LEAPING TO NEW ERA OF DIGITALISATION: TRANSFORMATION OF JOB ROLES FOR QUANTITY SURVEYORS, ARCHITECTS, AND FACILITY MANAGERS

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Abstract: Digitalisation enables construction professionals to achieve efficiency in construction projects. Knowing how digitalisation affects construction professionals can accelerate the transition from traditional roles to digital ones. However, there is a lack of research elaborating on the impacts of digitalisation on the different job roles of quantity surveyors, architects, and facility managers. Thus, this study aims to fill that research gap. A qualitative Delphi technique consisting of three rounds of interviews was used in the study. Content analysis was used to analyse the collected data. The research findings revealed that Building Information Modelling (BIM) is the most used digital technology by the selected professionals. Many roles of these three professionals are affected by digitalisation. New roles such as BIM manager, BIM modeller, and technical advisor also emerged with digitalisation. Technologies such as BIM, digital twin, artificial intelligence, and blockchain are mainly used to digitalise the roles of these professionals. Cost and time reductions are realised as the most frequent impact of digitalisation on these construction professionals' roles. This research assists professionals in identifying specific changes in each of their job roles by digitalising and improving themselves to thrive. Further, this research will be useful for education bodies' future curricula developments.

Keywords: *Architects, Delphi, Digitalisation, Facility Managers (FMs), Quantity Surveyors (QSs).*

1. Introduction

Digitalisation is adopting digital technologies and changing the connectivity of individuals, organisations, and objects (Cijan et al., 2019). Newman et al. (2021) point out that digitalisation has empowered many industries to perform their tasks efficiently and effectively, as in the construction industry. Skyrocketing labour costs and the requirement to improve efficiency have fostered recent advancements in digitalisation processes in the construction industry (Elghaish et al., 2020; Rasheed et al., 2024). Further, the demand for a collaborative working environment promotes digitalisation in construction projects (Alaloul et al., 2018). In that case, diverse digitalisation technologies such as Building Information Modelling (BIM), Internet of Things (IoT), Virtual Reality (VR), Augmented Reality (AR), blockchain, and smart contracts are gaining popularity in the construction industry (Karlsson, 2020; Osunsanmi et al., 2018; Kapoor et al., 2024). Moreover, advanced technologies such as cloud computing, artificial intelligence, digital twins, and robotics enable the construction industry to leap into the new era of digitalisation (Martinez et al., 2020; Perera et al., 2023).

With the rising popularity of digitalisation, there is a higher probability of influencing professionals and the industry's job market. It may increase the possibility of unemployment in the long run (Alaloul et al., 2018). However, new professional roles are initiated with digitalisation (Ariyachandra et al., 2020). Hence, with the advent of digitalisation, professionals working in the built environment tend to possess digitalisation-related skills and competencies in their careers and adopt innovative roles (Ametepey, 2024; Liu et al., 2019). The construction industry involves a complex network of professionals, each playing a unique role. Quantity surveyors, facilities managers, and architects are key players in different stages of a construction project. Aghimien et al. (2020) have identified that construction-related cost controlling, cost planning and estimating are the most viable processes in adopting digitalisation. Quantity surveyors (QSs) play a crucial part in those processes. Thus, QSs are significantly impacted by digitalisation. Architecture is undoubtedly a materialistic and haptic area which certainly requires human touch (Słuchocka et al., 2020). Therefore, integrating the architects and related digital technologies is a sensitive area requiring due care (Słuchocka et al., 2020). Building maintenance, construction, and post-construction sustainability management are core components of facility managers' (FM) functions that have received imperative attention in digitalisation (Wong et al., 2018). Therefore, the application of various digital technologies is rapidly increasing among FMs (Wong et al., 2018). Accordingly, these construction professionals' roles are significantly impacted by the process of digitalisation. Therefore, a detailed study will be necessary to discuss the impact of digitalisation on those professionals.

Even though digitalisation significantly affects these professionals' roles, their overall understanding about the process is yet to be updated (Saka & Chan, 2020). Evolving discussions on this topic foster progress and highlight the positive changes required to harness the ultimate benefits of digitalisation (Ametepey, 2024; Glock, 2018). Quantity surveyors, facilities managers, and architects over other professionals, focus on capturing key aspects of the construction process, covering financial management, operational efficiency, and design innovation (Sharafadeen et al., 2014; Chandramohan et al., 2020; Jenuwa et al., 2020). These roles represent critical functions in the industry and studying them collectively provides

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a comprehensive understanding of the digital transformation in construction.

Despite extensive research on digitalisation barriers and drivers in construction, significant gaps remain regarding role-specific impacts. Research concerning the digital transformation process in the construction sector remains at its early stages, primarily focusing on identifying benefits and barriers while focusing less on specific cases of transformation in professionals. While studies have examined BIM-related skills and new roles such as BIM managers (Ariyachandra et al., 2020; Uhm et al., 2017), there is insufficient exploration of how traditional roles are being modified. Despite 53% of professionals agreeing that digitalisation would improve performance, only 12% use digital tools across all projects, with non-adoption increasing from 40% in 2021 to 43% in 2023, suggesting inadequate understanding of practical implementation (Perera et al., 2023).

Recent studies call for research on people-related features required for digitalisation (Aghimien et al., 2022) and transformation impacts (Yilmaz et al., 2023), yet role-specific analyses remain scarce. This gap hinders targeted training development, particularly as many construction professionals lack the training needed to confidently use digital tools, with firms citing lack of digital expertise as a reason for avoiding new technology. This study addresses these gaps by providing detailed, role-specific analysis of how digitalisation impacts different roles of quantity surveyors, architects, and facility managers. The objectives of this study are to identify the current applications of digital technologies by architects, QSs, and FMs, identify their roles affected by digitalisation, investigate how digital technologies are adopted in each role of these construction professionals and analyse the impact of the use of digitalisation in each role of them.

2. Literature Review

2.1 DIGITALISATION IN THE CONSTRUCTION INDUSTRY

Application of digital technologies in the construction industry increase productivity and solve major concerns (Manzoor et al., 2021). BIM is considered the foundation for the Architecture Engineering Construction industry's digital revolution (Autodesk, 2021). It is often used at construction sites due to its ability to deliver simulations of information regarding building estimates, material inventory, cost scheduling corrections, clash detection, structural analysis, energy analysis, space management, and progress details (Saka & Chan, 2020; Seidu et al., 2020). In addition to BIM, digital twin is becoming central in data-driven and model-centric work systems (Ghosh et al., 2021). IoT collects and shares large amounts of data over a network system without human intervention (Newman et al., 2021; Rasheed et al., 2024). Cyber-Physical Systems are used for various applications such as site management, building efficiency monitoring, defect management, material tracking, and 3D printing (Bock, 2015). AR was invented to create systems to merge real-world settings with virtual items, and it smoothens the processes of a project by enabling a walkthrough function that allows an observer to evaluate a proposed project's design and construction abilities (Ahmed, 2019). Blockchain technology is a ledger where all committed transactions are stored in a block, and the chain grows as new blocks continue to be added (Perera et al., 2020). In addition, blockchain technology may improve construction information management systems, increase automation, and avoid many potential legal issues by default (Shojaei, 2019). Therefore, the encouraging adoption of digitalisation in the construction industry has become necessary for all professionals willing to enhance construction projects' productivity and efficiency. Karlsson (2020) stated that the construction industry needs to develop an awareness of how the fundamentals of their current roles should reshape to overcome their hesitation in adopting digitalisation.

