GIRI RESEARCH
Get It Right Initiative

THE USE OF DIGITAL TECHNOLOGY ON SITE TO REDUCE ERRORS IN CONSTRUCTION

RESEARCH REPORT

November 2023

The construction industry lacks the maturity of other industries when it comes to the implementation of digital solutions on site, hence there is a huge opportunity to drive innovation and efficiency in the sector by speeding up this process.

The Get It Right Initiative commissioned this study to examine the technologies that are available to support error reduction on site, establish how they are currently being used and identify whether certain types of products are more widely used than others.

Our insights are drawn from two primary sources — an online questionnaire and a series of discussions with professionals working on 11 live construction sites across the UK.

We sought to understand how digital tools are viewed by the professionals using them, explore barriers to implementation, the opportunities for wider use of the technology, and gain some understanding of the costs and timescales involved in implementing them.

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EXECUTIVE SUMMARY

This report explores how technology is being used on live construction sites and whether it is having an impact on error reduction. It identifies the technologies that are currently at the forefront of the industry, providing the most beneficial outcomes in terms of error reduction, enhanced project delivery, budget and timeline savings.

This report was commissioned in parallel with the **GIRI Technology Guide** — launched in October 2023 — which is an overview of the types of technology that are currently available on the market, and the opportunities they offer for reducing error throughout construction projects.

We first surveyed as broad a range of industry professionals as possible to understand current perceptions of digital tools and how they are being used on site. In the second phase, eleven construction sites supported the research by accommodating site visits and supplying information on the technology they are using and the impact it is having on error reduction.

We interviewed those who use the technology out on site to get a true reflection of the impact it is having not just on the project but also on the users. These ranged from industry professionals such as BIM managers who are likely to be more familiar with the technology, to contract/project managers, site managers and quality engineers.

Three quarters of the sites we visited said that clients are not mandating BIM processes or the implementation of specific technology on projects.

The findings suggest that the industry still has a lot of room for development and improvement when it comes to implementing digital tools and embracing new technologies. Despite the fact that 90% of respondents were using common data environments (CDEs), most sites identified email and/or messaging platforms as their core mode of communication and data sharing between site and design teams.

However we also established that the 'single source of truth' that is provided by a CDE is considered a pivotal factor for supporting error reduction out on site, being highlighted by all 11 projects. Our results suggest that fewer errors occur when a single source of up-to-date information is used, and project teams are more confident in the accuracy and relevance of the data being shared.

One of the main barriers to greater use of technology that was identified by many of those surveyed was the fact that project leaders and/or senior management were unable to identify immediate benefits and therefore could not visualise the value such technology would bring to the project. Thus it was considered easier to continue using processes and ways of working which they knew to be adequate from previous projects.

This was a recurring theme; project teams were reluctant to trial new products or processes, considering that the potential benefits did not outweigh the risks they perceived in terms of delays, the difficulties of procuring such systems and the need to skill-up staff ahead of implementation.

Overall there was general agreement that when properly implemented, digital tools offer huge potential for reducing error.

> **"DIGITAL TECHNOLOGY IS DEFINITELY THE WAY FORWARD FOR OUR INDUSTRY, IT COLLATES THE INFORMATION AND STANDARDISES IT. IT REDUCES MANUAL ADMIN TASKS AND THEREFORE REDUCES HUMAN ERROR. WE CAN MAKE INFORMED DECISIONS FROM THE DATA GENERATED."**

1. RESEARCH CONTEXT AND BACKGROUND

The purpose of this research was to examine to what extent technology is being used on site to reduce error. The report aims to complement and further substantiate work by the Get It Right Initiative, which has a strategic aim to **improve construction productivity and quality by eliminating error.**

GIRI identifies the top ten **root causes** of error as:

- Inadequate planning
- Late design changes
- Poorly communicated design information
- Poor culture in relation to quality
- Poorly coordinated design information
- Inadequate attention paid in the design to construction
- Excessive commercial (financial and time) pressure
- Poor interface management and design
- Ineffective communication between team members
- Inadequate supervisory skills.

To examine how and why design information is so poorly communicated within the construction sector, we carried out case study surveys and site visits focusing on how technology is used to communicate design information to personnel on site at the construction stage.

We wanted to discover what technologies are being used on projects to ensure that clear, concise and correct information is easily accessible to people carrying out construction work on site, and whether this information contains everything that is needed to complete the work correctly. Our research was focused solely on the technology being used on site.

GIRI's initial research was the basis for the report ***A Strategy for Change***, which focuses on the improvement of construction productivity and quality by eliminating error. The report found that the measured direct costs of avoidable errors are in the region of 5% of the project value, but when

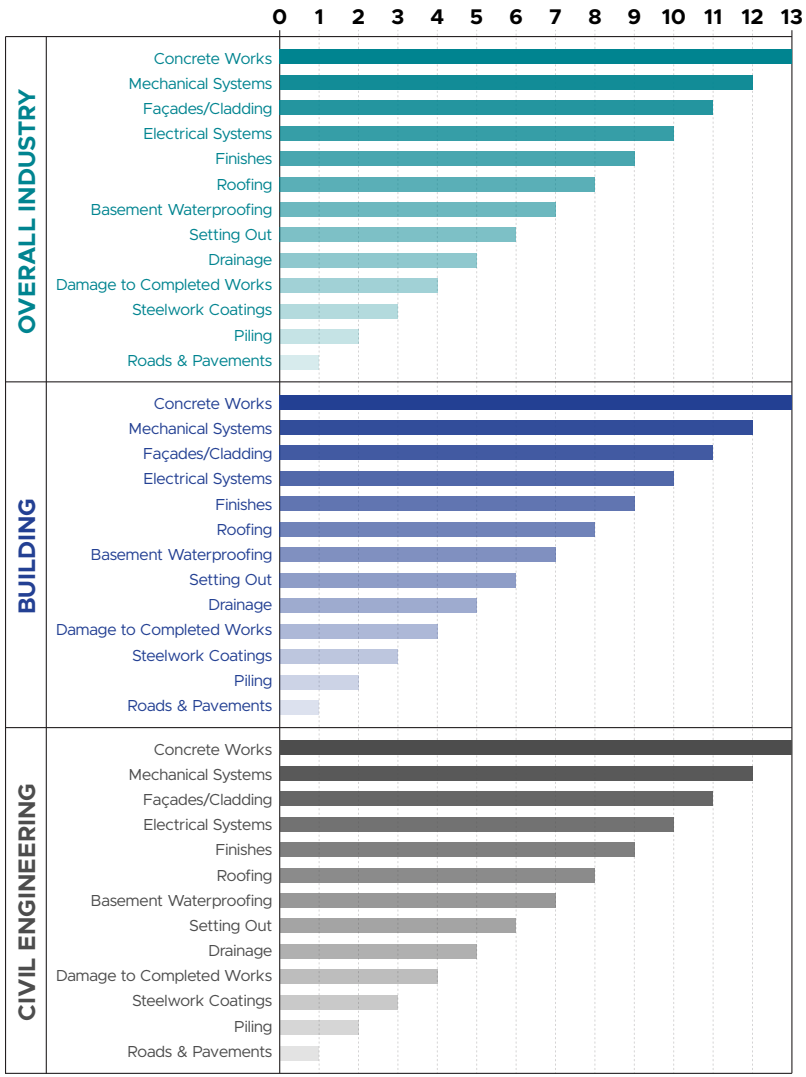

FIGURE 1 *Construction activities which generate the most losses through error; from GIRI's Call to Action report.*

unmeasured and indirect costs are included, the situation gets much worse. The total costs are estimated to range from 10% and 25% of project cost or between £10–25 billion per annum across the sector[1].

A Call to Action illustrates the construction activities which generate the most losses through error (Fig 1). The findings reflect the processes that are in place — or in some instances not — to reduce or eliminate error.

We sought to engage directly with construction sites to establish the extent to which technology is influencing error reduction, and to provide suggestions as to how others might use technology to drive error reduction and improve productivity.

The construction industry has traditionally been associated with challenges such as cost overruns, schedule delays, and errors that can significantly impact project outcomes. However, the advent of digital technologies offers opportunities to improve construction site efficiency and minimise errors throughout the project lifecycle.

By harnessing the power of digital tools, construction companies can revolutionise their practices and enhance their ability to prevent and mitigate errors on site. It is unreasonable to assume that all errors or even the majority that take place on-site are the result of errors that were made during the design and development stage. Deviation from actual values, inadequate precision and inconsistencies in measurement can also result in errors[2].

