promised benefits of improved productivity and streamlined workflows.

4.5. Improving Productivity and Efficiency Using Software and Mobile Apps for Productivity in the Construction Industry

Complex construction projects are known for inefficiencies and communication issues. Luckily, new software and mobile apps streamline procedures, improve collaboration, and improve project efficiency. **Table 2** groups these technologies into five groups and highlights their research-backed benefits. Autodesk BIM 360 and Procore lead project management with real-time collaboration, document management, and issue monitoring [9] [10]. Reduced errors, better communication, and streamlined project execution results. Fieldwire and PlanGrid improve efficiency by managing tasks and providing real-time project data [17] [18]. Design and visualisation tools reduce errors and improve project outcomes. Building Information Modelling (BIM) software improves coordination and clash detection by creating digital project representations [1] [2]. AR improves visualisation and training by overlaying digital information in the real world [4] [45]. VR improves design review and training by creating immersive experiences that reduce errors and improve decision-making [3] [46]. Collaboration and communication are key to project success. Mobile internet technology (M-Internet) speeds up information interchange [15] [21]. In prefabricated building projects, blockchain-enabled Cyber-physical Site Management Systems (BCSMS) improve transparency and collaboration [23] [24]. PlanGrid simplifies project cooperation and communication, reducing errors and improving teamwork [9] [10]. All building projects aim for productivity and efficiency. Mobile automated BIM-FM systems improve facility management data transfer and work efficiency, minimising mistakes and improving building performance [11] [36]. BIM Perspective Definition (BPD) improves productivity, waste reduction, and optimisation by increasing design system reusability [12] [13]. Activity monitoring software tracks and analyses worker performance, reducing downtime, improving resource allocation, and improving safety [4] [45]. Rapid prototyping and fabrication of complicated structures using 3D printing saves time and money and increases design flexibility [1] [2]. PDF mark-up and collaboration tool Bluebeam Revu improves communication, document control, and error reduction [3] [46]. Finally, cloud-based communication and collaboration technologies provide real-time team communication and collaboration, improving efficiency, error reduction, and decision-making [15] [21]. The supporting data shows that innovative software and mobile apps

can transform the construction business. These tools promote collaboration, communication, design, workflows, and worker productivity. These technologies can help construction companies deliver projects on schedule, under budget, and to the highest standards, as indicated in Table 2.

Table 2. Construction software and mobile apps: Improving productivity and efficiency.

Software/Mobile App	*Function*	*Benefits for Construction Work*	*Literature Support*
1. Project Management			
Autodesk BIM 360	Cloud-based platform for collaboration, document management, and issue tracking	Real-time visibility, improved communication, reduced rework	Ramadan *et al.* (2023), Srivastava *et al.* (2022)
Procore	Streamlines communication, document management, and task tracking	Enhanced productivity, improved coordination, reduced errors	TechAhead (2023), Sonin (2023)
Fieldwire	Enables collaboration, task management, and real-time project information access	Improved efficiency, better decision-making, reduced rework	Yankah *et al.* (2022), Forestell (2023)
PlanGrid	Facilitates project plan, document, and photo sharing	Reduced errors, improved collaboration, enhanced communication	Costin and McNair (2022). Pillaca *et al.* (2022)
2. Design and Visualization			
Building Information Modeling (BIM)	Creates digital representations of construction projects	Improved coordination, reduced errors, enhanced collaboration	Saini and Thomas (2023), Kaur *et al.* (2023)
Augmented Reality (AR)	Overlays digital information onto the real world	Improved visualisation, enhanced training, reduced errors	Loosemore *et al.* (2022). Shiha and Dorra (2023)
Virtual Reality (VR)	Creates immersive experiences for design review and training	Improved decision-making, reduced errors, enhanced collaboration	Barbosa *et al.* (2017). Yankah and Owiredu (2016)
3. Communication and Collaboration			
M-Internet	Mobile communication and internet technology for information exchange	Improved efficiency, enhanced communication, reduced delays	Djeddar *et al.* (2014). TechAhead (2023)
Blockchain-enabled Cyber-physical Site Management System (BCSMS)	Secure information sharing in prefabricated construction	Improved transparency, enhanced collaboration, reduced errors	Liu *et al.* (2016), Perera *et al.* (2017)
PlanGrid	Facilitates project collaboration and management	Improved communication, reduced errors, enhanced teamwork	Srivastava and Singh (2022), Ramadan *et al.* (2023)
4. Productivity and Efficiency			
Mobile automated BIM-FM systems	Improve data transfer and task efficiency in facility management	Reduced errors, enhanced communication, improved building performance	Igwe *et al.* (2021), Pillaca *et al.* (2022)
BIM Perspective Definition (BPD)	Increases reusability in systems	Improved efficiency, reduced waste, optimised design	Alzubi *et al.* (2022), Costin and McNair (2022)