2.2 TRADITIONAL ROLES OF ARCHITECTS, QUANTITY SURVEYORS, AND FACILITY MANAGERS

Researchers identified architects' traditional roles as building design, design drawings, feasibility studies, design specifications, and detailed drawings (Sharafadeen et al., 2014). Moreover, QSs' traditional roles are preliminary estimation, contract administration, cost planning, measurement, quantification, procurement advice, interim valuations, and interim certification (Chandramohan et al., 2020). Further, FMs' traditional roles are building operation management, post-occupancy evaluation, space planning, service integration, sustainability monitoring, health and safety management, and building maintenance (Jenuwa et al., 2020). Identifying their traditional role is the initial step in analysing the impacts of their roles due to digitalisation. When the industry moves toward digitalisation, it is mandatory for professionals to gradually move away from historical paper-based processes to a new way of digital working (Sawhney & Knight, 2022). The authors further explained that this 'truly digital working nature' will contribute to the betterment of the industry in aspects such as cost efficiency, project certainty, maintainability, and sustainability. Therefore, discussion on the impact of digitalisation on professionals' current roles is vital to reduce the fear of transforming.

2.3 IMPACT OF DIGITALISATION ON THE CONSTRUCTION PROFESSIONAL'S JOB ROLES

Digitalisation enhances construction professionals' job roles while creating new job positions in the industry (Wao, 2016). Maritz and Hattingh (2015) state that digitalisation simplifies the task of construction professionals by enhancing their decision-making capabilities to increase accuracy and efficiency. Ultimately digitalisation can contribute to reducing project costs without compromising functionality or quality. It also significantly reduces the negative environmental impacts and promotes safety in construction (Sawhney & Knight, 2022). New job roles, such as BIM managers, BIM analysts, software developers, BIM researchers, technical advisors, information managers, and design managers, are promoted in implementing digital technologies (Ariyachandra et al., 2020; Uhm et al., 2017). Furthermore, facilitators and consultants specialised in digital technologies have also been established due to the digitalisation of the construction industry. However, particular digitalisation-related roles could become less relevant when other construction participants acquire the relevant technology expertise (Bosch-Sijtsema & Gluch, 2019). Therefore, it is essential to discuss the knowledge required for the digitalisation of the construction professions to replace these roles and survive in the transformation. Researchers have identified new requirements from the job roles as knowledge of technology and its process, collaboration and coordination skills, innovative thinking, knowledge of supporting software, and related training (Ariyachandra et al., 2020). Further, professionals in the construction industry need to have the competency in their career as well as need to be familiar with the relevant software for their profession, such as AutoCAD, Revit, SketchUp, Civil 3D, CostX, BIM 360 Ops/BIM 360 Field, QFM, IBM TRIRIGA, ARCHIBUS (Wong et al., 2018). These requirements will be essential in adopting digitalisation to facilitate current tasks such as feasibility checking, cost estimating, procurement advice, design development, energy management, maintenance management, health and safety management, and service integration (Wong et al., 2018). Digitalisation is the construction industry's future (Osunsanmi et al., 2018), and this transformation is inevitable for all professionals. Researchers attempt to address the need for the innovative job market and emerging professionals' skills and competencies ((Uhm et al., 2017), and many of those studies are limited to BIM-related skills and competencies (Ariyachandra et al., 2020). Olanrewaju et al. (2020) reveal the hesitation of professionals is a significant barrier to the successful adoption of digitalisation in the construction industry. This barrier can be mitigated by showing the correct direction to them from their usual job roles and the new digitalised job roles. Even though architects, QSs and FMs are considered key construction professionals directly affected by the construction industry's digital transformation, there is a lack of discussion regarding the changes that occurred and will be occurring in their job roles. Also, there is a dearth of literature regarding the changes in job roles and in-detail studies about how digitalisation will affect each role. Thus, it is vital to conduct research to identify how these professionals' job roles are impacted due to the digitalisation in the construction industry, considering the above-mentioned industrial needs and the literature gaps.

3. Research Methodology

This research aims to conduct an in-depth study on the impact of digitalisation on architecture, quantity surveying, and facility management professionals' job roles and to determine digitalisation's current application and effect on their profession. In that case, this study primarily addresses the 'how' and 'why' questions which require qualitative outcomes than numerical data (Maxwell, 2018). Furthermore, this approach allows the participants to deliver their opinions which is essential for this study (Fassinger & Morrow, 2013). Therefore, a qualitative approach was selected for the study. Amongst different qualitative data collection techniques, Delphi can be employed to develop a 'consensus' of opinions by conducting several data collection rounds with the respondents (Moragane et al., 2022; Garusinghe et al, 2023; Senanayake et al; 2024). Further, the Delphi technique aids the researcher in capturing clear and in-depth views of the panel of respondents regarding research questions (Aghimien et al., 2020). Thus, the present study incorporates a qualitative Delphi technique for data collection. In Delphi technique, no standard number of rounds needed to be conducted to obtain the consensus. However, in most studies, the respondents' agreement is achieved by two or three Delphi rounds (Ameyaw et al., 2016). Therefore, this study employed a three-round Delphi study, considering the availability of time and resources. Data saturation was reached after the third round. Content analysis was used because it enables the researcher to summarise the data collected from the respondents and match it with the responses according to the research criteria (Niels & Jacobs, 2017). Table 1 shows the details of the Delphi rounds.

The study's effectiveness increases when the Delphi rounds are conducted with a heterogeneous sample of experts (Skulmoski et al., 2007). Purposive sampling is used to select the survey respondents because it allows the researcher to collect data from the most suited group of experts in a particular subject matter (Rahi, 2017). Thus, the selected 15 respondents for the study have at least five years working experience in the digitalisation-built environment from Australia, the United Kingdom, New Zealand, United Arab Emirates, and Sri Lanka. The sample was selected based on compulsory and additional criteria, as shown in Table 1. Moreover, fifteen respondents participated in the first round, and thirteen participated in the second and third rounds. According to the literature, the participation of 10-20 experts in the first round is sufficient to generate a robust result in a Delphi study (Soriano et al., 2021). Therefore, fifteen respondents were considered appropriate for robust results in the present study. Table 1 shows the respondents' profiles of the Delphi study.

