

Making Innovation Happen in a Megaproject: London's Crossrail Suburban Railway System

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ABSTRACT ■

Isolated pockets of innovation can be found in projects—such as the novel solution used to redesign the Velodrome roof during the London 2012 Olympics—but there have been few, if any, systematic efforts to manage innovation in a megaproject. This paper presents the initial findings of an ongoing three-year (2012–2014) action research project between Crossrail and researchers at Imperial College London and University College London. Action research is well suited to a setting where an intervention is required to diagnose and solve an organizational problem and produce scientific findings (Miles & Huberman, 1994; Van de Ven, 2007). Undertaken in collaboration with practitioners, the aim of action research is to transform the research setting through a process of critical inquiry and action. Our engagement with Crossrail aimed to formulate and implement an innovation strategy to improve the performance and outcomes of the project. We identified four stages—or windows of opportunity—to intervene to generate, discover, and implement innovation in a megaproject: (1) *the bridging window* during the front-end when ideas, learning, and practices from other projects and industries can be used to create an innovative project process, organization, and governance structure; (2) *the engaging window*, when tendering and contractual processes can be used by the client to encourage contractors and suppliers to develop novel ideas and innovative solutions; (3) *the leveraging window*, when all the parties involved—clients, delivery partners, and suppliers—are mobilized to develop novel ideas, new technologies, and organizational practices to improve performance; and (4) *the exchanging window* at the back-end, when ideas and resources for innovation can be (re) combined with those of other projects in the wider innovation ecosystem to improve performance. The first two stages had largely occurred when we became involved in the Crossrail project in 2012. Our intervention addressed the final two stages, when we assisted in the development and implementation of an innovation strategy. Core to this strategy was a coordinated mobilization of the innovative capabilities across the project supply chain. Though, to be successful, this approach had to be open enough to span organizational boundaries beyond the supply chain, reaching into the broader ecosystem. The four windows provide a valuable new heuristic for organizing innovation in megaprojects, pointing to areas where project managers can craft targeted innovation interventions and compare their efforts with those of others.

KEYWORDS: megaproject; innovation; action research; strategy; engaged scholarship; project management

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INTRODUCTION ■

This paper explores how the innovation process can be systematically organized to improve the performance of a mega infrastructure project—a temporary multi-party organization established to create large-scale, complex, and multibillion-dollar physical assets such as transport, energy, water, waste, and ICT systems (Altshuler & Luberoff, 2003; Flyvbjerg, 2006, 2014; Flyvbjerg, Bruzelius, & Rothengatter, 2003; Gil & Beckman, 2009; Merrow, 2011; Morris & Hough, 1987; Morris, 2013a, 2013b; Thamhain, 2013; Turner & Zolin, 2012; Yang, Wang, & Jin 2014; Yang, Chu, & Huang, 2013). Megaprojects are often late, over budget, and fail to achieve their original specifications and revenue targets. This presents a paradox, because more megaprojects continue to be executed despite their poor record for productivity (Flyvbjerg et al., 2003). In most industries it is widely understood that improvements in performance depend on innovation (Dodgson, Gann, & Salter, 2008), whereas in the world of megaprojects innovation is often avoided because of its association with uncertainty and increasing costs (Van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008). Sponsors, clients, and contractors are reluctant to introduce novel ideas and innovative approaches and often seek to minimize the risks involved by relying on tried-and-tested techniques, established routines, and proven technologies. They prefer to select the lowest-price bid, transfer risks to contractors, freeze the design as early as possible, and stick rigidly to the original plan.

Over the past decade, the United Kingdom has stood out as a laboratory for experimentation, learning, and innovation in megaproject delivery models (Brady & Davies, 2014). In the 1990s, the UK government commissioned two influential studies—the Latham (1994) and Egan (1998) reports—to investigate why construction projects had such poor performance records and how this could be overcome by developing new ideas and learning and by adopting successful practices from other industries. Both reports emphasized the need for innovation. Sir John Egan, one of the report's authors and CEO of British Airports Authority (BAA) in the 1990s, used lessons learned from other projects and industries to develop a radically new model based on a risk-bearing client, integrated project teams, and advanced construction techniques for delivering BAA's US\$8.5 billion Heathrow Terminal 5 (T5) project (Davies, Gann, & Douglas, 2009). In a review of the progress of the Egan agenda over the previous decade, Wolstenholme (2009) emphasized the continuing importance of the original report's recommendations and need to overcome

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obstacles to change by encouraging innovation. The Armitth Review (2012) of UK infrastructure planning highlights how the transfer of innovation from megaprojects, such as High Speed One (HS1) and T5, has contributed to the successful delivery of the London 2012 Olympics construction program and the ongoing progress of London's Crossrail suburban rail project.

Despite industry-led efforts to drive such innovation, the literature on megaprojects has focused on the management of risk (Flyvbjerg et al., 2003), project culture (Van Marrewijk, 2007; Van Marrewijk et al., 2008), contracts (Gil, 2009), and technology adoption (Gil, Miozzo, & Massini, 2012). Where research has dealt with innovation, it has focused on how learning from other practices and industries can be used to create an innovative process for delivering a megaproject (Davies, Gann, & Douglas, 2009; Brady & Davies, 2014); how radically new projects transform institutional structures (Michaud & Lesard, 2000); and how projects can deal with the risks and uncertainties associated with innovation (Loch, De Meyer, & Pich, 2006; Shenhar & Dvir, 2007). Informed by the assumption that such risks have only "down-side" effects, which, if they occur, can only impair project performance (Ward & Chapman, 2003), prior research neglects to consider the "upside" benefits obtained by strategically innovating to deal with unanticipated risks, overcome technical challenges hindering progress, and create new sources of value in the project. Emphasis was also placed on learning from the past mistakes and how to avoid them, rather than recognizing and seizing the vast future innovative opportunities that megaprojects may offer.

Isolated pockets of innovation can be found in other projects—such as the novel solution used to redesign the Velodrome roof during the London 2012 Olympics—but, to the best of our knowledge, there have been few, if any, systematic efforts to promote innovation within megaprojects. This

paper presents findings of an ongoing three-year (2012–2014) research project between Crossrail and researchers at Imperial College London and University College London. More specifically, we focus on the findings emerging from the action research phase of the study, which aimed at formulating and implementing an innovation strategy to improve the performance and outcome of the Crossrail project. In line with the principles of action research (Van de Ven, 2007), we collaborated closely with practitioners¹ with the aim of transforming the research setting through a process of critical inquiry and action. Action research is well suited to such settings, where an intervention is required to diagnose and solve an organizational problem as well as produce scientific findings (Miles & Huberman, 1994; Van de Ven, 2007).