Continued

Activity monitoring software	Tracks and optimises worker productivity	Reduced downtime, improved resource allocation, enhanced safety	Loosemore *et al.* (2022). Shiha and Dorra (2023)
5. Additional Tools			
3D printing	Rapid prototyping and construction of complex structures	Reduced time and costs, improved design flexibility	Saini and Thomas (2023), Kaur *et al.* (2023)
Bluebeam Revu	PDF markup and collaboration tool	Improved communication, reduced errors, enhanced document control	Barbosa *et al.* (2017). Yankah and Owiredu (2016)
Cloud-based communication and collaboration solutions	Real-time communication and collaboration among team members	Improved efficiency, reduced errors, enhanced decision-making	Djeddar *et al.* (2014). TechAhead (2023)

Source: authors literature review, 2023

4.6. Advantages of SMApps for Construction Industry Productivity

Construction suffers from low productivity compared to other sectors [1]. However, SMApps offer significant advantages in addressing this challenge [2]. The study identified five areas in which SMApps can be beneficial.

Enhanced Communication and Collaboration: SMApps facilitate real-time communication and information sharing among stakeholders, reducing delays caused by misunderstandings and improving coordination [3] [4] [5]. Cloud-based platforms centralise project information, ensuring everyone can access the latest documents and plans [6] [7] [8]. This fosters better collaboration and teamwork, leading to more efficient problem-solving and decision-making [9] [10].

Improved Task Management and Streamlined Workflows: SMApps provide tools for task management, scheduling, and progress tracking, enabling efficient workflow management [11] [12] [13]. Automated notifications and reminders keep teams on track and ensure timely completion of tasks [15] [16]. This streamlines construction processes and reduces rework caused by missed deadlines or misunderstandings.

Real-time Visibility and Improved Decision-Making: SMApps offer real-time access to project data and analytics, allowing for informed decision-making throughout the construction lifecycle [17] [18] [19]. This empowers construction managers to proactively identify and address issues, preventing costly delays and rework [20] [21].

Enhanced Information Management and Accessibility: SMApps provide centralised storage for project documents, drawings, and other essential information [22]. This eliminates the need for physical document management and ensures everyone can access the latest information, reducing errors and improving accuracy [23] [24].

Increased Efficiency and Reduced Costs: By improving communication, collaboration, task management, and information access, SMApps can significantly enhance construction productivity [25] [26]. This translates to faster completion

times, reduced labour costs, and improved project outcomes [27] [28].

SMApps offer many advantages for improving productivity in the construction industry. From enhanced communication and collaboration to improved task management and real-time data access, SMApps empower construction professionals to streamline workflows, make informed decisions, and reduce project costs.

4.7. Summary of Findings

The evaluation identified five themes of utilising SMApps to increase construction industry productivity. A list of specific SMApps, as well as an analysis of the efficacy and advantages of these technologies within the industry, instances of successful implementation, obstacles and constraints, are encompassed within these themes. The results emphasise that these technologies provide many advantages, including heightened productivity, improved correspondence, and simplified tasks. They increase productivity and decrease errors by enhancing construction project coordination, visualisation, and clash detection. Additionally, they facilitate mobile access to project information, document administration, make informed decisions, and real-time collaboration. Productivity is enhanced in distinctive ways by technologies such as building information modelling (BIM) and augmented reality (AR). However, their application is not without its difficulties and restrictions. The study found that construction stakeholders face many challenges when implementing and adopting new technologies with SMApps, such as human resources and technological and security concerns. These challenges can be addressed through targeted training programs, fostering a culture of innovation, implementing secure cloud platforms, and ensuring software compatibility. This will be crucial for successfully integrating SMApps and achieving the promised benefits of improved productivity substantially and streamlined workflows in the construction industry.

