Transforming the civil engineering surveyor

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Key words: BIM, information management, digital engineering, surveying

Summary: This white paper from the Chartered Institution of Civil Engineering Surveyors considers the changing nature of surveying professions amid the onset of various applications and processes including digital engineering, artificial intelligence, machine learning, data sharing and building information management (BIM) during the full infrastructure asset lifecycle.

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INTRODUCTION: EMBRACING DIGITAL ENGINEERING AND INFORMATION MANAGEMENT

Digital transformation is key to delivering a construction industry that is fit for 2050 and beyond. In this paper, the Chartered Institution of Civil Engineering Surveyors (CICES) considers the changing nature of the surveying professions amid the development of digital engineering, encompassing information management, data sharing and building information modelling (BIM) during the full infrastructure asset lifecycle.

The pace of technology development, particularly artificial intelligence, machine learning and data management, means surveying roles will change, requiring different skills on top of those honed in their rich history of being the key suppliers and curators of geospatial information throughout the civil engineering plan of work.

All the engineering professions are facing change, some more than others. The UK government mandate for the use of BIM on all centrally procured projects by 2016 instigated change in many contractors and consultancy firms. The ‘BIM4’ groups sprang up under the BIM Task Group and the BS1192 series of standards developed as the precursor to the international BS EN ISO 19650 series we have today. Throughout these early days, the challenge lay in demonstrating the relevance of information management to surveyors.

Geospatial surveyors have witnessed lost opportunities because of a lack of awareness of their expertise and understanding of location data and data capture methods. Commercial managers have faced new ways of working using software platforms that they could not interact with to reflect the true progress on a project, which has exacerbated the ‘silo mentality’ information management has tried to counter.

Two factors since 2016 have accelerated the pace of digital transformation. The first is the growing awareness of climate change and the commitments that governments globally are making to mitigate its effects in a timeframe of just a few decades. The second is the COVID-19 pandemic which led to an increase in digital communications, reduced site visits and brought remote technologies such as automated monitoring and drone (also known as unmanned aerial vehicles/UAV, or small unmanned aircraft/SUA) progress reporting to the fore. ‘Agility’ and ‘pivot’ have become terms that businesses take pride in achieving. The information

management trailblazers of the 2010s are now sharing their successes and lessons with their supply chains.

The remit of the BIM Task Group was taken forward by the Centre for Digital Built Britain and now by the Construction Innovation Hub, British Standards Institution and UK BIM Alliance, within the UK BIM Framework. The National Digital Twin Programme is underway, with the underground currently being digitally mapped through the National Underground Asset Register (NUAR). The Centre for the Protection of National Infrastructure has been engaged to protect all that is digital in the digital twin, demonstrating that data about infrastructure is as critical as the infrastructure itself and is supporting the development of a standard interoperable approach to asset information through the Government & Industry Interoperability Group (GIIG). The pace of change shows no sign of slowing. As emerging technology drives surveyors to acquire new capabilities and competencies, their expertise is essential in realising the efficiencies of digital engineering.

In 2021, CICES supported the global study Accelerating Digital Transformation Through BIM.[1] The study showed that 70% of civil engineers have adopted BIM since 2016, demonstrating the rapidly growing use of information management for infrastructure work. Contractors deploying information management on at least 50% of their projects reported significant benefits in areas such as bid efficiency, fewer defects, cost control, forecast accuracy, schedule control, reduced rework and fewer on-site challenges.

CICES was established in 1969 and has as its Latin motto, *omnia metimur quae videmus*, we measure all that we see. The fashion for having a Latin motto may have gone, but the principle is relevant today and will be in 2050 and beyond. Measurement equals accuracy. Accuracy equals efficiency. Transforming the civil engineering surveyor simply reshapes that function for the future.

Key to this transformation is a better understanding of the expertise of geospatial engineers and commercial managers, and how they can inform decision making on infrastructure projects. This paper recommends a shift in the traditional timing of when civil engineering surveyors are engaged in projects, identifying that they will have more impact in the planning phase. Knowing what data will be needed when and to what accuracy and how this data will be used in scenario planning, costing, scheduling and monitoring will realise efficiencies and make full use of the surveyor's expertise.

While the majority of papers and initiatives referred to in this paper are from the UK, digital transformation of civil engineering surveying is global. We recognise that each country faces its own unique challenges and hope that lessons learned and shared here will benefit our colleagues overseas.

[1] *Accelerating Digital Transformation Through BIM SmartMarket Report, Dodge Data & Analytics https://www.construction.com/toolkit/reports/Digital- Transformation-Through-BIM*

PERCEPTIONS AND PURPOSE THROUGHOUT THE PHASES OF A PROJECT

Transforming the civil engineering surveyor also means transforming the perception of the civil engineering surveyor. Better understanding of the expertise of geospatial surveyors and commercial managers and how they can inform decision making at all phases of a project is a relatively simple step that can have a large impact.

For geospatial surveyors this was an issue tackled in 2016 by Survey4BIM[1], a specialist group under the UK government's BIM Task Group umbrella. Survey4BIM published Survey and the Digital Plan of Works[2] to address a gap in the published UK BIM Level 2 standards for the role and responsibilities of the surveyor. The guidance followed a series of eight (0-7) work phases broadly aligned to those within PAS1192-2:2013 describing survey activities and recommendations for each phase.

The past few years has seen the move to the UK BIM Framework.[3] The framework is intended to be applicable to all types of appointment and project, under any procurement route and for all participants. Consequently, it has framed guidance around a simplified set of phases focused on information management; design, build, operate, integrate.

Design, build, operate, integrate

The role of the surveyor within the UK BIM Framework remains critical to correctly specifying geospatial requirements at the outset of a capital delivery project to how survey data is used in asset operation and connected to other datasets. Obligations within the UK BIM Framework are described as:

— Design: Where digital techniques are deployed to design better performing infrastructure. Information management should be secure by default and managed in a way that gets data right from the start.