Table 1: Details of the Delphi rounds and respondents' Profiles

<table>
<tr><th colspan="8">Details of Delphi Rounds</th></tr>
<tr><td colspan="2" rowspan="2">Round 1</td><td colspan="2">Phase I</td><td colspan="4">Identify current application of digital technologies by selected professional</td></tr>
<tr><td colspan="2">Phase II</td><td colspan="4">Investigate the roles of selected construction professionals</td></tr>
<tr><td colspan="2" rowspan="2">Round 2</td><td colspan="2">Phase I</td><td colspan="4">Identify the roles of selected construction professionals that are affected by digitalisation</td></tr>
<tr><td colspan="2">Phase II</td><td colspan="4">Identify impacts of the use of digitalisation</td></tr>
<tr><td colspan="2" rowspan="2">Round 3</td><td colspan="2">Phase I</td><td colspan="4">Investigate how digital technologies are adopted by each key role of selected construction professionals</td></tr>
<tr><td colspan="2">Phase II</td><td colspan="4">Matching the impact of digitalisation with each key role of selected construction professionals</td></tr>
<tr><th colspan="8">Respondents' Profiles</th></tr>
<tr><td></td><td></td><td></td><td></td><th colspan="2">Compulsory qualifications</th><th>Additional qualifications</th><th rowspan="2">Participation</th></tr>
<tr><td></td><td></td><td></td><td></td><th>At least one</th><th>Must</th><th>At least two</th></tr>
</table>

Coding for expert	Designation	Profession	Experience (Yrs.)	At least three years of experience in construction digitalisation	PhD candidate (or obtained the PhD) in construction	Availability for at least one round	Graduated in a related discipline	Mastered degree in a related discipline	Member of a construction-related professional institution	R1	R2	R3
QS1	Director	QS	20	√		√	√	√	√	√	√	√
QS2	Director	QS	22	√		√	√	√	√	√	√	√
QS3	PhD Scholar	QS	10		√	√	√	√	√	√	√	√
QS4	PhD Scholar	QS	8		√	√	√	√	√	√	√	√
QS5	PhD Scholar	QS	7		√	√	√	√	√	√	√	√
A1	Director	Architect	12	√		√	√	√	√	√	√	√
A2	Senior Architect	Architect	14	√		√	√		√	√	√	√
A3	Chartered Architect	Architect	10	√		√	√	√	√	√		
A4	Senior Architect	Architect	18	√		√	√	√	√	√	√	√
A5	Senior lecturer	Architect	15	√		√	√	√	√	√	√	√
FM1	PhD Scholar	FM	5		√	√	√		√	√	√	√
FM2	Project manager	FM	6	√		√	√	√	√	√		
FM3	Facility manager	FM	5	√		√	√	√	√	√	√	√
FM4	Facility manager	FM	11	√		√	√		√	√	√	√
FM5	Senior lecturer	FM	5		√	√	√	√	√	√	√	√

4. Research Findings

4.1 CURRENT APPLICATIONS OF DIGITAL TECHNOLOGIES BY SELECTED CONSTRUCTION PROFESSIONALS (ROUND 1 PHASE 1)

Through the literature review, twenty-seven (27) digital technologies were identified. In Delphi Round 1 Phase 1, the respondents were asked to validate the literature findings and identify any other digital technologies applicable to their professional careers. Technologies exceeding 75% of agreement rate of respondents were considered applicable. The experts' responses are illustrated in Table 2.

Table 2, Application of digital technologies by selected construction professionals

Digital Technology	Agreement<75%	Digital Technology	Agreement<75%
Building Information Modelling (BIM)	√	Blockchain	√
Computer-Aided Design (CAD)	√	Autonomous vehicles	
Cloud computing	√	Building automation	√
Augmented Reality (AR)	√	3D Printing	√
Sensors	√	Robotics	√
Artificial Intelligence	√	Machine Learning	√
Geographical Information Systems (GIS)	√	Internet of Things (IoT)	
Virtual Reality	√	High-resolution automated Camera	√
Simulations	√	Radiofrequency identification (RFID)	√
Drones	√	Smart wearables	√
Enterprise Resource Planning (ERP)	√	Ultrasound position tracking	√
Big data	√	Lidar (Light detection and ranging)	√
Laser Scanning	√	Data collection apps	√
Digital twins	√		

During the interviews, IoT was removed from the list because it did not receive 75% agreement, which contradicts the literature findings. Respondents described rather than digital technology, IoT is an interface that integrates physical and virtual 'things' together. Also, IoT was identified as a platform that uses a combination of digital technologies and devices.

However, there was some contradiction of ideas among the respondents on this idea. Further, interviewees emphasised that BIM, CAD, Cloud computing, AR, sensors, and AI are the widely used digital technologies in the construction industry.

According to the interviewees, architects use AR-based applications and tools mainly for modelling (Real-time information visualisation). Further, FM1 stated that "*nowadays AR is used to visualise system components like pipes, conduits, ducts, and underground structures may be dangerous to walk through for maintenance purposes*." Besides, FM4 and QS5 emphasised that "*with the COVID-19 pandemic, access to construction sites is restricted, so developed countries use AR technology to inspect sites remotely up to a considerable extent*".Interviewees highlighted that light, fibre-optic, temperature, and pressure sensors are mainly used in construction safety management. Regarding other sensor-based applications, FM2 specifically mentioned that RFID identifies radio signals and is used for asset tagging, barcode reading, and material tracking. Moreover, QS2 noted ultrasound position-tracking systems are used primarily in ultrasonic cross-hole tests for deep foundations, a vital cost item related to the testing and commissioning section.

Commenting on digital twins, interviewees identified it as a system that can automate and accelerate design, production, and operational processes. Further, it was described as an integration of BIM with IoT devices to use real-time monitored data. FM4 noted that digital twin is applicable in all the lifecycle phases of a construction project. Furthermore, FM3 mentioned that digital twins connect with smart buildings, which is also beneficial for maintenance.

FM2 emphasised that artificial intelligence is a digital terminology covering BIM, digital twin, big data, machine learning/deep learning, and robotics. Additionally, many respondents identified VR technology for 3D modelling related to BIM adoption, virtual site visits, and simulated workplaces. Besides, BIM is recognised by many respondents as the existing platform that can apply to many roles of QSs, architects, and FMs, promoting collaboration. Further, A3 and A4 affirmed that BIM/ digital twin technologies incorporating machine learning, different sensors, and scanners digitalised their traditional drawing drafting with 3D modelling software such as Revit, 3D Max, Sketchup, ArchiCAD, and Vector works. QS5 emphasised that "*if we connect blockchain and BIM, will have a better chance of tracking information flow, and all the information will be secure*." However, QS1, QS2, and QS4 stated that people still do not effectively adopt digitalisation in construction roles and still rely on traditional methods. As identified by the respondents, many professionals adopt various digital technologies, and their current professional roles have emerged accordingly.

4.2 ROLES OF SELECTED CONSTRUCTION PROFESSIONALS THAT ARE AFFECTED BY DIGITALISATION (ROUND 1 PHASE 2, AND ROUND 2 PHASE 1)

The literature findings identified fifty-one (52) existing roles of selected professionals. In Delphi Round 1 Phase 2, the respondents were asked to validate the literature findings and identify new roles of them. In addition to the literature findings, seven new roles were identified through this stage. Out of fifty-eight roles, fifty-seven with 75% or more agreement percentages were carried forward. Then in Round 2 Phase 1, respondents were asked to determine the application of digital technologies in each professional's role. Out of fifty-seven roles, fifty-two that exceeded 75% of agreement rate were considered acceptable. The experts' responses are illustrated in Table 3 (roles newly identified by the interviewees are shown in bold texts).