Our research identified four windows of opportunity where an innovation strategy can drive innovation in a megaproject: (1) *the bridging window* during the front-end, when ideas, learning, and practices from other projects and industries can be used to create an innovative project process, organization, and governance structure; (2) *the engaging window*, when tendering and contractual processes can be used by the client to encourage contractors and suppliers to develop novel ideas and innovative solutions; (3) *the leveraging window*, when all the parties involved—clients, delivery partners, and suppliers—are mobilized to develop novel ideas, new technologies, and organizational practices to improve performance; and (4) *the exchanging window* at the back-end, when ideas and resources for innovation can be (re) combined with those of other projects in the wider innovation ecosystem to improve performance. These windows provide a new heuristic for organizing innovation in megaprojects, pointing to areas where project managers can craft targeted innovation interventions

¹Led by our non-academic co-authors.

and compare their efforts with those of others.

The article is divided into the following sections. The literature review in the second section identifies our current understanding of how innovation occurs in megaprojects and what is required to establish an innovation strategy in this setting. The third section explains the use of action research to engage with Crossrail's research problem and its efforts to formulate and implement an innovation strategy for the project. The fourth section introduces the Crossrail case study, and the fifth section presents our main findings. We conclude in the sixth section with a brief discussion about the role of action research in supporting innovation in megaprojects and offer some suggestions for future research.

Understanding Innovation in Megaprojects

The purpose of this brief literature review is to identify what is currently known about how innovation occurs in megaprojects and to consider how an innovation strategy can be applied to this kind of temporary organizational arrangement. But before we can consider these issues, it is important to define what we mean by innovation. Innovation is a novel product, process, service, or system of organization that changes the prevailing order of an organization, market, or society (Van de Ven, 1986; Dodgson et al., 2008). It ranges from radically new ideas, which transform the practices and structures of existing institutional environments, through to incremental improvements to existing products, processes, and services. Innovation emerges through the recombination of old ideas into new.

Megaprojects

The literature on megaprojects provides different explanations for project failure (Flyvbjerg et al., 2003; Van Marrewijk, 2007; Van Marrewijk et al., 2008; Merrow, 2011; Sanderson, 2012), but largely neglects to consider how innovation



may impact on performance. In their influential book, Flyvbjerg et al. (2003) emphasize that megaprojects often fail to achieve their original objectives because of “optimism bias.” Proposers of a major capital investment assume that they can accurately estimate the costs and benefits of a project and submit a low-cost bid to win the contract (Flyvbjerg, Garbuio, & Lovallo, 2009). But, in reality, things are often unpredictable and rarely turn out as originally intended. Costs outstrip projections and projects often result in lower-than-predicted revenues. Other studies emphasize the importance of culture in explaining poor megaproject performance (Van Marrewijk, 2007; Van Marrewijk et al., 2008).

Innovation in megaprojects is associated with high risks and often results in cost increases, which are not accounted for in original estimates (Van Marrewijk et al., 2008, p. 591). As result, megaprojects are characterized by conflict, uncertainty, and poor cooperation between partners. This tendency to associate risk with adversity and “downside threats” ignores the “upside opportunities” acknowledged to flow from innovation. In reality, the threats and opportunities associated with project uncertainty are two sides of the same coin: they must be managed simultaneously to reduce or mitigate potential threats, while exploiting opportunities to improve performance (Ward & Chapman, 2003, p. 98).

A few important studies have examined the different aspects of innovation in complex and uncertain projects. Miller and Floricel (2000, pp. 63–64) identify an initial stage of radical innovation in the development of megaprojects associated with new governance structures (e.g., Build-Operate-Transfer and the Private Finance Initiative), new technology (e.g., ICT control and Building Information Modeling) and organizational change (e.g., partnering and integrated project teams). Michaud and Lessard (2000, p. 156) identify a process of change starting with innovative

“breaker projects” and resulting in standardized repeated projects. Loch et al. (2006) argue that learning and selectionism (e.g., parallel trials) are required to deal with high degrees of uncertainty in complex and innovative projects. Shenhar and Dvir (2007) argue that innovation in projects is associated with uncertainty, complexity, and pace. Davies et al. (2009) studied a radically new model for delivering megaprojects at the Heathrow Terminal 5, a design that has gone on to influence subsequent projects in the United Kingdom, including the London 2012 Olympics and Crossrail (Davies & Mackenzie, 2014; Brady & Davies, 2014). Although these studies help to identify important features and uncertainties associated with innovation and how these can be more effectively managed, prior research has not considered how a strategy and process can be established to systematically generate and manage innovation “within” a megaproject.

Innovation Strategy

The innovation management literature has largely assumed that innovation is driven by the needs of a permanent organization (e.g., 3M, IBM, General Electric, and Canon) and its ability to leverage internal and external ideas to achieve corporate objectives for long-term growth, profitability, and competitive advantage (e.g., Dodgson et al., 2008). Many construction firms involved in megaprojects—such as Parsons Brinckerhoff, Skanska, and Laing O’Rourke—have recently developed strategies for innovation (see, for example, Parsons Brinckerhoff, 2012). However, our review of the literature² found no examples of organizations—sponsors, clients, prime contractors, or joint-venture delivery partners—creating deliberate strategies and organizational processes designed to generate and implement innovation within a megaproject. Consequently, our intervention in the Crossrail project was influenced

²Conducted in early 2012.

by prior studies explaining how innovation strategies are formulated and implemented by permanent firms.

An innovation strategy articulates an organization’s ambitions and long-term vision for innovation. It establishes an organizational process that creates, and captures value by combining and coordinating resources—people, knowledge, finance, and technology—to achieve a desired outcome (Afuah, 2003; Dodgson et al., 2008; Dodgson, Gann, & Philips, 2014). Developing an innovation strategy is a dynamic process undertaken iteratively and informed by learning, drawing on evidence from the external environment, and appraising internal resources, capabilities, and processes, to build, supplement, and organize a firm’s knowledge and innovative capabilities in a changing environment. A successful strategy depends on an innovation culture (e.g., 3M) that is tolerant, supportive, and encourages learning from failure (Dodgson et al., 2008).

In an increasingly open and networked world, the search for innovative ideas extends beyond the boundaries of the individual firm to combine both internal and external ideas to create value (Chesbrough, 2003). This more open model of innovation recognizes that people with good ideas are not solely resident within one’s own organization, but are instead to be found distributed across multiple organizations (Boudreau & Lakhani, 2009). An innovation strategy must equip the organization to learn about new ideas and existing practices in other industries and contexts and leverage in-house resources and the external capabilities of suppliers, universities, other organizations, and individuals to achieve its corporate objectives in a rapidly changing environment.