— Build: Where new and emerging digital construction and manufacturing technologies, processes and techniques should be exploited. Secure, shared information should enable clients, design teams, construction teams and the supply chain to work more closely together to improve safety, quality and productivity during construction.

— Operate: Where real-time information should be used to transform the performance of the built environment and its social and economic infrastructure. Smart asset management should predict and avoid disruption of services, while existing assets and infrastructure should be digitalised.

— Integrate: Where it is understood how spaces and services can improve quality of life. That information should be fed into the design and build of economic and social infrastructure and the operation and integration of services they deliver.

These phases are entirely applicable to the surveyor, whose role in the project and asset lifecycle needs to be better appreciated and integrated. The obligation of the surveyor is to align to standardised information management processes, identify and embrace appropriate technologies and commit to trusting the data they receive from other participants. The risk averse nature of the construction sector, reliance on inefficient legacy procedures and limited investment in technology and people needs to be retired in order for effective change to happen.

Geospatial considerations

By considering the standards and guidance for the phases within the UK BIM Framework, coupled with the still applicable recommendations in Survey and the Digital Plan of Works, geospatial surveyors can better demonstrate the criticality of their role in the asset lifecycle and ensure their data needs and outputs are integral to successful project outcomes.
Information management solutions and processes have become familiar to many professionals and organisations over the past few years. Moreover, the pace of technology innovation has introduced new solutions and opportunities to increase productivity, improve quality and challenge traditional thinking. For example, surveyors are able to undertake unmanned aerial surveying, set out directly from models, leverage sensor data for real-time information, drive machinery remotely and many other options to improve their work and collaboration with other project participants.

The Transforming Infrastructure Performance: Roadmap to 2030 (TIP)[4] from the Infrastructure and Projects Authority notes that there are technical capabilities that are not yet being asked for or applied on government projects. It particularly highlights 5G networks, artificial intelligence, wireless sensors, monitoring, fixed and mobile sensors, photogrammetry, 3D laser scanning robotics and augmented reality, and calls for improvement and acceleration of their adoption. Such innovations need to be introduced with consideration for the value they bring to a project and wider downstream operational and service provision. Technology for technology's sake is not worth adopting without both a resulting material improvement and an assurance of no unintended negative consequences. The geospatial surveyor is the expert on this technology, and as an appointed consultant will be able to advise on the most appropriate technology and data requirements for every stage of the project. The geospatial surveyor can assist in the specification of requirements, advise on where coordination is missing and what is required, and plan how information quality will be developed over the design, construction, handover, operation, maintenance and decommissioning of an asset.

The emergence of geospatial project execution plans shows that with the right data capture and management methods in place, other project team members can focus on their specialist contribution, using technology as an enabler, not a distraction.

Commercial management considerations

The commercial manager and quantity surveyor roles are transforming to ones of proactive data management to drive value and monitor project progress.

The TIP highlights the increasing use of information management as a planning tool to coordinate construction to a critical path and undertake clash detection in line with resource management, capacity planning and scheduling. Taking this further to cost modelling, some software already has the capability to incorporate costed components and materials in the information model, alongside linked availability and access. This can then drive bills of quantities and optimise resources whether work is on site or during offsite manufacturing.

The key message in TIP is that embracing information management and a multidimensional approach starts in the planning phase with highly detailed information and better integration

that can then inform the work packages. By establishing the core contribution of the commercial team early, and with regular engagement throughout the project to ascertain how data can be used to drive efficiencies, the data measurement role of the commercial civil engineering surveyor can be fully exploited. As cost modelling becomes more mainstream, now is the time for commercial surveyors to reaffirm the key role they play in ensuring project efficiencies, with a focus on data and value, as well as cost.

1 https://survey4bim.wordpress.com

2 https://survey4bim.files.wordpress.com/2017/08/survey-and-the-digital-plan-of-works.pdf

3 https://www.ukbimframework.org

4 https://www.gov.uk/government/publications/transforming-infrastructure-performance-roadmap-to-2030

PLANNING: ALL ABOUT TIMING

The timing of when to engage a surveyor needs to be rethought. Early engagement with both commercial managers and geospatial engineers is key to releasing efficiencies. The first step is to determine what data the project needs throughout its lifecycle.

Engage early, plan for life

Engineering surveyors are often called to provide professional services within a very narrow window of requirements by the project stakeholders to meet an immediate need. However, by working with clients, as an appointed consultant, they are best placed to specify, procure and manage geospatial information throughout the planning phase through to operation of an asset. This holistic approach enables clients and appointed parties access to geospatial information at an appropriate level of need in the lifecycle of the project.

The geospatial engineer is a custodian of location data. This kind of data has until now been managed in appointed party silos through the phases of an asset's lifetime. Geospatial information needs to be managed through a balanced and structured approach throughout each phase. Engaging a geospatial engineer as an appointed consultant is key to unlocking the transformation from individual stakeholders managing and setting their own requirements for geospatial information to a collective plan of project needs embracing specification, collection, added value and handover of geospatial data between stakeholders. This adds value to design integrity and provides as-built information to aid and inform asset management and monitoring.

Survey4BIM's Survey and the Digital Plan of Works[1] can help pinpoint what survey data is essential at what stage of a project and is a useful resource when commissioning and planning geospatial data requirements.

Ask and you shall receive

Our focus groups revealed some commercial managers still struggle to see the benefit of information management. One quantity surveyor commented:

"The 3D models I'm told to use present a pretty picture but the data behind them is often unusable." The perception persists that planners and BIM managers provide data they think the commercial team needs without talking to them first. This can lead to mistrust and the contractor's commercial team commissioning its own data and working on that independently in a silo. To get over this mismatch of presumed usage and actual take-up, a combined data/commercial cost plan is needed. Monitoring integrated cost models, data levels and reports needs to be a key activity on the programme, with all involved responsible for driving it forwards.

