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From Iconic Design to Lost Luggage: Innovation at Heathrow Terminal 5

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Abstract:

This paper aims to contribute to understanding of how organizations respond to risk and uncertainty by combining and balancing routines and innovation. It shows how approaches to risk and uncertainty are shaped by the contractual framework in large multi-party projects. The paper addresses a gap in the literature on how risk and uncertainty is managed to deliver innovation in large-scale 'megaprojects'. These megaprojects are notorious for high rates of failure that conventionally evoke organizational strategies avoiding risks and uncertainties. Yet strategies for managing risk and uncertainty are essential to the routines and innovation that overcome the challenges of successfully delivering large-scale, complex projects.

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INTRODUCTION

This paper aims to contribute to understanding of how organizations respond to risk and uncertainty by combining and balancing routines and innovation. It shows how approaches to risk and uncertainty are shaped by the contractual framework in large multi-party projects. The paper addresses a gap in the literature on how risk and uncertainty is managed to deliver innovation in large-scale ‘megaprojects’. These megaprojects are notorious for high rates of failure that conventionally evoke organizational strategies avoiding risks and uncertainties. Yet strategies for managing risk and uncertainty are essential to the routines and innovation that overcome the challenges of successfully delivering large-scale, complex projects.

Since the pioneering research of Joan Woodward in the 1950s and 1960s, the relationship between innovation and industrial organization has been understood to be influenced by the scale and standardization of production (Woodward, 1965). The mass production of standardized products poses very different organizational challenges than the production of customized small batches. When production is unique and one-off, as in projects, organization is more likely to be exploratory, and less able generally to exploit economies of scale and established routines (March, 1991). Innovation is commonly associated with risk (Wiseman and Bromley, 1996), and risk is greater where organizational objectives are unknown or emergent.

There are huge stakes involved in the successful execution of large projects resulting from the common failure to achieve original cost, time and quality objectives; large commitments in financial capital; integration of advanced technologies; lack of alignment among stakeholders; and system accidents or failure (Perrow, 1984; Shapira and Berndt, 1997; Miller et al., 2000). Recent literature on “large-engineering projects”, “grand-scale construction projects”, and “megaprojects” suggests that there has been an accelerated growth since the early 1990s in the number, size and diversity of large projects (Shapira and Berndt, 1997: Miller et al., 2001; Flyvbjerg et al., 2003). While drawing upon various studies of large projects, this paper uses the term megaproject which describes an organizational structure set up to produce a large-scale investment in complex infrastructure, such as an airports, high-speed rail network, metro system, telecommunications networks, dams, and oil and gas pipelines. It is defined as an investment of $1bn or more to produce physical infrastructure (Flyvbjerg et al., 2003).

Efforts to eliminate or minimize risks must take advantage of standardized, repetitive and carefully prepared routines, processes and technologies. However, emergent events and problems encountered during the project also require innovative, novel or unique solutions to keep the project on track to successful completion. Therefore, managing risks and uncertainties in megaprojects involves finding a judicious balance between performing routines and promoting innovation.

The research setting for this study is London Heathrow Airport's Terminal 5 (T5), and a 10-year research study into its planning, design, construction and operation. T5 was a large and highly complex project, with a budget of £4.3 billion and involving over 20,000 contracting organizations. Overseen by the British Airport Authority (BAA), the project client, airport owner and operator, it entailed the construction of major buildings, a transit system, road, rail and subway links, alongside the world's busiest airport working at overcapacity. The T5 project used a contractual framework that differed considerably from industry norms, and encouraged collaboration, supplier responsibility and shared risk. The project was delivered to budget and on time.

The following section of the paper presents background literature from a range of disciplines on risk and uncertainty in megaprojects. This is followed by a description of our research method. We then present our case study of the Heathrow T5 Project. A discussion of the case and the importance of contractual forms follows, with final section presenting our conclusions.

BACKGROUND LITERATURE

All types of organizations face the challenge of preparing for an unknown future. They must distinguish between the risks of a possible range of outcomes from occurring and uncertainties that cannot be predicted. In this section, we review the literature on how organizations identify and respond to risk and uncertainty in the extreme case of megaprojects.