An innovation strategy needs to contain four interrelated elements (Dodgson et al., 2008, p. 95): a strategy that fits with the firm’s corporate objectives and context within which it operates; the assets and resources that are available to support innovation;



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the innovative capabilities that enable those resources to be assessed, configured, and deployed; and the managerial and organizational processes required to deliver innovation.

Whereas an innovation strategy helps an organization “decide on the right things to do,” an innovation process “help them do things in the right way” (Dodgson et al., 2008, p. 98). Processes established to implement and achieve the strategy include: providing appropriate resources (e.g., technology support, knowledge management, and training); coordinating innovative activities across the organization; networking internally and externally to build collaboration and foster partnership with key suppliers, users, universities, standard bodies; and other groups; delivering new products, processes, and services on time, within budget and to the required specification; and auditing innovative performance, setting benchmarks, milestones, targets, and indicators to provide feedback (Dodgson et al., 2008, p. 124).

Research Approach

Our research focused on the formulation and development of Crossrail’s innovation strategy. This rare case was purposively selected because, although there are many studies of innovation strategies deployed by firms, we had a unique opportunity to observe and participate in this pioneering effort to develop an innovation strategy for a megaproject.

Action Research

Our use of action research was motivated by a desire to learn about the innovation process in megaprojects through close engagement and participation in this organizational setting. The aim of action research is to assist in the transformation of the research setting through a process of critical inquiry and action. It involves a clinical intervention to diagnose and treat a specific problem, while simultaneously generating scientific research (Van de

Ven, 2007, pp. 281–282). It holds that for knowledge to be useful, it must be actionable: this involves specifying the intended consequences, identifying the action sequences required to achieve those consequences, and understanding the relationship between actions and consequences (Algeo, 2014). To achieve such outcomes, researchers “must often play the highly visible and proactive role of change agent in helping” practitioners solve a problem (Van de Ven, 2007, p. 282).

Action research requires new ways of integrating research and experience of practice and “cannot be achieved by researchers who keep themselves removed from contexts of action, nor by practitioners who have limited time, inclination or competence for systematic reflection” (Schön, 1983, p. 320). It depends on new forms of collaborative agreements between “practitioner-researchers and researcher-practitioners” (Schön, 1983, p. 323). In action research, practitioners often seek out a set of researchers comfortable with undertaking the proposed action and willing to engage in the process in real time (Miles & Huberman, 1994, pp. 8–9).

Researchers must enter into a formal agreement with the industrial partner because some important matters have to be clarified with participants at the outset to define the purpose and scope of the collaboration, ethical issues (who benefits from the research and who may be harmed), and confidentiality. Whereas a typical research agreement often rests on the assumption that well-trained researchers will gather good data and produce well-founded findings, a collaborative action research agreement specifies outputs such as assistance, advice, shared royalties, and joint authorship. Action research acknowledges that expertise resides in the participant practitioners as much as the researchers: “participant expertise is developed through the researcher’s facilitation during the process” (Miles & Huberman, 1994, p. 48). Practitioners

may benefit by having an opportunity for reflection, clarifying ideas, empowerment, learning from other contexts, and developing new competencies. The intervention should have a catalyzing effect on the research setting by enhancing the ability of participants and other stakeholders to take action during and after the research study has been completed.

Action research begins by diagnosing the problem or needs of the industrial partner. Researchers join closely with people in the practitioner’s organization from the beginning to help them study and tackle the problem. The team of researchers and practitioners share control over the research design and the conduct and steering of the research. Data are collected and presented to the partner both as feedback and used to design the next stage of engagement. This approach requires sensitivity to the partner’s concerns, a focus on descriptive data in the early stages, some participant observation, and a search for underlying themes or patterns.

Action Research in Crossrail

The scope of our research collaboration with Crossrail was first discussed in an initial meeting in 2011 between Andrew Wolstenholme, Crossrail’s Chief Executive Officer; Terry Hill, member of Crossrail Board; and Professor David Gann of Imperial College London. The two organizations subsequently agreed to fund a three-year research program (January 2012–December 2014). Crossrail contributed access and matched funding³ for a three-year program of research into the organization and management of innovation in megaprojects. The action research presented in this paper forms the first part of the study. Once this phase was completed, the research program shifted to focus in on an inductive study of the management of innovation in infrastructure.

³Matched with that provided by the EPSRC Innovation Studies Centre at Imperial College Business School.



A core team of practitioners and researchers was established to create the innovation strategy, including Mark Thurston (John Pelton took over this role in 2014), Tim DeBarro, Professor Andrew Davies (who joined University College London in 2012 but continued his involvement in the project), and Dr. Samuel MacAulay. Crossrail Limited (CRL) established the Crossrail Innovation Forum to provide the support, resources, and advice required to steer the innovation strategy. The forum is a biannual meeting established to monitor and steer the development and implement the innovation strategy involving senior members of Crossrail, Imperial College London, main contractors, and suppliers.

After an extended period of negotiation, a research agreement was established, which specified the scope of the work, research questions, and envisaged outputs of the collaboration, including work required to produce an innovation strategy tailored to the requirements of the project, two separate academic (post-doctoral and PhD) research projects, participation in the Crossrail Innovation Forum (CIF), and assistance with the creation of a process to implement the strategy.

It is recognized that case studies can be undertaken to generalize or expand theoretical propositions (Yin, 2003, p. 10). However, rather than seeking to generalize a theory from a single case, our action research was designed to identify the opportunities for intervening in this specific case and the collaborative research process required to make innovation happen.

The action research team held monthly three-hour meetings to understand and plan what was required to develop the innovation strategy. Although there were many examples of innovation strategies developed by firms, the team found no examples of innovation strategies developed for a megaproject. They conducted an “external scan” of industry-wide innovation practices and an “internal scan” of

innovative activities within the Crossrail project and its partner organizations. The external scan was a review of innovation management practices conducted by the researchers and Dr. Dheeraj Bhardwaj, an industry consultant with extensive knowledge and experience of innovation practices in construction firms and other industries. The internal scan produced an innovation status report to identify innovation within the Crossrail program and how it was currently being managed. It was based on interviews undertaken by the two academic co-authors—each typically one hour in length—with 16 managers involved in the Crossrail project, including the CEO, program director, technical director, procurement, and other senior staff, undertaken between April and July 2012. Interviews were undertaken with four senior managers in November 2013 to gain their reflections and insights about the progress and challenges involved in implementing the strategy one year after its initial introduction.

After gaining the approval of the CIF, the 18-page “Crossrail Innovation Strategy: Moving London Forward” document was published in September 2012 (Crossrail, 2012). The strategy document outlined Crossrail’s vision and highlighted how it was crucial to equip individuals in the client and supply chain organizations with the knowledge, processes, and incentives required to help them collaborate, search for novel ideas, and generate innovation.

