Chapter 16 - The new role for emerging digital technology to facilitate IPD and improve collaboration: a disruptive innovation perspective.

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Introduction

In order to achieve Integrated Project Delivery (IPD) traditional ways of contracting, working and the culture of the industry itself must change. Such transformational change invariably requires some form of catalyst (DeGroote and Lefever, 2016). The significance of construction to the global economy, the broadly ageing workforce, low productivity, high risk, accelerating costs, widespread vertical and horizontal organisational integration, and various other key factors might each provide the necessary impetus for change (Hong Kong Development Bureau, 2018). However, it is emerging digital technology that is set to disrupt the industry perhaps more than any other factor (World Economic Forum, 2018). Certainly emerging digital technologies will facilitate many of the key changes required for IPD to be realised (Kahvandi et al., 2017). However, this Chapter focusses on the role of emerging digital technology as a disruptive agent, and role that emerging digital technology can play simply as the catalyst of change.

Disruptive innovation is not something any organisation can formalise (Christensen et al., 2015). There is an old adage that change will take far longer to take effect than you might predict, and will be far more significant than you can imagine. Significant change is the result of a revolution not of evolution. All this to say, that transformational change cannot be legislated for or planned in detail. Fundamental change, which is what the adoption of IPD would represent, like disruptive innovation, must be facilitated (Christensen and Overdorf, 2000). This Chapter will propose a new role for emerging digital technology in the context of IPD, in the role as a catalyst for change.

Thus there is a deep and fundamentally complex question to be addressed in this Chapter. How might the industry, an organisation or a motivated individual most effectively leverage an emerging digital technology to disrupt the extant construction industry and promote fundamental change?

The Chapter begins with a consideration of the construction industry and why it is ripe for disruptive innovation. It then broadly overviews the emerging digital technologies of particular relevance to the construction industry at this time. Adopting virtual reality as a case in point, the Chapter frames a three-phase approach to disruptive innovation: sourcing and evaluating emerging digital technologies; developing and producing digital prototypes; and pitching for a pilot evaluation project. A fourth phase that deals with the entrepreneurial and business development aspects of disruptive technology innovation is beyond the scope of this Chapter.

This Chapter links to Chapter 17 on taking a Lean Construction perspective of IPD that includes discussion on agile and scum approaches and also to Chapter 30, the case study of an advanced factory manufacturing pre-cast concrete elements in an integrated supply chain.

Why is a new role required?

Report after report internationally, from Murray and Langford (2003) onwards, has identified the same key characteristics of a construction industry facing fundamental challenges and, consequently, increasing pressure to change (see, for example, HM Government, 2013; Hong Kong Development Bureau, 2018). The broadly common set of fundamental challenges can be summarised as follows:

- **workforce:** the construction industry has long adopted a fragmentation of skills across design, engineering, construction, trades, management, supply, operation, etc. Most especially in the trades and site labour context, the age of the workforce is increasing, there is a crisis in the number of young workers coming into the industry, and a significant and enduring gender imbalance. The contracting labour supply market promotes lower quality entrants with reduced training requirements.

- **structure:** a generally adversarial contractual arrangement, with separation not only between supply and demand but across the entire production team and along the complete delivery and operational process. The strictly competitive nature of most construction activities tends to promote poor procurement decisions and raises difficult barriers for efficiency improvement and change management.

- **nature:** the predominantly bespoke nature of much construction work renders the industry as characteristically high risk and high cost. There appears to have been a general acceptance (by the industry itself as well as by its clients) that the time, cost and/or quality of construction will almost inevitably perform poorly.

- **business:** construction is one of the critical national economic levers and consequently, more than most sectors, is subject to highly fluctuating cycles of demand. With fluctuating demand comes pressure to drive up volume, minimise overheads (such as sunk costs in research, workforce, or capital equipment), to price gouge, and over-rely on litigation.

- **industry image:** there is now a deeply-entrenched public perception, generally well-founded, that construction is physically and mentally over-demanding. The financial rewards and job satisfaction may be high, the achievements may be tangible, but the shadow cast by poor health and safety outcomes, the traditionally austere working environment and evidently embedded prejudices remains pervasive.

- **productivity:** construction is an industry plagued with the reputation of low productivity growth. There are clear grounds for claiming that construction has failed to match the productivity improvement of other, more manufacturing-based, industries. Given the significance of the construction industry to most national economies and growing investment in the built environment in general, the relatively poor productivity performance of construction is highlighted as perhaps the major challenge for the industry going forward.

These challenges determine that the construction industry is primed for change (Farmer, 2016). At the same time, emerging digital technology is offering a broad palette of industrial change enablers (Pricewaterhouse Coopers, 2017). Here again there is broadly consistent scoping internationally of which emerging digital technologies will most impact the construction industry. Indeed there is broadly consistent scoping of which emerging digital technologies will most impact industry and society in general. The significant technologies include:

- **cloud computing:** this is a general term for anything that involves delivering hosted services over the Internet. Cloud computing is accelerating the uptake of digital innovation in construction by delivering improved software services and enhanced mobility.

- **building information modelling (BIM):** where the digital representation of a building geometry is supplemented with an integrated database of related construction and operational information, such as material type, manufacturer, cost, maintenance regime, etc. In particular, BIM promises to integrate the design, construction and operational phases of a project, aiming to reduce the incidence of rework and better enable production efficiencies.

- **augmented and virtual reality:** is able to immerse the user in a highly realistic rendition of a proposed building, and/or superimpose elements of a digital model onto the real world. The technologies are being used to improve design communication and support technical work activities on site.

- **scanning and automated data capture:** creating digital representations of the as-built project (whether existing, in progress or completed) is critical to the design, construction and operation of a built facility. The rapid development of LiDAR (laser scanning) and photogrammetry, twinned with the availability of low-cost drones (unmanned aerial vehicles) has allowed for safe, efficient, timely and accurate digitisation to drive significant gains in the overall project management.