Commercial teams have to step up in adopting new work practices that leverage the opportunities from information management. Reliance on traditional trusted, but actually inaccurate, methods has to go or the efficiencies of digitalisation will never be realised. Within a project controls team, this shift is naturally facilitated, but on smaller projects where commercial, planning and design teams sit separately, it is imperative that these teams no longer see each other as stumbling blocks. The commercial management team should be fully engaged and asked at the start what their information requirements are and how they need to see information presented. By integrating commercial, planning, design and BIM specialists – or at the very least, having weekly interdisciplinary meetings – information requirements can be clear from the outset and processes around sharing and management defined.

When data and information deliverables are agreed, they should be recorded in task information delivery plans. These are amalgamated into a master information delivery plan, together with the geospatial project execution plan encompassing the data requirements and the technologies it has been agreed will manage the process. This will provide a foundational framework to maximise data efficiencies.

1 https://survey4bim.files.wordpress.com/2017/08/survey-and-the-digital-plan-of-works.pdf

SKILLS: CUSTODIANS OF ACCURACY

Engineering knowledge is no longer a prerequisite to working in construction. Data analysts, information managers and gaming/visualisation specialists are increasingly regular appointments. These new roles work hand in hand with surveyors and the skills of each should complement each other in the digital engineering team.

The Construction Innovation Hub's Digital Capabilities: A Framework for early career professionals across built environment disciplines[1] set out six digital capabilities required in construction:

— Data collection and instrumentation

— Information management

— Data interpretation and analysis

— Data governance

— Data visualisation

— Software development

The current civil engineering surveyor could lay claim to involvement in the first five of those six, with many contributing to all six with their involvement in software development through bespoke systems and early adopter relationships with developers. While project teams do not centre their career on software development, they have to embrace new technology as a digital capability.

The skill-set of the commercial manager in particular is in danger of not developing in line with the systems being used and not fulfilling the potential it has to transform projects.

For the geospatial surveyor, the fast pace of technological development over the last half-century has resulted in an agile profession at remarkable ease with new tools. However, its chief concern is the lack of entrants to the profession.

New skills: what might we need?

The commercial manager and quantity surveyor roles are transforming. Commercial and planning teams are increasingly coming together under the joint banner of project controls. They no longer stand in silo functions, this is about bringing together their expertise to give a full picture of a project's health and progress.

While measuring cost continues to be a key commercial role, especially in the post-pandemic and post-Brexit UK, this is just a part of one of the capitals that need to be measured under the UK government's focus on value. The Value Toolkit[2] from the Construction Innovation Hub aligns with HM Treasury's Green Book[3], against which public sector investment decisions are made. Value is measured over four capitals:

— Natural capital: valuing the natural environment and addressing solutions to climate impacts

— Social capital: valuing engagement and consultation, equality and diversity, and the positive impact of the built asset on society

— Human capital: valuing employment opportunities and skills development

— Produced capital: valuing a combination of capital cost, operational cost and revenue, taking a whole-life approach to efficiency and quality of design, construction and operational processes

The commercial manager is a specialist at measuring produced capital. Transformation will involve acquiring skills in measuring the other three capitals as well.

Clients have to think differently about their long term plans. Balancing affordability and the four capitals will naturally change tender specifications. This shift is a challenge and the Construction Innovation Hub recognises that it "demands considerable rigour in defining the outcomes to be delivered and understanding the client's approach to project delivery and risk."[4] Again, success will lie in early and regular engagement between the commercial, design and planning specialists.

Tackling a skills shortage: The role of CICES

When looking at skills in civil engineering surveying, one has to consider both the shortage of digital skills in the current surveyor and the shortage of skilled new surveyors. As a professional qualifying body, CICES has a role to play in addressing both issues.

For new entrants, CICES needs to ensure it continues its collaboration with organisations involved in schools engagement, including Construction STEM Ambassadors, Get Kids into Survey and Class of Your Own (the organisation behind the Design Engineer Construct! curriculum). CICES must maintain its involvement with steering groups for the Geospatial Survey Technician, Geospatial Mapping and Science Specialist, Construction Quantity Surveying Technician and Construction Quantity Surveyor apprenticeships; and build on its successful university accreditation programme. Involvement with the Construction Leadership Council Skills Plan is a necessity to avoid a fragmented approach to careers promotion.

The image of the surveyor as 'data custodian' needs to be better promoted. Protocols and standards focus on quality process, while surveyors focus on quality data – this and the technology and expertise required to capture and define quality is rarely recognised by the wider project team, and almost never in schools' careers departments.

Civil engineering surveying is rightly proud of its openness to all as a career. Many industry leaders talk about joining the construction industry straight from school, and progressing to attain company directorships with professional, rather than academic, qualifications. Historically, construction is seen as a male-oriented career, and with CICES female membership sitting at just over 10%, CICES has a duty to build on that socially mobile heritage and ensure that the profession is open to a diverse range of talent.

CICES plays a vital role in linking industry requirements with education and apprentice providers. For this to be effective course accreditation and re-accreditation needs to reflect the digital astuteness necessary for civil engineering surveying. As this area develops and the standards around it grow, regular engagement between professional and academic institutions is crucial.

To upskill its existing membership, CICES has already committed to embedding digitalisation within its membership competencies. However, the award of membership is a point in time. Professional bodies need to look at how they engage existing qualified members to upskill through their continuing professional development requirements. The Construction Innovation Hub calls on professional bodies to develop a common understanding of sector-wide core digital capabilities and to work with members to determine what digital capabilities they need in their work[5]. Answering this call rests with both individual institutions and the UK BIM Alliance, whose Affiliates Programme can assist in providing a forum for professional bodies to share experiences and best practice.