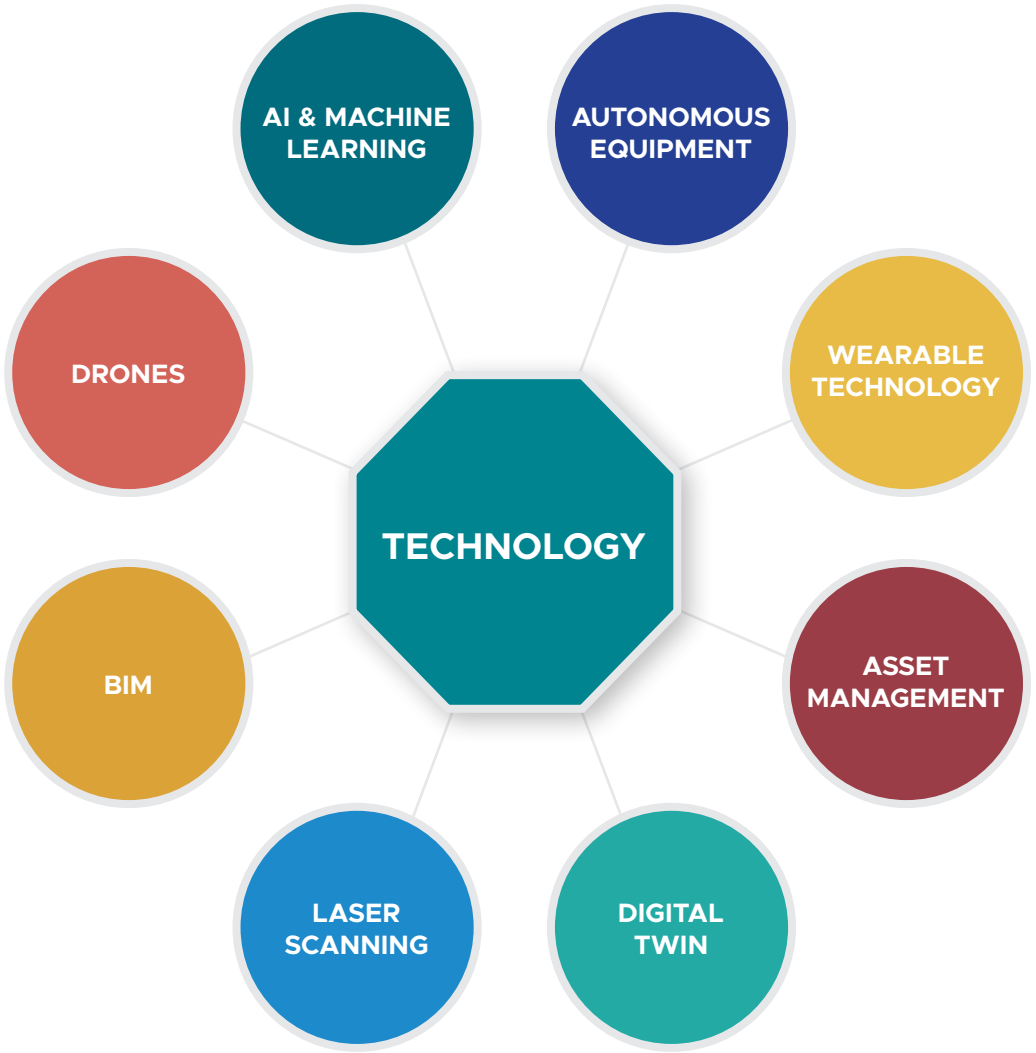

FIGURE 2 *High level list of technologies currently on the market*

2. METHODOLOGY

Research followed a two-phase methodology allowing first-hand data collection from GIRI members and non-members to seek a comprehensive view from across industry. The surveys were carried out between March and June 2023, and questions were developed with feedback from members of the GIRI technology working group.

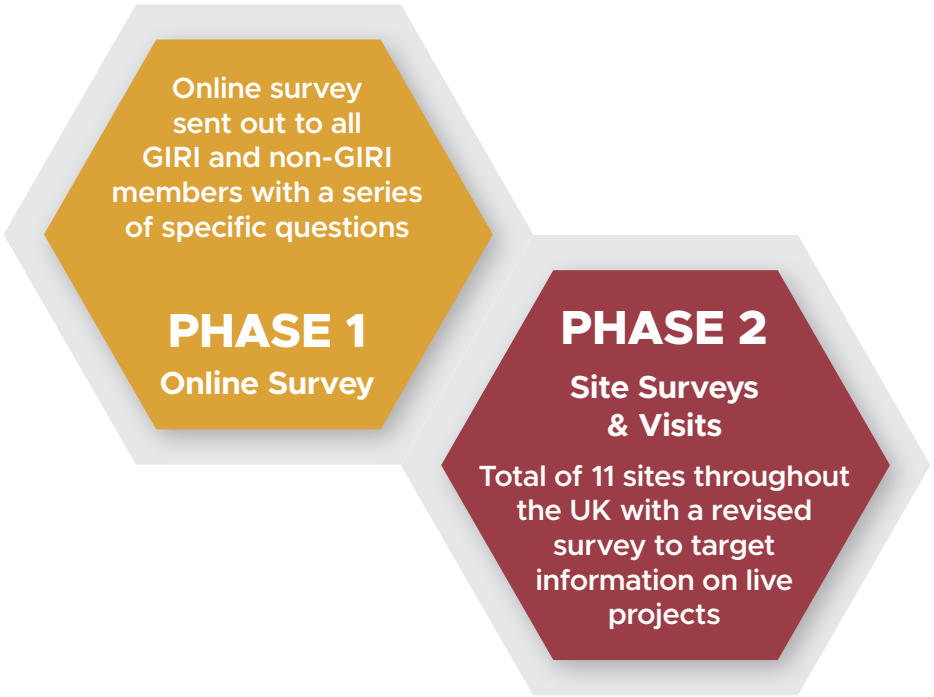

FIGURE 3 *Research methodology*

PHASE 1 – ONLINE SURVEY

This was an open, online survey, with the intention of reaching as broad a range of industry professionals as possible to gain insights into how digital tools are currently perceived, and how they are being used on site.

The survey was created as a Google Form and publicised through GIRI platforms including the requested mailing list and LinkedIn profile, with regular reminders ahead of the closing date.

Using an online survey allowed us to reach a larger and more diverse audience rather than simply reaching out to industry professionals individually. Potential participants were given three weeks to complete the online survey, this is a relatively short timeline and may have restricted the number of responses received.

The questions were intended to establish the respondent's level of knowledge in relation to available digital tools but also, the impact the tools may have had and the respondent's personal opinions on how technology on site may be useful on future projects.

PHASE 2 – SCOPING STUDY

For phase 2, we selected 11 projects that were on site at the construction stage, and specifically targeted projects where the design consultants' work was finished, subcontractors procured and work on site 40–60% complete. For each project we captured a description, including the procurement method, outline programme, and details of project participants.

Research involved a one-day visit to each site for discussions with the client (where applicable); main contractor's project manager, design manager and/or site supervisors; and sub-contractors' site personnel.

Most of the questions in phase two invited open answers, with the intention of truly reflecting how the industry is handling errors on site. This allowed the participants to speak openly and in more detail about the root causes of errors on site and how technology is impacting on error. Interviews were carried out either face to face on site or in head offices, or by video call and were recorded to enable conversations to flow naturally while still capturing all the information.

In some cases respondents reported reluctance from colleagues to get involved with the interviews and questionnaires, regarding them as a quality control checking mechanism and making them wary that they were being monitored.

It is important to acknowledge the limitations of this methodology. The findings are based on the available literature, industry reports, and the perspectives of a selected group of construction industry professionals. The error categories identified may not be exhaustive, and are subject to personal opinions and individual interpretation. Despite these limitations, the methodology provides a solid foundation for understanding the variety of ways errors can occur on site during construction.

Job roles of survey respondents were aggregated by department, with the results shown in Figure 4.

We sought the participation of respondents from a wide range of sectors. The highest percentage (17.9%) identified as coming from the housing/residential sector, followed closely by rail and road projects each at 15.4% (Figure 5).

Figure 6 shows the variation of site budgets/value from our phase 1 survey.