Table 3, Roles of selected construction professionals that are affected by digitalisation.

No	Roles	Agreement > 75%		Related Professional		
		Round 1	Round 2	QS	FM	Architect
R1	Feasibility/ Viability studies	√	√	√		
R2	Site investigation	√	√	√		√
R3	Sustainability advising	√	√	√	√	√
R4	Procurement advice	√	√	√		
R5	Life cycle costing	√	√	√		
R6	Construction technology			√		√
R7	Environmental services				√	
R8	Investment appraisal	√	√	√		
R9	Building Surveying	√	√		√	
R10	Preliminary estimation	√	√	√		
R11	Cost estimation	√	√	√		
R12	Tendering procedure	√	√	√		
R13	Measurement and quantification	√	√	√		
R14	Preparation of BOQ	√	√	√		
R15	Specification preparation	√	√			√
R16	Cost planning and control	√	√	√		
R17	Contract documentation	√	√	√		
R18	Contract administration	√	√	√		
R19	Subcontract administration	√	√	√		
R20	Financial management	√	√	√		
R21	Accounting principles and procedures	√	√	√		
R22	Negotiation on financial issues	√		√		

No	Roles	Agreement > 75%		Related Professional		
		Round 1	Round 2	QS	FM	Architect
R23	Value management	√	√	√		
R24	Risk management	√	√	√		
R25	Project management	√	√	√		√
R26	Planning and supervision	√	√	√	√	√
R27	Arbitration and dispute resolution	√		√		
R28	Interim valuation and payment	√	√	√		
R29	Final accounts	√	√	√		
R30	Settlement of contractual claims	√		√		
R31	Technical and legal advice	√	√	√		
R32	Building design	√	√			√
R33	Develop design drawings	√	√			√
R34	Produce detail drawings	√	√			√
R35	Schematic design preparation	√	√			√
R36	Consult design /construction issues.	√				√
R37	Final construction plans	√	√			√
R38	Preparation of application for planning and building control	√	√			√
R39	Building information services	√	√			√
R40	Building operations and maintenance	√	√		√	
R41	Energy management	√	√		√	
R42	Waste management	√	√		√	
R43	Space planning and management	√	√		√	
R44	Renovations	√	√		√	
R45	Post occupancy evaluation	√	√		√	
R46	Real estate asset management	√	√		√	
R47	Health and safety management	√	√		√	
R48	Communication, access, and control systems	√	√		√	
R49	Information management	√	√		√	
R50	Supply chain management	√	√		√	
R51	Stakeholder management	√			√	
R52	Quality assessment	√	√		√	
NR1	**BIM Coordination and management**	√	√			√
NR2	**Earn value management**	√	√	√		
NR3	**5D BIM quantification**	√	√	√		
NR4	**Data management**	√	√	√	√	√
NR5	**Progress monitoring**	√	√	√		
NR6	**Carbon accounting**	√	√	√	√	√
NR7	**Clash detection and coordination**	√	√			√

According to Table 3, respondents suggested BIM coordination and management, earned value management, 5D BIM quantification, data management, progress monitoring, carbon accounting, and clash detection and coordination as new roles emerged with digitalised. In Round 1 Phase 2, construction technology and environmental services roles obtained less than 75% agreement rate. Interviewees explained that these roles are not common for selected professionals and are done by engineers and environmental consultants. Further, in Round 2 Phase 1, many interviewees noted that roles such as arbitration and dispute resolution, settlement of contractual claims, negotiation, consult design/construction issues, and stakeholder management have less possibility of involving directly with digitalisation. QS3 explained that these roles required "human touch/ human processer" and highly depended on the "circumstances and emotions". Commenting on site investigation, traditionally done through on-site visits, QS1 explained about adopting digital technologies such as GPS/GIS systems and laser scanning to increase efficiency. Traditionally, standards are checked using manual rating systems, and recommendations are given in the sustainability advising process. Respondents emphasised that 6D BIM packages, simulation models, GPS-based environmental monitoring, and drones-based monitoring can digitalise the sustainability advising process. Moreover, respondents highlighted traditional surveying methods such as total-station, theodolite and measuring tapes could be replaced with AR, electronic distance measurement (EDM), GPS, and Lidar. Also, the risk management process, which necessitates the timely engagement of many stakeholders, can be improved by digitalisation. Q2 explained: "*Cloud-based technologies allow users to make changes in real-time and facilitate all users' immediate access, so it reduces risks on security and accessibility*". Further, QS3 discussed Monte-Carlo simulation, which can be used in risk analysis. Moreover, 4D BIM, which connects 3D point clouds with schedule-related information, is also significant regarding progress monitoring.

Interviews revealed that preliminary estimation and cost estimation had been digitalised by adopting specialised software (Planswift, Bluebeam, CostX), BIM, and Photogrammetry, offering competitive accuracy and efficiency advantages over traditional manual methods. Rather than using conventional manual measurement methods, measurement and quantification can be automated by employing digital technologies such as BIM, sensors, estimating software, high-resolution automated cameras, and drones. Moreover, ERP system is highlighted as the best digital solution for automating and improving efficiency and accuracy in the cost planning and controlling process. Respondents further discussed how architects could successfully adopt into digitalised new roles such as BIM coordination and management, data management and clash detection. Digitalised clash detection role provides accurate design documentation, better collaboration, and automated clash resolution and helps eliminate upcoming conflicts and disputes. Regarding digitalisation in FM roles, respondents mainly emphasised implementing building management systems (BMS), integrating different systems such as heating, ventilation and air conditioning (HVAC), security systems, power systems, and lighting systems.

The interviewees identified EVM as a beneficial decision-making tool that can predict cost and time overruns and potential risks and enhance the planning process. Significantly, many respondents emphasised that EVM delivers real-time data on project performance, secures project budgets and planning data, and conforms with industry standards and legal regulations. Additionally, data management-related role is also essential in Common Data Environment (CDE) for sharing and storing many data files among the stakeholders and team members without confusion or disruption. The role of progress monitoring can be digitalised using cloud-based BIM systems, web-enabled digital cameras, 3D scanners, Lidar technology, and 360-degree images. These digitalised progress monitoring methods facilitate monitoring construction activities in real time. Commenting on a blockchain-based carbon accounting (BEC) system, QS3 stated, "*I am using Bec in my project. In the same way you store financial transactions, I am storing embodied transactions using blockchain to resolve problems in carbon accounting*". Furthermore, QS4 highlighted that the tally tool add-in to Revit software is used for BIM-enabled carbon estimating.

4.3 DIGITAL TECHNOLOGIES USED IN EACH ROLE OF SELECTED CONSTRUCTION PROFESSIONALS (ROUND 1 PHASE 1, ROUND 1 PHASE 2, ROUND 2 PHASE 1 AND ROUND 3 PHASE 1)

In Delphi Phase 3 Round 1, interviewees were requested to match different digitalised technologies (identified in Round 1 Phase 1) adopted to each role of selected professionals (identified in Round 1 Phase 2 and Round 2 Phase 1). The results of this phase are illustrated in Figure 1. As shown in Figure 1, it can be discerned that BIM is the most significant digital technology that can be used in many roles of construction professionals. Respondents identified several dimensions of BIM as 3D, 4D, 5D, 6D, and 7D BIM, which affect different roles. Technologies such as cloud computing, AR, VR, drones, CAD, Lidar, big data, and blockchain are digital technologies that can be adopted in higher number of construction professionals' roles. Furthermore, 3D printing, robotics and smart wearables are used in fewer roles. Respondents drew attention to the fact that these technologies are still in their infancy, even though they are thought to be adaptable to specific functions. The effects of digitalisation on each role are outlined to understand how different roles adopt digitalisation.