Professional bodies should be 'safe spaces' for the sharing of lessons learned and mistakes overcome in digital transformation. Members need to be aware of their own professional accountability to upskill and should be encouraged to assess their own digital maturity to gauge where they need further development. CICES, and other professional bodies, need to play a

non-judgmental role in signposting to further information and knowledge banks, providing time for discussion at events – rather than rushing Q&A at the end of webinars and seminars – and they must promote support from specialist technical committees and regions.

1 https://survey4bim.files.wordpress.com/2017/08/survey-and-the-digital-plan-of-works.pdf

2 https://constructioninnovationhub.org.uk/value-toolkit/

3 https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

4 Page 7, Value Toolkit

5 Page 17, Digital Capabilities: A Framework for early career professionals across built environment disciplines

DATA: NAVIGATING A NEW CURRENCY

The Construction Playbook[1] stresses that: "A critical success factor for the effective completion and transition of a project or programme is the sharing of high quality, robust data and information between parties during the project lifecycle and into operation."[2]. A few years earlier in 2018, the Gemini Principles[3] around data sharing for the forthcoming National Digital Twin valued this assumption, stating that greater data sharing could release an additional £7bn per year of benefits across UK infrastructure, which is equivalent to 25% of total spend[4].

Establishing protocols and processes around data sharing is essential for the transformation of construction. While data sharing practices have yet to be fully established and normalised, they will happen – and civil engineering surveyors should be enacting best practice and ensuring their continuing professional development factors in skills in data management. While protocols and standards focus on quality processes, surveyors focus on quality data and therefore are natural leaders in managing and specifying data requirements.

The information delivery lifecycle

Information is developed and built up through the lifecycle of a project, commonly referred to as the digital plan of work (DPoW). The unified CIC/APM digital plan of work consists of eight generic stages:

— Strategy

— Brief

— Concept

— Definition

— Design

— Construct and commission

— Handover and close-out

— Operation and end-of-life

The level of information need (formally known as the ‘level of definition’) is defined for each stage gateway and is the aggregate of level of detail and level of information.

The ‘level of detail’ is the description of graphical content required to address the decisions at each stage gateway. And the ‘level of information’ is the description of non-graphical content required for this.

As information progressively develops at each stage throughout the project delivery it collectively forms the Project Information Model. The graphical representation may not change at each stage but ‘Information’ will be added at each stage.

For example, at concept stage graphical detail may look very realistic but spatially inaccurate, plus information is likely to be low grade with a lot of unknowns. Whereas at handover and close-out, graphical detail will accurately reflect the as-built position of the works and information delivered will be sufficient to maintain and operate it.

The production and delivery of information on a project is assigned to specific Task Teams (Disciplines) - for example civil, mechanical and electrical. These ‘own’ the information they are responsible for producing and only they can create or edit that data.

All information, regardless of the work stage it is developed at, can be assigned one of three states:

— Work-in-progress (the only state in which files can be edited by the discipline/task team that ‘owns’ that output)

— Shared (non-contractual, used for collaboration)

— Published (contractual - such as client deliverables or instruction to fabricate or build)

The work-in-progress state is used for information while it is being developed by its task team/discipline. Information in this state is not visible or accessible to any other discipline.

When the discipline is ready to share its information, it must pass through a check, review and approval workflow and is given a status code (often referred to as a suitability code). This is necessary so the receiving party can have confidence in the information shared and has some understanding of the purpose for which it was shared. The status codes that can be assigned are:

— S1: suitable for geometrical and/or non-geometrical coordination within a delivery team

— S2: suitable for information or reference by other disciplines within a delivery team

— S3: suitable for review and comment within a delivery team

— S4: suitable for review and authorisation by a lead appointed party

— S5: suitable for review and acceptance by an appointing party (client)

The purpose of the shared state is to enable constructive and collaborative development of the Information Model within a delivery team.

When a discipline promotes information to the published state it must pass through a further review and authorization workflow. The published status codes assigned - A0, A1, A2, A3, A4, A5, A6, A7 - all indicate the stage gateway of the digital plan of work they refer to.

The information at shared and published states is visible and accessible by other disciplines within a delivery team but is not editable by them. If the information requires editing it is returned to the work-in-progress state for amendment and resubmission by the discipline that owns it.

This process of information development and exchange is defined by BS EN ISO 19650-2:2018 and is undertaken within a common data environment (CDE). A CDE is the single source of information for a project, used to collect, manage, and disseminate all relevant project information through a managed process. A critical function of the CDE is to provide a clear and secure audit trail or journal of all changes and amendments to that information, including who created it, who read it, who edited it, who shared it (and for what purpose), who checked and reviewed it, who approved it, who authorised it to be 'published' and when all these activities took place.

At the end of Stage 6, the as-built information represents the as-built asset in content and dimensional accuracy and is submitted to the client for acceptance, along with the commissioning and handover documentation.

The complete PIM is handed over at the end of the project and culminates in the transfer of relevant information from the PIM to the asset information model (AIM), for use in asset management and potentially within a digital twin.

Leading up to this state of high quality and robust information requires a careful and structured approach, which includes adherence to strict processes and standards and an element of risk management.

Standards and standardisation

The UK government's National Data Strategy[5] of December 2020 stated that while the standards were 'well recognised', SMEs generally do not use information management. The key hurdles to be overcome included software licensing and cost; lack of in-house training and skills; interoperability; a perception that BIM was only for larger construction projects; and a lack of demand from clients.

Since then, the Construction Playbook has clearly set out to ensure that client demand is there (at least in the public sector); the Government and Industry Interoperability Group (CIIG) has been established to support interoperability; software houses and market forces are addressing licensing costs; and training is filtering through the supply chain from the major contractors. Perception will change in time and professional bodies have a role to play in providing learning

opportunities around specification requirements and standards, and the importance of a balanced and structured approach to data management throughout the lifetime of an asset.

