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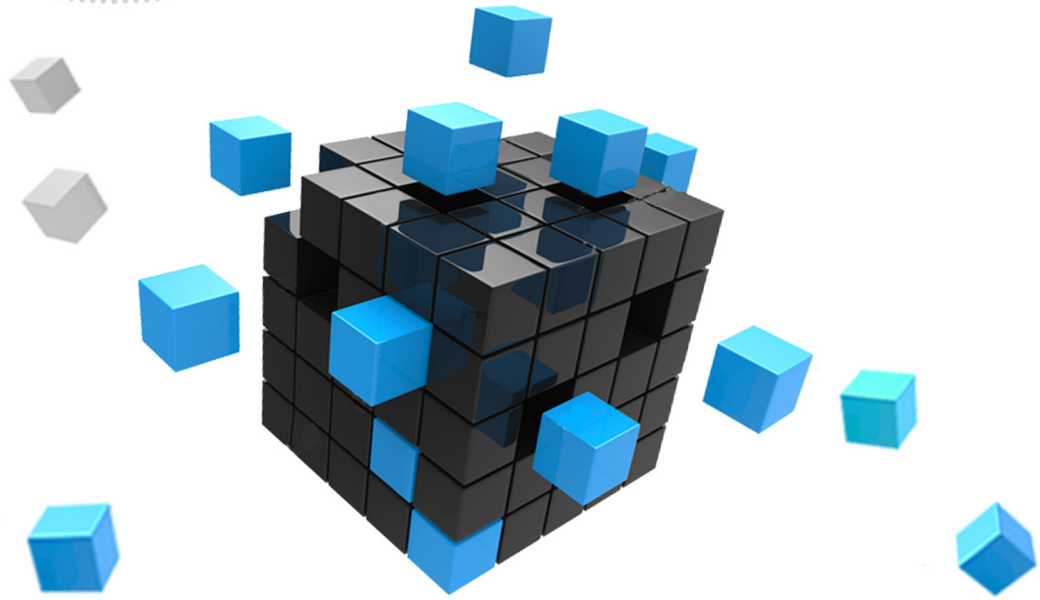
WHITEPAPER

Application of Spatial Solutions for time in construction

- Karen Sanders



Overview

Building Information Modelling (BIM) is gaining currency as a platform for central integrated design, modelling, planning and collaboration. BIM provides all stakeholders with a digital representation of a building's characteristics – not just in the design phase but throughout its life cycle…Above all, BIM facilitates collaboration among all stakeholders – from early design through to O&M and even to the decommissioning phase – and thereby holds out the promise of large efficiency gains…By providing a neutral and unbiased view, BIM can also contribute greatly to creating a level playing field in this regard, and more effective dispute resolution. (World Economic Forum & Boston Consulting Group, 2016)

This paper focuses on spatial solutions that are slowly being implemented globally, by early adopters in the construction sector, with an aim to make sector-wide improvements on time and cost management on major Engineering and Construction (E&C) projects.

This paper focuses on spatial solutions that are slowly being implemented globally, by early adopters in the construction sector, with an aim to make sector-wide improvements on time and cost management on major Engineering and Construction (E&C) projects. The key topic relates to spatial technologies, as an enabler, for knowledge management and communication, specifically pertaining to the other industry actors who work alongside major contracting firms, like facilitators, mediators, arbitrators, legal firms and professional associations. The importance of streamlined, symbiotic, multi-stakeholder approaches to monitoring major projects is one of the keys to managing time and cost.

Whilst this paper will focus on technologies, there is a need to mention that the successful adoption and implementation of technologies into the Engineering and Construction sector (E&C) relies on a successful business framework, that considers a whole of business approach. For example, the SURF framework: supply chain, user, relations, and future, enables a systems-level approach, and subsequently a systems-level impact, for decisions made even on a very microscopic level…SURF moves beyond the triple-bottom-line approach to sustainable development to place emphasis on the quadruple bottom line…Full stakeholder engagement tends to take place when there is a major infrastructure project in a location with a strong civil society and accountability mechanisms. However, full stakeholder engagement is necessary at all levels of a project (small and large, at inception and at closing). The Project Management Institute has recently added Stakeholder Management as its tenth knowledge area in the Project Management Body of Knowledge®, indicating a shift towards engaging all stakeholders for project managers (Waite, 2013).