4.4 IMPACT OF THE USE OF DIGITALISATION ON EACH ROLE OF SELECTED CONSTRUCTION PROFESSIONALS (ROUND 1 PHASE 2, ROUND 2 PHASE 1, ROUND 2 PHASE2, ROUND 3 PHASE 1 AND ROUND 3 PHASE 2)

In Delphi Round 2 Phase 2, interviewees were requested to identify the impact of digitalisation on the selected construction professionals. In Round 3 Phase 2, the results from Round 2 Phase 2 were matched with each role of selected professionals and asked to cross-examine with the different digital technologies adopted in each professional's role. The impact on existing roles and the newly emerged roles due to digitalisation is illustrated in Figure 2 and 3. Impacts with more than 75% agreement rate considered acceptable in this round. Further for easy reference, clarity, simplicity, and understanding, the identified impacts were consolidated and categorised into 12 constructs as shown in Table 4.

Figure 2 shows major impacts common to almost all roles are time and cost saving. In this case, QS4 stated that "implementing technologies required high initial investment. Many clients think this is a loss at a glance. However, in the long run, the project can prevent unnecessary losses and conflicts and increase productivity, saving money. Further, by increasing the efficiency, which will improve the value of the project. Ultimately, there is a huge saving compared to the initial investment in properly adopting digital technologies". QS3 and A5 identified that Microsoft Access, Microsoft Excel, and ERP Systems are currently used in paperwork reduction. Even though they use software for documentation, they keep printed documents. Therefore, QS4 specifically suggested that "*if we use a document management system like Aconex, we can upload all the drawings and information to it, so all the users will know when a change happens". Under contract administration, QS1 added that* "CIC BIM protocol amends the traditional contracts with BIM and provides a fully digitalised environment to the construction process".

QS3, QS4, and QS5 highlighted several digital technologies such as Estimating software (Planswift, Bluebeam), BIM, and Photogrammetry impacted to digitalise this role in the current situation. QS2 noted that "*we can create a 3D model at the beginning of the project and present it to the client and design team to understand the client's needs*". Further, QS2 described that "it helps to get an idea about what are we going to build, and it reduces the time on decision making at an early stage". Furthermore, QS1 stated that "developed countries use 3D model taking off software like CostX, Cubicost, Planswift, Bluebeam and BEXEL Manager, which can generate real-time automated calculations and highly accurate and easy to process". Further commenting on BOQ preparation, QS3, QS4, and QS5 noted that BIM and taking off software integrated with cyber workplace impacted reducing the time consumption for the BOQ preparation. However, in this process, updating quantities is still done manually. As QS1 emphasised, "We can automate the BOQ preparation process. For example, by using Cubicost 5D BIM software, we can generate BOQ sheets easily without manual quantity input. This automation of quantity extraction and calculation increases accuracy and transparency. Additionally, it is simple to conduct cross-checks this way."Furthermore, QS1 and QS5 emphasised that 5D BIM software packages contributed to automating the cost control process by scheduling and costing, design integration of calculation, and generating auto quantity reports, including productivity rates and labour costs.

Discussing digitalisation's impact on the architects' profession, A2 emphasised that concept design and detail design traditionally use hand sketching. A1 mentioned that "*we can use Microsoft Surface or digitalised sketchbooks and easily sketch with touch pen*".

Further, in that case, he explained that "like traditional hand sketching, we will not lose our sketches, and we can store our sketches on a digitalised platform that is not physically likely to be destroyed". In addition, respondents identified BIM as the most significant digital technology that facilitates drafting work effortlessly for architects due to the efficient and time-saving software such as Revit, Sketchup, and ArchiCAD. Respondents explained the importance of using a single digitalised platform by all professionals, which will help them increase the design's practicality from the initial stages and avoid future variations.

Moreover, A2 and A3 emphasised that technologies such as AI, text mining, and expert systems impacted many architect roles by reducing the complexity of the task and increasing efficiency. A1, A2, and A5 noted that applications such as AR Sketch Walk enable architects to dive into their sketches to deliver their clients and themselves a real sense of space. In that case, A1 mentioned, "using a smartphone or tablet, you can position your sketch in the plan and navigate through it as the walls grow. Also, smart helmets and AR glasses can visualise 3D environment." Besides, A2 stated that AR-based applications that view 3D models in real-time and right scale convert 2D plans into a 3D model hologram. In that case, users should use smartphones or tablets to experience this hologram. Moreover, A5 highlighted that recently AR-based applications had been developed to transfer 3D models to complete construction instructions with measurements and step-by-step guidelines. It is mainly useful in the construction of complex projects. When discussing the digitalisation impact on the FM profession, FM1 emphasised that AR, VR, QR scanners, and sensors are used in the maintenance works in places which are hard to reach and to access inspection for underground tunnels. FM2 emphasised that "*we are still in the early stage of using AR and VR technologies in facility management, but this technology can save huge costs and provide value-added benefits*". Further, FM3 and FM4 mentioned that adopting IoT devices and facility management software provides early building maintenance plans. Moreover, FM5 emphasised that using AI to monitor physical assets makes forecasting the asset's lifecycle easier before the asset fails and helps FM in preventive maintenance. FM4 stressed that digital twin facility management software provides an extra dimension to the BIM model by showing issues with real-time digital representation, and this can be helpful for the FM to identify the faults immediately. Further, FM5 highlighted that AI-based BMS systems help to deliver higher work efficiency, enhance building occupancy comfort, and reduce carbon footprint and energy consumption. Under the space planning and management role, FM3 specifically noted that workplace management software and BIM models contribute to simulating space management. FM traditionally use 2D drawings and hand sketches. Moreover, FM3 remarked that digital twins could save the time of facility managers by providing information from all sites, reducing unnecessary travel and operational issues, optimising, and allowing operation and maintenance work more efficiently. As revealed from the findings, there are considerable positive impacts for architects, QSs and FMs due to adopting digitalisation in the construction industry.