Standardisation of data is necessary for collaboration. The Construction Playbook is very clear about government expectations of contractors around data management, explicitly saying they should use the UK BIM Framework to standardise the approach to generating and classifying data, data security and data exchange, and to support the adoption of the Information Management Framework and the creation of the National Digital Twin.

Naming protocols for information containers for objects and layers should be established early in a project and align to the needs of the client. It is imperative that these requirements are communicated to the project delivery team via the BIM Execution Plan (BEP) and that everyone adheres to them. The Geospatial Commission uses FAIR terminology[6] to assess the fitness for purpose of data, with data that is:

— Findable

— Accessible

— Interoperable

— Reusable

The term Q-FAIR is also used by the commission and adds 'quality' to the data ideal. Civil engineering surveyors – both commercial and geospatial – should keep the Q-FAIR principle in mind when commissioning, capturing and managing data. The role of the surveyor in determining quality is key to the success of projects and will cover the currency, accuracy level, verification and suitability of data – addressing concerns around how much the data can be trusted and how it will be used with other data. This relates to the 'level of information need', which might require a higher level of detail and accuracy at DPoW Stage 4 (detail design), than at DPoW Stage 2 (concept design), for example.

Another initiative that will aid data standardisation is the International Cost Measurement Standard (ICMS)[7]. ICMS provides a high-level structure and format for classifying, defining, measuring, recording, analysing and presenting life cycle costs and carbon emissions associated with construction projects. CICES is one of 49 global bodies in the coalition steering the development of the standard.

Sharing securely

Geospatial surveyors should be mindful of the adage, capture once, use many times. The geospatial project execution plan should be developed as part of early engagement with the client and address what existing data is known about and available, and ensure that new data capture is carried out with the whole project life-cycle in mind.

The potential for sharing data in future projects needs to be addressed in the contract. The surveyor is best placed to comment on how the data could be used in future projects for other clients.

Surveyors have access to a huge range of data, and need to be mindful of their responsibility to keep that data secure, especially on national infrastructure projects. Clients will increasingly specify data security requirements, such as Cyber Essentials[8] accreditation, in tender documents. The Centre for the Protection of National Infrastructure (CPNI) has a wealth of guidance material on developing a security-mindedness approach[9] and assessing the security of data management systems. The National Cyber Security Centre (NCSC) has developed guidance on cyber security for construction businesses[10]. For underground utility surveys, the cross-industry endorsed Secure Data Management for Utility Surveys[11] published by CICES is also useful.

Facing the risks

Data sharing can appear highly risky to those whose careers have been shaped though the traditional adversarial culture of construction. This leads to a reluctance to share between stakeholders, particularly where added value has been embedded based on personal judgments and interpretation of information.

Further work needs to be carried out to determine the most effective processes for data validation. Currently, the recipient of data expects it to have been validated by the sender. However, there is a chain of thought that turns the table on this expectation and recommends that the recipient verifies the data it receives. Recipient verification transfers risk from the sender and has a commercial implication around who is paying for verification and the actions that may need to be managed stemming from the outcome of verification and any resulting change management. This model is outlined in the Construction Playbook where in a list of dos and don'ts, one is: "Don't... hold incoming suppliers responsible for errors in data (excluding forecasts) where they are unable to complete due diligence. Where data turns out to be incorrect, there should be a contractual mechanism for reflecting this adjusting for errors."[12]

However data validation is carried out, the process should be collaborative with a structure in place to notify parties of any discrepancies and clashes. Who is in charge of the truth and when needs to be thought about right at the start of a project. In the Construction Playbook, the second step in the delivery model assessment for public works projects and programmes is to identify data inputs. This sits right after framing the challenge of what type of sponsor and governance approach is being taken, and before considering the delivery model.

With data thought about early and often, and an accurate and reliable pipeline of information flowing through a project, the natural progression is to put it to further work. Good data should be used as a benchmark to aid decisions in forthcoming projects. Ensuring the quality of this data as it is used in future evaluation is a further role where the skills of the commercial manager will be beneficial. Machine learning programs are already being used by public sector clients to manage risks on mega-projects by assessing historical data. As machine learning and AI become more developed and familiar tools, this kind of analysis will become more common.

We cannot not share

Open data initiatives, where non-sensitive data is made available without constraint for transparency, engagement and innovation purposes, are increasingly encouraged by the UK

government. Surveyors need to take care that legal and security liabilities are considered when sharing data for the public good.

Commercial barriers to data sharing were addressed in Data for the Public Good[13] from the National Infrastructure Commission in December 2017, where perceived commercial risk was studied under the glare of overall industry efficiencies. Putting it simply, the report stated that: "By refusing to share data, a private company or organisation keeps control of that data as it grows... as the volume of data increases and machine learning techniques are applied, the quality of the data improves and so becomes more valuable. Thus there are increasing returns to data, which if retained in the private sphere, will remain as narrow returns to the private company rather than wider returns to the economy as a whole."[14]

Professional civil engineering surveyors are bound by the royal charter that governs them to benefit society. That narrow view of protecting commercial returns has to widen.