Construction has been very slow to adopt innovation (Woudhuysen & Abley, 2004.), however there is a recent movement towards the adoption of technologies that foreshadow significant changes and improvements over past methods.

The new wave of IT innovation in Spatial Data analysis and micro-satellites now allows any nation to have extremely cheap access to information about many aspects of their natural resource management, urban design and planning. (Smith, et al., 2013.)

There are a number of multi-national software and hardware firms developing very sophisticated technologies to assist with the delivery of the ideal project, one that can effectively implement lean management practices across both the project and the projects area of impact, being the stakeholders and the broader community. These technologies include GPS tracking devices, LiDAR surveying, photogrammetry, Computer Aided Drafting (CAD), Building Information Modelling (BIM), machine learning, as well as computer gaming.

The application of the full range of new technologies is too great to consider in this paper, and, as such, the focus will be on 3D-BIM, 4D-BIM and computer gaming where the following items describe the high level attributes achieved by the implementation of these technologies:

3D BIM

A fully integrated 3D CAD model, 3D-BIM provides improved coordination and consistency of documentation among the E&C firms as well as the opportunity to inform the whole supply chain;

4D BIM

4D-BIM - linking the 3D model to a comprehensive database of project attributes enables a systems-level approach for decision making at a microscopic level. 3D-BIM captures objects and assemblies and 4D BIM introduces schedule and time;

Computer Gaming

Spatial gamification, utilising serious-gaming (, n.d.) technologies and can be applied to demonstrate logistics and phasing. Gamification facilitates the application to pedagogy and knowledge mapping for purposes of scenario modelling, tuition, and capturing experience/ best practices (Paper, 2015). Gamification introduces interoperability for users, allowing complex information to be broadcast more widely, interrogated, interpreted and understood by non-technical experts, creating a spatial data driven source of truth for project documentation.

This paper discusses the potential these three technologies have to transform the operating models of professional firms, where the three key themes addressed will be