- **internet of things (IoT):** describes the system of connected electronic sensors and actuators attached to objects in the real world. Electronic sensors now come in a multitude of forms and can be used to monitor operating conditions, performance levels and/or the physical state of any entity at any given time. This capacity to create a digital twin of the real world is driving an explosion in new applications and services where live data and data captured over time can be used to better inform decision-making. What is especially exciting about this live data and data collection over time is that it can also include user behaviour data. That means the circular dependency between building performance and user behaviour can finally begin to be closed.

- **data analytics:** few corners of the economy, and life in general, are not being or have the prospect of being impacted by digitalisation and the massive data sets that this process of digitalisation will produce. Data analytics refers to the growing range of techniques and algorithms used to interrogate and make sense of these super-large data sets (so-called, big data). For the construction industry this offers a transformative opportunity to shed the traditional find-and-fix approach to problem solving, and to adopt instead a predict-and-prevent approach. The impact of data analytics on the structure and very nature of the construction industry can be expected to be rapid and ubiquitous.

- **blockchain:** due in part perhaps to its initial association with bitcoin and the dark net, blockchain is often considered something of a sinister technology. In operation it could have quite the opposite implication on the construction industry, as it offers the potential to make any transaction (whether financial, contractual, communicative or any other form of exchange) secure and transparent. That is to say, blockchain technology moves any transaction record into a distributed representation that is permanent, virtually impossible to hack, and lodged in a sequence of related past and future transactions. Given construction activity generates masses and masses of complex and critical transactions as a matter of course, the potential for blockchain technology to provide improved transaction management is hugely significant.

- **machine learning and artificial intelligence:** the promise of machine learning and artificial intelligence seems in hindsight to have been long coming, but is now very definitely upon us. Machine learning is a particular branch of artificial intelligence that employs increasingly sophisticated algorithms to identify patterns from data records and utilise these to automate model building and make decisions with minimal human intervention. How completely artificial intelligence will replace human decision making is a subject for ongoing debate, but it will certainly have significant capacity in that regard. The accelerating computational power available and increasing digitalisation of processes is advancing the capabilities and applications of artificial intelligence substantially.

Collectively, these and other digital technologies are referred to in general as Industry 4.0, and specifically as Construction 4.0 (Pricewaterhouse Coopers, 2016). This is the term used to describe the fourth generation of industrial revolution, the digitalisation of industries. There is a strong sense of Construction 4.0 being the next, almost inevitable, evolution of the construction industry. However, the construction industry is renowned as being slow to adopt digital or any other form of innovation. There is a strong justification for this reputation (Frost and Sullivan, 2018). Certainly different construction organisations are at different stages of the digital transformation process, with the majority still to embrace digital innovation as a fundamental driver of business operations.

The broader impact of Industry 4.0 has also been discussed elsewhere in terms of collaboration and the integration of knowledge, skills and attributes (Walker and Lloyd-Walker, forthcoming). The workforce must adapt to these emerging digital technologies as a fundamentally novel economy with creative new ways of working. The relevance of this Chapter to wider discourse is also highlighted.

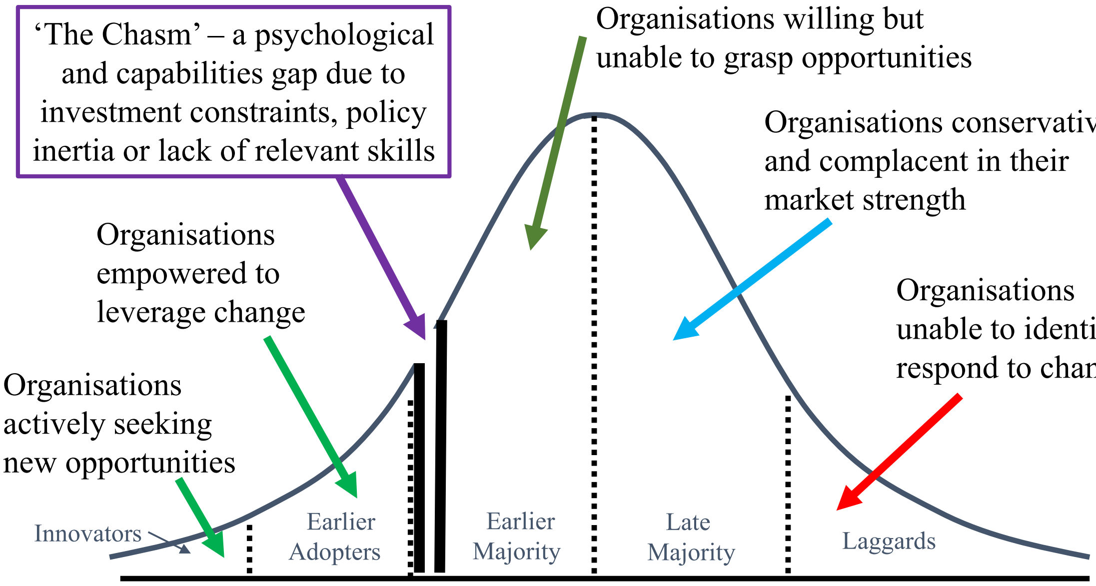

Figure 16.1 – The innovation adoption curve (Adapted from Rogers, 1962)

Figure 16.1 represents the classic innovation adoption curve initially proposed by Rogers (1962). It illustrates what is perhaps the natural intuition, that there will be a proportion of businesses keen to engage with digital technologies as early adopters, and the significant majority of businesses that prefer a more conservative approach. This conservative majority tends to comprise the larger, industry leading and more complex incumbents, for whom change often represents a direct challenge to the very business and operational models that made them successful in the first place. The remainder of the conservative majority comprises the many smaller, potentially more agile businesses. However, for the majority of small construction organisations digital transformation can require a level of capital investment they may be unable to achieve, a whole of industry change they may feel unable to influence, and demand new digital skills they may find difficult to acquire (Ernst and Young, 2017). Within the construction industry sector there is a strong sense of systemic inertia.