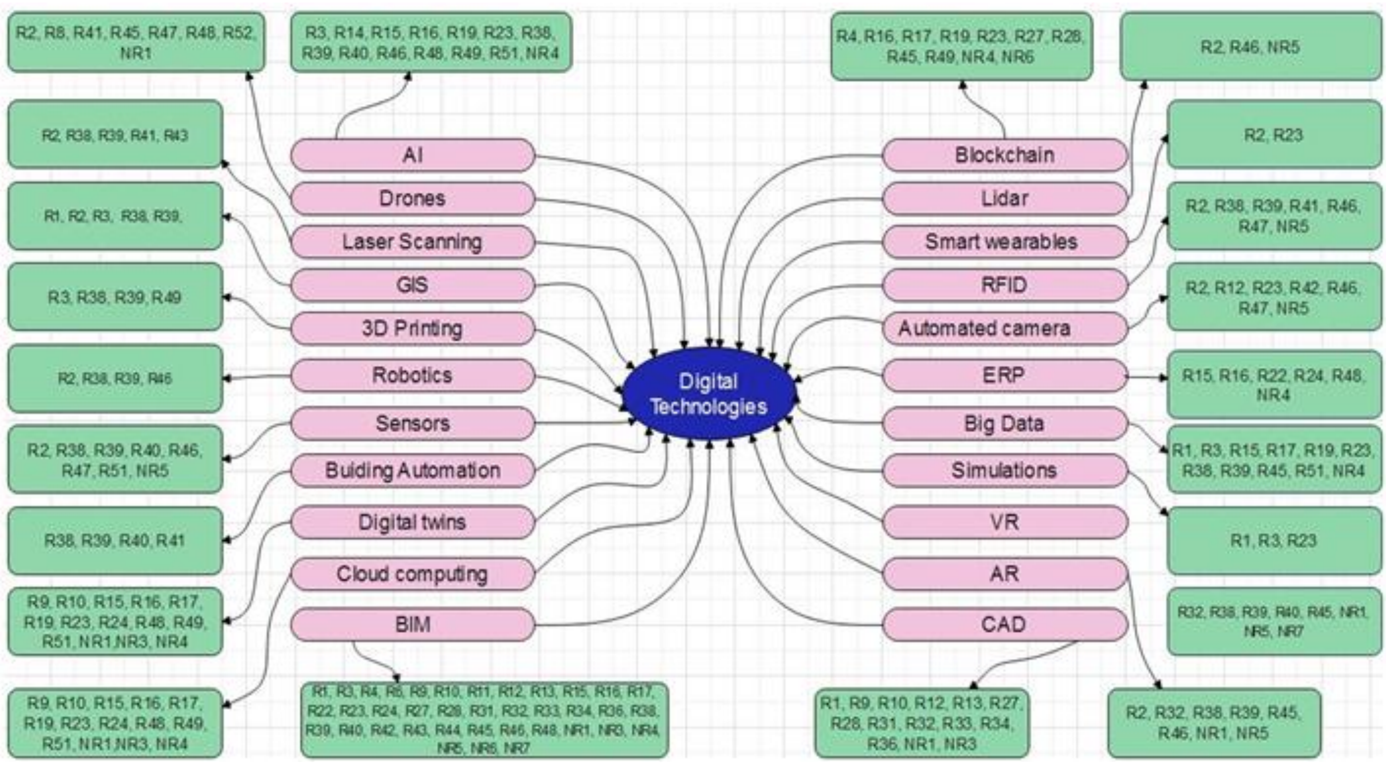

Figure 1, Digital technologies used in different roles of selected construction professionals.

Table 4: Impacts categories with rationale for categorization

Category	Rationale for developing the category	Impact ID
1. Accuracy and Quality Improvement	This category was developed to capture how digital tools enhance the precision and reliability of outputs such as design documentation, cost estimation, and quantity take-offs, areas traditionally prone to manual errors.	IM2, IM9, IM10, IM11, IM12, IM33, IM36, IM44, IM48, IM49, IM59, IM63, IM67
2. Efficiency and Productivity Enhancement	Grouped to reflect how automation, digital workflows, and process optimisation improve overall project efficiency, reduce time and cost, and streamline repetitive manual tasks.	IM16, IM17, IM18, IM20, IM24, IM26, IM34, IM54, IM55, IM56, IM73, IM74, IM75, IM76, IM77
3. Collaboration, Communication, and Data Sharing	Established to show how digitalisation breaks boundaries between professionals by providing shared digital environments that promote integrated communication and coordination.	IM21, IM23, IM31, IM32, IM35, IM43, IM52, IM64, IM65
4. Risk Management, Safety, and Monitoring	Created to represent the preventive capabilities of digital tools in identifying risks, improving site safety, and enabling continuous project performance monitoring.	IM3, IM8, IM15, IM27, IM45, IM47, IM50, IM57, IM61
5. Decision-Making and Planning Enhancement	Focuses on how predictive analytics, simulation tools, and real-time data improve strategic decisions, project forecasting, and resource allocation.	IM4, IM13, IM22, IM29, IM30, IM37, IM38, IM39, IM53, IM60
6. Cost and Resource Management	Developed to highlight the financial and resource control benefits offered by digital tools, supporting early cost prediction, waste reduction, and value optimisation.	IM22, IM30, IM38, IM39, IM42, IM72, IM78
7. Security, Confidentiality, and Data Integrity	Introduced to emphasise the importance of secure data storage, communication, and transaction systems.	IM6, IM29, IM51, IM58, IM64, IM69, IM79, IM80, IM81
8. Visualisation and Design Integration	Reflects the transformative role of 3D visualisation, BIM, and digital twins in improving spatial understanding, design coordination, and stakeholder communication.	IM5, IM26, IM28, IM46, IM62, IM66
9. Maintenance, Operations, and Facility Management	Represents digitalisation's contribution to the operational phase, supporting predictive maintenance, facility monitoring, and lifecycle asset management.	IM4, IM13, IM40, IM41, IM68, IM83
10. Digital Integration and Automation	Encompasses the integration of multiple digital systems and the automation of data flows, highlighting the move toward interconnected and intelligent project delivery systems.	IM1, IM7, IM18, IM60, IM70, IM82, IM84
11. Limitations and Transitional Challenges	Acknowledge areas where digital adoption remains partial or challenging, providing a realistic view of the transformation process	IM19, IM71
12. Client and Market-Related Benefits	Added to represent the external impacts of digitalisation, including client satisfaction, transparency, and access to property or project information.	IM14, IM42, IM78