Chapter 1

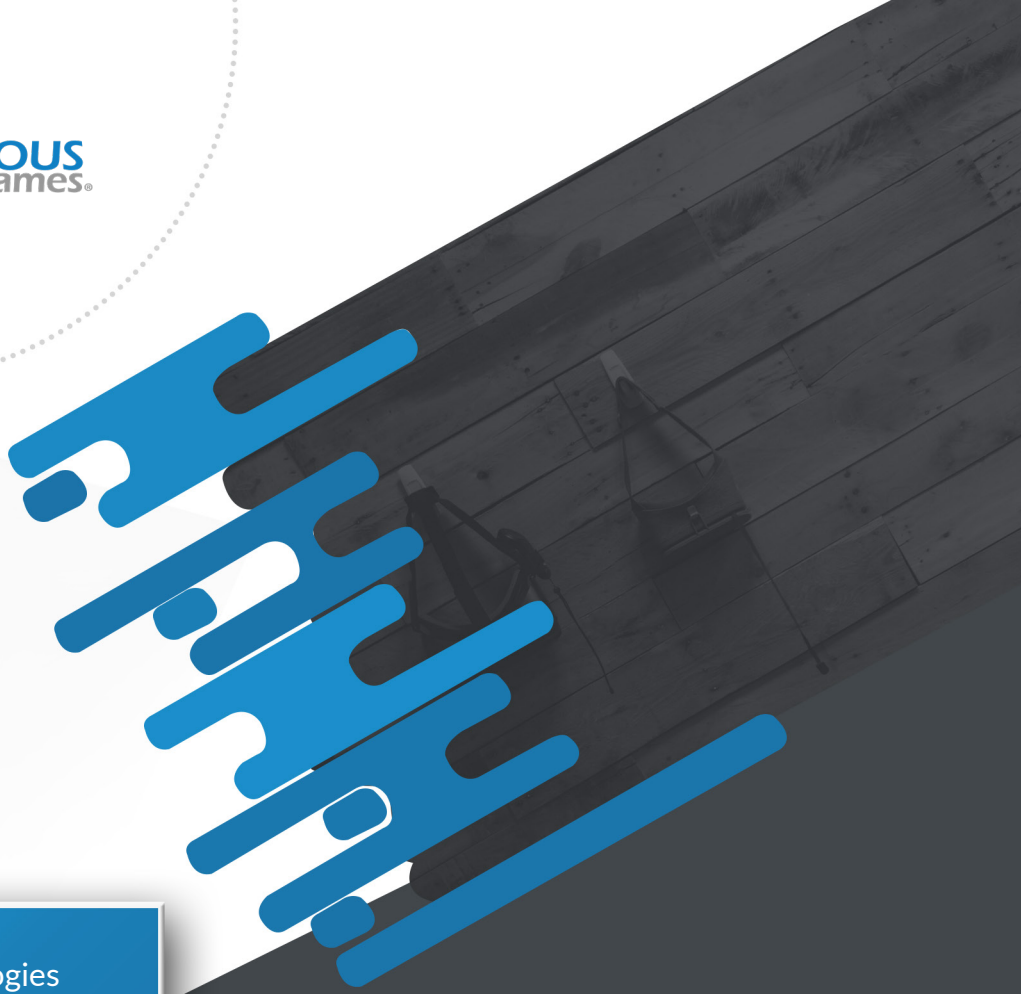
Seeking Innovations

"Construction is likely to be one of the most dynamic industrial sectors in the next fifteen years and is utterly crucial to the evolution of prosperous societies around the world.", says Fernando A. González, Chief Executive of global building materials company CEMEX.

The Engineering and Construction (E&C) sector has been slower to adopt and adapt to new technologies than other global sectors. While innovation has occurred to some extent on the enterprise or company level, overall productivity in the sector has remained nearly flat for the last 50 years. (World Economic Forum & Boston Consulting Group, 2016)

Technology is rapidly changing the way we do business on all levels, through all sectors. But what about construction? There has been incremental innovation over the centuries but the industry has tended to stay within the craft paradigm where it is confident it can deliver (Sebestyén, 2006).

When specifically considering 3D-BIM, 4D-BIM and computer gaming, these technologies provide a significant increase in precision, where reason and rationale hold sway over assumption and opinion, providing the mechanism for the demonstration of truth.



This makes this suite of technologies extremely valuable to the legal professional. As the complexity of projects has increased, a divide has been established between the designer/ engineer who is a technical specialist and the supporting professions, making real understanding of a problem increasingly more difficult. For a legal professional to assure themselves that their understanding of a dispute matter is correct, the process has become so complex that it can be perceived as unreliable.

The question that needs to be answered is - "Is there a positive cost-benefit model, within a SURF framework, for project wide implementation of an accurate 4D-BIM model?" This question is becoming more easy to answer favourably, particularly due to the trend towards the design of smart cities driving the need for a 3D-BIM model, that, in the future, will be incorporated into 5D-BIM (estimating/cost) and 6D-BIM (sustainability) and 7D-BIM (FM (Facility Management)) models.

'According to a recent study, full-scale digitalisation in non-residential construction would, within 10 years, be capable of producing annual global cost savings of $0.7-1.2 trillion (13-21%) on E&C and $0.3-0.5 trillion (10-17%) in the Operations phase.47 The core technologies enabling this transformation are listed in Figure 8 and described below.

(World Economic Forum & Boston Consulting Group, 2016)'

3D BIM

When considering major projects, they can generally be separated into vertical build sequences or horizontal build sequences. Vertical being buildings, facilities, plants or horizontal (or linear) projects like road, rail, tunnels, marine.

A 3D-BIM model provides full governance over the geometric design of a project, allowing for selection of design options and generation of survey and procurement data.

Vertical build projects are more likely to adopt a 3D-BIM model as the central repository of spatial data, as CAD based software platforms have been designed to support structural and architectural work flows, where standard API's have been developed for interoperability between different CAD suppliers, making a cloud hosted, integrated model achievable now. An integrated design model allows for rapid prototyping of both the design and construction of a project.

During the designing process fewer re-designs, processing, revisions and changes were found. The total cost of BIM implementation paid back with accurate ordering of materials and elements. Quantity of materials was consistent and there were no unnecessary or incompatible elements. In such a large project case the total amount of time needed to produce the documentation has decreased by around 30%. Such result was possible thanks to working on one model rather than on several dozen of different CAD files (PČkala, 2014).

A number of iconic horizontal build projects, London's Crossrail and Mexico's New Airport Tunnels for example, have experimented with the implementation of a 3D-BIM model as the single spatial data repository for the project. Horizontal projects are still designed with disparate software tools, where software is both GIS based and/or CAD based, and these software's operate independently. GIS modelling software's are moving towards 3D/4D-BIM capability meaning the civil construction sector will be later adopters of 3D/4D-BIM solutions than the vertical build sectors but that the technology is almost available for adoption broadly in horizontal build projects.