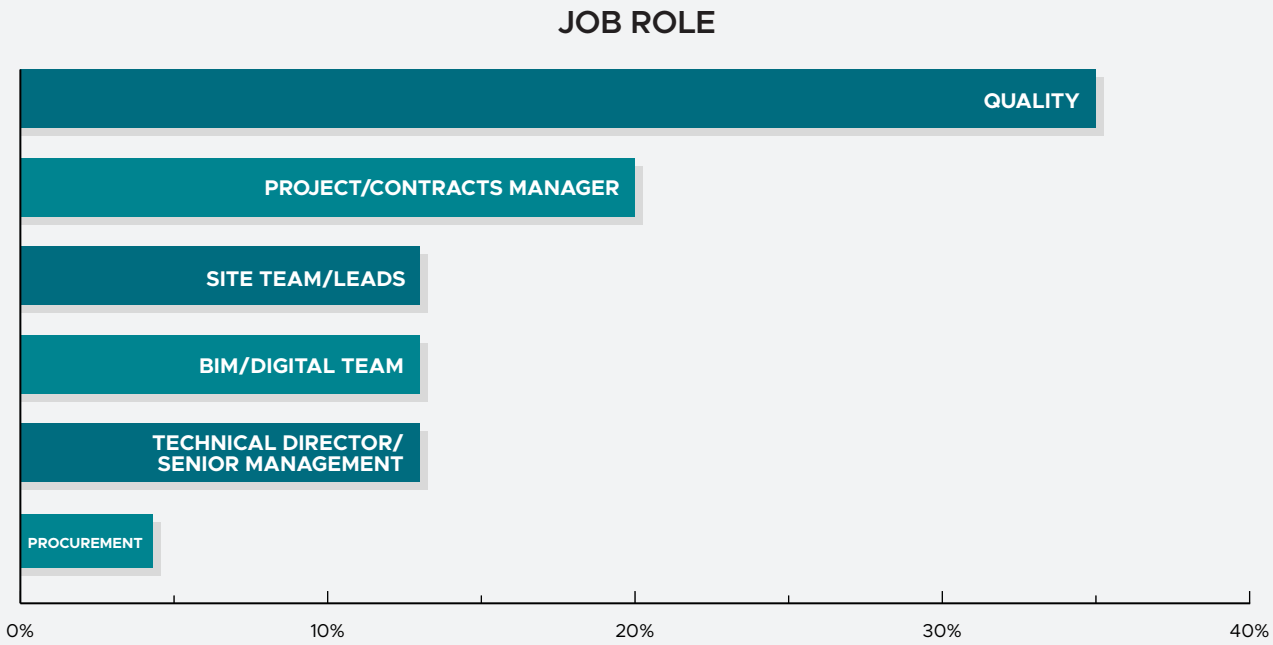

FIGURE 4 *Job role — aggregated by department*

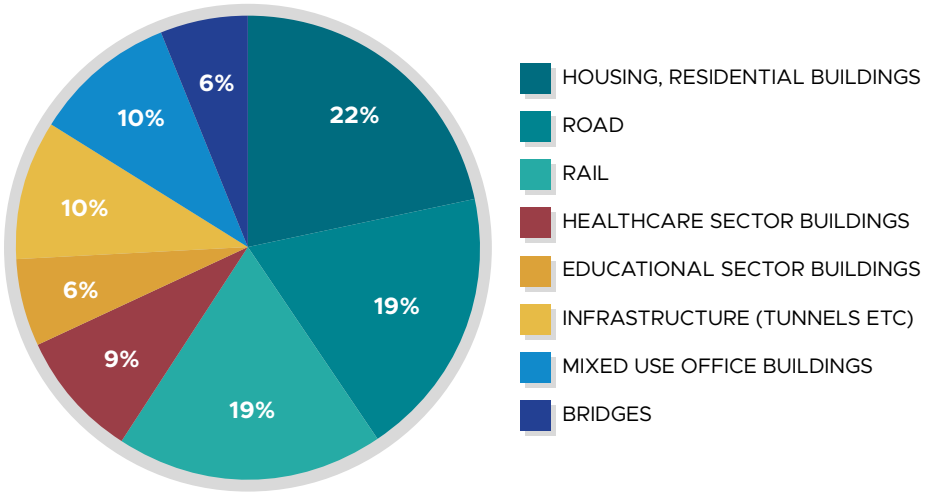

FIGURE 5 *Industry sector*

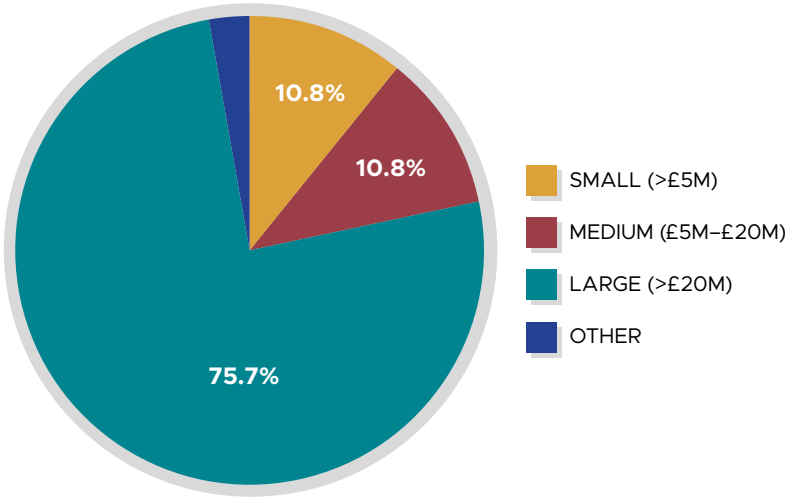

FIGURE 6 *Phase 1 – site budgets*

PROJECTS FEATURED IN PHASE 2 INTERVIEWS

COMPANY NAME	SITE LOCATION	PROJECT BUDGET (£M)	PROJECT TYPE
McAvoy Group	Hampshire	Less than 10	Property
Henry Boot	Sheffield	Less than 10	Public sector
McAvoy Group	Newham	Less than 10	Property
Bowmer & Kirkland	Coventry	10 to 20	Property/Residential
BSG Civil Engineering	Northern Ireland (multiple locations)	10 to 20	Public sector — Water Treatment
BAM Nuttall Ltd	Wales (multiple locations)	20 to 50	Property
Graham Construction	Brentwood	50 to 100	Roads
Graham Construction	Teeside	100 to 150	Property
Translink — Farrans, SACYR, Graham Construction, Babcock	Belfast	150 to 500	Rail
Infraco-Consulting	England (multiple locations)	Multi-billion	Rail
BAM	Manchester	Multi-billion	Rail

3. RESULTS

More than two thirds of respondents (68.6%) confirmed that they are currently using technology to reduce error on site. We asked which technologies participants had adopted on site to help reduce error in construction.

The fact that 70.6% of respondents have adopted some form of BIM software within their projects to help in the overall reduction of potential errors is promising (Figure 7).

The level of adoption of technologies such as photo/data capturing tools is much higher than robotics and machine-learning tools. Robotics are expensive to integrate in a project and onboard, so construction companies may be reluctant to invest significant capital without a guarantee of immediate return. Implementing robotics in construction requires specialist knowledge and expertise, and training staff to operate and maintain these technologies also requires time and resources. The challenge of integrating them with existing processes may also be a concern[3].

Another valid point is that construction projects can vary significantly in scope, design, and environment. Robots might not be versatile enough to handle a wide range of tasks or adapt to different conditions, limiting their practicality.

We asked respondents to identify the reason(s) for resistance to implementation of digital tools within a construction project; most chose 'organisation commitment' followed by 'employee resistance' as a close second. Both can be classified as company/business buy-in (Figure 8).

Interestingly, the resources required for training and software installation were considered lesser barriers, suggesting cost is not one of the key reasons preventing digital tools from being implemented. A company's commitment to implementing new ways of working and employees' willingness to adapt are the most important factors and if these are absent, project teams will never truly see the benefits of the tools.