ID	Impact	ID	Impact	ID	Impact	ID	Impact
IM1	The efficiency of using GPS-based environmental monitoring	IM22	Early predictions of cost, time overrun, and potential risks.	IM43	Helps to share and store many data files among the team members in a common data environment	IM64	Promote efficient and secure access and storage of the information
IM2	Increase the accuracy	IM23	Easy access to data	IM44	High accuracy in measurements	IM65	Promote one digital platform with all related data
IM3	Ability to eliminate risks and reconstruction works at an early stage.	IM24	Easy digitalised documentation, cost analysis, and supplier management	IM45	Immediate identification of faults using the live digital representation	IM66	Proper visualisation using 3D model
IM4	Ability to forecast the lifecycle of physical assets	IM25	Easy monitoring of the process	IM46	Improve the ability to detect spacing issues at an early stage	IM67	Provide accurate automated quantity extractions
IM5	Ability to generate the graphic display of construction activities over time	IM26	Easy to prepare sketches and drafting	IM47	Improve the ability to monitor the process	IM68	Provide early predictions regarding building maintenance
IM6	Ability to incorporate blockchain integrated with BIM (BIM chain) as the data source	IM27	Effective risk identification	IM48	Improve the transparency and accuracy of the estimates of embodied carbon	IM69	Provide high security and confidentiality
IM7	Ability to obtain automatic updates on elements	IM28	Efficiency in visualising different space arrangements	IM49	Increase accuracy	IM70	Real-time automated calculations
IM8	Ability to predict accidents earlier with real-time notifications	IM29	Enable the easy access of participants to the blockchain database with a secured process.	IM50	Increase safety in accessing risky places which are difficult to inspect	IM71	Reduce complexity
IM9	Accuracy of the new technology-based extracted quantities	IM30	Enables easy derivation of productivity rates and labour costs and design integration in calculations	IM51	Increase security and confidentiality of communication	IM72	Reduce future disputes and disruptions
IM10	Accurate and easy clash detection	IM31	Enhance better communication and collaboration	IM52	Increase the coordination and collaboration between professionals	IM73	Reduce manpower requirement
IM11	Accurate and easy revisions of drawings	IM32	Enhance collaboration	IM53	Increase the effectiveness of handling operational issues	IM74	Reduce massive paper-based documentation process
IM12	Accurate design documentations	IM33	Enhance data collection quality and accuracy using documentation with BIM software	IM54	Increase the efficiency and simplify the process of taking photos of the site, making plans, taking on-site measurements	IM75	Reduce paper-based works
IM13	Analytical predictions for maintenance activities	IM34	Enhance productivity and collaboration among stakeholders	IM55	Increase the efficiency in labour monitoring	IM76	Reduce time and cost
IM14	Assist the buyers to access the details about properties efficiently	IM35	Enhance speedy and effective communication	IM56	Increase the efficiency in the waste segregation process with automation	IM77	Replacement of traditional software
IM15	Assist to prepare safety work planning methods using real-time data	IM36	Enhance the accuracy of the information and input values	IM57	Increase the safety of workers with smart wearables	IM78	Save cost and eliminate the multitude of intermediaries in the traditional process
IM16	Automated quantity bill generation	IM37	Enhance the process of planning.	IM58	Increase the security in the data storage without physical damage	IM79	Secured and trustworthy payment transactions by blockchain
IM17	Automated quantity extraction	IM38	Ensure the highest value for the invested money	IM59	Increase the validity and accuracy of the output	IM80	Secured storage of project data in cloud space
IM18	Automation in quantification, documentation, and coordination	IM39	Ensure the most suitable proposal using real-time data	IM60	Make changes in real-time and facilitate all users' immediate access	IM81	Secured transactions
IM19	Comparatively less impact on manual site investigation due to lack of physical data extraction with digital technologies	IM40	Facilitate access to underground tunnels	IM61	Monitoring the as-planned against actual status with real-time data	IM82	The evolvement of BIM-based procurement contracts
IM20	Deliver high-efficiency of work	IM41	Facilitate to inspect equipment with difficult physical access	IM62	More clear/ presentable outcome	IM83	Timely identification of elements and components that require renovation
IM21	Deliver real-time data on project performance	IM42	Greater control and clarification about cost, time, and distance to the consumer	IM63	Obtain an accurate early estimate by Revit-based energy and embodied carbon estimations.	IM84	Usage of real-time automated data inputs

Figure 2, Identified impacts of use of digitalisation

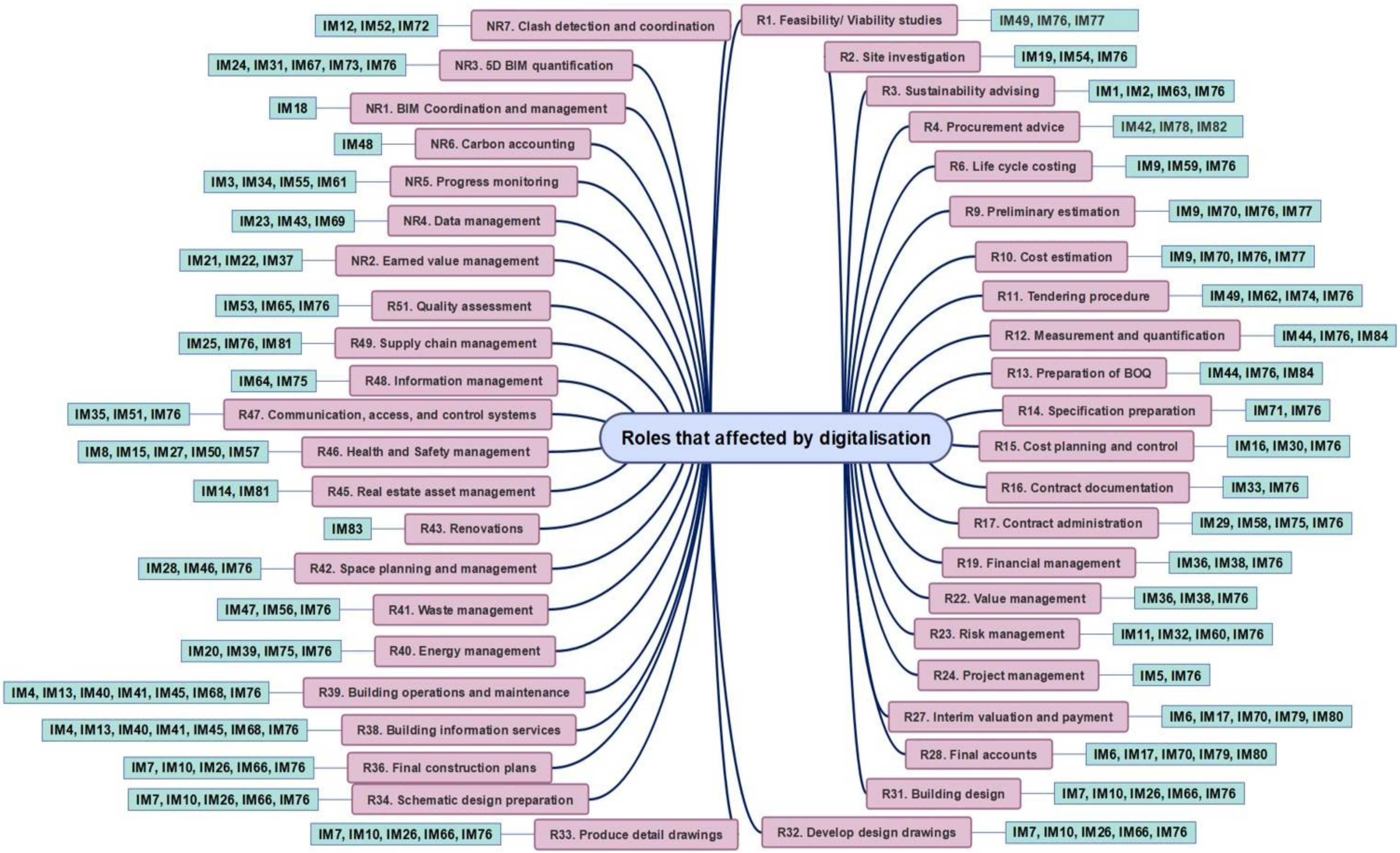

Figure 3, Impacts of the use of digitalisation on each role

5. Discussion

While digitalisation in construction has been widely studied, most research has focused on technology adoption and new competency requirements rather than on how it redefines existing professional roles (Uhm et al., 2017; Ariyachandra et al., 2020; Aghimien et al., 2020). This study addresses that gap by exploring how digital technologies reshape the roles of these three professionals. Respondents identified the frequent use of AR/VR, drones, GIS, cloud computing, sensors, CAD, BIM, and ERP systems, consistent with Thelen et al. (2021). Among these, BIM emerged as the most extensively adopted technology, confirming earlier findings by Osunsanmi et al. (2018), Saka and Chan (2020), and Seidu et al. (2020). Other tools such as high-resolution cameras, RFID, LiDAR, and smart wearables are increasingly used, while 3D printing, robotics, and advanced wearables remain at early stages of implementation. IoT-based sensors were described not as standalone technologies but as enabling platforms that integrate physical systems through software and sensors (Nguyen & Simkin, 2017; Rasheed et al., 2024), revealing conceptual ambiguity regarding their classification.