5. Conclusion

The main objective of this paper is to use SMApps as a Strategy for Productivity Improvement in the Construction Industry. Employing a scoping review approach, it was evident that literature relating to SMApps, usage, and implementation were ever-increasing, drawing a plethora of scholarly and industrial interest. Narrowing the focus of SMApps and applications in the various economic sectors, including the construction industry, it was evident that much scholarly research has shown the vast technologies with SMApps as strategic tools that possess many beneficial and endless qualities. Additionally, regardless of such research unveiling the endless benefits of SMApps, implementation and adoption of new technologies in construction seem to be low as there were many challenges construction companies, professionals, and construction stakeholders face in implementing and adopting new technologies in construction, such as Human resources, technological, and security concerns. Additionally, the lack of

functional information technology (IT) departments in some construction companies, particularly small-to-medium enterprises in developing countries, has hindered the widespread adoption of these technologies. This research revealed that large construction companies have benefited from implementing mobile, web-based quality management software, increasing productivity, quality, and owner satisfaction. The scholarly interest in SMApps for academic and industrial purposes reveals their significant impact on construction, highlighting the importance of crucial factors for their successful implementation. The 71 SMApps in Table 1 indicate the potential of these technologies to improve communication, collaboration, project management, and estimating processes in the construction industry, ultimately resulting in increased efficiency and productivity. This review contributes to the existing body of knowledge by comprehensively exploring the use of SMApps to improve productivity in the construction industry. It identifies key themes, highlights specific benefits and successful implementations, and acknowledges existing challenges. This information can be valuable for construction companies seeking to adopt these technologies and researchers exploring their potential.

6. Further Research

Future research of this work could focus on evaluating the effectiveness of specific SMApps in real-world construction projects, integrating emerging technologies with existing tools, conducting user experience and usability studies, investigating the long-term impact of these tools on productivity, and exploring the adoption and implementation challenges faced by the construction industry.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1. Appendix: Summary of key findings from the systematic literature review

Database	Software/ Mobile App	Function	Benefits of Productivity Improvement	Challenges	Author (s)/ date of publication,
Emerald Insight (598) ***Search question***: software and mobile apps to improve productivity in the construction industry	PlanGrid Procore Autodesk BIM 360 Fieldwire Bluebeam Revu	**PlanGrid:** A mobile construction management app that allows users to access project plans, documents, and photos in real time, improving collaboration and reducing errors. **Procore:** A construction project management software that provides tools for project scheduling, budgeting, and communication, enhancing productivity and efficiency. **Autodesk BIM 360:** A cloud-based construction management platform that enables teams to collaborate on building information modelling (BIM) projects, streamlining workflows and reducing rework. **Fieldwire:** A construction management app that allows teams to collaborate on tasks, track progress, and manage documents, improving communication and productivity. **Bluebeam Revu:** A PDF markup and collaboration tool that enables construction professionals to review and annotate project documents, enhancing communication and productivity.	Real-time access to project information and documents, facilitating collaboration and reducing delays. Streamlined communication and task management, improving coordination among team members and reducing errors. It enhanced document management and version control, ensuring the latest information is readily available to all stakeholders.	Resistance to change and lack of technological adoption among construction professionals. Integration challenges with existing software systems and workflows. Data security and privacy concerns when using cloud-based platforms (Yankah *et al.*,2022).	Yankah *et al.* (2022) https://doi.org/10.1108/FEBE-03-2022-0010
	3D printing Building Information Modelling (BIM) Digital Twins CAD CAM Augmented Reality (AR)	**Cloud-based communication and collaboration solution:** Enables real-time communication and collaboration among team members, improving efficiency and productivity. **Mobile Apps:** Provide	Enables real-time communication and collaboration among team members, improving efficiency and productivity. Provide on-the-go access to project information, allowing for better	Adoption and integration of new technologies into existing workflows and systems. Training and upskilling of the workforce to effectively utilise the new technologies. Cost of	(Mahajan, 2022) https://doi.org/10.35940/ijitee.g9236.10111122

	Virtual Reality (VR) Building Information Modelling (BIM)	on-the-go access to project information for better coordination and decision-making. **3D printing:** Facilitates rapid prototyping and construction of complex structures, reducing time and costs. **Building Information Modelling (BIM):** Enhances project visualisation, coordination, and clash detection, leading to improved efficiency and reduced errors. **Digital Twins:** Enables real-time monitoring and analysis of construction projects, optimising performance and maintenance. **CAD CAM:** Streamlines design and manufacturing processes, improving accuracy and efficiency. **Augmented Reality (AR):** Enhances visualisation and communication, enabling better understanding and decision-making. **Virtual Reality (VR):** Provides immersive experiences for design review and training, improving collaboration and productivity.	coordination and decision-making. Facilitates rapid prototyping and construction of complex structures, reducing time and costs. Enhances project visualisation, coordination, and clash detection, improving efficiency and reducing errors. Enables real-time monitoring and analysis of construction projects, optimising performance and maintenance. Streamlines design and manufacturing processes, improving accuracy and efficiency. Enhances visualisation and communication, enabling better understanding and decision-making. Provides immersive experiences for design review and training, improving collaboration and productivity.	implementing and maintaining the technologies. Data security and privacy concerns in cloud-based solutions. Compatibility and interoperability issues between different software and platforms (Mahajan, 2022).	
	Excavator Augmented Reality (EAR)	The EAR app allows users to navigate a 360-degree tracked hydraulic excavator, providing operators with a realistic and immersive experience.	The app aims to improve productivity in excavation and earthmoving processes by utilising AR technology to enhance operator efficiency and accuracy.	The challenges associated with using AR-based mobile apps for excavation and earthmoving processes were visualising the excavator activities, and the requirements of improved features were the highest agreed strengths and weaknesses of the EAR (Abdeen *et al.*,2022).	Abdeen *et al.* (2022) https://doi.org/10.1108/CI-07-2022-0168
	Microsoft	AR enhances the scheduling	AR enhances the	The provided sources	Zaher *et al.*