Research Setting: The Crossrail Project

This section provides an introduction to the Crossrail project to help contextualize our research intervention.

Project Goals

The idea for Crossrail, an east-west railway across London, first appeared in the 1974 London Rail Study when it was recognized that another underground line would be insufficient to meet the demand for growing capacity. These ideas were taken forward in a more con-

crete scheme proposed by the Central London Rail Study in 1989 and, in October 1990, the government gave the go-ahead, which safeguarded the Crossrail route. After further delays, the Crossrail Hybrid Bill was finally approved in July 2008, becoming the Crossrail Act 2008, and construction of Crossrail formally began on 15 May 2009, when the mayor of London and the Transport Secretary launched the first pile at the site of the Canary Wharf station.

Crossrail is currently Europe’s largest civil engineering project. It involves the construction of a new metro railway from Reading and Heathrow Airport in the west through central London to Shenfield and Abbey Wood in the east. This 118-kilometer route (approximately 73 miles) route includes 21-kilometer (approximately 13 miles) of central twin-bore 6.2-meter (approximately 6.8 yards) diameter rail tunnels running straight through the heart of central London and its former docks. The tunnels being constructed must weave their way between existing underground lines, sewers, utility tunnels, and building foundations at depths of up to 40 meters (approximately 44 yards), eventually connecting to ten new stations at Paddington, Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, Whitechapel, Canary Wharf, Woolwich, Custom House, and Abbey Wood with existing rail infrastructure.

The total funding envelope available to deliver Crossrail is £14.8 billion (approximately US\$24.15 billion). Crossrail trains will be just over 200-meters (approximately 220 yards) long, made up of nine walk-through carriages, with the capacity to carry 1,500 passengers, but station platforms are designed to accommodate 250-meter long (approximately 270 yards) trains to provide the capacity required to adapt to forecasted increases in demand. The signaling system will control the movement of 24 trains an hour through the central section, with the possibility of increasing to 32 trains an hour if extra



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capacity is required. The new trains will be progressively introduced to sections of the existing rail network in advance of full Crossrail services commencing in December 2018. It is predicted that, upon completion, Crossrail will increase London's rail-based capacity by 10% and be used by approximately 200 million passengers a year. The new railway will bring an additional 1.5 million people within a 45-minute commute from London's major commercial districts.

Project Organization

Crossrail is a large and complex program of interrelated projects that have to be integrated to create the new railway system. Crossrail Limited (CRL) was established in 2008 as a temporary public client and special purpose delivery organization responsible for the development and delivery of the system, including all its component projects. CRL is the overall program manager and systems integrator for the railway. It is accountable to the joint project sponsors: the Department for Transport (DfT) and Transport for London (TfL).

CRL is supported by a program delivery partner called Transcend (a joint venture between AECOM, CH2M-Hill, and the Nichols Group) and a project delivery partner called Crossrail Central (a joint venture between Bechtel supported by Halcrow and Systra) employed to manage the delivery of the Central Section works. CRL employed the program and project delivery partners to support the design and construction of the railway. After experiencing difficulties in coordinating the different parties involved, CRL decided to bring together the program and project partners to form a co-located Integrated Program Team. This matrix team, which employed about 850 staff members in 2012, is responsible for managing the large and diverse number of firms involved in the design, construction, and handover of Crossrail, including design consultants, major

works package contractors for tunneling and stations, rolling stock and depot suppliers, utility companies, The City of London Corporation, and oversight developers.

Contractors have often formed joint ventures to bring together the capabilities needed to manage individually complex projects for tunnels, shafts, station boxes, and sprayed concrete underground structures. Construction of the first tunnel portal at Royal Oak began in January 2010. Seven tunnel boring machines will be used to construct the tunnels. Precast concrete segments manufactured off-site are being erected in rings behind the cutter shield as the tunnel boring machine advances forward. Sprayed concrete lining is being used to build the larger platform and passenger tunnels at stations. The first two tunnel boring machines started work in 2012, moving east from Royal Oak, where they were joined by two other tunnel boring machines later in the year moving west from the Docklands. In 2013–2014, up to 14,000 workers will be employed on 40 sites, working 24 hours a day to complete the tunnels, build new stations on the central section, and upgrade the existing rail network.

In 2017 and 2018, Crossrail will begin the transition from a delivery organization into an operating railway. CRL is responsible for the handover of the assets and working closely with Crossrail infrastructure managers and operators throughout the project life cycle from conceptual design, through construction, integration, testing, trial running, handover, and operation of rail services. CRL is part of a complex ecosystem of independent but interdependent organizations responsible for operating different aspects of London's transportation network, including:

- Rail for London (RfL) is the infrastructure manager, future operator of several Crossrail stations (Paddington, Canary Wharf, Custom House, and Woolwich);
- MTR (the Hong Kong metro operator) won a contract for eight years with an option to extend to 10 years to run the Crossrail train service;
- Network Rail, the owner and operator of most of Britain's railway infrastructure, is undertaking a major upgrade over its overground network to prepare for the cross-London service and interfaces with the Central Section;
- London Underground Limited (LUL) owns and operates London's public rapid transit system and works with CRL to integrate Crossrail works with its own capital projects; and
- Transport for London (TfL), which is responsible for most components of London's transportation system including LUL (a wholly owned subsidiary of TfL).

Innovation in Crossrail

Our literature review, interviews with senior managers in Crossrail, examination of project documents, and the trade press (e.g., *New Civil Engineer*) helped us identify four opportunities to intervene and promote innovation in a megaproject:

1. *The bridging window* occurs during the preparations and front-end planning when there are opportunities to learn lessons from other projects and industries and use successful practices, technologies, and approaches to develop an innovative approach for the organization and governance of the project.
2. *The engaging window* is an opportunity to develop new ways of tendering and contracting so that suppliers are incentivized and rewarded for developing innovation solutions in bids for components of work within the overall project.
3. *The leveraging window* occurs after contracts have been awarded when there are opportunities to mobilize delivery partners, contractors, and suppliers to develop new ideas, technologies, and organizational practices, which can be applied to