The early adopters follow the innovators who enjoy or have a propensity to experiment and drive innovation through a belief that there is always better ways to do things. They want to make changes to capture potential value from product and process improvement and share that value with their customers. The early adopters, however, frequently are intelligent smart adapters rather than the more 'copycat' adopters who follow later. Through cross-disciplinary, cross-generational and other forms of diversity of people engaged in the adoption strategy, early adopter organisations experiment in how the innovation impacts their organisation's systems and routines and so form an intelligent way to adapt effectively. This is a positive outcome to early adoption regardless of the success or otherwise of any particular innovation. Early adopter organisations find collaboration and integrated group experiences useful in drawing together the multiple perspectives required to more fully explore and anticipate potential unintended benefits and adverse consequences of innovation.

Early technology adopters everywhere face the challenge of traversing the, so-called, chasm that can block broader uptake. There is a real sense that any one part of the conservative majority will avoid adopting a new technology until the rest of the conservative majority has already adopted that technology (Saxon, 2018). As Christensen *et al.* (2015) point out, this group of organisations may have good reason to hold back from adopting and adapting technology changes. Change often requires an established organisation to provide extra value (at extra cost to their margin) for services and features that the client may not immediately perceive to be of equal value to them. For the conservative majority of organisations, disruptive innovation may actually not be developed or promoted for sound short term reasons. We experience this impasse with many forms of digital innovation. At the same time as the more risk averse businesses are most comfortable sustaining current market dynamics, there is an unfortunate but understandable tendency for many digital technology commentators to focus on the future and what more comprehensive digital transformation will deliver in the future. For example, the vision is painted of a construction site of the future where robots replace humans, new materials self-assemble, drones monitor progress and machine learning predicts and solves problems before they arise – or some such vision (see for example, Balfour Beatty, 2017). Regardless of the veracity of such predictions, their very futuristic nature can only feed the reluctance of the conservative majority to implement digital technologies now – "we can deal with the future, in the future". Where early adopters are attracted by the futuristic nature of these new technologies, such innovations regularly fail to cross the chasm and gain broader uptake by the conservative majority because the message does not change accordingly.

The chasm illustrated in Figure 16.1 can also be addressed more directly through IPD adoption. For example, the rigidity of being restricted by legacy systems can play a significant role in blocking innovation. However, that role may be obviated through an IPD approach where participating organisations are required to adopt a single, more unified approach – to digital communication technologies, for example. The, so-called, skunkworks nature of an IPD project, wherein a project alliance allows freedom to experiment and broadens the diversity of the integrated team, applies multiple perspectives to make sense of the application and adaptation requirements of an innovation. The use of a skunkworks approach has been used to trigger the successful adoption of radical innovation technology for many years (Wolff, 1987; Gwynne, 1997; McKenna, 2010).

One might conclude that emerging digital technology will fail to facilitate IPD and improve collaboration beyond the early adopters, as long as the chasm phenomenon on the innovation adoption curve applies. The chasm phenomenon applies in large part because successful construction companies are adept at the stepwise/continuous and breakthrough improvements in their operations that allows for products and services to evolve with the technologies over time. This is the conventional model where innovation is driven by the market leaders (Christensen *et al.*, 2015). As things stand, there will be a minority group of early adopters for any new technology, but the conservative majority will evolve their uptake of the technology over a longer term. The chasm will take time to breech, and the evolution of IPD and improved collaboration will mark a similar pace of change. In order for new technology innovation to provide the necessary catalyst for the substantive, whole of industry changes required to drive IPD and radically improve the performance of the construction industry, a different perspective is required. The new role for emerging digital technology required to facilitate IPD and improve collaboration called for in this Chapter is an entirely more disruptive model of innovation.

A Disruptive Innovation Perspective

There is a growing literature specific to disruptive innovation which all stems from the original formulation by Christensen (Christensen and Overdorf, 2000). However, disruption is one of those terms that has been eagerly appropriated in common parlance, and as a consequence has come to mean pretty much anything that changes the dynamics of a market. The formal definition of disruption is more specific. A more specific definition of disruptive innovation is important as it provides a more discerning lens for particular forms of innovation and more particular lessons on how to be successful in driving substantive industry change through new technology innovation.

The theory of disruptive innovation is particular to a process where emerging organisations with limited resources are able successfully to challenge, and ultimately displace, the established incumbents in an industry (Christensen *et al.*, 2015). In so doing the industry is radically changed and improved. More specifically, where the incumbents evolve in response to new technologies and market forces, the disruptive organisation often leverages new technologies to establish low end or new market footholds and develops these to displace previous incumbents by reinventing the market dynamics. Disruption has occurred when the mainstream market adopts the new business model, practices, and/or technologies of the disruptive innovator.

The theory as explained by Christensen *et al.* (2015), is generally applied to radical product or service innovations that fundamentally challenge an entire industry. In a literature review paper, Christensen et al. (2018) traces the origins and history of disruptive technology change from rapid advances in the disk-drive industry through to the rise of Uber and Netflix. However, in this Chapter we are more interested in how the nature of disruptive change might be applied at the project level, more specifically at the project level of the infrastructure engineering sector. Little has been written on disruptive digital technological change in this context, but we can certainly learn from the lessons and build on the foundations laid by scholars such as Christensen and his colleagues (Christensen *et al.*, 2015; Christensen *et al.*, 2018).

At the level of the project, disruption may be considered through the lens of the individuals that change the way that the projects are delivered. IPD, as stressed throughout this book, is a relational approach to project delivery in which the project owner and delivery teams collaborate, and often in the case of alliancing this includes the facility operator. IPD itself already implies a degree of innovation. But transformational change, the kind of quantum change to how a sector operates, at this moment in time is best be driven through the disruptive application of digital technologies. Specific to IPD, this refers to the digital technologies that are capable of creating a more collaborative project setting for design, construction and operation. The key potentially disruptive digital technologies already identified relevant to IPD include cloud computing (making access to data more ubiquitous), and advances in BIM (including the use of immersive technologies to create a virtual and augmented reality perspective of a project that may have been captured in using drones or data point clouds from digital sensors). These key digital technologies will inevitably drive significant change, but the aim of this Chapter is to highlight how such technologies can also be leveraged through a more disruptive agenda.