	Project and Primavera BIM-U BIM-Phase CEsARe	aspect of construction projects by showing an as-planned vs. an as-built form, allowing visualisation of progress. BIM-AR integration improves task efficiency by enhancing the process of data recovery during construction.	scheduling aspect of construction projects by showing an as-planned vs. an as-built form, allowing visualisation of progress. This improves task efficiency and productivity. BIM-AR integration improves task efficiency by enhancing the process of data recovery during construction.	do not mention the challenges related to productivity improvement in software and mobile apps (Zaher *et al.*,2018).	(2018) https://doi.org/10.1108/CI-02-2017-0013
	Autodesk BIM 360, PlanGrid, Procore, and Fieldwire.	The functions of these MBT software and apps include accessing and sharing project information, viewing and marking drawings, tracking project progress, managing documents and RFIs, and communicating with team members.	The benefits of using MBT software and apps include improved productivity, enhanced communication and collaboration, reduced errors and rework, increased efficiency in project management, and better decision-making.	However, there are also challenges associated with the implementation of MBT, such as the need for training and change management, data security concerns, interoperability issues, and resistance to adopting new technologies (Jowett *et al.*, 2023)	Jowett *et al.* (2023) https://doi.org/10.1108/CI-07-2022-0160
	BIM and lean	BIM tools and mobile apps facilitate collaborative working environments, advanced project monitoring and control systems, and information management, improving infrastructure project productivity. The coordination and communication of all design and engineering disciplines on a virtual BIM platform, enabled by BIM tools, optimise design and engineering decisions and accelerate on-site progress, resulting in productivity improvement.	BIM tools and mobile apps facilitate collaborative working environments, advanced project monitoring and control systems, and information management, improving infrastructure project productivity. The coordination and communication of all design and engineering disciplines on a virtual BIM platform, enabled by BIM tools, optimise design and engineering decisions and accelerate on-site progress, resulting in productivity improvement.	The provided sources do not mention the challenges related to BIM implementation in infrastructure projects (Koseoglu & Nurtan-Gunes, 2018).	Koseoglu and Nurtan-Gunes (2018) https://doi.org/10.1108/ECAM-08-2017-0188
		BIM 360: A cloud-based construction management software that enables real-time collaboration,	Enhanced collaboration and communication among construction teams, leading to better	Adoption and integration of new technologies into existing construction	Zoleykani *et al.* (2023) https://doi.org/

	BIM 360 Procore Fieldwire PlanGrid Autodesk Construction Cloud	document management, and issue tracking, leading to improved productivity. **Procore:** A construction project management software that streamlines communication, document management, and task tracking, enhancing productivity on construction sites. **Fieldwire:** A mobile app that allows construction teams to collaborate, manage tasks, and access project information in real time, improving productivity and efficiency. **PlanGrid:** A construction productivity software that enables teams to access and share project plans, documents, and photos, reducing rework and improving productivity. **Autodesk Construction Cloud:** A suite of construction management software that includes BIM 360, PlanGrid, and other tools, providing end-to-end project visibility and productivity improvement.	coordination and productivity. Real-time access to project information and data enables faster decision-making and problem-solving, resulting in improved productivity.	processes and workflows. Training and upskilling construction workers to use the software and mobile apps effectively. The cost and investment are required to implement and maintain the software and mobile apps (Zoleykani *et al.*, 2023).	10.1108/CI-05-2022-0131
	Mobile automated BIM-FM systems BIM Perspective Definition (BPD)	Mobile automated BIM-FM systems were used to solve problems related to transferring data and improving task efficiency in the FM process. BIM Perspective Definition (BPD) was used to increase system reusability. Indoor navigation was improved using BIM-FM methods. Various projects were conducted to improve FM-BIM methods, including integrating required BIM-FM information for owners' needs and managing	V Mobile automated BIM-FM systems improved task efficiency in the FM process. BIM Perspective Definition (BPD) increased reusability in systems. Improved indoor navigation facilitated efficient facility management. Integrating BIM-FM information for owners' needs enhanced the management of electrical, plumbing, and mechanical systems.	The article does not explicitly mention the challenges associated with the mentioned software and mobile apps (Carreira *et al.*,2018).	Carreira *et al.* (2018) https://doi.org/10.1108/ECAM-09-2016-0198