The findings support prior evidence that digitalisation enhances traditional professional functions while creating hybrid roles such as BIM coordinators, digital cost managers, and facility data analysts (Wao, 2016; Ametepey et al., 2024). Unlike earlier work that identified distinct digital roles (Ariyachandra et al., 2020; Uhm et al., 2017), this study indicates that digital literacy is becoming embedded across mainstream professional activities. Some respondents even anticipated that specialised BIM positions may diminish as digital proficiency becomes a baseline competency, aligning with Bosch-Sijtsema and Gluch's (2019) observation of converging digital skills. However, the pace of digitalisation remains uneven across professional domains. Rapid transformation is evident in data-intensive functions such as design visualisation, quantity extraction, and maintenance forecasting, whereas roles involving negotiation, arbitration, and contractual advice remain less automated due to their reliance on contextual judgment and emotional intelligence (Aghimien et al., 2020; Wong et al., 2018). Moreover, technologies such as robotics, blockchain, and wearables continue to face adoption challenges due to financial, structural, and cultural barriers (Olanrewaju et al., 2020).

Several key themes emerge from these findings. First, BIM stands out as the core integrative framework underpinning digital transformation across professions. Rather than operating as an isolated tool, BIM functions as a multi-dimensional platform that supports cost management, scheduling, energy modelling, and facility management. Its collaborative environment replaces traditional siloed processes and facilitates cross-disciplinary coordination, reflecting the industry-wide shift towards integrated digital ecosystems (Autodesk, 2021). Consequently, BIM literacy is becoming a fundamental professional skill and a major focus of both education and training.

Second, the findings reveal a coexistence of automation and human judgment. Automation has streamlined tasks such as measurement, estimation, and documentation, improving accuracy and efficiency. However, decision-making, negotiation, and dispute resolution remain primarily human-driven, reaffirming the limits of algorithmic substitution (Aghimien et al., 2020; Wong et al., 2018). This dynamic illustrates a hybrid model of practice where digital systems manage data-intensive operations, enabling professionals to focus on interpretive, ethical, and strategic dimensions of work.

Third, digitalisation is driving the emergence of hybrid roles and transforming professional identities. QSs are evolving from manual measurers to data-oriented financial strategists through the use of automated quantity take-offs and blockchain-enabled cost management. Architects are becoming digital designers and BIM coordinators, employing AR/VR and parametric modelling to enhance design quality and client collaboration. FMs are transitioning into smart building operators and data managers, using AI, IoT, and digital twins for predictive maintenance and performance optimisation. These changes align with the findings of Słuchocka et al. (2020) and Wong et al. (2018), who documented the shift toward technology-enabled, data-intensive operations. The present study extends these insights by showing that digitalisation not only modifies existing tasks but also fuses technical and domain expertise, redefining professional boundaries and competencies.

Finally, despite these advancements, a persistent implementation gap remains. Although the potential benefits of technologies such as 3D printing, robotics, and wearables are well recognised, their use is constrained by high costs, limited interoperability, and inadequate training. Ambiguities such as inconsistent classification of IoT further illustrate limited understanding of integration within construction processes. These findings confirm that digitalisation is still uneven and shaped by technical, organisational, and human barriers (Olanrewaju et al., 2020; Thelen et al., 2021). Addressing these challenges requires targeted strategies focusing on capacity building, clearer integration frameworks, and gradual implementation suited to project-based contexts.

Across QS, architect, and FM professions, common trends are evident: a shift from execution to strategy as automation reduces routine work; stronger interdisciplinary collaboration through BIM and common data environments; greater engagement with data analytics; and increasingly blurred role boundaries connecting design, construction, and operations. Nevertheless, each profession experiences transformation differently QSs encounter the greatest automation, architects balance technological efficiency with creativity, and FMs manage both legacy and smart infrastructures. Thus, effective digital transformation depends not only on technological adoption but also on maintaining professional judgment, contextual adaptability, and ethical awareness.

6. Conclusions and Recommendations

The aim of the study was attained through three rounds of the Delphi study. This research identified twenty-seven (27) digital technologies that selected construction professionals currently use. In that case, the respondents identified BIM, AR, VR, AI, CAD, Cloud computing, and sensors as frequently applicable digital technologies in QS, Architect and FM professions. Further, many respondents concluded that BIM is the most relevant, often used, and feasible digital technology for these professionals. Additionally, it has been explored that new technologies such as blockchain are significant for construction professionals to make secured transactions and integrate them with BIM to track details in the construction industry.

Regarding the second objective, fifty-two (59) roles were identified as impacted by the effects of digitalisation. Under the next objective, digital technologies used in each role were identified and illustrated in Figure 1. In that case, BIM is selected as the digital technology that affects highest number of identified roles of these professionals. Additionally, cloud computing, AR, VR, drones, CAD, AI, big data, and blockchain are also frequently used digital technologies in these construction professionals' roles. The final research objective investigates the impacts on job roles due to digitalisation. By adopting digital technologies, time and cost saving from each role are common impacts for almost all the identified roles of these professionals. In addition to increasing efficiency, reducing paper-based work and reducing errors are also significant impacts on the roles with the effect of digitalisation.

There is a dearth of literature that discuss how digitalisation affects current job roles in the construction industry in detail manner. Therefore, as the theoretical contribution this research will provide a source of reference when conducting further studies on digitalisation in the construction industry and its impact on construction professionals. Currently, digital technologies have become popular among many construction professionals. Thus, as the contribution toward the industry the impacts identified in this study can reduce the fear of losing/altering their job roles and make them understand how digitalisation may improve their current role. Furthermore, the study findings will benefit the professionals to successfully implement digitalisation in their future projects with proper background knowledge. Further, this research will be a guideline for the professional bodies of Architects, QSs, and FMs to identify the future requirements with digitalisation. Also, this will be significant for the related programmes to enhance curriculum development. Despite the significant contributions of this study, the limitations should also be acknowledged. The study was limited to QSs, architects, and FMs since they are greatly affected by digitalisation. Considering future research, this study can be extended to focus on the competencies required to adopt digitalisation to these professional roles and how digitalisation affect professional roles in different stage of the project lifecycle are a highly important area to consider in future studies.

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