Innovation Windows	Key Activities	Crossrail	Other Examples
<i>Bridging</i> During the preparations and front-end planning	Targeted search for and integration of innovative practices, technologies, and organizational processes that will improve the current project's performance. Search focused on previous projects and related industries.	Illustrative example: learning from other megaprojects (e.g., High Speed 1, Heathrow Terminal 5, and London Olympics) led to formation of new organizational form: an integrated project team.	Heathrow Terminal 5 project created a new contractual, partnering model, and advanced construction techniques based on their research into the oil, gas, and automobile industries.
<i>Engaging</i> During design of tendering process and contracting processes	Develop new ways of contracting/tendering. Create incentives and rewards to encourage the search for innovative solutions.	Illustrative example: Develop a system called 'Optimized Contractor Involvement' based on NEC pain/gain contract. Facilitated early and structured collaboration between designers and constructors to identify opportunities for innovation.	Channel Tunnel Rail Link (High Speed 1) implemented risk-sharing contracts. Heathrow T5 Agreement risk-bearing contract rewarding efforts to innovation to deal with risk and opportunity.
<i>Leveraging</i> Occurs after contracts have been awarded and core supply chain formed	Develop a strategy and process to mobilize delivery partners, contractors, and suppliers to develop new ideas, technologies, and organizational practices. Apply innovation to improve the performance of different phases of the project.	Illustrative example: central organizational process, team, and online platform that works to identify, evaluate, select, resource, and implement innovation ideas across the supply chain.	The Thames Tideway Tunnel is now working to emulate selected elements of Crossrail's process.
<i>Exchanging</i> Occurs during and after the project has been executed	Connect with the wider project ecosystem to share and trade innovations. Partner with other parts of the ecosystem to pool resources to fund the pursuit of common innovation needs.	Illustrative example: Selective revealing of Crossrail's innovation portfolio to other projects to identify opportunities to exchange innovation successes and learn from failures. Crossrail is now exploring opportunities to connect with other megaprojects and clients, including Thames Tideway Tunnel, High Speed 2, and Network Rail to pursue joint innovation opportunities.	London 2012 Olympics Learning Legacy program invested in identifying, articulating, and codifying innovative practices for future megaprojects. ^a

^aRetrieved from <http://learninglegacy.independent.gov.uk/>

Table 1: Innovation windows in megaprojects.

improve the performance of the project as it moves towards completion.

4. *The exchanging window* begins at the back-end when ideas and resources for innovation can be (re)combined with those of other projects in the wider innovation ecosystem to improve performance.

These distinct but slightly overlapping stages are described in Table 1. CRL had a temporary opportunity to generate and implement innovation during each of the four windows. Each intervention could be accomplished by CRL on its own, with external parties (e.g., consultants), or with the assistance of academic collaborators. When we initiated our action research

with Crossrail, the project had passed through the bridging stage, signed all the civil engineering contracts, and was tendering for rolling stock and railway systems. Our research involved identifying retrospective and current innovative practices in the project (windows 1 and 2) and working with CRL to develop an innovation strategy to leverage the innovative capabilities of the project supply chain and broader ecosystem (windows 3 and 4).

Bridging

The bridging window occurred when Crossrail's sponsors were planning the project and establishing CRL as the client organization responsible for managing the program. Efforts were made to

learn lessons and recruit senior managers able to apply experience gained on other megaprojects and combine successful practices, technologies, and approaches in innovative new combinations for delivering Crossrail.

When Crossrail gained approval to proceed in 2008, Doug Oakervee, Crossrail Executive Chairman, clarified in an interview with *New Civil Engineer* the project's overall strategic approach to innovation. He announced that: "We will always be looking for innovation and ways of doing things more economically and they will be prime motivators in all of the incentive schemes" and that "Innovation is the thing we have to work with—and that will be a partnership between us and the delivery partner



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and designers to deliver in the most efficient way to produce the best economies” (Oliver, 2008a, p. 6).

Systematic efforts were put into searching for innovative practices, products, and processes developed and utilized on other megaprojects—such as Heathrow Express, Channel Tunnel Rail Link (or High Speed 1), Heathrow T5, the Jubilee Line Extension, and London 2012 Olympics projects. These innovations were often associated with changes in organizational structure; for example, the development of an integrated project team and the early embedding of infrastructure owners (RfL) into Crossrail’s senior management team. This later innovation was motivated by the observation that the transfer to operations is where many infrastructure projects fail (e.g., baggage handling at Heathrow’s Terminal 5). Integrating the RfL team into the broader Crossrail Integrated Program was viewed as a powerful way to inject an “operations logic” into organizational decision making while there was still an opportunity to make significant changes (e.g., where to situate Crossrail’s depots).

Engaging

The engaging window occurred when CRL began the tendering process of selecting the major works involved in the design; construction of tunnels, platforms, and stations; and supply of rolling stock and signaling systems. As Andy Mitchell, CRL Program Director pointed out in an interview with *New Civil Engineer*, “when it comes to innovative ideas...on major projects the natural state of mind is to control risk by using the tried and tested” (Oliver, 2012b, p. 11). Yet CRL took a different approach and established a tendering process to encourage innovation well before the strategy to stimulate and manage innovation was formally implemented (see the following section).

CRL created a procurement approach called “Optimised Contractor Involvement” (OCI) where each individual contractor, joint venture,

and supplier can bring new ideas and practices to the project, while sharing the risk and reward. OCI was established to reduce the downside risks impacting on the project, while exploiting upside innovative opportunities to improve performance. Based on the United Kingdom’s target cost, pain/gain share new engineering contract (New Engineering Contract), OCI incentivized contractors to invest in generating new innovation on the project by guaranteeing that value created through innovation would be shared between the client and the contractor. Under OCI, the contractor is brought in after the target price has been established but early enough to have some input into the design and value engineering. To avoid encouraging suppliers to submit lowest-cost bids, Crossrail put increasing emphasis on the technical element to help select the best solution. This is underlined by the recent move from a 60:40 to a 70:30 technical/cost assessment ratio. Each of the contracts is evaluated on the technical ability of the joint ventures rather than primarily on the price. The CRL team tried to play a “light touch client role, giving the contractors room to bring their skills and innovation and using the target cost, pain/gain share NEC contract to drive performance” (Oliver, 2012b, p. 11).

In addition to helping to mitigate the well-known risks that can hinder progress, the OCI process has been used to generate innovative solutions to deal with a variety of risks and unforeseen uncertainties. For example, it was used to promote cost-saving innovation after the Comprehensive Spending Review of October 2010 called for a major reduction in Crossrail’s budget. CRL engaged in discussion with its bidding joint venture organizations about how to create a more efficient way of constructing tunnels and stations. A joint venture between Bam, Nuttall, Ferrovia, and Kier (BFK) won the contract in December 2010 for the western section tunneling from Paddington to Farringdon.

The original plan had been to construct the tunnels and stations simultaneously. Under the new “flipped” approach, BFK bored the tunnels ahead of the excavation and performed the sprayed concrete lining work for the platform tunnels at Paddington, Bond Street, and Tottenham Court Road. Although considerably cheaper, the flipped approach did, however, mean that station platform work could not be carried out until tunneling was completed and this contributed to the one-year delay in completing the overall program. BKF’s process innovation helped it win sprayed concrete lining contracts for the Bond Street and Tottenham Court Road stations.