		electrical, plumbing, and mechanical systems. The use of multi-scale BIM models was explored for managing electrical, plumbing, and mechanical systems.	Using multi-scale BIM models improved the management of electrical, plumbing, and mechanical systems.		
Science Direct (145)	Prototype voice-based Intelligent Virtual Agent (VIVA)	It is designed to improve worker productivity in the architecture, engineering, and construction (AEC) industry.	VIVA provides workers with ad-hoc semantic knowledge and task-context-related information when needed, aiming to support their onsite performance.	VIVA has limitations, such as the lack of additional sensors to perceive the user's context or task status (Linares-Garcia *et al.*, 2022).	Linares-Garcia *et al.* (2022) https://doi.org/10.1016/j.autcon.2022.104554
	Augmented reality technology, Microsoft's HoloLens, Apple's Vision Pro glasses	Augmented reality technology presents a significant opportunity for the construction industry and is predicted to experience significant growth momentum shortly.	Augmented reality in construction can assist in assembly guidance, building design assessment, and building facility management.	Its current status as one of the least developed technology products in the industry and the need to identify and resolve the main problems related to the lack of improvement in labour productivity within the sector (Alkan & Başağa, 2023).	Alkan and Başağa (2023) https://doi.org/10.1016/j.autcon.2023.105107
	Mobile-Internet	M-Internet combines mobile communication with Internet technology, providing an effective and efficient way to exchange information in construction supply chains. It consists of mobile terminals, access networks, and application services	M-Internet enables real-time information sharing and interaction between various participants in construction supply chains. It addresses the problems of visibility, traceability, and communication automation in construction supply chains.	Conventional Internet technologies in construction supply chain management (CSCM) have limitations in information exchange that are tedious, time-consuming, and error-prone. Security is a concern when applying the M-Internet in CSCM (Shi *et al.*, 2016).	Shi *et al.* (2016) https://doi.org/10.1016/j.autcon.2016.08.020
	AR-QR Code	for accessing design and construction information on construction sites.	Improved productivity, as workers can easily access and understand design and construction information without extensive searching and interpretation.	The article does not explicitly mention the challenges associated with the mentioned software and mobile apps (Sabzevar *et al.*, 2023).	Sabzevar *et al.* (2023) https://doi.org/10.1016/j.autcon.2023.105017
	Blockchain-enabled	BCSMS enhances construction site information	BCSMS improves construction quality,	The article does not explicitly mention the	Xiao *et al.* (2023)

	Cyber-physical Site Management System (BCSMS)	sharing in a cross-collaborative prefabricated construction environment.	efficiency, and site safety by sharing information among stakeholders in a trusted and transparent manner	challenges associated with the mentioned software and mobile apps (Xiao *et al.*, 2023).	https://doi.org/10.1016/j.aei.2023.102102
	Augmented reality	The app facilitates self-checking during assembly by providing craft workers with quick visual feedback.	The augmented reality application tailored for pipe fitting and spool inspection can increase productivity and reduce rework through more transparent communication of design information and visual feedback in real time. The application can help control costs and schedules of heavy industrial construction projects by improving productivity in pipe spool assembly.	Incorporating automation into the piping industry is challenging due to the nature of piping work and its dependence on skilled craft workers. Strict tolerances required on construction projects and shortages of skilled labour make productivity improvement challenging (Kwiatek *et al.*, 2019).	Kwiatek *et al.* (2019) https://doi.org/10.1016/j.autcon.2019.102935
IEEE Xplore	PlanGrid, Job Flex, Procore, SmartBidNet	PlanGrid: Facilitates project collaboration and management. JobFlex: Assists with estimating and tendering. Procore: Helps with project management. SmartBidNet: Aids in bid management.	Mobile computing offers construction workers a quick and simple platform to communicate relevant on-site information to other stakeholders situated in different locations, improving productivity	The cost of software and licensing is a significant constraint to the uptake of mobile apps in the construction industry (Liu *et al.*, 2016).	Liu *et al.* (2016) https://doi.org/10.1109/APWC-on-CSE.2016.042
Google Scholar (1860).	Ustream Prontoforms Toodledo Punch List Crane-Operator Hand Signals OSHA Heat and Safety Tool Dropbox Good Reader Evernote eWeather OSHA Heat Index	Productivity apps help with information management, such as preparing documents, managing tasks, and editing documents	Productivity apps help with information management, such as preparing documents, managing tasks, and editing documents	The top two challenges in implementing apps in the construction industry are lack of training and difficulty viewing documents on mobile devices. Lack of training is a significant problem as companies do not provide the necessary training to use the apps effectively. Difficulty viewing information on the mobile device's screen is another challenge, so companies should consider screen size	Azhar *et al.* (2015) https://doi.org/10.22260/ISARC2015/0008