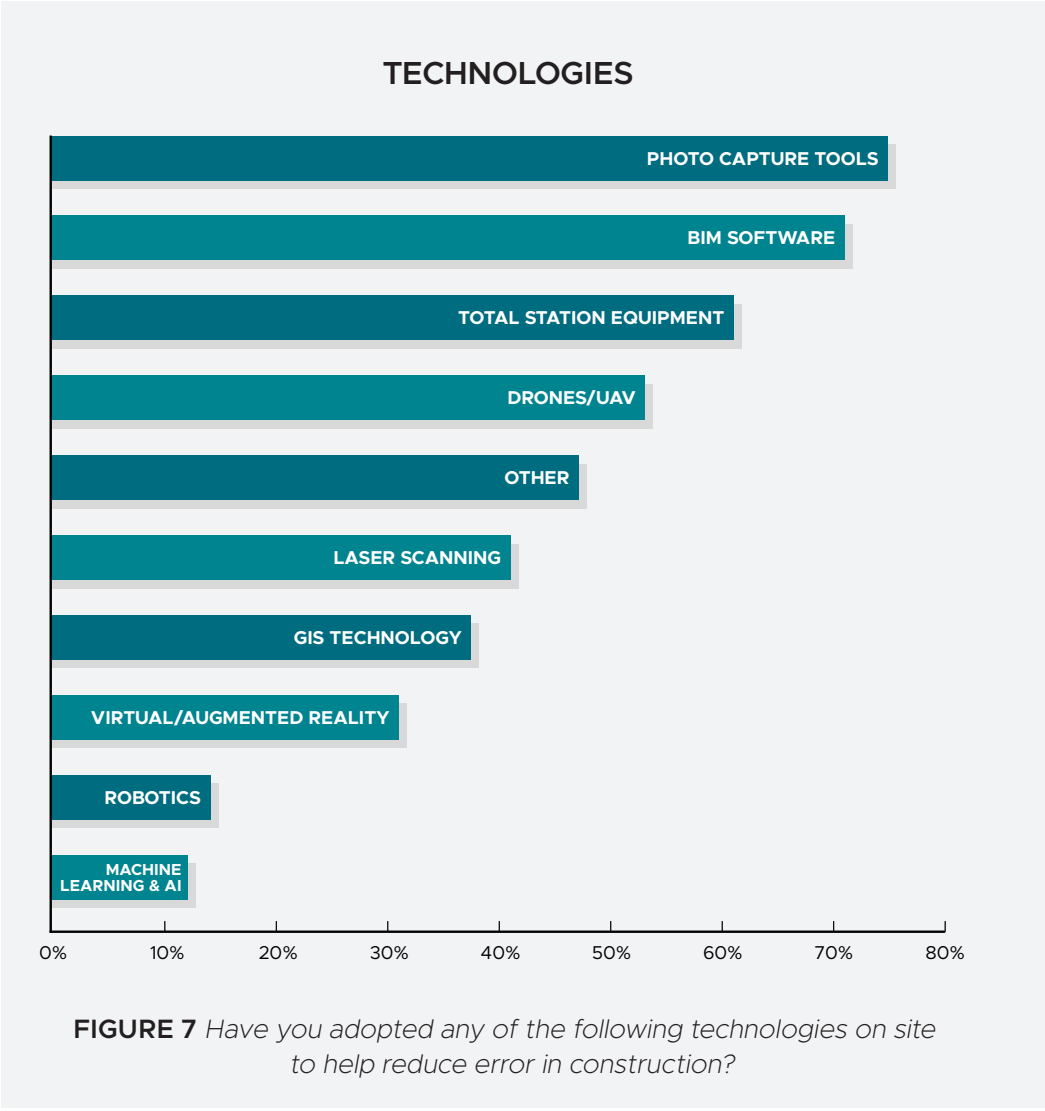

FIGURE 7 *Have you adopted any of the following technologies on site to help reduce error in construction?*

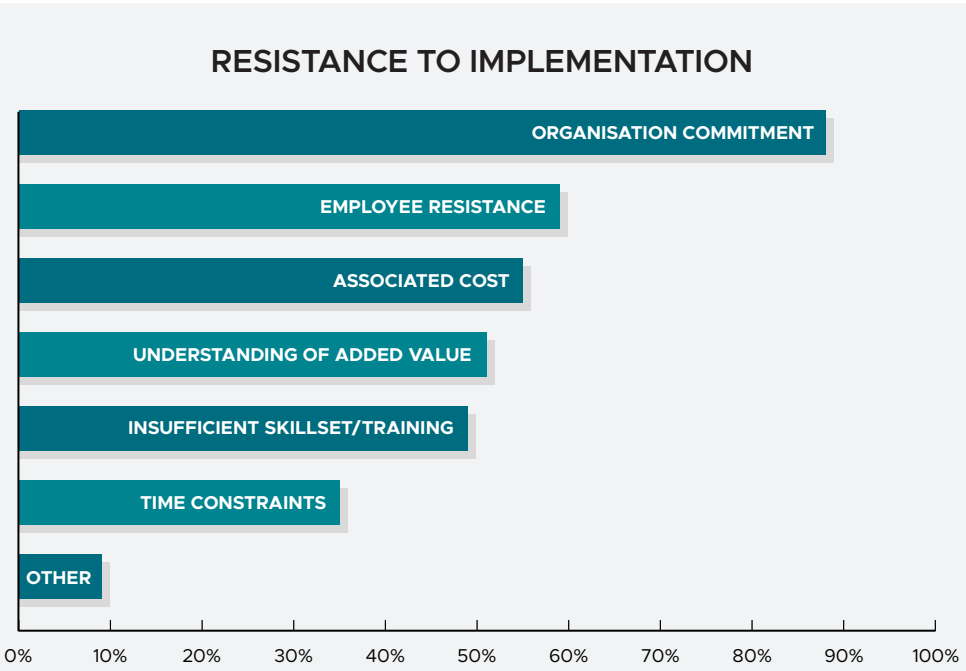

FIGURE 8 *What is/are the main reason(s) for resistance to adoption of technology on construction projects.*

Other factors that respondents noted as barriers to the adoption of technologies were surprising. Some felt the software they had invested in had failed to deliver the capabilities that vendors had promised. Some reported that short-term gains were prioritised over long term goals, which raises concerns as any business should be focused on the long-term goals and how to stay competitive in the market.

Some respondents said there were too many digital tools on the market and they found it challenging and time consuming to figure out which would be most suitable for their business or application. The lack of consistency was considered problematic.

Human nature can be resistant to change; for the most part we prefer to remain within our knowledge capabilities and comfort zone. But with increased digitisation, the construction industry must embrace the opportunities and use them to its advantage in order to gain the most benefit.

Asked to rank in terms of importance, the processes/outcomes where digital tools could offer the most benefit, respondents placed quality improvement and assurance at the top (Figure 9).

However a third of respondents had a role within the quality department and this factor quite likely influences the results.

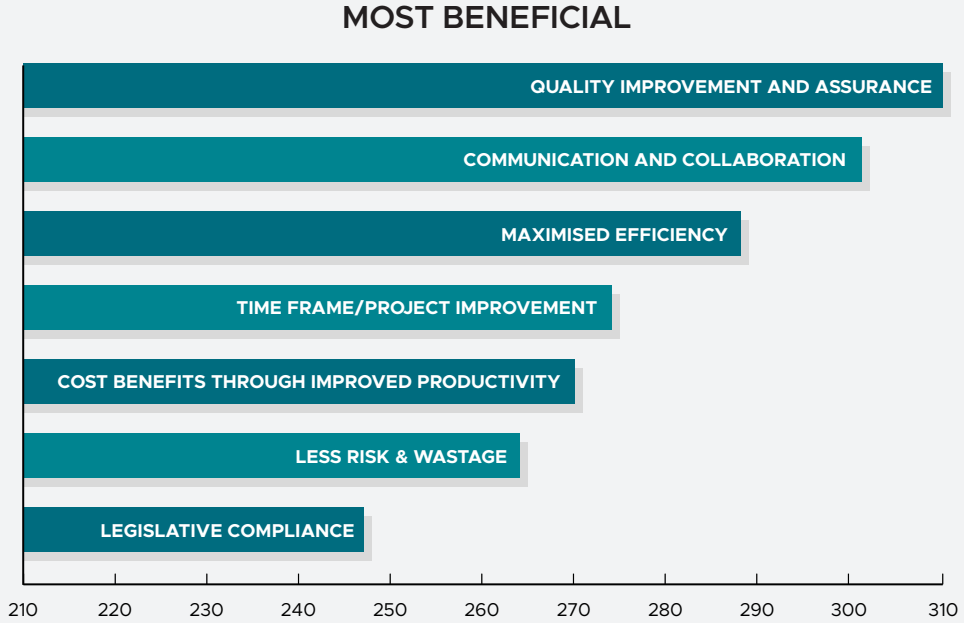

FIGURE 9 *Rank in terms of importance*

When asked to identify technology solutions that they would like to add to or improve on their projects, with the aim of improving efficiency or quality, 59% chose digital forms, test plans or quality check sheets. This would suggest in terms of quality control on site, traditional ways of working are still the norm. From the answers offered, this would be considered the least technical solution and is still very much focused on filling out physical forms or paperwork.