Leveraging

The leveraging window occurred after the CRL contracts were procured and involves encouraging selected contractors and their suppliers to develop and apply innovation in different phases of the project. Andrew Wolstenholme became Crossrail’s CEO in September 2011 after all the major contracts to build tunnels had been tendered and when station contracts were just about to be let, but well before contracts for major rolling stock and signaling systems had been put out to tender. He had previously been Director for Innovation and Strategic Capability at Balfour Beatty and was a well-known critic of lowest-price tendering and contractors who avoid risk to maximize their own profits (Wolstenholme, 2009). From the start, Wolstenholme wanted Crossrail to adopt advanced technologies such as compensation grouting, which was originally developed on the Jubilee Line extension project and Building Information Modeling (BIM), a tool providing a digital representation of the infrastructure asset used through the life cycle from design and construction to handover, operation, and maintenance. In an interview in *New Civil Engineer*, Wolstenholme clarified that there was a strategic opportunity to use the Crossrail project “to lever in new ideas, techniques and processes that



will genuinely change the industry in future" (Oliver, 2012a, p. 8). He wanted to do what he could to help Crossrail's winning contractors and their suppliers exploit opportunities to promote innovation by sharing risks and collaborating in integrated project teams.

In late 2011, CRL initiated a research-oriented collaboration with Imperial College London (see earlier) to create an organizational mechanism for identifying and resourcing innovation across the supply chain. Given the multiple organizations working within the supply chain, it was crucial that this process would enable contractors and suppliers to strategically reveal, combine, and build on their intellectual property without incurring undue risk. In early 2012, CRL established the Crossrail Innovation Forum and assembled the team of Imperial College researchers and CRL practitioners to develop an innovation strategy for realizing this vision. Senior members of the team had previously developed innovation programs to help large contractors leverage internal and external sources of ideas to achieve long-term corporate strategies. These efforts and lessons learned from innovation programs developed by firms in construction and other industries helped identify what was required for the Crossrail project. But innovation strategies developed for firms could not be copied exactly and transferred to a megaproject like Crossrail. The innovation strategy had to be specifically designed to take into account the temporary nature, specific challenges, and context of a megaproject, including a client organization and temporary coalition of delivery partners, contractors working in joint ventures, and suppliers that would be disbanded on completion of the project.

The Crossrail Innovation Strategy was designed to achieve the project's overall goals and vision of creating a world-class railway. The strategy document outlines the vision and the organizational processes that will enable it to be achieved. The core principle

was the creation of an organizational pathway whereby people from across the supply chain could channel their ideas for innovation, gain the resources required to implement them, and then share these successes across the organizational boundaries that proliferate in megaprojects like Crossrail. This process was supported by a small and dedicated "innovation team" that was tasked with helping identify, evaluate, and develop ideas; project manage a portfolio of invested projects; and broker successful innovations across the project. A suite of online tools were developed for the organization to provide a mechanism to submit ideas (innovation portal); to manage, track, and report on the progress of ideas (Innovation Management System); and to communicate and share innovations across the Crossrail community (via the website).

Under the guidance of the Crossrail Innovation Forum, the practitioner team is responsible for the strategic direction and day-to-day implementation and management of the innovation program, including the online tools and portfolio of innovation projects. The team consists of a program manager, two innovation coordinators, an Innovation Reporting Assistant, and an academic researcher who studied the implementation of the strategy and feedback findings to influence their action (e.g., organizational slack was difficult to come by on some sites).

The Innovation Program Manager provides strategic management of the innovation program to ensure the objectives of the Crossrail Innovation Strategy are delivered.

The Innovation Coordinators are responsible for facilitating collaboration between the Innovation Site and Project Champions and to help to build relationships between the champions and other parts of Crossrail. They are responsible for facilitating the technical evaluation by the relevant specialists and that, if necessary, task groups are organized during the development of an innovation idea. The role includes

monitoring progress and providing regular status updates to the Innovation Program Manager.

The Innovation Reporting Assistant is responsible for reporting the status and health of the innovation program, including communications and publications. The role includes the collection and presentation of monthly innovation program reports. They are also responsible for the production of the innovation remits and reporting/monitoring during the implementation of innovation projects.

CRL established a larger group of innovation champions located in projects and functional departments with the specialized knowledge needed to help the CRL innovation team evaluate and select good ideas.

The innovation process begins when one or more members of the Crossrail project supply chain submit a new idea via an online portal. An innovation coordinator contacts the person who submitted the idea and works with technical experts and innovation champions to evaluate its potential. Ideas that are likely to provide benefit to Crossrail are developed, gaining the relevant sponsorship and commitment from the necessary parties. Every six months, ideas are evaluated by an innovation working group comprised of industry experts, representatives of the contractors, and senior representatives of the Innovation Program, which selects those ideas worthy of consideration for investment to develop selected ideas into useful products, processes, and technologies. Their recommendations are then ratified by the Crossrail Innovation Forum, which is ultimately responsible for deciding which proposals will receive investment. By mid-2014, the innovation program had completed three rounds of evaluation and provided funding to support 30 innovations.

The process used to leverage innovation is illustrated with two vignettes. The first is an example of an innovation that received support—"Automatic transfer between Crossrail's Enterprise Bridge



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(eB) and each contractor's own document management system." Malcolm Nelson (Liverpool Street Project Director, Laing O'Rourke) submitted an idea for a more efficient document management system that could be implemented on Laing O'Rourke's Liverpool Street Station contract and had the potential to be used across the entire program. Laing O'Rourke used a software system called ASite for its own internal project documentation. They had to manually copy files and information to and from Crossrail's Enterprise Bridge (eB) system, which was time consuming because many administrators and protocols were needed to ensure that both systems held the latest versions of the documents. Each contractor on other parts of the program using their preferred document management systems was required to do something similar. Malcolm suggested that the efficiency of Crossrail's whole program of work could be improved by developing an interface that would automatically transfer data between eB and each contractor's document management system.

The innovation team recognized the benefits of the proposed innovation. After clarifying the idea with Malcolm, the innovation was discussed further in a technical review meeting chaired by the innovation team involving Crossrail's IT team, eB and ASite developers, and document controllers at Crossrail and Liverpool Street. An application for £15,000 (approximately US\$24,000) to develop a new method was reviewed in early 2014 by the Innovation Working Group. Representatives from the supply chain agreed that the proposed interface would increase the efficiency of individual project teams and the program as a whole. The Innovation Working Group recommended that money be made available to support the new idea on the condition that it would be made freely available—with no Intellectual Property restrictions—to all contractors and document management system suppliers. The Crossrail Innovation Forum agreed to invest in the innovation to improve

the performance of the program, progress the industry toward level 3 BIM and benefit other UK infrastructure projects adopting the eB system.