4D BIM

On a construction project, a single item is measured an average of sixteen times, often by different parties (Holes, 1967). Considering the mechanism for measuring data is usually a spreadsheet, resulting in the capture of unstructured data, with little data integrity assurance, where the 94% of spreadsheets contain errors in 1-2% of cells (Stephen G. Powell, 2008). The single largest error found by [Powell et al, 2007b] had an impact of greater than $100 million.

This is an example of one micro-level task that still occurs on projects, where the implementation of a robust CAD model, incorporating all design reference files, would optimise this task and provide a single source of accurate data, where all actors have access to a wide range of data.

The financial and reputational risk associated with the use of unstructured data sets is having a significant impact on the E&C industry.

One of the key value adds of 4D-BIM is that a relational database facility has been created that supports the 3D model within the same software package, creating a model-based technology solution. This means an increase in efficiency and functionality when compared to individual software tools and improved integration of data and the creation of interoperability between the design team and the planning team. Due to the long life cycle of projects and the progressive change in management teams throughout this life cycle, the implementation of a model-based technology solution provides greater certainty in data, where this automation reduces the overall time and effort required to measure items on a project.

Another key benefit that is rarely mentioned is the time interval between successive revisions of the 4D-BIM model. This automated solution allows for smaller time intervals between program updates where updates can be undertaken in real-time. The frequency of updates has a direct correlation to the minimisation of risk, and provides the mechanism for a time-optimal solution.

4D-BIM software packages have been created to ensure a single database holds the entire projects design data and this asset can be accessed by interdisciplinary teams, including support stakeholders like the legal professions.

At least nine countries around the world, including the UK (RIBA Enterprises and NBS © 2016, 2016), UAE, Scandinavia, Germany, France, Singapore, China, South Korea and USA have mandated the use of BIM, to a low LOD (Level of Detail), on all government funded projects.

Benefits of BIM are reinforced if companies exploit the new ancillary opportunities it offers – notably, a new way of collaborating and sharing information between stakeholders. Large productivity improvements can be achieved by optimising existing processes: the broader use of "lean" principles and methods, for instance, could reduce completion times by 30% and cut costs by 15% (World Economic Forum & Boston Consulting Group, 2016).

The tremendous potential of 4D-BIM is becoming more and more self evident. The challenge now is for professions like the legal profession to change their business models to include the promotion and adoption of these technologies.

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(RIBA Enterprises and NBS © 2016, 2016)

Computer Gaming

'Applying gaming technologies into E&C sector creates value adds in planning (time), approvals (time), training (time) and handover (time) and most importantly in dispute resolution.'

Computer gaming offers a range of further opportunities that are yet to be broadly understood or adopted by the E&C sector, including virtual tours of facilities, virtual trials to ensure operational readiness, and simulations, where users can experience the operational functions of various assets, prior to their installation. Computer gaming introduces the concept of a federated model, where incorporation of the 3D-BIM model, 4D-BIM database and additional large volume data sources are often linked via API's, to a single repository of data that links all these different systems.

The use of game engines provides new and exciting opportunities for technologies such as BIM. However, this sort of utilisation is still in its infancy... This model (BIM model) is then used in the game engine across a number of network connected client ends to allow end-users to change/add elements to the design, and those changes will be synchronized back to the original design conducted by the professional designer. Currently BIM does not provide a method to involve the end-users of the structures and promote collaboration between them and the design team... Currently many of the design review systems that are available provide insufficient allowance for the inclusion of all of the stakeholders who may sensibly contribute to this process. Current methods generally are conducted using peer review. An example of this is the use of a light box to overlay drawings to facilitate discrepancies to be identified between different elements of the design. Due to this sort of process becoming tedious it is found that the process is quite often not conducted efficiently and in some cases is not conducted at all (Shiratuddin & Thabet 2011). A prototype has been created by (Shiratuddin & Thabet 2011), where a game engine has been used to create a game where multiple users (members of the design team) can review a design together and interact with the design. (Edwards, 2015).

The entertainment gaming sector has, somewhat inadvertently, created a working stakeholder engagement tool that is ready for widespread use across the E&C sector. Applying gaming technologies into this sector creates value adds in planning (time), approvals (time), training (time) and handover (time) and most importantly in dispute resolution.