A good example of significant digital technology-driven change is discussed elsewhere in this book relating to the Victorian Level Crossing Removal Program alliance (see Chapter 14 section on digitisation for project stakeholder engagement). In that example, a digital model was created from drone data capture as well as sensors that created data point clouds. The model was then used to test the design practicality and safety with train drivers and other stakeholders to ensure that the design would work as anticipated without unintended consequences that may prove dangerous or costly later, after handover of the facility. These are significant innovations as they radically change the way that the design of this type of structure may be undertaken. Similarly, other digital technologies promote major improvement in the operational efficiency of project delivery - including the use of radio frequency identity tags to know the location of objects, or to monitor such things as moisture, movement or functional efficiencies. In the case of IPD projects, where the project owner is likely to be relatively sophisticated and appreciate the value (both short term efficiency cost/time value and longer term operational effectiveness value), radical innovation can have a significant market advantage for those who participate in this kind of collaboration. First, for example, those IPD participants in an alliance that work with an owner participant in developing the effective adoption and adaptation of digital innovation may gain confidence to be invited to tender for further work, thus reducing the transaction costs of their seeking such opportunities. These non-owner alliance participants may also find that their absorptive capacity affords them significant advantage against future alliance syndicate competitors. Absorptive capacity, the ability to absorb new learning and knowledge and develop the dynamic capabilities to exploit these, has been identified as an important advantage of IPD participation and alliancing in particular (Love *et al.*, 2016).

The following Figure 16.2 combines ideas proposed by Christensen *et al*. (2015) together with ideas about gaining dynamic capabilities through absorptive capacity gains. Teece was an early scholar of dynamic capabilities (Teece *et al.*, 1997; 2012; 2014) and describes them as sensing, seizing, and transforming. This approach seeks to combine sophisticated opportunity identification for improvements and innovation, together with the ability to take action to capture these improvements and to change direction and transform processes and strategies, to rapidly adapt to improvement changes. Manley and Chen (2017) demonstrate how organisational learning, through developing enhanced absorptive capacity, occurs in alliance projects. As a consequence, we see the growing acceptance of IPD as a means to gain enhanced competitive advantage through collaboration on the application of emerging digital technologies. While at this point this process seems to occur piecemeal, there is a growing realisation of the strategic benefits of engaging with these technologies and experimenting or 'playing' with them to ultimately gain competitive advantage while enhancing productivity and value creation in a broader sense.

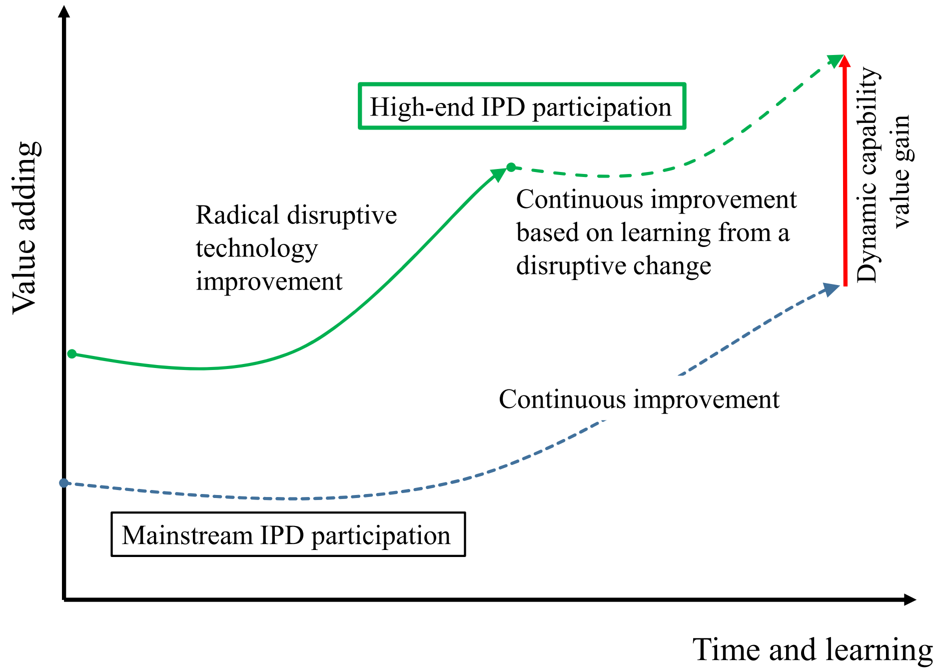

Figure 16.2 - Disruptive innovation in an IPD context

Figure 16.2 illustrates one view of how the disruptive entrant might enter the market. In this IPD context we see the difference in value creation by two hypothetical IPD syndicates. The mainstream IPD participation experience assumes continuous improvement, and greater value adding normally occurs through this process. The line dips a little but rises over time because it takes time for organisations within an IPD syndicate to effectively collaborate and so at first there may be alignment and adjustment inefficiencies that later become resolved and overcome. The higher-end IPD syndicate, with greater propensity for innovation, is also more likely to have high levels of absorptive capacity. Indeed, their potential value adding may even start at a higher level than comparable mainstream potential. However, where an IPD syndicate can be configured to include and enable the groups of innovators and early adopters illustrated in Figure 16.1, embracing and experimenting digital and other process innovations becomes both intrinsic and potentially more disruptive. This capacity is illustrated in Figure 16.2 by the steep solid curve. The higher-end IPD syndicate does not merely *adopt* digital technologies but develops them as disruptive innovations and ultimately *adapts* them further through continuous improvement and adjusting to changed contexts caused by the introduction of disruptive technologies.