The second is an example of an innovation proposal that, although extremely promising did not receive support—"Field Engineering Site Diary via Google Glasses." With the assistance of the innovation team, Archie Heaton-Renshaw and Howard Crane (Crossrail Field Engineers, Whitechapel), were encouraged to explore how the new Google Glasses could be applied to improve construction activities. Digital mobile devices and cameras were not approved to record activities. Each site used the traditional method of a pen and paper to record events in the daily diaries, such as operative activities; materials used; weather conditions; and health, safety, environment, and quality inspections. Collating and filing this information in digital format was a time-consuming task, which diverted resources from more important site activities. Archie and Howard suggested that Google Glasses could provide an efficient hands-free tool with a head-up display equipped with cameras to capture still images with cloud-based storage and HD video live streaming.

A proposal was submitted for a two-phase trial to test whether the Google Glasses could improve the collection of Site Field Engineer information. In phase 1, £5,000 (approximately US\$8,000) was requested to test the new technology in a live construction environment. Subject to the success of phase 1, £20,000 (approximately US\$32,000) was requested in phase 2 to identify the potential industry-wide uses for the device and seek collaboration with application developers to design customized software that empowers site-based staff and improves efficiency. The Innovation Working Group recommended an investment of £5,000 (approximately US\$8,000) to pursue phase 1, but the Crossrail Innovation Forum decided not to support the idea; they were concerned that the

device might be a distraction for site operatives and that developers would not need financial encouragement to develop software and specialized applications to support the widespread use of the hardware.

Exchanging

The exchanging window describes the opportunity associated with connecting the Crossrail megaproject with the wider project ecosystem to trade existing innovations, as well as partnering to pursue common innovation objectives. The sharing of innovation with other megaprojects was viewed almost as one of Crossrail's ethical responsibilities. This view was championed by the senior management team who viewed it as incumbent on them to contribute something to future projects (e.g., Thames Tideway Tunnel; High Speed 2) in much the same way previous projects had invested in sharing their innovations (e.g., organizational structures) with Crossrail. However, this sharing aspect is only one half of the exchanging window; the other component speaks to the opportunity to pool resources with other projects in the pursuit of common objectives. It was this aspect of Crossrail's Strategy that we saw as most novel.

What Crossrail recognized was that the innovation challenges they faced often had important similarities to other mega infrastructure projects in the UK infrastructure ecosystem. For example, Crossrail is currently the United Kingdom's largest user of the sprayed concrete lining tunneling method and it is likely that other projects on the horizon, such as the Thames Tideway Tunnel and High Speed 2, will also require significant SCL work. It is widely acknowledged that there is significant room for innovation to make this technique safer and cheaper, yet there are few mechanisms in place for exchanging such knowledge across organizational boundaries. Instead of tackling innovation challenges in isolation, Crossrail recognized that there was an opportunity to share the burden and benefits of



making the required investments with other megaprojects and organizations in the infrastructure ecosystem. These discussions are now underway.

Discussion and Conclusions

Our action research with Crossrail provided us with a unique opportunity to observe and participate in a pioneering effort to develop and implement an innovation strategy. Our review of the literature about innovation strategies developed by firms—or permanent organizations—helped us identify some key challenges involved in making innovation happen in a large multi-party temporary organization. However, innovation strategies developed by firms could not be simply copied and transferred to our research setting. Instead, Crossrail had to design an innovation strategy, which was tailored to the requirements of a megaproject involving a large coalition of contractors and suppliers who were coordinated by a temporary client organization.

Our study identified four opportunities for intervening in megaprojects to promote innovation: the bridging, engaging, leveraging, and exchanging windows. We believe that this innovation framework provides a useful heuristic tool, helping managers create and capture significant additional value during each phase of a megaproject. Since our collaboration was initiated after the bridging and engaging stages were already underway, the focus of our intervention has been to assist with leveraging and exchanging innovation. Although we emphasized the benefits of innovating during the project, future research might address the difficulties and challenges (e.g., institutional, behavioral, and contractual) that have to be overcome to achieve successful outcomes.

We engaged in five steps of action research to promote innovation in Crossrail. First, we identified and established a research-oriented collaboration between practitioners and researchers willing to invest the time

and resources required to implement the strategy. Second, we worked together to diagnose the research problem and identify appropriate forms of intervention. Third, we entered into a research agreement, which specified in some detail the scope of work, alignment of expectations, and outputs of the research. Fourth, we conducted research—including an external evaluation of industry practices and internal review of existing innovation activities in Crossrail—to formulate, articulate, and codify the innovation strategy. Fifth, we had to create a process to support, monitor, and implement the strategy, including an evaluation of Crossrail innovations.

CRL implemented the strategy in early 2013 and it is too early to assess the impact of the innovation program on the performance of the project. Because our research is confined to a single case, further research is required to verify if these steps can be replicated to promote innovation on other megaprojects. For example, future work could consider how action research could create a more comprehensive innovation strategy for a megaproject that embraces all four stages of the innovation interventions identified in our study. Although our intervention in the leveraging and exchanging stages could be applied to other megaprojects, other forms of research may be needed to support efforts to intervene and make innovation happen in the bridging and engaging stages.

The UK megaproject ecosystem was and remains a fertile ground for innovation. Crossrail followed in the footsteps of highly innovative projects, such as T5 and the London Olympics. These projects had already introduced radically new delivery models, which were led by highly respected and experienced project leaders and champions of innovation. Although our research setting was clearly conducive to innovation, other megaprojects undertaken elsewhere in the world may not benefit from such favorable contextual conditions. Future

research may need to identify how different contingencies and institutional mechanisms shape opportunities for innovation across a variety of megaprojects. Such research would be especially valuable in helping us understand how well the four windows for innovation generalize to different institutional settings.