Figure 10 shows the answers given in response to this question, with 'other' prompting the following suggestions:

- BIM models extended to operation & maintenance.
- Provision of funded training
- Use of dashboards — illustration of project progress

In terms of facilities management (FM) and operational maintenance for example, this can currently be managed through a wide range of CDE software that is currently on the market. A slight lack of understanding around this may suggest participants currently are unable to visualise the full potential of the tools and their capabilities of digital collaboration. Dashboards or project insight pages are another feature that CDEs currently offer and can provide up to date stats on the project progress to create an illustrative interactive dashboard.

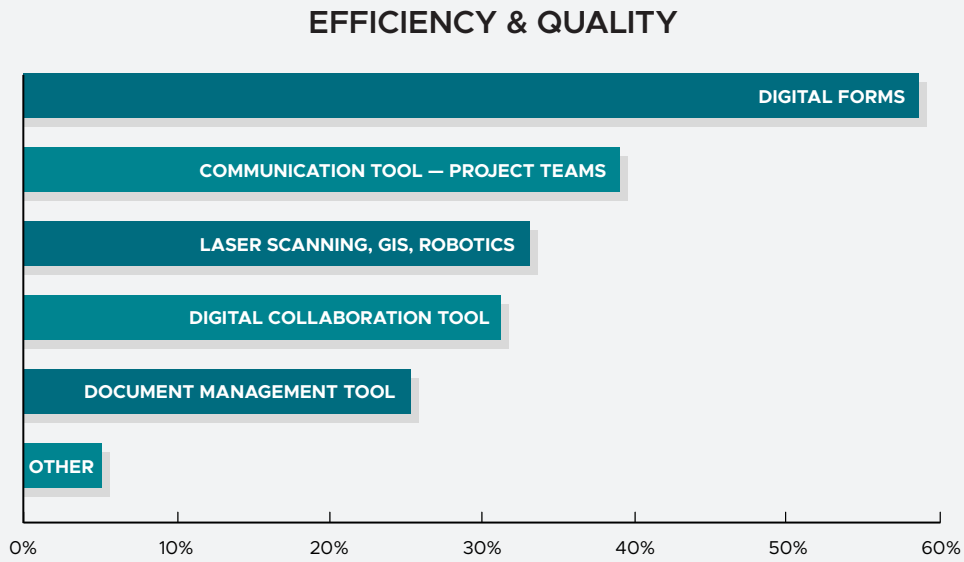

FIGURE 10 *To improve efficiency and quality, are there any key error reduction technology solutions you would like to add to or improve on your projects?*

We asked participants to identify those stages of a construction project at which they felt digital technologies could be a useful tool for reducing error (Figure 11). Construction/delivery attracted the highest rating with 90.2% of respondents seeing the benefits that could be gained during this phase. High scores were also recorded for technical design (86.3%) and handover & close-out (88.2%), with the lowest (client initiation) still ranking more than 60%. This confirms that professionals across the industry believe digital tools can enhance working processes throughout the project lifecycle.

A strong 90% of respondents said that they were using a CDE on the project, with the top four systems cited as Viewpoint, Asite, Sharepoint and Aconex. Our results also suggest that cost is not a main consideration for implementation of such systems, as we did not find any correlation between the size and budget of a project, and the use of a CDE.

We asked respondents to identify ways in which poorly-communicated design might lead to error in construction.

- 68.6% said it results in out-of-date information being shared and more accurate and recent data being missed.
- Equally, 68.6% believe it results in delays to the project timeline/ schedule

However our results suggest that a lot of professionals in construction still have a strong preference towards more traditional ways of communicating.

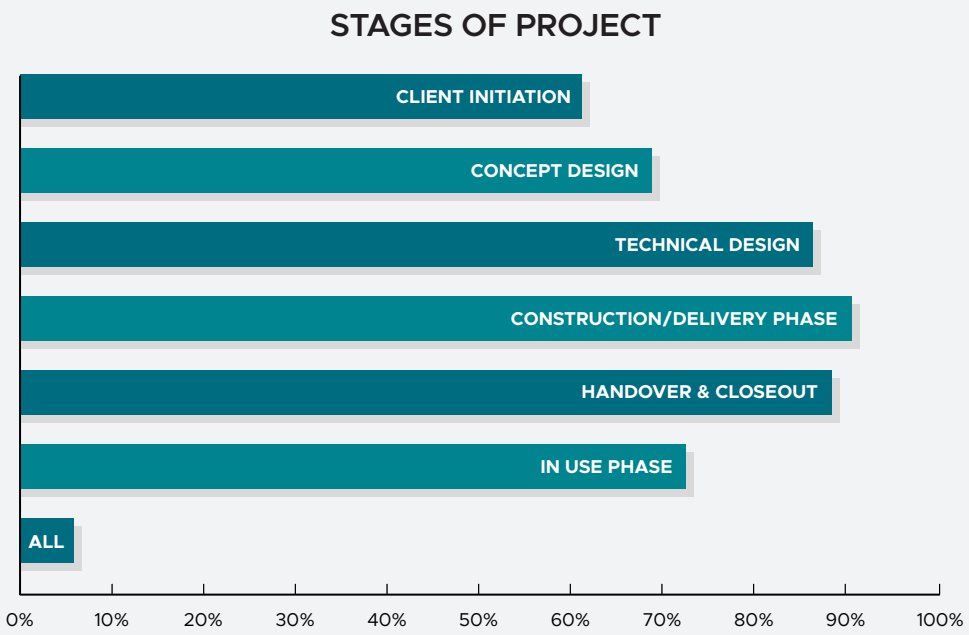

FIGURE 11 *At which stages of a project can digital technology be a useful tool?*

Asked to identify the main tool they currently use to encourage rapid and accurate communication from design team to those on site, the top three responses were:

- 58.8% — Email
- 33.3% — Phone Call
- 23.5% — WhatsApp/ Text Message

More than half of the respondents are using emails as their main communication platform, for sharing, updating and continuous communication on their projects. While 90% said that they had a CDE implemented on the project, less than 10% identified this platform as the main tool for collaboration or communicating information from design office to site. Common data environments are intended to enable more accurate and up-to-date collaboration throughout project teams with the aim of creating a centralised repository for all project data, documents, and information for all stakeholders. This can enable construction professionals to work together more efficiently, make informed decisions and deliver successful projects on time and within budget. As the construction industry continues to embrace digital transformation, CDEs will play an increasingly vital role.

These answers might suggest a lack of maturity within the sector, especially when taken alongside responses shown in figure 10. It may be that a CDE has been implemented either as a client requirement or to meet industry standards/progression, but is not being used as a central repository and more traditional ways of working continue to be used.

Three quarters of those interviewed in the scoping survey confirmed that use of digital technologies was not a requirement of the client. The majority pointed out that the client had stipulated compliance with the current regulatory standards for auditing purposes, but there was no formal mandate to include digital ways of working or specific technology.

We wanted to gain an understanding of the technologies that sites are using and that are considered to have a positive impact on error reduction. All interviewees mentioned use of a CDE and the most common products mentioned were:

- Viewpoint
- BIM360/ACC
- Projectwise
- Acconex
- Procore
- ASite

A comment made in relation to the benefits of implementing a successful CDE:

> **"THE CHECKS ON AUTODESK BIM360 ALLOWS US TO RECORD QUALITY CHECKS CONTINUOUSLY QUICKLY ON THE PROJECT, THE PROCESS OF RECORDING THOSE CHECKS AND THE EVIDENCE CAPTURED ALLOWS US TO BE SURE THAT THE FREQUENCY AND ACCEPTANCE CRITERIA OF QUALITY INSPECTIONS HAS BEEN SUCCESSFULLY ACHIEVED."**

We also wanted to gauge which technologies are being used the most throughout projects and why these tools were chosen. Selecting the right digital technologies and processes is critical if project outcomes are to be improved and the chance of errors on site reduced. Figure 12 illustrates the hardware and software tools that were mentioned most frequently on the site visits.