Figure 16.2 illustrates how the higher-end IPD syndicate increases the dynamic capabilities of all participants, including the owner participant, and this also prepares them better to embrace the next set of radical innovation opportunities. Positioning the project syndicate as a higher-end IPD organisation transforms the individual participants and organisations to be more responsive to change and opportunity, providing tangible competitive advantage over mainstream competitors.

With the explosion in functional capability brought by new digital technologies, the early adopters with experience in the application of the technologies are seizing new opportunities to disrupt established construction markets. It follows that the accelerating scope of new technologies is challenging the incumbent organisations on multiple fronts. Of course not all disruptive entrants will be successful, but their number, speed and capacity make for a particularly challenging environment for the executives of incumbent organisations.

In summary, the construction industry is ripe for exactly the kind of change needed to facilitate IPD and improve collaboration. The emergence of new digital technologies brings new capabilities and new opportunities to the construction industry, but the conservative majority of incumbent organisations (consciously and subconsciously) tend to block or delay the widespread adoption of these innovations. For the substantive, whole of industry changes required to drive IPD and radically improve the performance of the construction industry, a particular perspective on technology innovation is required. This Chapter proposes disruptive innovation as a specific approach to achieving radical change for good in the construction industry. What might such an approach actually require?

We propose a particular framing of disruptive digital technology innovation around three key phases: sourcing and evaluating; developing and producing; and pitching and piloting. A possible fourth phase that deals with the entrepreneurial and business development aspects of disruptive technology innovation is beyond the scope of this Chapter at present.

Phase One: Sourcing and Evaluating Digital Innovations

To become an effective innovator requires first and foremost thoughtful imagination (Horth and Buchner, 2014). The disruptive innovator needs to recognise the commercial potential of a new technology to deliver an effective new service or product to the low end of the market. Thoughtful imagination needs to be informed through relevant, direct experience in the application and development of digital technologies.

Sourcing information and feeding the imagination needs to extend across a raft of research initiatives. For example:

- **academic research:** a systematic review of the academic literature may be appropriate in certain circumstances. However, the rapid development of new digital technologies tends to outpace traditional academic publishing, and access to academic publications is generally problematic for non-academics. Far from offering a comprehensive literature search, there is of course the Google Scholar search engine which does provide a rudimentary search of scholarly literature across many disciplines and sources (https://scholar.google.com/). More specific to the construction industry is the searchable database of construction management research publications managed by the Association of Researchers in Construction Management (ARCOM) (http://www.arcom.ac.uk/abstracts-search.php).

- **creative thinking:** disruptive innovation is not necessarily seeking some unique technological invention, rather it draws on initiatives from other contexts and reappropriates new ideas. Many inspiring concepts and ideas are presented in a readily digestible form through the now 2,900 plus TED Talks (https://www.ted.com/talks). TED is a clearinghouse of free knowledge presentations from the world's most inspired thinkers. In addition to accessing great ideas, access to innovative technology applications can also seed new possibilities in construction.

For example, KickStarter (https://www.kickstarter.com/) has successfully connected over 150,000 project initiatives with the resources and support needed to turn the ideas into projects. A regular search of one or more of the many crowd funding websites provides excellent exposure to how other creative thinkers are looking to develop their innovations. Along with proposed project ideas, a review of recently launched project initiatives can also be really helpful in identifying potential applications in construction. For example, the novel features and functions of recent game and resources launched on the Oculus Store (https://www.oculus.com/experiences/gear-vr/) can provide specific inspiration for virtual reality applications in construction.

- **technology newsletters:** the pace of change in digital technology is accelerating. Staying abreast with the latest developments is a daunting task. A number of online resources now cater to the growing community with an interest in digital innovation. There are regular newsletters on digital technology innovation in general, with the likes of TechCrunch (https://techcrunch.com/). Other online feeds are more specific to digital innovation in the construction industry, such as JB Knowledge (https://jbknowledge.com/). There is also a growing support community specific to particular technologies applied to the construction industry, where we find the likes of BIM+, a broad-based construction technology newsletter initiative by the Chartered Institute of Building (http://www.bimplus.co.uk/).

- **technology reports:** a more in-depth complement to the technology newsletters are the technology reports. These are now produced by dedicated technology analysts, such as Frost and Sullivan (https://store.frost.com/); on behalf of construction industry bodies and government agencies by insight consultants, such as Ernst and Young (https://www.ey.com/en_gl); and through reports and commentary by the larger construction industry organisations, for example, Arup (https://www.arup.com/). Each of these and their equivalent organisations are excellent resources for contemporary commentary on emerging digital technology innovations.

There seems no end to the information available on digital technology innovation, but as previously indicated, technology commentaries can tend to blue-sky their predictions. Future perspectives have their place, but disruption requires more immediate action and first steps. The initial focus needs to be on what is technically possible currently. For this reason, effective evaluation of any new digital technology as a disruptive innovation really requires direct experience in the use of the technology. Ideally this would be direct personal experience, but an acceptable alternative is the experience gained from a balanced and well-documented case study. Find case studies of how the technology is actually being used and applied.

Having experienced the technology (personally or vicariously), the aim is always to describe that technology in functional terms. In this situation, the functions are expressed in the context of a specific product experience and/or product use case. The future perspective then comes from an examination of the current functional capabilities as affordances. Affordances provide the clues to how a new technology could be used in the future in a more generic sense (Norman, 1999). This generic sense is how specific current applications are transformed into specific future applications of known/extant functionality.

A final development of the technology evaluation, following on from the examination of affordances, is to highlight their potential value in a business context. What might the particular advantages or opportunities be that could arise should the functional affordances offered by the technology be applied to a current market dynamic. This is a more projective and creative exercise than the precursor sourcing and evaluation steps. However, the rawness of much emerging technology does open an encouragingly broad compass of potential advantages and opportunities to explore.