References

- Afuah, A. (2003).** *Innovation management: Strategies, implementation, and profits*. New York, NY: Oxford University Press.
- Algeo, Ch. (2014).** Exploring project knowledge acquisition and exchange through action research. *Project Management Journal*, 45(3), 46–56.
- Altshuler, A., & Luberoff, D. (2003).** *Mega-projects: The changing politics of urban public investment*. Washington, DC: The Brookings Institution.
- Armitt, J. (2012).** *The Armit review: Independent review of long term infrastructure planning commissioned by Labour's policy review*. London, England: Labour Party. Retrieved from <http://www.armitreview.org>
- Boudreau, K., & Lakhani, K. (2009).** How to manage outside innovation. *MIT Sloan Management Review*, 50(4), 69–76.
- Brady, T., & Davies, A. (2014).** Managing structural and dynamic complexity: A tale of two projects. *Project Management Journal*, 45(4), 21–38.
- Chesbrough, H. W. (2003).** *Open Innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business School Press.
- Crossrail. (2012).** *Crossrail Innovation Strategy: Moving London forward*. Retrieved from www.crossrail.co.uk
- Davies, A., Gann, D., & Douglas, T. (2009).** Innovation in megaprojects: Systems integration at Heathrow Terminal 5. *California Management Review*, 51(2), 101–125.
- Davies, A., & Mackenzie, I. (2014).** Project complexity and systems



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- integration: Constructing the London 2012 Olympics and Paralympics Games. *International Journal of Project Management*, 35(4), 773–790.
- Dodgson, M., Gann, D., & Philips, N. (2014).** *The Oxford handbook of innovation management*. Oxford, England: Oxford University Press.
- Dodgson, M., Gann, D., & Salter, A. (2008).** *The management of technological innovation: Strategy and practice*. Oxford, England: Oxford University Press.
- Egan, J. (1998).** *Rethinking construction: The report of the construction industry task force*. Department of Transport, Environment and Regions.
- Flyvbjerg, B. (2006).** From Nobel Prize to project management: Getting risks right. *Project Management Journal*, 37(3), 5–15.
- Flyvbjerg, B. (2014).** What you should know about megaprojects and why: An overview. *Project Management Journal*, 45(1), 6–19.
- Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003).** *Megaprojects and risk: An anatomy of ambition*. Cambridge, England: Cambridge University Press.
- Flyvbjerg, B., Garbuio, M., & Lovallo, D. (2009).** Delusion and deception in large infrastructure projects: Two models for explaining and preventing disaster. *California Management Review*, 51(2), 170–193.
- Gil, N. (2009).** Developing project client-supplier cooperative relationships: How much to expect from relational contracts? *California Management Review*, 36(7), 1434–1169.
- Gil, N., & Beckman, S. (2009).** Infrastructure meets business: Building new bridges, mending old ones. *California Management Review*, 51(2), 6–29.
- Gil, N., Miozzo, M., & Massini, S. (2012).** The innovation potential of new infrastructure development: An empirical study of Heathrow Airport's T5 project. *Research Policy*, 41(2), 452–466.
- Latham, M. (1994).** *Constructing the team*. London, England: Her Majesty's Stationery Office (HMSO).
- Loch, C. H., De Meyer, A., & Pich, M. T. (2006).** *Managing the unknown: A new approach to managing high uncertainty and risk in projects*. Hoboken, NJ: John Wiley & Sons.
- Merrow, E. W. (2011).** *Industrial megaprojects: Concepts, strategies, and practices for success*. Hoboken, NJ: John Wiley & Sons.
- Miles, M. B., & Huberman, A. M. (1994).** *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage Publications.
- Morris, P. W. G., & Hough, G. H. (1987).** *The anatomy of major projects: A study of the reality of project management*. Chichester, England: John Wiley & Sons.
- Morris, P. W. G. (2013a).** *Reconstructing project management*. Chichester, England: Wiley-Blackwell.
- Morris, P. W. G. (2013b).** Reconstructing project management reprised: A knowledge perspective. *Project Management Journal*, 44(5), 6–23.
- Oliver, A. (2008a).** Doug on the dig. Douglas Oakervee interview. Building Crossrail: Major Project Report. *New Civil Engineer*, November, 4–6.
- Oliver, A. (2008b).** Coming up with the goods: Procurement. Building Crossrail: Major Project Report. *New Civil Engineer*, November, 20–22.
- Oliver, A. (2012a).** Applied experience: Lessons from the past. Andrew Wolstenholme interview. Crossrail Tunnelling Starts: Major Project Report. *New Civil Engineer*, May, 6–8.
- Oliver, A. (2012b).** Putting things in perspective: The technical challenge. Andy Mitchell interview. Crossrail Tunnelling Starts: Major Project Report. *New Civil Engineer*, May, 10–11.
- Parsons Brinckerhoff. (2012).** *Exploring innovation: 17 stories of innovation*. London, England: Parsons Brinckerhoff. Retrieved from www.pbworld.com
- Sanderson, J. (2012).** Risk, uncertainty and governance in megaprojects: A critical discussion of alternative explanations. *International Journal of Project Management*, 30, 432–443.
- Schön, D. A. (1983).** *The reflective practitioner: How professionals think in action*. London, England: Ashgate Publishing Limited.
- Shenhar, A. J., & Dvir, D. (2007).** *Reinventing project management: The diamond approach to successful growth and innovation*. Boston, MA: Harvard Business School Press.
- Thamhain, H. (2013).** Managing risks in complex projects. *Project Management Journal*, 44(2), 20–35.
- Turner, R., & Zolin, R. (2012).** Forecasting success on large projects: Developing reliable scales to predict multiple perspectives by multiple stakeholders over multiple time frames. *Project Management Journal*, 43(5), 87–99.
- Van de Ven, A. (1986).** Central problems in the management of innovation. *Management Science*, 32(5), 590–607.
- Van de Ven, A. (2007).** *Engaged scholarship: A guide to organizational and social research*. Oxford, England: Oxford University Press.
- Van Marrewijk, A. (2007).** Managing project culture: The case of Environ megaproject. *International Journal of Project Management*, 25, 290–299.
- Van Marrewijk, A., Clegg, S. R., Pitsis, T., & Veenswijk, M. (2008).** Managing public-private megaprojects: Paradoxes, complexity and project design. *International Journal of Project Management*, 26, 591–600.
- Ward, S., & Chapman, C. (2003).** Transforming project risk management into project uncertainty management. *International Journal of Project Management*, 21, 97–105.
- Wolstenholme, A., (2009).** *Never waste a good crisis*. London, England: Constructing excellence in the built environment. Retrieved from http://www.constructingexcellence.org.uk/pdf/Wolstenholme_Report_Oct_2009.pdf
- Yang, J.-B., Chu, M.-Y., & Huang, K.-M. (2013).** An empirical study of schedule delay causes based on Taiwan's litigation cases. *Project Management Journal*, 44(3), 21–31.



Yang, R. J., Wang, Y., & Jin, X.-H. (2014). Stakeholders' attributes, behaviors, and decision-making strategies in construction projects: Importance and correlations in practice, *Project Management Journal*, 45(3), 74–90.

Yin, R. K. (2003). *Case study research: Design and methods*. Thousand Oaks, CA: Sage Publications.

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