> **"WHAT WE HAVE SEEN IS THAT THE BENEFITS OF CERTAIN TOOLS ARE MORE APPLICABLE TO EITHER THE DESIGN OR CONSTRUCTION PHASE. CERTAIN TOOLS WE HAVE USED MAY BE MORE UTILISED IN THE DESIGN PHASE I.E. PROJECTWISE AND HOLOBUILDER BUT STILL PLAY A KEY PART WITH OVERALL CONSTRUCTION DUE TO UPDATES ON PROGRESS AND SCANS OF THE SITE AND TIMELINE UPDATES."**

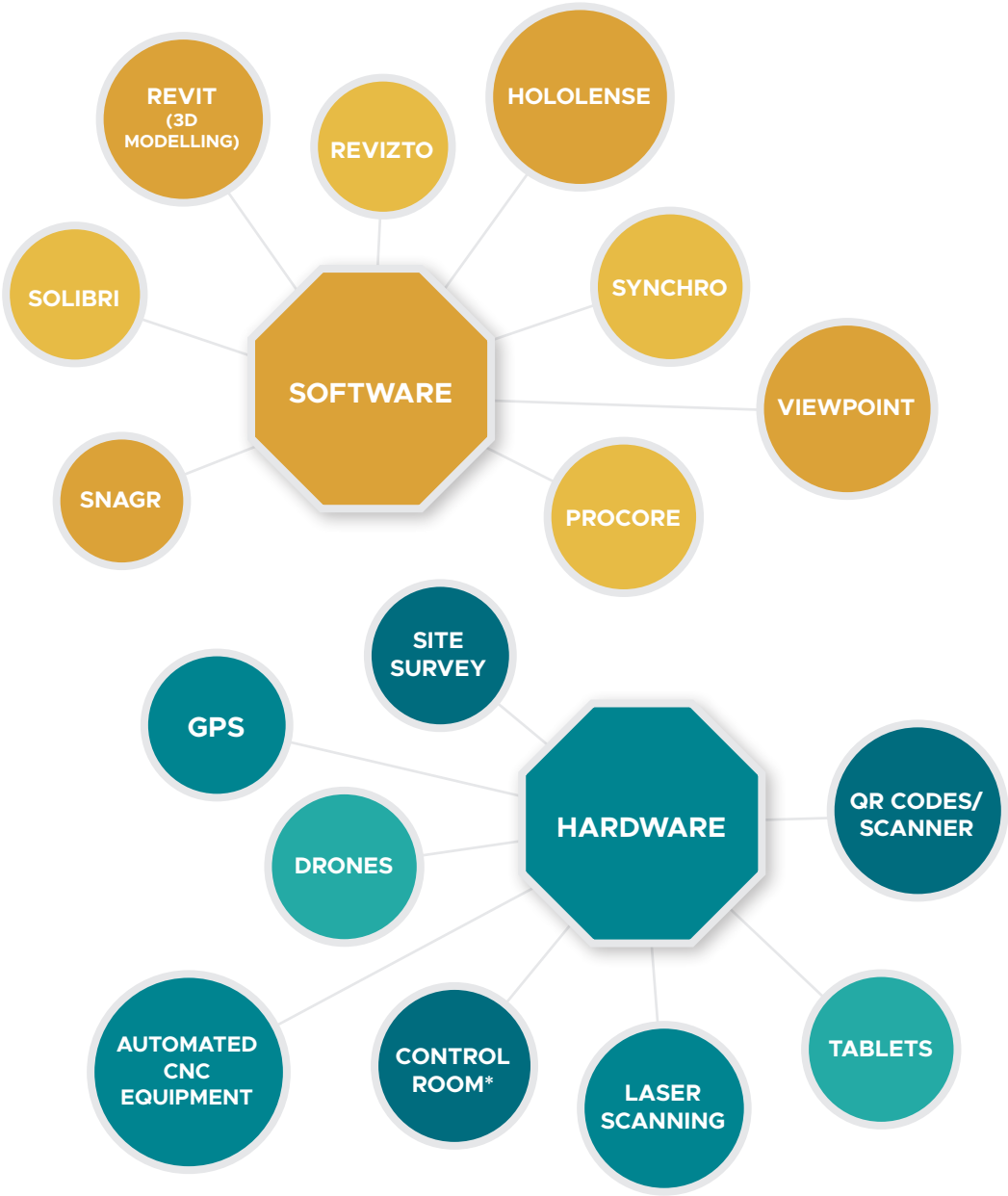

FIGURE 12 *Software and hardware systems mentioned*

* CONTROL ROOM (FLOOR TO CEILING INTERACTIVE SCREENS)

All sites that participated in the phase two interviews were receptive to implementing digital tools and all of those interviewed agreed that where digital tools have been successfully implemented on projects they have minimised risks and potential errors on site.

They said:

- Having a central model helps with design coordination.
- More efficient and can be very useful on site in comparison to paper-based methods.
- More accurate representation of what is ongoing on site, constant updates and scans are the best way to monitor performance.
- Human error on site is very hard to monitor 100%, but by implementing these methods it is a lot easier to correct errors.
- More streamlined process – constant communication regarding the same models, drawings and project transmittals.

But although many benefits can be anticipated from using digital tools on site, interviewees found it hard to quantify how many errors have been avoided, instead expressing a general conviction that digital technologies do deliver improvements.

Half our interviewees said they could not identify benefits for the project timeline or increased efficiency on site due to the implementation of digital tools. They felt that the time necessary to train staff and implement technology tended to outweigh any impact on project timeline efficiency. They agreed that this might change over time and once the technology had been fully adopted. The other half suggested there would always be unplanned delays in a construction project but that these could be reduced through better communication, collaboration and consistency.

The investment of time and money required to implement new technologies or ways of working can be daunting, and our research demonstrates the difficulty of measuring whether digital tools have any positive impact on project deadlines. It can depend on the tools that are being used, the extent to which they are being exploited, and the willingness of individuals to adopt new ways of working. Although the initial transition may take time and effort, half of our respondents were clear that the improved collaboration, up-to-date information and consistency of work can only be beneficial to how a project is run.

COMMENTS INCLUDED

"HAVING EVERYTHING DOCUMENTED DIGITALLY IS THE WAY FORWARD. GRENFELL HAS HAD THE BIGGEST IMPACT; IDENTIFYING WHEN SOMETHING GOES WRONG, WHY IT WENT WRONG AND LEARNING FROM IT IS KEY."

"SUCH TOOLS ENABLE US TO CATEGORISE INFORMATION AND STANDARDISE PROCEDURES. IT ALSO HAS THE POTENTIAL TO ELIMINATE MANUAL ADMIN TASKS AND REDUCE THE RISK OF HUMAN ERROR."

"ADOPTING THESE TECHNOLOGIES ALLOWS PROCESSES TO BE STREAMLINED AND MAKES THEM MORE EFFICIENT."

"THERE IS LESS LEEWAY FOR ERROR WHEN TECHNOLOGY IS IMPLEMENTED."

"CONSISTENCY IS KEY, FOLLOWING THIS THROUGH THE PROJECT WITH THE TOOLS AND DATA SETS."

> **"FROM ACCESS TO DESIGN INFORMATION THROUGH TO ANSWERING QUERIES THROUGH RFI PROCESSES, THE CDE HAS HELPED EFFICIENTLY RECORD AND TRACK RESPONSES TO CLOSE OUT. DURING CONSTRUCTION, 4D HELPED WITH CLIENT COMMUNICATION AND IN EXPLAINING LOGISTICS FOR HEALTH AND SAFETY. WE USE BIM 360 FIELD FOR ALL QUALITY CHECKS, AND NON-CONFORMANCE REPORTING WHERE WE LOOK AT TRENDS AND TRAIN OUR TEAM TO REDUCE THE LIKELIHOOD OF THESE ERRORS OCCURRING IN FUTURE."**

Ten out of eleven interviewees gave an estimate of how much had been spent on the introduction of digital technologies on the project; none selected the lowest bracket (below £5k), and just one said that more than £50k had been spent, with the rest falling between these brackets. One of the larger scale projects where the overall budget was approx. £104 million, had spent the equivalent of just 0.048% of its budget on digital tools. Conversely on a smaller scale project with a budget of just £3.5 million the digital tool expenditure was closer to 1.43%. Hence even where larger scale investment in digital tools is supported, it is still a relatively low priority item in relation to overall project budget.

Participants were also asked to estimate how long it had taken for implementation of digital tools to have a positive impact on reducing costs due to error. Responses were very varied with 36% estimating it took less than two years, 18% saying several years, and the remaining 46% stating that it was extremely hard to tell whether it has made an impact.

This suggests that many project teams still struggle to measure the long-term benefits of implementing digital tools. Without the ability to prove how BIM and the implementation of digital technologies saves costs through time, training, business buy-in and the incentive to fully incorporate digital working, projects will continue to miss out on the full benefits of these tools.