Risk and Uncertainty

An understanding of how organizations cope with risk and uncertainty must start with Knight's (1921) original contribution. In his view, there is a fundamental difference between risk and uncertainty. Both relate to imperfect knowledge about a future situation, which depends on the behaviour of an indefinitely large combination of objects and is shaped by many factors. Our orientation towards the future is inherently ambiguous:

> "It is a world of change in which we live, and a world of uncertainty. We live only by knowing *something* about the future; while the problems of life, or of conduct at least, arise from the fact that we know so little" (Knight, 1921: 199).

Risk is a known chance or measurable uncertainty. The distribution of a group of alternative outcomes is known through the use of probability calculations or from statistics based on previous experiences. Uncertainty is an unmeasurable or truly unknown outcome. It is not possible to identify a group of alternative outcomes because the situation being dealt with is highly unique. Uncertainty is generally associated with personal opinions or judgements about a future course of events that cannot be verified or falsified using scientific methods.

Knight (1921) identifies two different ways in which organizations and managers reach decisions about how to identify risks. An "intuitive judgement" is based on common sense, judgement and estimation. Decisions about what to expect in a situation, and how to respond to it, are made on the basis of what we infer from our knowledge of previous experiences. A “probability judgement” is based on either the application of mathematical logic to calculate the probability or the empirical method of applying statistics to work out the chance of an outcome occurring. Statistical probability is commonly used in business, while the mathematical logic rarely applies. When the probability of an outcome occurring is known, it is possible to take actions to prepare for the contingency. Taking out an insurance policy to guard against risks – such as a fire or tunnel collapse – on a project is an example of how such contingencies can be converted into a fixed cost.

Project risks and uncertainties

Previous studies have examined the risks and uncertainties associated with large projects from a variety of theoretical perspectives. Shapira and Berndt (1997) develop a cognitive-behavioural “risk-taking model” which links individual perceptions of risks to some level of aspiration. They identify two different decision-making approaches to risk. A “normative approach” uses statistical analysis (a form of probability judgement) of large samples of repeated events to estimate the probability of an expected outcome. A “descriptive approach” (similar to intuitive judgement) claims that people evaluate risky alternatives by comparing them to some reference point before choosing among them. Empirical research suggests that in practice managers define risk as the range of negative outcomes that might result in real danger. Managers often do not respond to risk using probability estimates and “feel more ‘at home’ with detailed descriptions of particular events, such as the ‘worst possible outcome’, than with summary statistics” (Shapira and Berndt, 1997: 307). The risk-taking approach argues that cost and time overruns and poor revenue predictions may be due to an over-reliance on descriptive decision-making and judgemental errors of managers suffering from cognitive biases.

Lessard and Miller (2000) offer a strategic management perspective on risk and uncertainty, which together with indeterminancy create an ambiguous context for decision making. They distinguish between two types of project risks: those that can be anticipated, and those that are more difficult to predict, but do emerge as the environment becomes more turbulent. Increasing uncertainty refers to situations where there is such limited knowledge that decision making is ambiguous. Indeterminancy means that future outcomes are not only difficult to comprehend, but also depend on a variety of exogenous and endogenous events that can produce a variety of alternative outcomes.

Flyvbjerg et al (2003) develop a sociological perspective to examine the interests and power relations involved in managing megaproject risks. They identify a “megaproject performance paradox”. Despite the growing number major projects being built around the world and opportunities to use experience gained to improve performance, many projects have poor performance records. Cost and time overruns, failures to achieve the desired outcomes, and lower-than-predicted demand and revenues undermine the viability of projects. A major cause of the megaproject paradox is inadequate understanding that “the world of megaproject preparation and implementation is a highly risky one where things happen with only a certain probability and rarely turn out as originally intended” (Flyvbjerg et al., 2003: 6). In their view, project risks should be explicitly acknowledged by all of the stakeholders – such as business, NGOs, scientific and technical interests, media and users – involved a project. By promoting greater accountability towards risk, all stakeholders can participate in a carefully designed set of deliberative processes through all phases in the project life cycle.