In summary, the critical factors to consider in the sourcing and evaluation of a digital technology in disruptive terms should include:

1. How mature is the technology? How does the promise and hype compare with what is actually possible and available to users today? How well might the technology transfer from its current business application to the proposed application? These questions revolve around establishing the key affordances provided by the technology as it presently is implemented.

2. How mature is the market? Is this an established market or a new market? If established, is it ripe for disruption? Is it a niche market or a whole of business solution? Does it offer a different, low-end or high-end business model? These questions focus attention on the relevance of the market to the proposed technology intervention.

3. How competitive is the innovation domain? Are there business barriers to entry? Are there market barriers that preference the incumbents? Where are we on the Innovation Adoption Curve? These questions ensure that the timing of the intervention is appropriate to the maturity of the innovation domain.

4. How well positioned are you to succeed? How readily available are the talent and skills required? To what extent does the innovation require broader policy or legislative change? How aware and willing to invest in this technology are the industry stakeholders? These questions focus on the capacity of the organisation to drive the technological intervention.

Explicit data on all of these factors is unlikely to be at hand, but the questions are to be taken more as thought prompts – a check box of factors to consider when evaluating the disruptive potential of the technology innovation.

Phase Two: Technical and Production Considerations

Direct experience in the use of a technology is one thing. Understanding and appreciating the development requirements of a technology is quite another. Where the use case can provide pointers and inform the imaginative evaluation of the disruptive potential of a technology, it is the technical and production considerations that as often as not create the primary barriers to digital technology application (Ramilo and Embi, 2014). Having sourced and evaluated a potential technology the next phase is to develop and produce a prototype for testing and trialling in practice. Whilst there is no especial need to develop and produce the application in-house, and most likely the resources required will not be available in-house, nevertheless understanding the production requirements is essential to commissioning any prototype system.

Every emerging digital technology will have its own technical and production requirements. By way of illustration, this Chapter will review the resource requirements for development of a virtual reality application. The aim is to demonstrate those aspects of digital production common across digital technologies, as well as to better illustrate both the challenges and possibilities for those new to digital technology production. The theme of this Chapter is that a great deal can be achieved in-house using consumer-level products and services versus large-scale and bespoke third-party developments. More especially, there is much of significance to be learned from experimenting and playing with technology options.

New approaches to technology development are emerging as the days of prescriptive technology development quickly make way for an entirely more agile approach to digital technology development in particular (Moran, 2015). Traditional development approaches follow a so-called waterfall of cascading specifications, where the key requirements of a problem are first matched to particular features of a technology in an explicit product specification. That specification then drives a clear sequence of module developments for each component or feature of the final product which the developer then implements and tests. There is typically an extended period of development from specification to implementation where the client has limited input. New methods of agile technology development, such as SCRUM and KANBAN (see Chapter 17 for more detailed discussion on agile and lean concepts) are being developed and honed, where the traditional linear process is replaced with a more iterative, short-burst development process. In an agile development, each cycle results in something of an overall prototype as opposed to a module by module progressive build. This approach lends itself to better collaboration and greater, more frequent engagement between the developer and the client. Since clients rarely know in advance exactly what they might specify and developers can rarely predict exactly how a system will perform in practice, the iterative prototyping method is especially well suited to emerging digital technology development.

In the context of virtual reality development, for example, there are particular technical and process resource considerations. Let us begin with a review of the key technical components.

- **delivery technology:** virtual reality refers to quite a range of technical devices, from generic options such as so-called *caves* (where the user is surrounded with projected images) and headsets (where the user views a single image that changes in response to head movements), to bespoke simulators of particular plant and equipment (much like a flight training simulator). These are all immersive methods, where the aim is to convince the user that they are actually experiencing what is in fact a virtual simulation.
  The consumer level products to be preferred in this regard are the virtual reality headsets. This product family has developed significantly over recent years, precipitated by the entry of major technology developers such as Google, Facebook, Apple, Sony and Samsung. What began as a quantum leap forward with consumer-level devices such as the Oculus Rift (https://www.oculus.com/rift) and HTC Vive (https://www.vive.com/us/product/vive-virtual-reality-system/) (supporting extensive movement and interaction but tethered by cables to

high-end graphics computers and motion tracking) is evolving into more standalone devices such as the Oculus Quest (https://www.oculus.com/quest/) and the Vive Focus (https://www.vive.com/cn/product/vive-focus-en/).
Standalone headsets are not encumbered by cables and the restricted movement control is actually a welcome limitation as, in combination with higher resolution screens, it helps avoid the motion sickness that some users suffer initially with motion tracking devices. Of course one of the key advantages of the standalone consumer device is price point. For the cost of an Oculus Rift and associated laptop you can purchase around 10 times the number of standalone headsets. The standalone headset is also more robust, far easier to transport (to site or another office location, for example), and much, much simpler to set-up and use.

- **simulation software:** the major consumer technology developers continue to invest heavily in making virtual reality something for everyone. Whilst the investment in simulation software development is a fraction of that pouring into virtual reality hardware, content remains king. Having an in-house capacity to develop and trial virtual reality simulations is a significant opportunity for the innovative enterprise to engage with and evaluate emerging digital technology. The top-end authoring software for virtual reality applications are the interactive video game engines that offer total access to the latest and most sophisticated modelling and rendering engines available. The leading video game engine platforms include Unity (https://unity3d.com/), CryEngine (https://www.cryengine.com/), and Unreal Engine (https://www.unrealengine.com). A recent change in the business models for such engines has opened access to these state-of-the-art technologies for no or minimal cost. Of course specialist expertise in programming and compiling is required to produce virtual simulations using the game engines. The more adventurous and higher quality productions demand significant expertise.
  On the other hand, if a rudimentary or particular virtual experience is required, dedicated software (such as Revizto (https://revizto.com) and Lumion (https://lumion.com/)) is available to translate digital models directly into virtual reality content. The advanced geometric modelling software (such as Revit (https://www.autodesk.com/products/revit/) and AutoCAD (https://www.autodesk.com/products/autocad/) is also offering direct export into reasonable virtual reality content. The majority of direct export/translation content is currently only really of use in visualisation, but there is no doubt that interactivity and other important functionality required for full-scale virtual reality experiences will increasingly be available out of the box.