We asked if there were any other stages of a project at which our interviewees would like to be able to implement additional digital tools with the goal of reducing error. Handover, asset management, offsite construction and tendering were all mentioned.

- Using digital tools could mean handover is quicker with less potential review returns (errors) being highlighted and make documentation easy for the end user to understand.
- Asset management stage
- Hire modules for off site construction companies.
- Tendering – the more accurate our tenders, the more competitive we can be, the fewer errors will occur and the better the profit margins will be.

These comments reflect the widespread confidence that digital tools create a standardised and reliable process, also acting as a secondary check against human error, which can occur in any stage of a project. Data-driven decision-making, analytical tracking of site progress and predictive modelling enable the accuracy of forecasting, risk assessment, and resource optimisation to be improved.

> **"JUST IMPLEMENTING PROCORE HAS TAKEN SEVERAL YEARS TO GET OTHERS TO USE IT OUTSIDE OF OUR DOCUMENT MANAGER OR DESIGN MANAGER AND EVEN NOW THERE ARE PROJECT MEMBERS THAT STILL RAISE ISSUES BY PHONE OR EMAIL"**

4. DISCUSSION AND CONCLUSIONS

The UK government's mandate for public sector projects to adopt BIM Level 2 has encouraged the widespread use of digital technologies. Government initiatives such as the Construction Innovation Hub for example, promote collaboration, research, and development of digital technologies to address industry challenges and drive innovation.

> **"INFORMATION MANAGEMENT IS THE KEY TO UNLOCKING INDUSTRY'S POTENTIAL, PROVIDING THE GOLDEN THREAD THAT ENABLES TRANSFORMATION TO EVOLVE AND IMPROVE OUR INFRASTRUCTURE."**

But the results of our surveys demonstrate the significant hurdles still faced in implementing digital tools to achieve the full benefits of error reduction. Obstacles identified included interoperability issues, data management, and upskilling the workforce sufficiently to use digital tools effectively. Addressing these challenges demands industry-wide collaboration, training programmes and standardisation of processes[4].

Our research acknowledges that each construction project is unique, and the potential for errors varies depending on project complexity and size. Larger projects have bigger budgets and their delivery and development may be more challenging.

Analysis shows that budget/value has minimal effect on the implemented technology. The most influential factor was organisational commitment and buy-in from the business. We cannot assume that those with a higher project budget are more likely to have a high investment in digital tools; the higher budget would suggest a more complex or larger scale project, rather than additional budget.

We considered whether geographical location had any influence on how implementation of technology on construction projects was perceived or executed, and found no evidence to support this suggestion.

But the financial savings can be considerable. For example, a case study presented to a GIRI members' meeting in 2023 highlighted the potential of visual collaboration tools to reduce error, in this case a simple whiteboard tool. Dumitru Borcan from Infraco Consulting explained that using the cloud-based digital workspace Mural for project visualisation led to a saving of around £1 million by eliminating a proposed diversion that was identified through use of this collaborative tool.

The results of our study show that the level of integration of CDEs and cloud-based collaboration platforms varies widely. While all projects were using one, many comments reflected the fact that respondents felt they could be using these tools more effectively to benefit from the full potential of reducing error on site. CDE platforms and software offer a variety of tools such as:

- Project data and file management, including assigned access levels
- Submittal, RFI and change order processes
- Model viewers, mark-ups and issue flagging/reports
- Meeting organisation tools

(This is not an exhaustive list, tools will vary depending on CDE software provider.)

There was also no consistency as to how project teams were using CDEs — some use it as a central repository for the latest documents and data, whereas others use it to analyse and manipulate models using the model viewer and mark-up tools. So although CDEs can have a beneficial impact and they create a central location for all project information, many also have powerful tools that are not being used to their full advantage.

4.1 CHECKING PROCEDURES

A theme from our site survey highlighted the importance of having a hierarchy of checks, or assigning responsibility appropriately. At times, relying on a single person for each task or quality check can be the root cause of error.

While some element of human error is inevitable, this participant highlighted the fact that projects benefit from a hierarchy of assigned checks within the team. This is something that digital tools such as CDEs can offer, as they have built-in review and transmittal tools. A level of due diligence by incorporating these tools, along with a series of checks by assigned members of the project team would be a robust and reliable way to reduce these types of errors during the construction stage.

All sites agreed that digital tools automate manual repetitive tasks and streamline construction, resulting in increased efficiency and productivity. Some examples given were:

- Construction management software and its automated document management.
- RFIs (Requests for Information)
- Change order tracking
- Audit/traceability

These tools reduce administrative overheads, improve accuracy, and free up time for value-added activities. The use of mobile applications and tablets on site facilitates real-time data capture, enabling faster data entry, improved data accuracy, and immediate access to project information.

"ACCONEX HAS BEEN UTILISED AS MUCH AS POSSIBLE IN TERMS OF ITS BUILT-IN TOOLS. THE CDE HAS BEEN VERY IMPORTANT TO MAINTAIN PROJECT INFORMATION ON THIS PROJECT."

"THERE IS AN OVER-RELIANCE ON LETTING THE SUBCONTRACTOR TAKE FULL RESPONSIBILITY FOR THEIR WORK AND WE FELL VICTIM TO HUMAN ERROR BY ACCEPTING THE WRONG CONCRETE ON SITE AND HAVING TO REORDER, AND BREAK OUT THE EXISTING CONCRETE. EITHER THE WRONG PRODUCT HAD BEEN ORDERED OR THE ORDER HAD BEEN INCORRECTLY FULFILLED. THE GROUND FLOOR SLAB WAS INTENDED TO BE ONE GRADE, WITH THE SUSPENDED SLAB INTENDED TO BE A HIGHER-GRADE CONCRETE."

4.2 ERROR ANALYSIS

Error analysis can be made more efficient by the implementation of digital technologies, as these tools enable the collection of real-time data from across sites. While this may seem obvious, it's clear from our sample that emails and text messaging are still the main tools used to share information from site. This is a worrying statistic, as it introduces many more opportunities for error; information may not be shared with the correct person/group of individuals and email trails can be lost overtime. CDE platforms not only store this information where it is accessible by all project members, it is also automatically date stamped so the most recent version can always be identified.

Our site visits showed that implementing BIM and digital technologies can have a positive impact on quality management systems no matter what the size of the project. Such systems enable inspection checklists and quality control processes to be standardised, and errors systematically identified, recorded, and addressed.

On one site visit, the quality control manager pointed out:

> **"REAL-TIME QUALITY CONTROL DATA CAN BE COLLECTED, ANALYSED, AND SHARED WITH STAKEHOLDERS TO ENSURE ERRORS ARE PROMPTLY ADDRESSED AND RECURRENCES PREVENTED. UPLOADS TO SOFTWARE SUCH AS VIEWPOINT MEANS RECORDS ARE AUTOMATICALLY KEPT UP TO DATE AND CHANGES CAN BE COMMUNICATED TO SITE INSTANTLY."**

4.3 FUTURE POTENTIAL FOR DIGITAL/ TECHNOLOGICAL SOLUTIONS

A key aspect we wanted to explore through this research was to establish how industry professionals view the potential for digital solutions to reduce error across the lifecycle of a construction project, how they think this might evolve over the next decade and whether they think these benefits outweigh the difficulties when it comes to the implementation of digital tools on site.

We asked participants to identify the digital tools they have used, or are currently implementing and to identify their impact throughout the project timeline.

The top three were laser scanning (mentioned by 60% of sites), drones (40%) and BIM360 (40%).

4.3.1 LASER SCANNING

Laser scanning enables the creation of precise documentation by capturing existing conditions on site. This data can be used in 3D models, floor plans, cross sections and other documentation, facilitating accurate design and construction planning, and to create topographic mapping and digital terrain models, to provide better insight and understanding of site conditions including slopes, elevation changes and potential hazards. This information aids in site planning, logistics, and safety assessments, enhancing project efficiency and minimising risks[5].

4.3.2 DRONES

The responses indicate that drones are often used to create visual representations that can be presented to clients and to provide live updates on site progress. These representations enable all project stakeholders, including the design team, to understand the project in context, and by overlaying digital models onto the drone-captured imagery, stakeholders can gain a better understanding of the project's impact on the environment.

Our survey also suggests drones are a reliable tool to enhance safety inspections. At a GIRI members' meeting, Mark Lawton of Skanska said: "Drones are in regular use to record progress and carry out topographical surveys with an accuracy of up to 30mm, and for photogrammetry of inaccessible elements such as roofs, to establish whether in-person inspections are necessary." Not only does this improve quality control and safety, but it also provides a much more efficient way to inspect inaccessible parts of a project.