The risk-management perspective developed by Loch et al (2006; see also DeMeyer et al., 2001; Pich et al., 2002) claims that many projects fail because organizations do not appreciate the difference between project risk and project novelty. Project risk is defined as the probability of an event’s occurrence and the extent of impact on a project if the event does occur. Project novelty refers a combination of unforeseeable uncertainty (rather than risk) and complexity. Complexity is defined as the number of system components, project tasks, stakeholder relationships and the interaction between them. An example of a novel project is one established to move from an organization’s traditional capabilities into the unknown terrain required to develop new technologies and markets. Whereas it is possible to prepare for risky projects, novel projects are difficult to plan due to such a high degree of uncertainty or complexity, or both. However, managers can make use of two different techniques to cope dynamically with project novelty: “learning” provides a flexible way of adapting a project approach as more knowledge and experience is gained about the project, its environment and their interactions; and “selectionism” makes use of multiple approaches, each running simultaneously but independently of each other, and selecting the best one.

Shenhar and Dvir (1996 & 2007) provide an analysis of projects, uncertainty and complexity using concepts derived from contingency theory and innovation studies. They argue that most projects fail because managers do not understand the uncertainty and complexity involved and fail to adapt their project management approach to each unique situation. They have developed a diamond model for analyzing the four dimensions shaping the benefits and risks of a project. The model is devised to offer an assessment of risk by breaking a project down into components (the four dimensions) and focusing attention on the resolution of riskier dimensions to improve the chances of success (Shenhar and Dvir, 2007: 173). (1) Novelty represents the uncertainty of the project’s goal and the risks associated with misunderstanding a customer’s needs. (2) Technology represents the project’s level of technological uncertainty in terms of how much new technology is integrated into the product and risks of overruns associated with higher levels of technological uncertainty (Shenhar, 1993). (3) Complexity refers to the complexity of the system produced and the risks associated with coordinating and integrating its components. (4) Pace refers to the risks of failing to meet a project’s schedule goals or failing to resolve problems because of time constraints.

Organizational Response to Risk and Uncertainty

The literature shows how a megaproject is an extremely risky and uncertain endeavour when we consider a number of dimensions, such as the level of complexity and interdependence of tasks, ambiguity in choices in areas such as technology, diversity of stakeholders with different interests, novelty and time challenges, and managerial decision making dependent upon intuition.

Managers responsible for a managing a megaproject must decide what form of organization is required in response to risk and uncertainty. In organization theory, the main difference between a project and repetitive operation is the "*uncertainty about what to do* in projects, which must be *resolved by decisions*" (Stinchcombe and Heimer, 1985: 26, original emphasis). In repetitive operations such as high-volume manufacturing, productive tasks are well known and stable because they are carefully planned, standardized and repeated on a daily basis. Located at the extreme one-off and bespoke end of Woodward's (1965) typology of industrial organizations, a project has to deal with many unforeseen, unique and rapidly changing circumstances (Davies and Frederiksen, 2009). In highly uncertain projects such as the construction of offshore oil and gas platforms, each new situation must be confronted flexibly on the basis of the previous experience and knowledge of the managers and organizations involved. Under such a high degree of uncertainty, each part of a project must be "administered as it if were an innovation or response to an unusual happening" (Stinchcombe and Heimer, 1985: 26).

Decisions must be reached about how a megaproject is organized to strike a balance between repetitive operational routines and innovative problem-solving behaviours. Routines refer to repetitive and predictable patterns of productive activity involved in operations that are "visibly 'the same' over extended periods" (Nelson and Winter, 1982; 97; March and Simon, 1958: 13). An organization's previous experience, learning and tacit knowledge are embodied in well-defined routines stored in its organizational memory. Written records and other explicit knowledge play a role in maintaining an organization's memory, but organizations only remember when they perform routines (Nelson and Winter, 1982). The concept of "exploitation" refers to the routine behaviour and organizational learning involved in refining and extending an organization's existing capabilities and improving the performance of current routines (March, 1991).