- **other functionality:** The visual experience has driven recent technology development, but other aspects of haptic, aural, movement and olfactory sensations also play a significant role in the immersive experience of a virtual simulation. For example, recent binaural spatial sound technologies (such as ambisonics) are now able to reproduce location-based soundscapes using stereo audio delivery that map onto a 360 degree surround environment and sync the sound location with head movements. That is to say, stereo audio is able to make the source of a sound appear to be coming from any specified position in 3-dimensional space relative to the moving head position of a user, in real time (http://www.ambisonic.net/).
  One recent development related to simulation software is the availability of high quality 360 degree video cameras. These cameras (such as the Insta 360 Pro (https://www.insta360.com/)) are able to video fully immersive virtual reality experiences in high resolution with spatial

sound recording which can later be played back using virtual reality headsets. Equivalent green-screening and post-production processing is being developed for 360 video as is currently available for traditional video, meaning live action video can be post-produced to create highly tailored virtual reality content.
In a similar vein to 360 video capture, developments in LiDAR and photogrammetry are also offering new opportunities to generate virtual reality experiences of environments and situations. LiDAR systems (such as Faro (https://www.faro.com/) and Leica Geosystems (https://leica-geosystems.com/)) use laser scanning and photography to generate high resolution point clouds that represent the geometric location and colour of all points visible from a particular point of view.

In addition to key technical components there is a range of issues to consider in terms of the production workflow process for any virtual reality application.

- **geometry:** creating entirely virtual worlds will always require geometric modelling and rendering capability. Advanced video game engines all have on-board geometric modelling functionality, but the most effective solution generally requires the geometry to be imported. The workflow for importing geometry will begin with a dedicated geometric modelling solution (such as 3DS Max (https://www.autodesk.com/products/3ds-max/) or AutoCAD (https://www.autodesk.com/products/autocad/)). For most applications the fixed models then need to be articulated and animated, and for this special purpose animation software (such as MAYA (https://www.autodesk.com/products/maya/), MotionBuilder (https://www.autodesk.com/products/motionbuilder/), or Blender (https://www.blender.org/)) is required.
  For higher quality rendering solutions the texturing of geometric models is also important. Typically, generic image processing software (such as Adobe Photoshop (https://www.adobe.com/photoshop/) or GIMP (https://www.gimp.org/)) is sufficient, but efficient and high resolution texturing requires specialist expertise of itself. Complex geometries, including human and other more organic forms, have dedicated geometry and animation software applications of their own (such as MakeHuman (http://www.makehuman.org/) and Mixamo (https://www.mixamo.com/)). For the best animation outcomes motion capture solutions are important (such as OptiTrack (https://optitrack.com/) and Rokoko (https://www.rokoko.com/)).

- **object stores:** basic model creation and animation is achievable by most skill levels given the automatic tools available in especially high-end geometric software. However, creating effective and efficient models (for rendering and animation purposes) does require advanced and varied skill sets. A growing number of these professional modellers now produce off-the-shelf packs of resources and make them available for purchase on the booming online market-places dedicated to virtual reality. Models (such as GrabCAD (https://grabcad.com/) or 3D Warehouse (https://3dwarehouse.sketchup.com/)), textures (such as textures.com (https://www.textures.com/)), and entire virtual reality solutions (such as UnrealEngine Marketplace (https://www.unrealengine.com/marketplace/)) provide ready-made solutions for a growing range of virtual reality applications.

- **production management:** the expanding specialist expertise required to produce the highest quality of virtual reality experience can be daunting. In addition to modelling, rendering and animation, the impact of best quality sound, motion capture, lighting, programming, scripting, post-production, compiling, and the ever-expanding suites of associated specialist roles/software can make the production of a virtual reality experience as complex and resource intensive as that of a conventional movie production. However, whilst that may be true for the more ambitious virtual reality productions, the production management tools incorporated into the best video game engines already enable sophisticated product development for no more investment than an enthusiastic graduate from the many virtual reality training programs now available.

In summary, the critical factors to consider in the production and prototyping of any emerging digital technology should include:

1. How many digital resources are required? For a virtual reality simulation, these might include: Models, Environments, Textures, Animations, Programming, 360 Stills and Video.
2. What is the timeframe? How much time is there to complete the project? How urgent is it to complete sooner rather than later? What quality and functionality goals are realistic in that timeframe?
3. How much experience does your firm have with digital technology development? How explicit is the overall project brief and/or project goals? How committed is the company to providing resources (including people, data, site access, etc.) to support the development of the project? Is there a champion for the project at a senior level of the organisation?
4. How mature is the hardware and software that will be used to realise the project? New hardware and software will require a period of upskilling and may also impact the availability of expert developers.

Phase Three: Piloting a Disruptive Innovation in Your Organisation

There are many and varied ways in which to approach a formal evaluation of a digital innovation prototype (Richter and Flückiger, 2014). Notwithstanding the need to undertake a formal evaluation at some point, the greatest imperative for a pilot study by far is to begin. Any experience in prototyping an emerging technology is useful experience. Given the nature of digital technology, the experience will reveal unanticipated opportunities for the application, the technology will in any event evolve and develop new functionality and possibilities, the organisation will learn something about prototyping digital innovations and the flexibility and change required to respond to digital disruption. New technology initiatives are likely to become the life-blood of the modern organisation (McKinsey Capital Projects, 2017). The sooner an organisation begins to experiment with and prototype potentially disruptive applications, the better the organisation will be placed to respond to the changes that digital technology will inevitably bring. So, the essence of Phase Three deals with how you might convince the organisation to approve a pilot project.