1 https://www.gov.uk/government/publications/the-construction-playbook

2 Page 68, The Construction Playbook

3 https://www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf

4 Page 2, The Gemini Principles

5 https://www.gov.uk/government/publications/uk-national-data-strategy/ national-data-strategy

6 https://www.gov.uk/government/collections/best-practice-guidance-and-tools-for-geospatial-data-managers

7 https://icms-coalition.org

8 https://www.ncsc.gov.uk/cyberessentials/overview

9 https://www.cpni.gov.uk/developing-security-mindedness-approach

10 https://www.ncsc.gov.uk/guidance/cyber-security-for-construction-businesses

11 https://www.cices.org/content/uploads/2022/03/Secure-Data-Management-for-Utility-Surveys.pdf

12 Page 50, Construction Playbook

13 https://nic.org.uk/app/uploads/Data-for-the-Public-Good-NIC-Report.pdf

14 Page 48, Data for the Public Good

CONTRACTS AND PROTOCOLS: CAREFULLY ENABLING THE DIGITALISATION JOURNEY

Contracts should enable, and not constrain or conflict, with the digitalisation journey. Data sharing and collaboration need to be carefully supported. This can be addressed either through conditions of contract or dealt with in a protocol that overlays contracts.

Data takes the form of outputs and deliverables identified as part of the scope of works or service that the supplier is to provide, the format in which it is to be provided and when. Data will in many ways be the same as any other deliverable under the contract, however there are issues that need to be considered due to the fact digital information will be shared with others and combined and developed in an integrated or federated information model. The timing of information releases, the liability and responsibility for the information provided and the development and use of this in an integrated or federated model have to be thought about carefully. Ultimately, the end product will be a model that combines information provided by the parties that the client will use to manage the completed asset.

In order for the information model to meet the client's overall requirements there will be a need for each party to have a guiding hand on its development, following requirements which may need to change as the project develops. There may be clashes with the requirements in individual bi-party contracts and commercial managers should be prepared for this.

Traditional bi-party contracting creates a hierarchical structure with risk and responsibilities split across the different parties, including responsibility for the creation, sharing and development of data which can be ultimately used in an information model. This way of contracting creates multiple interfaces that need to be effectively managed. However, due to the individual allocation of risk to each party, the approach can drive a silo mentality in which each party seeks to protect its own position, instead of collaborating on the basis of what is best for the project. To overcome this silo approach, clients and their suppliers are moving to more collaborative engagement models such as alliancing.

Alliancing

In practice, there is a sliding scale of alliancing from simply having some form of partnering charter or non-binding agreement overlaying another engagement model, all the way through to the creation of a formal contractual alliance. In all cases, the parties are encouraged to work together on a best-for-project basis and are incentivised to do so via shared performance measures. When a contractual alliance is created, the parties sign up to the same contract and share the majority of risk and reward.

There is support for alliancing from government in the Construction Playbook[1], which states that while alliancing arrangements are not always appropriate, "they should be considered on more complex programmes of work as the effective alignment of commercial objectives is likely to improve intended outcomes as well as drive greater value for money."[2]

Enterprise

Project 13[3] from the Institution of Civil Engineers is an illustration of what currently constitutes 'good'. Described as an enterprise model for infrastructure delivery, Project 13 brings together numerous partners and suppliers who integrate their capabilities, processes and information

under incentives and long-term relationships. The asset owner, or client, is the central driver of change, and the parties are rewarded based on their value to the overall project outcome – not on a transaction of time or volume of work. Risk is aligned with capability, and is not cascaded down the supply chain.

Coming from an adversarial and competitive approach to contracting, the shift to enterprise and alliancing is immense, but it is doable. Success lies in the hands of the client, or 'capable owner' as Project 13 calls them. However, many owners will take time to become capable. Contractors need ways to transform their methods of working that can be driven by themselves in the meantime, whilst forming those long term relationships with the supply chain that will be called upon in the future.

Change takes time

Whilst the use of alliancing and enterprise ways of contracting may be the way forward, we need to consider how to deal with the more traditional bi-party contracts that pervade the industry. Even in a move to alliancing, not all members of the supply chain will form part of the alliance and there will still be bi-party contracts at subcontract and subsubcontract level. We therefore need to consider the digital maturity of all parties and recognise that the expertise and ability to transform will vary, and yet each part of the chain has a part to play in the move to a more digitally enabled industry.

The wider supply chain needs to be engaged in information management, however the level of their involvement, the data they supply and the format of this needs to be proportionate to their role and their level of digital maturity. The approach adopted across contracts should be scalable to reflect the differing levels of maturity. Levels of IT literacy will vary and Tier 1 contractors have a duty to engage with their supply chains and train them on the systems they are employing on projects at an appropriate level of detail to ensure12 the project's security. While the wider supply chain may need an incentive to 'do BIM' – to contribute to the collaborative information management of a project and to work with that information themselves, whether accessing the model interface or inputting data, everyone must take responsibility for their part in the information delivery process.

Protocols

Protocols allow a consistent set of requirements to be used for all parties that contribute to the information model, however this can lead to clashes between the terms of the protocol and the contract it overlays. Careful consideration has to be given as to how protocols and contracts interact and the interfaces between them need to be actively managed.

Where alliancing approaches are adopted, the need for protocols to manage the interfaces between the parties contributing to the information model is reduced or removed as the parties share in the performance risk of the information model.

The Construction Industry Council (CIC) BIM Protocol was the first to guide information sharing and collaboration as responsibility for the design model changed on a project. A second edition was released in 2018. These have since been developed into two information protocols

within the UK BIM Framework[4] (for ISO 19650-2 and ISO 19650-3). While there is a wealth of helpful processes and procedures, parties will still need to find a way to 'talk to each other' digitally and trustfully.

Protocols are 'points in time' and do not address the wider behavioural change that needs to occur. Ways of working with protocols and standards in general need to be addressed by contractors. While there has been a government information management mandate since 2016, neither clauses nor protocols can be forced onto parties arranging a contract outside of the mandate. The only persuasive argument will be demonstrative. Contractors and clients need to share case studies and experiences, facilitated by professional bodies and their knowledge sharing platforms, highlighting reduced re-work and reduced disputes on projects.

Whatever contracting model is adopted, successful information management requires the parties to work collaboratively and this should be made a contractual obligation, such as the requirement in the NEC4 suite of contracts for the parties to act in a spirit of mutual trust and cooperation.