4.3.3 BIM360 FIELD

Our research established that BIM360 Field is being used on some sites as daily diaries, to complete quality checks, and snagging, NCRs and audits

are also being completed via the integration of tablets using the same application. Project sites have been able to store checklists for QA/QC, where they can also track issues, which includes outstanding work to be completed and tasks which have been assigned but not yet executed. This tool is incredibly useful, not only enabling those on site to be aware of outstanding tasks but also giving project or contract managers an overview project-wide progress or lack thereof.
One of the most impressive tools we came across on our site visits was a 180˚ control room, with full interactive screens from floor to ceiling. The facility also incorporated another immersive interactive screen room, known as a 'BIM Cave', which was used to help monitor site progress using live dashboards and live streams of site activity (Figures 13 and 14).

Participants in the phase two research had differing levels of confidence in the impact digital tools can have on minimising errors on site. All were aware of the benefits such tools offer, but they expressed reservations in terms of procurement and timelines for training and onboarding. In order for teams to successfully implement digital tools, they need to be convinced that the tools will create a seamless process and also that they will enhance their day-to-day work. Overcoming initial resistance can maximise the benefits of digital tools and lead to a safer, more efficient, and error-free construction process in the long-term. This not only reassures the site team, design teams and senior management that the project is being delivered to the highest standard but it can also create a higher level of reassurance for the client.

4.4 THE DEVELOPMENT OF ON-SITE PROCESSES

Our surveys highlighted the fact that there are still a lot of gaps preventing the creation of a single environment within which all software platforms can interact easily and efficiently. Participants said the process of transferring information between platforms can be time consuming, and if wider implementation is be achieved, the process needs to be seamless.

FIGURE 13 *Site visit — 180˚ control room*

FIGURE 14 *Site visit — 'BIM Cave'*

Abhishek Srivastava of Teknobuilt highlighted the issue of siloed systems during his presentation at a GIRI members' meeting in 2023, saying: "simply collecting the data is not enough; better methodology is also required. All the systems need to talk to each other". Development towards interoperability is crucial; if project teams are forever having to move between different systems, and learn from scratch they will become less willing to invest their time on something that they consider temporary.

In fact, in our site surveys the main reason given for resistance to adoption of technology was indeed employee resistance to change (51%), with cost coming a close second at 49%.

These results alongside the individual comments suggest that having buy-in from senior staff within a company is crucial for successful implementation. Top-level management play a vital role in setting the strategic direction and vision for an organisation, so their support and endorsement of BIM and digital technologies demonstrate a commitment to innovation and efficiency, and will motivate others to embrace these changes. Their leadership ensures that the implementation process receives the necessary resources, funding, and organisational backing.

Project team members may be unsure how implementation of digital tools will impact their roles and they may worry about their ability to adapt, and the need to gain new skills. If adequate training and support is not provided, there is a risk they will fell overwhelmed and become more resistant to change.. Clear and open communication can help alleviate fears and misconceptions, and management should be receptive to employees' concerns and address them in a transparent and empathetic manner.

Implementation of BIM and digital tools often requires significant investment in hardware, software, training, and infrastructure. Senior members hold the authority to allocate these resources and ensure that the necessary budget is allocated for procurement, implementation, and ongoing maintenance. Without their buy-in, it may be challenging to secure the required financial support for these initiatives[6]. In May 2022 the Royal Institution of Chartered Surveyors (RICS)'s report analysing digitalisation in construction asked participants to identify blockers that may hinder progress. More than half said that 'Cost, effort and changes needed' was the most significant obstacle, with 'Shortage of skilled persons' a close second.

"WE NEED A DETAILED STRATEGY TO SHOW THE VARIETY OF BENEFICIAL OUTCOMES TO OUR SENIOR MEMBERS, TO PROVE THAT IT WILL BE A VERY USEFUL AND ADVANTAGEOUS IMPLEMENTATION. WE NEED TO RELY ON EXISTING FACTS AND FIGURES AND PRESENT THAT BACK TO THE BUSINESS AND THIS WILL USUALLY WIN THEM OVER TO SHOW HOW EFFICIENCY OF CERTAIN TASKS CAN/WERE IMPROVED. ONCE PROJECT MEMBERS HAVE THE BUY IN AND TRY THE TECHNOLOGY, THEY CAN USUALLY SEE THE BENEFITS INSTANTLY AND ARE HAPPY TO RUN WITH IT."

Both buy-in from senior staff, and adequate training are critical. Without the initial investment in the right level and commitment to training, employees will not have the right platform and opportunity to successfully implement the tool and will view it as more of an inconvenience to any project than a benefit.

GLOSSARY

CONSTRUCTION TECHNOLOGY

The Construction Industry Institute (CII) defines construction technology as the range of innovative tools, machinery, modifications, and software including semi-automated and automated construction equipment used during the construction phase of a project to enhance field/on-site construction and increasingly to enable off-site modular construction. These tools facilitate efficient design visualisation, data management, collaboration and documentation of a construction project, with streamlined processes, a reduction in manual labour and enhanced productivity.
Advances in machinery and equipment combined with digital tools, enable faster construction, more accurate measurements, and precise project execution while BIM-orientated processes and analysis tools allowing for better project planning, and a reduction in errors and rework. Integration with smart cities and the use of big data analytics is expected to further enhance construction technology's potential[7].

BIM AND DIGITAL CONSTRUCTION

BIM (building information management) refers to a collaborative process that involves generating and managing digital representations of physical and functional characteristics of built assets[8]. Digital construction, on the other hand, is a broader concept that incorporates various digital tools, technologies, and processes to enhance project planning, design, construction, and operation.

ERROR

In the context of construction, an error can be defined as any deviation from the planned or intended design, specifications, construction processes, or quality standards[9]. These deviations can result from various factors such as human actions, systematic issues, design flaws or unforeseen circumstances. In reference to the GIRI Design Guide:

"Even a minor error can have far-reaching consequences at a design gateway stage; whether the information that is being handed over is drawings, specifications, digital models or schedules, designers must ensure that it is both appropriate and correct."

Errors within construction more commonly occur during the construction phase and can be a result of inadequate supervision, misinterpretation of drawings or instructions, poor workmanship, or lack of coordination among different stakeholders within the project team[10].

APPENDIX

SUGGESTED READING MATERIAL & REFERENCED PAPERS

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APPENDIX

AUTHORS' BIOGRAPHIES

Melanie Dawson has more than 18 years' experience in the construction industry, from working on challenging design projects in architectural practices, through to managing complex multi-disciplinary teams and experiencing the real-life challenges that come with construction projects and driving forward change. She supports companies across the globe with wide-ranging and transformative BIM and digital construction consultancy services. Melanie is a non-executive director of construction technology provider BuildData Group and InvestNI. She was awarded Fellowship of the ICE in 2018 through her contributions to industry, specifically in the digital construction field. Melanie was chair of the GIRI Technology Working Group in 2021/22.

Erin O'Kane has an academic background in architectural technology, and an MSc in Building Information Modelling Management & Integrated Digital Delivery. In the early stages of her career Erin took on a research analyst role at Ulster University where she worked on her dissertation: Mind the (performance) gap: Embracing technology to enhance on-site performance and also co-authored the research paper: The devil is in the detail: The link between building regulatory processes, on-site inspection, verification and technology. She continues to evolve and develop her understanding of the BIM and digital construction industry at Origin7 working with Melanie.

CONTRIBUTORS

The following organisations contributed to the second phase of the research, and we are very grateful to all the contributors for their time and knowledge shared.

- BAM
- BAM Nuttall Ltd
- Bowmer & Kirkland
- BSG Civil Engineering
- Graham Construction
- Henry Boot
- Infraco-Consulting
- McAvoy Group
- Translink (Farrans, SACYR, Graham Construction, Babcock)

GIRI research has shown that errors in design and construction contribute to between 10 and 25 % of project cost, depending on size and complexity, amounting to roughly £10-25 billion annually in the UK construction sector. This study was commissioned by GIRI to examine the technologies that are available to support error reduction on site, establish how they are currently being used and identify whether certain types of products are more widely used than others.

Insights are drawn from two primary sources — an online questionnaire and a series of discussions with professionals working on 11 live construction sites across the UK.

We sought to understand how digital tools are viewed by the professionals using them, explore barriers to implementation, the opportunities for wider use of the technology, and gain some understanding of the costs and timescales involved in implementing them.

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