				when deciding which mobile devices to use on the construction site (Azhar *et al.*, 2015)	
	Building Information Modeling (BIM) software IoT-enabled BIM platform Activity monitoring software Risk management software Resource and waste optimisation software	Building Information Modeling (BIM) software: BIM platforms enable real-time visibility and traceability in prefabricated construction, improving productivity. IoT-enabled BIM platform: Integrating IoT with BIM allows energy-saving on demand and intelligent building energy monitoring, further enhancing productivity. Activity monitoring software: AI applications in construction include activity monitoring, which can help track and optimise worker productivity. Risk management software: AI techniques, such as machine learning, can be applied to risk management in construction, improving productivity by identifying and mitigating potential risks. Resource and waste optimisation software: AI can optimise resource allocation and minimise waste in construction projects, increasing productivity.	Increased profitability, efficiency, safety, and security in the construction industry	Limited digitisation in the construction industry makes adopting AI and other advanced technologies difficult. Cyber threats, such as malware and phishing, pose challenges to increased access to the internet and interconnected systems in construction (Abioye *et al.*, 2021).	Abioye *et al.* (2021) https://doi.org/10.1016/j.jobe.2021.103299
	Internet of Things (IoT) Building Information Modeling (BIM) Augmented Reality (AR) and Virtual Reality (VR) Cloud-assisted AR/VR	IoT-based automation systems can be implemented in the construction industry to improve productivity and efficiency. These systems enable smart monitoring and control of various processes in construction sites, leading to better resource management and reduced downtime software allows for creating	Enhanced resource management Improved coordination and collaboration Reduced errors and rework Better visualisation and simulation Increased accuracy and efficiency Automation of repetitive tasks	Integration of different technologies and systems Cost of implementation and training Data security and privacy concerns Resistance to change and adoption Availability of skilled workforce (Srivastava	Srivastava *et al.* (2022) https://doi.org/10.1155/2022/6716987

	Edge and Fog Computing	and managing digital representations of construction projects. It facilitates collaboration among different stakeholders, improves coordination, reduces errors and rework, and enhances productivity. AR and VR technologies can be used in the construction industry for visualisation, simulation, and training. They enable workers to understand complex tasks better, improve accuracy, and enhance productivity Cloud-based platforms can support the deployment and management of AR and VR applications in the construction industry. They provide scalability, accessibility, and data storage capabilities, contributing to improved productivity.		*et al.*, 2022)	
	EDM (Electronic Document Management) Mobile application-based DMS (Document Management System)	for document management, which helps save project cost and time, improve quality, and reduce retrieval time of documents. administration work, drawing design, project scheduling, and project management. improves the efficiency of project managers.	save time and money on construction projects Mobile apps and software enhance efficiency and connectivity, making it possible for construction workers to be increasingly successful. Using mobile apps in the construction industry can lead to modernisation, digitalisation, and improved project management.	There is a need to explore more solutions and manage construction projects remotely using mobile apps. The use of software for document tracking and management is relatively low (29%), indicating a potential challenge in this area (Parikh *et al.*, 2021)	Parikh *et al.* (2021).
	Building Information Modelling (BIM) Augmented Reality (AR)	Maximize productivity: Integrating the Internet of Things (IoT) and BIM maximises productivity in the construction industry. Enhance information flow: IoT and BIM optimise the flow during a project lifecycle. Optimize energy efficiency: IoT and BIM help optimise energy efficiency in	Maximise productivity: Integrating the Internet of Things (IoT) and BIM maximises productivity in the construction industry. Enhance information flow: IoT and BIM optimise the flow during a project lifecycle. Optimise energy efficiency: IoT and BIM help optimise energy	Security: As Industry 4.0 involves data and systems in a virtual environment, security issues must be addressed to prevent negative consequences (Maskuriy *et al.*, 2019).	Maskuriy *et al.* (2019) https://doi.org/10.3390/app9142819