The question of responsibility

One of the largest questions that will need to be addressed contractually is around responsibility for the information model and the data within it. This issue needs to be considered both during the development of the model and upon its completion. This is unfortunately a common objection to collaboration in information management.

In alliancing, depending on the specific form of contract used, the parties share in the risk of the creation of the digital information, removing the need for each party to protect its own position and have this addressed in the contract or protocol. Such an approach is adopted in the NEC4 Alliance Contract in which the alliance as a whole is responsible for updating or creating the information model and correcting any errors within it.

With this kind of contract there is no requirement to allocate responsibility and risk for elements of the model that each party creates or inputs into, with all parties sharing the risk to the extent of their liability under the contract. This allows them to work collaboratively, without the need to protect their individual position, and the information within the model becomes the property of the client on completion.

However, this flow does not work with multi-party contracts. If the client holds a federated model, it needs to consider at the earliest planning stages how it will provide secure, relevant and proportionate access and how it will manage the information contributions of others. In some contracting models, such as Design, Build and Operate, the responsibility for the creation or modification of the federated model may be passed to the first tier supplier, who will coordinate the inputs into the model from the supply chain and then pass the federated model back to the client at the end of the contract.

Planning for the transferrence of responsibility should take in soft landings guidance[5] and the Line of Sight[6] methodology from the Centre for Smart Infrastructure and Construction, which echoe the principle of keeping the end use of the asset constantly in mind. As the National

Digital Twin programme ramps up, the information model has to be put to use. Asset management objectives and any client-operated information management platforms[7] have to be considered at the time of contract formation.

Contracts should enforce the principle that the client is ultimately paying for the information model and hence owns the delivered data. This does not preclude intellectual property or technical responsibility of those who have contributed to it. In general, while the output is project specific, the skills to create it reside within the professionals employed on the project. The 'golden thread' philosophy, set out in the Hackitt Report[8], supports this ideal of being able to go back in time to determine who made what decision, when and why, by having a robust history of decision making within an information model. A properly BS EN ISO 19650 compliant common data environment (CDE) archive should provide this. In BS EN ISO 19650:2018, the archive state is used to hold a journal of all files that13 have been shared and published during the information management process as well as an audit trail of their development and any revisions.This should not be confused with an IT archive, which usually refers to a process where a file is removed from a live computer system to an offline environment where it is archived for subsequent retrieval.

Reducing disputes

Better information management should in theory lead to fewer disputes, as design and scheduling clashes are spotted before work begins on site, and an audit trail – or golden thread – of digital information should support change management, and also mediation and arbitration should a dispute fully develop.

In 2016, the Centre of Construction Law and Dispute Resolution at King's College London released its research report Enabling BIM through Procurement and Contracts[9]. While almost six years old, it highlights many considerations for contract drafters and managers, notably that most contract forms in use are unsuitable alone for good information management. More recently in 2021, Constructing the Gold Standard – An Independent Review of Public Sector Construction Frameworks[10] was published by the Cabinet Office to aid government clients in adoption of the Construction Playbook.

While not highlighting digitalisation specifically, the Conflict Avoidance Pledge[11], supported by CICES as a member of the Conflict Avoidance Coalition Steering Group, demonstrates that signatories have committed to deliver value for money and work collaboratively. The behavioural changes that come with digital transformation will help signatories in fulfilling the pledge, which has been recognised by Government in the Construction Playbook.

Another initiative supported by CICES and a good example of industry-wide collaboration is the Multidisciplinary Steering Group for Cost Assurance and Audits on Infrastructure Projects and Contracts[12]. This brings together construction lawyers, contractors, clients and finance advisors to address issues around cost assurance.

The 2018 Winfield Rock Report: Overcoming the Legal and Contractual Barriers of BIM[13] is also imperative reading. The report gives a good overview of legal professionals' understanding of the contractual issues around information management.

The future

Contractual arrangements that enable data sharing to truly transform civil engineering surveying and construction itself are yet to be fully realised. The commercial component of projects has to mature to allow industry to exploit the potential of information management to deliver benefits during the capital and operational phases of assets. In a nutshell, if contracting carries on as normal, then information management will always be pushing water uphill.

Progress is being made. The UK government is very clear on that, saying: "We will ensure that contracts are structured to support an exchange of data, drive collaboration, improve value and manage risk."[14]

1 https://www.gov.uk/government/publications/the-construction-playbook

2 Page 45, Construction Playbook

3 https://www.project13.info

4 https://www.ukbimframework.org/resources/

5 https://ukbimframework.org/wp-content/uploads/2019/11/GSL_Report_PrintVersion.pdf

6 https://www-smartinfrastructure.eng.cam.ac.uk/files/line_of_sight_july_2021.pdf

7 https://www.cpni.gov.uk/system/files/documents/eb/2a/cpnigiigimp-guidance-document.pdf

8 https://www.gov.uk/government/publications/independent-review-of-building-regulations-and-fire-safety-final-report

9 http://alliancecontractingelectroniclawjournal.com/wp-content/uploads/2019/10/Kings-College-London.-2016-Enabling-BIM-through-Procurement-and-Contracts-Centre-of-Construction-Law-and-Dispute-Resolution.pdf

10 https://www.gov.uk/government/publications/an-independent-review-of-public-sector-construction-frameworks

11 https://www.rics.org/uk/products/dispute-resolution-service/conflict-avoidance-pledge/

12 https://www.cfbusinesslinks.com/steering-group-csr

13 https://www.ukbimalliance.org/wp-content/uploads/2018/11/The-Winfield-Rock-Report.pdf

14 Page 12, Construction Playbook

CHANGE:TRUSTING AND BEING TRUSTED

It is understandable that any mention of change in the construction industry is met with scepticism. A few civil engineering surveyors will remember the Banwell Report[1] of 1964, more will remember the Latham Report[2] of 1994, the Egan Report[3] of 1998 and even early career surveyors will be aware of the Farmer Review[4] from 2016. All incredibly sensible, but

the change these reports called for was never fully realised. In 2009, the Wolstenholme Report[5] assessed the lack of progress since the earlier reports. The key reason for little change was the acceptance of the status quo by investors and suppliers.