Innovation refers to the changes in an organization's routines or new combinations of previous routines required to create new products, processes or services in response to new opportunities, unusual circumstances or problems (Nelson and Winter, 1982). The concept of "exploration" refers to the innovative behaviour and organizational learning involved in problem-solving, risk taking and experimenting with unfamiliar alternatives (March, 1991).

March (1991) emphasizes the trade-off that managers must resolve between routine exploitative and innovative exploratory behaviour. An organization that focuses almost exclusively on exploring new innovative possibilities at the expense of exploitation may suffer from "too many undeveloped ideas and too little competence" (March, 1991: 71). On the other hand, an organization preoccupied with exploitation and short-term routine-driven improvements in performance will miss longer-term opportunities to search for and develop new and profitable technological, organisational approaches or markets.

Efforts to achieve a good balance between routine and innovative behaviour and learning are closely related to rate of change in the environment. Established routines and behaviour are well adapted to performing operations under stable conditions and low-levels of uncertainty. However, there may be little interest or incentives to engage in exploratory learning or finding solutions through innovation. There is a risk that the learning that does occur "single-loop" employs defensive routines to resist change and support self-sealing and self-repeating patterns (Argyis, 1977). Adhering too closely to standard operating procedures can encourage organizations to behave unreflectively and automatically (Starbuck, 1983 and 1985), which prevents them from seeking new solutions.

Organizations operating in rapidly changing environments under high-levels of uncertainty face a challenge of exploring new alternatives, radically changing existing practices and creating new innovative combinations of routines. Managers and organizations have to engage in self-reflective “double-loop learning” by confronting previously held assumptions and creating new more appropriate routines (Argyis, 1977). Second-order learning requires explicit decisions to transform the routines, structure and skills in ways that will deliberately improve performance and augment capability. When new innovations are created to solve a problem or improve performance, organizations tend to repeat them until they become new set standardized routines (Cyert and March, 1963).

Recent research suggest that while the outcome of a project is a one-off and highly customized product, many of the processes involved in its production are not necessarily novel or unique. Organizational efficiency can be improved by creating standardized processes – or routines – which are standardized, simplified and repeated within and across projects tasks (Davies and Hobday, 2005; Shenhar and Dvir, 2007; Davies et al., 2009). Stinchcombe (1985: 248-249) was the first to draw attention to the importance of “project routines” as a central source of efficiency and learning in projects. Project routines refer to tacit knowledge and experience required to perform clearly defined repetitive tasks, roles and responsibilities. Managers know what to do because they have performed the task in the past. Project routines can be embodied in project management process guide books and software for administering on future projects, so that the efficiency built into routines does not disappear when a project is dismantled. Although organizations “use project routines to reduce the liability of newness… when things are not routine, they are emergencies” which must be dealt with by innovation (Stinchcombe, 1985: 249). Project routines are pre-planned and prepared approach in anticipation of a predicted uncertainty or event. If and when it occurs, appropriate routines are enacted. Project innovation is a creative response to an unknown happening and the approach required to solve it is not known prior to the event.

We suggest that a megaproject is complex structure involving a combination of project routines and innovation. Each megaproject is organized to perform project routines to (a) manage predictable and known operational circumstances (e.g. project management procedures, prefabricated manufacturing, Just-In-Time deliveries of material and components) and (b) minimize the risk of known uncertainties from occurring (e.g. inadequate training in preparation for the operational phase of a facility). However, a megaproject must also be organized to provide innovative and unique solutions to unknown events or unique happenings that cannot be predicted at the outset, but must be resolved to keep the project on track to successful completion. Managers responsible for a managing a megaproject must therefore decide what form of organizational approach is required to perform repetitive operational routines in response to risk, while fostering innovation and project-based problem solving to cope with uncertainty.

Contractual decisions: transfer, share or bear the risks

The organizational approach chosen to achieve a balance between routines and innovation in response to high levels of risk and uncertainty hinges upon the nature of the project contract. Organizations typically face a choice between three major forms of contract: fixed-price, cost-plus, or mixed-incentive contracts (Shenhar and Dvir, 2007: 93-94; Loch et al., 2006: 68; Floricel and Miller, 2001).