		construction projects. Improve security and safety: IoT and BIM improve security and safety in construction projects. Planning, managing, and monitoring of resources: IoT and BIM aid in the planning, managing, and monitoring of resources in construction projects.	efficiency in construction projects. Improve security and safety: IoT and BIM improve security and safety in construction projects. Planning, managing, and monitoring of resources: IoT and BIM aid in the planning, managing, and monitoring of resources in construction projects.		
	Autodesk Revit ArchiCAD Vico Bentley Tekla	**ArchiCAD:** BIM software for architects, available for both Windows and Mac OS. It allows the creation of BIM models on mobile devices and offers a cloud-integrated model-sharing service called BIMx. It also provides a free trial and is free for students. **Vico:** Offers location-based scheduling for on-site work management and is compatible with popular BIM tools and scheduling software. It provides tutorials and training videos on its website. **Bentley:** Has mobile applications for on-site access to online databases and provides powerful work-sharing capabilities. It allows distributed team members to use their own applications and file formats. Owners and users can publish precise, data-rich engineering content in various mediums. **Tekla:** Offers an application for on-site communication with the offsite office and specialised configurations for different construction management needs. It develops software solutions to enhance building potential	Mobile apps and software enable real-time communication, access to relevant information, and the ability to modify plans and schedules, leading to improved productivity on construction sites	Challenges include the need for integration into traditional construction management procedures and the requirement for new skill sets in using progressive mobile BIM tools (Maghiar *et al.*, 2015).	(Maghiar *et al.*, 2015)
	Autodesk Revit	AR and VR technologies are	AR and VR technologies	The complexity of	Ahmed *et al.*

	Unity 3D Vuforia EnTiTi Creator Autodesk Navisworks Manage Miracle Primavera	used for construction project scheduling, progress tracking, worker training, safety management, time and cost management, quality and defects management, and visualisation. AR technologies help automate quality and defect management systems, reduce project failures, and improve communication between parties involved in a project. VR technologies allow workers and consultants to experience a project before it is built, helping in decision-making and minimising cost and delays	are used for construction project scheduling, progress tracking, worker training, safety management, time and cost management, quality and defects management, and visualisation.	on-site data retrieval and the need for lightweight mobile devices for construction-related information projection (Ahmed *et al.*, 2017).	(2017).
	Green Building Information Modelling	Embedding sustainability strategies through software and mobile apps can improve the competitive advantage of UAE construction organisations from a social, environmental, and economic point of view.	Embedding sustainability strategies through software and mobile apps can improve the competitive advantage of UAE construction organisations from a social, environmental, and economic point of view. Demonstrating the benefits of technology adoption can help the construction industry embrace change and understand the advantages of Industry 4.0 technologies.	The low uptake of green BIM and mobile applications for sustainability in UAE construction organisations poses a challenge to implementing sustainability initiatives. The lack of skills for successfully deploying sustainability strategies is a significant challenge for the UAE construction sector (Al_Neyadi, 2018).	Al_Neyadi (2018)
	Building Information Modelling (BIM) Internet of Things (IoT) Virtual Reality (VR) and Augmented Reality (AR) Big Data Analytics	Cloud-based solutions enable real-time collaboration, data integration, and remote access to project information, facilitating efficient communication and decision-making.	Using cloud computing in conjunction with emerging technologies like BIM, IoT, VR/AR, and big data analytics can improve construction industry productivity. This can result in reduced project delays, improved resource utilisation, and enhanced project performance.	Despite the potential benefits, there are challenges to the broader adoption of cloud computing in the construction industry. These include data security and privacy concerns, interoperability issues between different software and platforms, limited awareness and understanding of cloud	Bello *et al.* (2021) https://doi.org/10.1016/j.autcon.2020.103441