I know now, but did not know then, that jurors retain very little, perhaps as little as 20 percent, of what they hear. The retention rate goes up significantly, to as high as 60 percent, when they see something, and research has proven that jurors retain over 80 percent of what they simultaneously hear and see...

Some lawyers worry that a splashy, high-tech, obviously expensive presentation will prejudice their clients. They worry that a jury will view the party with lots of hardware and sophisticated graphics as the Goliath versus the poor and smaller David who makes do with handwritten poster boards, These worries are needless. I have interviewed lots of jurors and asked that specific question and never found one who admitted to having that perception. Rather, the jurors universally say that they give credit to the party bringing clear, concise graphics because it saves time and helps them understand the case (for which they are very grateful). The advantages of using visual aids far outweigh the risk of a litigant's being perceived as "slick" because of high-tech computers in the courtroom or "fancy" artistic depictions of the facts. Jurors bred on television expect lawyers to use this technology, just as they expect lawyers to provide the information needed to resolve a dispute. They are accustomed to receiving information this way and welcome visual aids as a learning device (Bloom, 2001).

The inclusion of the above suite of technologies, in the areas of arbitration and dispute resolution, provides an evidential, visual representation of a project's program. This in turn provides a single source of truth as compared to the ever present confusing array of documentation that often accompany claims, thereby introducing a level of simplicity and comprehension of highly complex and technical engineering projects to non-technical actors.

Chapter 2: Relationships and knowledge as risk

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Relationships and knowledge as risk

Two of the primary risks on major projects remain un-quantifiable, being people relationships and knowledge sharing. Behavioural scientists have undertaken studies on the significant negative impact the social sciences have on successful project delivery.

Over the past 20 years, project professionals and management experts have focused on improving the formal systems related to program governance, project management, and project-related technologies. However, while these new approaches have substantially improved results, today two-thirds or more of projects still miss their mark. Something is clearly missing. The surprising finding is that most projects fail for reasons that are widely perceived but rarely discussed. The study shows that the best predictor of the future of a project is the quality of just a handful of high-stakes conversations that must occur along the way—but tend not to. This silent crisis plays out in a deceptively simple dynamic that produces failure 85 percent of the time. (Grenny, et al., 2013).

For construction contractors, increased transparency through BIM will reduce the relevance of claims for change requests as a revenue stream (Boston Consulting Group, 2016).

This single statement shines a light on one of the key blockers for broader adoption of BIM. The introduction of BIM is seen to challenge traditional management paradigms around change requests being used to increase profitability on projects. Projects run in this manner generally have a culture that revolves around influencing, both positively but often negatively, Relationships and retaining key Knowledge, whether consciously or unconsciously, as a mechanism for advancement, where both relationships and knowledge are used to negatively intervene in strategies and create disruption to projects.

The introduction of technologies that increase transparency in process can be seen as a threat. BIM technologies influence a change in "The Silent Crisis", positively affecting both people relationships and knowledge. Project participants are more informed, blame culture is lessened and people move away from a culture of silence. The use of a BIM model means knowledge will be more broadly shared and understood. Transparency in these two areas are key for creating a step change in project savings, particularly related to time and materials.

The challenge is the adoption of these technologies by the E&C sector and the E&C's ability to change with the times.

In some particularly healthy systems, the entire set of beliefs and attitudes may shift to take account of changing times. But that is unusual. Most systems try to remedy new problems with old solutions. Implicit values, and the myths which are part of them, change slowly if at all. Of course, adjustments unavoidably take place at the level of behaviour; but these adjustments slowly increase the mismatch between the various levels. As Chris Argyris21 has pointed out often enough, there is a gap between what we think we believe and what our behaviour implies. And there are taboos against talking about the gap (Dick & Dalmau, 1994.).

Does BIM increase transparency of projects and reduce corruption? Arguably the legal profession, could be the initiator of corrective action by influencing the adoption of BIM technologies to remedy system problems. By becoming an advocator and implementer of these solutions, this will positively assist in closing the gap on the ever increasing number of projects that fail.

Chapter 3: Information and Communication Flow

'3D/4D BIM and computer gaming are all visual tools to enable better communication across complex projects.'

Digitalisation – the development and deployment of digital technologies and processes – is central to the required transformation of the construction industry. Innovations of this kind enable new functionalities along the entire value chain, from the early design phase to the very end of an asset's life cycle at the demolition phase.