In fixed-price – or lump-sum – contracts, the client transfers all of the risk to the contractor. Fixed-price contracts generally work well at lower levels of uncertainty, where risks are known and there is less likelihood of unknown happenings from occurring. When fixed-price contracts are used for projects with higher levels of uncertainty, it can create high risks for clients and contractors. When this type of project encounters unforeseen events, clients may receive inadequate outcomes if the contractor tries to remain within cost and time constraints. On the other hand, contractors may incur penalties for failing to achieve the project’s original performance targets, but can earn additional profits if the scope of the project changes.

In a cost-plus incentive – or cost-reimbursable - contract, the “risks are shared” between the client and contractor organizations. The client reimburses all costs incurred by the contractor. Under a pain/gain share arrangement, the contractor has an incentive of earn additional profits if it achieves or exceeds the performance targets. In some forms of cost-plus contracts, the client may decide “bear the risks” and invest considerable resources in building the capabilities required to lead the project from start to finish (Zack, 1996).

In mixed-incentive contracts, a combination of fixed-price and cost-plus contracts is used to address the varying requirements of different types of projects, sub-projects or phases in the project life cycle. A cost-plus contract is used during the early development phase of a project to cope with higher levels of uncertainty and a fixed-price contract is used at a later stage of construction as the level of uncertainty reduces. In other cases, intermediate contract types involving incentive fees, bonuses and penalties, and target prices are used to improve the performance of contractors. Some large projects use a combination of contracts to run sub-projects. For example, the Channel Tunnel between England and France used a cost-plus contract for tunnelling, a fixed-price lump sum contract for the construction of terminals and installation of mechanical and electrical equipment, and a procurement contract for rolling stock (Genus, 1997).

The nature of the contracts shapes the organizational behaviour, relationships between clients and contractors, and balance between routines and innovation on each megaproject. Risk-sharing contracts based on open-book transparency and pain/gain incentives used on offshore oil and gas projects in the North Sea were designed to foster collaborative behaviour, trust and a partnering approach (Barlow, 2000). In risk-sharing arrangements, the balance is tilted towards rewarding innovation and incentivizing problem solving behaviour to cope with many unknown outcomes. In fixed-price contracts, by contrast, the emphasis is on transferring responsibility for a standardized and routine response because it is assumed that the uncertainties are known and understood at the outset. The contractor often wins the bid by offering a low price and is encouraged to earn profits arising from scope changes. A contractor may be tempted by the opportunity of shirking – saving costs by comprising on quality. Such contracts promote adversarial relationships between clients and contractors, often ending in legal disputes unless both parties can reach agreement. This suggests that fixed-price contracts should be awarded on the basis of identified risk and a supplier's capabilities and performance records, rather than lowest price (Loch et al., 2006: 69).

RESEARCH METHOD

This study of the Heathrow Terminal 5 (T5) examines how innovation, risk and uncertainty were managed within a single megaproject drawing upon collaborative research conducted over a ten-year period (1998-2008). The research aimed to answer two main questions: How did BAA use previous knowledge and experience to develop its risk-bearing approach prior to the construction of the T5 project? What learning was gained from the implementation of the T5 approach during the delivery of the T5 project?

Although the focus of the study was on BAA's distinctive approach to innovation and the management of risk and uncertainty on T5, our efforts to answer the above questions benefited from research designed to frame, analyze and interpret the project in a wider organizational context. Case studies of two adjacent projects (1998-1999) undertaken by BAA while it was preparing for the construction phase of T5, enabled us to examine experimental efforts to test some of processes subsequently used on T5. Interviews with senior managers previously involved in the Heathrow Express project (1994-1998) – a new train line connecting with Paddington Station in London - enabled us to understand a major project, which became trial run for the approach to risk management and collaborative working later used on T5.