				computing among industry professionals, and the need for robust IT infrastructure and reliable internet connectivity on construction sites. Overcoming these challenges requires addressing security concerns, promoting industry-wide standards and guidelines, providing training and education on cloud computing, and investing in infrastructure development (Bello *et al.*, 2021).	
	3DPrinterOS" software,	"3DPrinterOS" software is a cloud-based operating system for 3D printers. It allows users to remotely manage and monitor their 3D printers, schedule print jobs, and collaborate with others in real time. It also provides analytics and reporting features for productivity tracking and optimisation.	Using software and mobile apps for productivity improvement in 3D printing can increase efficiency, reduce downtime, and improve collaboration among users.	However, there may be challenges in terms of compatibility with different 3D printers, connectivity issues, and the need for training and familiarisation with the software or app (Tay *et al.*, 2017)	https://doi.org/10.1080/17452759.2017.1326724 Tay *et al.* (2017)
	Primavera P6, Microsoft Project, Asta Powerproject.	These tools offer various functions such as automated schedule delivery, resource planning, security risk warnings, and 4D visualisation	The benefits of using these tools include better working practices and improved results in terms of productivity	However, the challenges associated with implementing these tools include the need for training and familiarisation, integration with existing systems, and potential resistance to change from industry stakeholders (Desgagné-Lebeuf *et al.*, 2020)	https://doi.org/10.1080/15623599.2020.1819583 Desgagné-Lebeuf *et al.* (2020)
	Google Maps and OpenStreetMap: Carto and Mapbox	Google Maps and OpenStreetMap: These platforms enable public users to upload and download their data and perform simple analyses such as distance	Google Maps and OpenStreetMap: These platforms allow users to upload and download data, perform distance measurements, and	Software Issues: Integrating multiple software in a project can be challenging due to differences in software compatibility.	https://doi.org/10.3390/ijgi6120397 Song *et al.* (2017)

		measurement. Carto and Mapbox: These commercial companies allow public users to generate online interactive maps and perform spatial analysis using their data and GIS methods.	analyse spatial information. This can improve productivity by allowing users analyse purposes to access and analyse geospatial data for various purposes quickly. Carto and Mapbox: These platforms enable users to create interactive maps and spatial analysis using their data. This can enhance productivity by empowering users to visualise and analyse spatial information in a customised and user-friendly manner.	This can hinder seamless integration and coordination between different software systems. To address this challenge, implementing IFC and CityGML models is suggested to integrate various functions and avoid details losses (Song *et al.*, 2017).	
	Trello Evernote	Trello is a project management tool that helps users organise tasks and collaborate with team members. It provides a visual interface with boards, lists, and cards to track progress and assign tasks efficiently. Trello can be used for personal productivity as well as team collaboration. It offers features like due dates, checklists, attachments, and notifications to enhance productivity. Evernote: Evernote is a note-taking app that allows users to capture and organise ideas, documents, and web clippings. It offers features like tags, notebooks, and search functionality to find and access information quickly. Evernote also supports collaboration, allowing users to share and work on notes together. It helps improve productivity by providing a centralised platform for storing and retrieving information.	Streamlined task management and organisation. Enhanced collaboration and communication. Centralised storage and easy access to information. Improved time management and prioritisation. Increased efficiency and productivity.	Learning curve and adoption challenges. Overwhelming number of features and options. Integration and compatibility issues with other tools. Security and privacy concerns (Naser, 2022).	https://doi.org/10.1201/9780367823467 Naser (2022)
	OpenAI's GPT	These advanced large	These advanced large	Implementing	https://doi.org/

	(Generative Pre-trained Transformer) Google's PaLM (Pattern- and Language Modelling) Meta's Llama	language models (LLM) can generate human-like content based on learning from existing content, which can benefit various construction industry tasks. They can assist in generating construction-related content, such as project proposals, reports, and documentation, thereby improving productivity and efficiency in the industry.	language models (LLM) can generate human-like content based on learning from existing content, which can benefit various construction industry tasks. They can assist in generating construction-related content, such as project proposals, reports, and documentation, thereby improving productivity and efficiency in the industry.	Generative AI (GenAI) in the construction sector poses certain challenges that must be addressed. However, the provided sources do not mention the specific challenges (Ghimire *et al.*, 2023).	10.48550/arXiv.2310.04427 Ghimire *et al.* (2023)
	Building Information Modelling (BIM):	BIM is a multifaceted computer software data model that applies augmented reality and virtual reality to solve contemporary issues in construction. It can improve project performance in the construction sector.	BIM enables the creation of a virtual representation of a construction project, allowing stakeholders to visualise and analyse the project before it is built. This helps identify and resolve identity and potential issues early on, reducing rework and improving overall project efficiency.	The costs associated with augmented reality (AR) have been a challenge, with only large enterprises being able to afford the technology's substantial up-front investments. However, introducing open-source mobile toolkits has reduced costs, making small-to-medium more accessible to small- to medium-sized contractors. Additionally, the lack of functional information technology (IT) departments in some construction companies, particularly small-to-medium enterprises in developing countries, has hindered the widespread adoption of these technologies (Adebowale & Agumba, 2022).	https://doi.org/10.1108/SASBE-06-2022-0128 Adebowale and Agumba (2022)