There are signs that things are different now, and mechanisms are starting to drive change. The first real enabler of transformation was the 2011 UK government's mandate for centrally procured construction projects to be delivered using BIM by 2016. This was followed in 2020 by the Construction Playbook[6], which specifically calls on contracting authorities to use the UK BIM Framework[7] of standards and guidance and to support the adoption of the forthcoming Information Management Framework, which will sit behind the National Digital Twin.

These requirements need change to happen. The Infrastructure and Projects Authority's Transforming Infrastructure Performance: Roadmap to 2030 (TIP)[8] calls for a "step change in productivity and efficiency in the ways we plan, design, manufacture, construct and operate infrastructure."

For this step change, "successful delivery will require clients and suppliers to develop and adopt new ways of working across the board; to share information and embrace new technologies that deliver better performance and more balanced outcomes across the asset lifecycle. Project leaders will need to steer innovative delivery in line with the government's complex policy objectives, and embrace responsibility for the delivery of outcomes as well as outputs."[9]

Added to these industry and government movements are two societal impacts; the COVID-19 pandemic and climate change. The pandemic brought the benefits of autonomous and remote technology on site to the fore, with video communications and augmented reality replacing site visits, whilst further minimising the associated safety risks of being on site. The UK government's Build Back Better commitments are centred on sustainability and carbon economy. It is impossible to achieve change using traditional approaches. Increased digitalisation, offsite assembly and manufacture, and modern methods of construction are seen as key to reducing carbon emissions. Balfour Beatty, Costain, Laing O'Rourke, Skanska, Kier, Galliford Try, BAM, Amey and many other major contractors all have net zero pledges with dates ranging from 2030- 2050 requiring them to embrace digitalisation as a carbon cutting benefit. All these things are happening now. There is no room for scepticism as change is finally underway.

Fitting into a changing landscape

Where does the civil engineering surveyor fit in this changing landscape? As civil engineering is chiefly from public funds for public good, change is largely going to be driven by government mandates, policies and procedures. This doesn't mean it will be without its challenges – as the TIP states, the government's policy requirements are 'complex'. One common theme that came through workshops with geospatial surveyors was that clients don't always know what to ask for. For example, a client will ask for a 'drone survey', without any prior discussion with the surveyor over what the purpose for the survey is and what data and accuracy is actually needed. One surveyor used the term 'digital handholding' to describe the client/surveyor relationship throughout this transformational period. The geospatial surveyor is ideally placed to offer

advice on the most efficient survey method to get the data that is needed and can 'hold the hand' of the client as they become more familiar with data-driven construction and asset management.

This kind of early communication is called for in the Construction Playbook, which stresses the need for early supply chain involvement when developing the business case for projects. Civil engineering surveyors, both commercial and geospatial, must be a part of this.

Within civil engineering surveying, as within construction as a whole, there is a huge variability in size and digital capability throughout the supply chain. There is a wealth of expertise and experience in some of the smaller links in the construction chain that should not be overlooked. The risks and responsibilities of information management need to be carefully managed by those higher up the supply chain to ensure the contributions of smaller, less digitally astute and equipped businesses are transformed to fit the world of digital engineering.

In a joint report[10] from the Centre for Digital Built Britain and KPMG in 2021, the importance of SMEs in realising the productivity gains and cost savings of information15 management was highlighted. According to the analysis, direct labour productivity gains are potentially between £5.10 and £6.00 for every £1 invested in information management, and direct cost savings are between £6.90 and £7.40 from reductions in delivery time, labour time and materials. However, the report states: "The wider economic returns we have estimated rely on the productivity gains of IM [information management] being realised by organisations of all sizes, including the sector's 'long tail' of SMEs... there are particular barriers for smaller firms adopting IM which still need to be overcome."[11]

Tier 1 contractors can play a part in overcoming this hurdle as role models and by providing training on data management software to their supply chains. The interfaces of software systems should be clear and tasks should mirror those in widely used systems such as Microsoft Excel, to reassure those who have worked on these systems all their working lives and encourage them as they move to more collaborative and interoperable platforms.

Expectations need to be realistic, and many will employ dual systems for a short time while they build up trust in new systems. Commercial surveyors are by their nature suspicious – that questioning and fact checking trait is one of the chief skills that they are employed for and will play a key quality assurance role in the construction team of the future. However, telling a commercial team to use a new system without any prior engagement and understanding of their concerns will delay change and could build resentment.

Leaders need to play a role in giving their teams time to explore new systems and become familiar with them. Contracting is incredibly fast paced, and while it may be quicker for a quantity surveyor to download data into a spreadsheet and work on it independently, it is not an efficient use of that data. In this changing world, contractors cannot lose sight of the fact that data efficiency is as, if not more, important than cost.

1 The Placing and Management of Contracts for Building and Civil Engineering Work, 1964

2 Constructing the Team, 1994

3 Rethinking Construction, 1998

4 Modernise or die: The Farmer Review of the UK construction labour model, 2016

5 Never Waste a Good Crisis, 2009

6 https://www.gov.uk/government/publications/the-construction-playbook

7 https://www.ukbimframework.org

8 https://www.gov.uk/government/publications/transforming-infrastructure-performance-roadmap-to-2030

9 Page 6, Transforming Infrastructure Performance: Roadmap to 2030

10 The value of information management in the construction and infrastructure sector, 2021

11 Page 5, The value of information management in the construction and infrastructure sector

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