3D/4D BIM and computer gaming are all visual tools to enable better communication across complex projects. Increasingly 3D BIM is being used to design projects, and more slowly we are seeing the adoption of 4D BIM and computer gaming. Unfortunately their has been no major shift by the legal professions to adopt these technologies to enhance their current business models.

In international arbitration, demonstrative exhibits are in many cases valuable and, in some cases, almost essential.4 The great benefit of an effective demonstrative exhibit is that it takes something that is complex and makes it simple. International arbitration abounds with complex factual situations, timelines, sequences of events, quantitative information and calculations. Construction arbitrations are often particularly complex because of the technical detail and volume of data central to the dispute. In these arbitrations, visual displays can capture information in ways that words cannot. Whether the demonstrative exhibit used is a chart, graph, model, video or other visual aid, it is a device that can get your message across to the tribunal so that the tribunal remembers it (Rovine, 2013.).

As arbitration has become more complex and the scrutiny of dispute resolution mechanisms has intensified, users have expressed the concern that arbitration is often too long and too expensive. One user has queried why a bridge can be built in one or two years but an arbitration to determine responsibility for delays and defects can take as long as three to four years (Commerce, 2017).

To achieve a step change in project management outcomes, which includes the time taken for an arbitration determination, there is a clear mandate for the adoption of spatial technologies to assist as visual aids in a dispute.

Chapter 4:
Sustainable Delivery Frameworks

"Current business models, strategies and capabilities will not be sufficient in any of these future worlds", says Michael Burke, Chairman and CEO of AECOM and Co-Chair of the World Economic Forum Infrastructure and Urban Development community. "Players along the construction value chain need to prepare strategically to thrive in the face of anticipated disruption." (World Economic Forum, n.d.)

The inclusion of spatial technologies on projects is still considered experimental. One of the earliest and well documented cases for the successful use of spatial technologies in project delivery is the MIT Stata Centre, designed by Frank Gehry. Due to it's complex design, implementation of a digitalisation strategy for the project was critical. One of the key lessons learnt from this project was the selection process undertaken for personnel onto the project. New recruits were hired based on their passion and ability to work within a new framework of project delivery. It was this key talent base that enabled success, the people before the technology.

A design and fabrication method that heavily involves computer technology changes the way not only the design team, but also the construction sectors, work. People involved in the process are required to have literacy in, and willingness to adapt themselves to, the new system. The organization of the project has to be structured by re-imagining the relation of design and construction in a way that blurs their traditional divisions, which means not only process integration, such as vertical integration, but also the integration of expertises (Matsushima, n.d.).

To achieve the above, good project governance must be assured from the outset. Rather than employing the traditional contacting model that encourages discontinuity across the phases of the project, where specialist consultants and legal professionals are engaged when and if required, projects should look at a different mechanism for engagement that enhances the efficacy of projects. An example would be to engage legal professionals on a monthly retainer model, attached to KPI's. This encourages firms to be a part of the journey of the project and, in turn, provides a secure cash flow for the legal firm, providing the necessary incentive to proactively participate along the course of the project. A project would outlay a similar quantum of funds over time, rather than a bulk outlay towards the end of a project when an external firm is engaged to pursue a claim. At the final stages of the project, the size and complexity of the claim can often be unmanageable.

Conversely, the legal professional needs to understand and be confident in the use of spatial technologies as a delivery framework for good project governance, as their advice in this area would go a long way to setting a project on a path to success. Introducing spatial technologies for project management means claims, be they cost or time related, can be identified in real time, and accurate supporting evidence provided, as part of the day to day reporting activities.
It is beholden on both the contractor and the legal firm to commercially engage in a manner that encourages good governance across the duration of the project.

Chapter 5: Implementation Examples - Claims

Taking the above into consideration, following are some key examples of recent projects that adopted spatial technologies to illustrate the cause-and-effect relationships of their commercial claims, where the argument was not obvious, or even counterintuitive, to non-technical professionals, engaged to examine and make a determination.

Timor-Leste - Maritime Boundaries

A landmark agreement to be signed in New York tomorrow (AEDT) will close the door on the long and bitter dispute between Australia and East Timor over their maritime boundary (Barker, 2018).