Much has been written about the best ways to win support for an idea (see for example, Fisher et al., 1991). Here we discuss some key ideas for a pitch based on the framework of a 3 minute presentation. Any approval will likely require more substantiation than is appropriate to a 3 minute pitch, but the pitch is a critical starting point.

- **constraints:** there are no true rules to a successful pitch, but recognising particular constraints often help give the structure and design of the presentation some direction. Begin by limiting the presentation to 3 minutes duration and a maximum of 3 slides/graphics. This constraint can be relaxed later, but as a target it forces the presentation to be both concise (a few key points) and engaging (keep to the points).

- **outcome:** design your presentation, starting with what specifically you want the outcome of the pitch to achieve. Everything should lead to that outcome – the key points, the supporting slides, the structure, even the feel of the presentation, everything is there to serve a purpose and the purpose is your intended outcome.

- **structure:** whilst you will have a very explicit intended outcome for the presentation, ideally you want the audience to feel that they have come to that conclusion rather than that you have delivered them there. Getting the audience to own the outcome starts with engaging them personally in the pitch. One of the best ways to promote a sense of audience ownership is to tell stories and paint scenarios that the audience will relate to. An emotionally engaging story will persuade far more effectively than statistics, and will make the pitch far more memorable.

- **style:** generally the best style is a conversationalist form of presentation. Aim for the feel of a friendly chat, albeit generally one-sided. Pauses can help prompt the audience to converse, even sub-consciously. If you have the time, ask questions, even if rhetorical, and listen carefully to the response. It is rare that you will know in advance exactly what the audience wants to hear about. Equally, do not assume that the audience will know precisely what the purpose of the presentation is. But remember, the pitch is about seduction rather than debate, so try to avoid lengthy discussions.

- **visual aids:** people seem to respond better to images and stories than to data and text. Certainly, do not simply read the text from your slides. The slides are your cues, they are not the presentation. That means you need to rehearse the presentation largely from memory.

- **key points:** be yourself. Engage with the audience. Focus on emotion and meaning over rational proof. Don't forget the purpose of the presentation is to achieve a particular outcome, and your aim is always to set up the next step you have in mind.

In summary, the critical factors to consider in the development of a pitch that is intended to lead to a pilot implementation should include:

1. Who will care about this project and why? Is there a clear value proposition? How easy is it to monetarise the benefits and opportunities?
2. Where are the opinion leaders in the organisation? Who are most likely to be the early adopters you need to make initial contact with?

3. What is the size of the potential market for your innovative idea? Is there a clearly defined problem that the technology will address? How significant is the problem/challenge/opportunity? Is it just a local, national or broader international issue? Does the same problem and/or solution have application across different industries? How resistant is your organisation to change?
4. Are you going to be able to progress the innovation directly (as a grass roots initiative) or will it require a whole of industry response/change (and thereby a more top down approach)?
5. What criteria would be appropriate to measure the potential impact of the technology on the organisation? Strategically, how might the pilot study be evaluated fairly and in a realistic context given the inevitable limitations of a prototype system?

An important point when making a 'pitch' to convince others to embark on any change that may be disruptive is that the outcome must meet the value proposition of those you seek to convince. In the case of IPD this is a different 'animal' to other potential organisations who may consider these disruptive technologies. Most organisations in a traditional setting only consider their specific value proposition and that is generally to increase their profits and/or to gain competitive advantage. Multi integrated organisations within an IPD context, such as an alliance, usually have a broader agenda and seek not only immediate efficiencies and perhaps cost or time savings but also other key result areas such as upskilling, more effective operation of the constructed facility, a safer environment and a number of social good objectives in the case of government agencies. Therefore, you can be honest about the potential for teething problems as learning and dynamic capability building opportunities, as well as being clear about operational or social-good potential advantages.

Finally, it is advisable to understand that knowledge is 'sticky' and difficult to transfer between groups and people (Szulanski, 1996;2003). How effectively a team will collaborate and learn is as much a function of their innate individual abilities as it is of how they are managed or behave. Chapter 18 discusses organisational learning and sticky knowledge in depth. The main point to be made here, with respect to IPD, is that the cross-disciplinary nature of the procurement form facilitates greater opportunity for effective innovation being developed and diffused on these projects, and greater chance of effective diffusion across projects in a program. This was the case with the Victorian Level Crossing Removal Program, where the design of the IPD form made the most of the talents and knowledge of project participants. Chapter 2 presents the Collaboration Framework that helps explain why this is the case.

Summary

Emerging digital technologies are critical to the delivery of many of the developments required to achieve IPD. Notwithstanding such a role, this Chapter has proposed a new, more disruptive role. It poses the question: How might the industry, an organisation or a motivated individual most effectively leverage an emerging digital technology to disrupt the extant construction industry and promote fundamental change? The answer, in short, is to begin. Begin to learn about emerging technologies. Become more familiar with the development and production of emerging technologies. Build experience in the application and evaluation of emerging technologies. To a significant extent, the choice of technology is of little consequence in this context. To experiment is to reveal the practical possibilities and barriers of change, to become familiar with the nature of change, and to develop a capacity for change.

Of course, the new constant is change (Epstein, 2018). Where conventional wisdom might claim that the majority is best served by waiting for the dust of change to settle, reality indicates the dust is unlikely to ever settle. Equally, when something like IPD demands such fundamental industry-wide change, it can be tempting just to sit back and wait for the tectonic shift to occur. This Chapter has sought to highlight the fact that disruptive change is upon us already, in the form of emerging digital technologies that every one of us can begin to experiment with, and that through such experimentation we can free ourselves, our organisation and our industry to the transformational changes required. The disruptive innovation perspective is a 'me' perspective. We should not leave emerging digital technologies to others. Consumerism is driving the development of emerging digital technology and the opportunity is there for every individual consumer to be the disruptive innovator that will kick-start the IPD revolution.

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