The first step towards resolution of any dispute is for the affected States to attempt to agree the boundary between themselves. Articles 74 and 83 of UNCLOS each provide that if no agreement can be reached "within a reasonable period of time" then the States shall revert to the formal dispute resolution procedures... (Emad Khalil, 2005)

The negotiation is being conducted before a panel of experts under a never before invoked dispute resolution process from the UN Convention on the Law of the Sea....An important element of any successful international negotiation is to 'sell' the deal to constituents. In this case, the invested audiences are the Timorese public and a small number of Australian-based advocates (Bec Strating, 2017).

To assist with "selling the deal to constituents", a GIS based computer gaming solution was adopted as one of the innovative exhibits in the arbitration. This was purposeful in its adoption as it was recognised that an accurate visual representation accompanied by a timeline of events would provide a sound basis for informing stakeholders.

Wiggins Island Coal Export Terminal Variations to Contract

'For a claim of this nature, visual assets were extremely valuable for both the applicant and the respondent, where an accurately represented BIM model presented a visual source of truth of the actual events that occurred on each day.'

A claim, by a contractor, for variations to their contract went to trial in the Supreme Court of Queensland. The respondents claim related to delay and disruption costs that included inclement weather, increased labour, plant and transportation, delayed access, re-sequencing and additional works. The claim included multiple variations, where there were many parts and items that made up each variation. The outcomes sought were varied, being cost and/or extension of time.

Given the "degree of overlap" of these claims and the technical nature of the evidence to support them, to aid in non-technical actors comprehending the events, the contractor developed two BIM-4D models of the project, one illustrating planned works and one illustrating actual works. These BIM models were hosted in a computer gaming interface allowing all actors to access an accurate visual narrative of the project where the user could view the planned versus actual sequence alongside each other.

As a large quantum of the claim related to plant, the 4D-BIM model was created such that major plant interactions could also be witnessed, providing the visual interpretation for delays and re-sequencing activities.

Duplication of content across claims was identified as a risk and at various stages through the proceedings, videos, with narrated voice over, were produced as an aid for all actors to be informed of the complex nature of the claim.

These same assets were used to provide the respondents board with certainty around the validity of the claim as well as being used on-board new talent to the claims team.

For a claim of this nature, visual assets were extremely valuable for both the applicant and the respondent, where an accurately represented BIM model presented a visual source of truth of the actual events that occurred on each day.

Of note, on a separate claim, an accurate BIM model has been considered as evidential, setting the precedence for the use of these technologies in legal and arbitration cases

Chapter 6

Industry's Capacity for Acceptance

Given the economic significance of the construction sector, R&D investments among E&C companies are surprisingly small. In fact, the 2014 EU Industrial R&D Investment Scoreboard ranks construction among the least R&D-intensive sectors, with a mere 1% of net revenues allocated to R&D.

World Economic Forum
& Boston Consulting Group, 2016

The challenge now is to achieve widespread adoption and proper traction. Wherever the new technologies have properly permeated this fragmented industry, the outlook is an almost 20% reduction in total life-cycle costs of a project, as well as substantial improvements in completion time, quality, and safety. (World Economic Forum, 2016)

One of the major dilemmas we face both as individuals and as a society is simplistic thinking - or the failure to think at all. It isn't just a problem. It is the problem ... Thinking well is more urgent now - perhaps more urgent than anything else - because it is the means by which we consider, decide and act upon everything in our increasingly complex world ... If we are to think well, we must be on guard against simplistic thinking in our approach to analysing crucial issues and solving problems in life (Peck, 1998, ©1997.)

The up and coming millennial generation may well be the catalyst for the change that the E&C sector has been slow to adopt. This generation has little desire to resist change and is not wedded to established traditions, being taught to look outside the current paradigm. Coupling this with an increased knowledge in technology, the next 10 years will see an unprecedented shift in technology adoption in the E&C sector.
In addition, the E&C sector now has the benefit of harnessing technology advances designed in other fields of endeavour, like 3D printing and robots for example, and using these to create a new level of understanding of how things can be done in the construction industry. This will shortcut R&D endeavours as the initial innovative thinking is done and the next step is application into industry, providing the much industry needed transformation.

For the E&C sector there is a long way to go before the impact of spatial technologies is felt on a global scale, but it is vital that legal professions understand these technologies and how to harness them. Whether it is 3D-BIM, Internet of Things, Robots or Smart Cities, all these industries are supported by spatial data, and the use and adoption of spatial data is increasingly being seen in our everyday lives and, when adopted into the E&C sector will see the dissolution of current business models as new approaches will be adopted to deliver in this sector.

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