Interviews with managers in Laing O'Rourke (LOR) (2005-2008) provided an opportunity to examine the how innovation, risk and uncertainty were managed from the perspective of a major contractor and first-tier supplier during the construction phase, revealing the "other side of the coin" of a client risk-bearing approach on the T5 project (see Appendix: Interviews on T5). As well as BAA, interviews were conducted with British Airways (BA), the occupier of T5.

In-depth case studies are appropriate for studying poorly understood phenomena (Marshall and Rossman 1995), and where contextualization and vivid descriptions of organizational behaviours is important (Lee, 1999). The case study is an appropriate method as the question of innovation, risk and uncertainty in the T5 project is exploratory and aimed at theory building (e.g. Eisenhardt 1989; Yin 2004). It was selected as it has a number of "rare or unique" qualities that make it a logical candidate for "theoretical sampling", and it displays characteristics of a "revelatory case" (Eisenhardt 1989; Yin 2004). T5 presented an unusual opportunity to study a research site in which inherent risks and uncertainties are extreme and innovation is a necessity.

CASE STUDY: HEATHROW TERMINAL 5

The following case illustrates the challenges and emergent events, and risks and uncertainties, encountered during T5's long gestation and project delivery periods, which shaped BAA's approach to innovation.

Background to the project

T5 is designed to be the home of all of BA's domestic and international passengers at Heathrow. It has a annual capacity of 30 million passengers and designed to be compatible with the A380 airliner, the world's largest aircraft. T5 is a large complex on a site of 260 hectares – the size of London's Hyde Park – between the northern and southern runways at the western end of Heathrow. It is comprised of a large four-storey terminal building (Concourse A) and a satellite building (Concourse B), which is connected to the main building by an underground people mover transit system, and 62 aircraft stands. A second satellite building is under construction and scheduled for completion in 2010. Additional airfield infrastructure, a 4,000 space multi-storey car park, a large hotel and an 87-metre high air traffic control tower have been constructed on the site. T5 is connected by road links to the neighbouring M25 motorway. An underground railway station with branches of the Heathrow Express and the London Underground's Piccadilly Line provides fast transportation to and from the centre of London.

Project Life Cycle

The sequence of the decisions shaping BAA's approach to innovation and risk management on T5 will briefly be discussed and plotted against the T5 project life cycle. As shown in Figure 1, the project consisted of four distinct but overlapping and interrelated phases: (1) planning, (2) design, (3) construction, and (4) integration into airport operations.

1985
1995
2005
1990
2000

(1) Planning phase – 1986 until Sept 2002
(2) Design phase – 1989 until around 2004
(3) Construction phase – Sept 2002 until 27 March 2008
(4) Operational readiness phase – final 6 months prior to opening

Figure 1: Heathrow Terminal 5 Project Life Cycle

Planning phase. BAA's planning for T5 began in 1986 and ended in 2001 when the project was granted consent to proceed with construction. This phase included the longest public inquiry in UK planning history, which lasted from 1995 to 1999. As a result of the inquiry, the project was subject to 700 restrictions, including the diversion of two rivers to meet tough environmental conditions. The project opening date of 30th March 2008 was set in 2001 and a budget of £4.3bn was established in 2003.

During this planning phase, BAA prepared, developed and refined the novel approach that would be used to deliver the project. In a project of such strategic importance and risk for BAA, it was decided that the T5 Project Director should occupy a position on the company's main Board to provide regular reports about the progress of T5 from planning through design and construction to commissioning and to acquire the resources and high-level support needed to overcome any problems hindering its progression.

When Sir John Egan, BAA's CEO from 1991 to 1999, first began to prepare for the delivery of the T5 project in the early 1990s it was widely recognized that the UK construction industry had a poor track record in delivering major projects. Initially, BAA's efforts to improve project delivery concentrated on developing routines and processes to improve the performance of routine and small-scale capital projects. A standardized process called "Continuous Improvement Project Process (CIPP) was implemented, which was based on a set of replicable processes such as standardized designs and modular components, integrated project teams involving BAA, and framework agreements to work on a long-term basis with selected first-tier suppliers. While this process was developed for less risky capital projects, BAA used the experience to prepare a set of standardized processes that could be used on T5. Experience with co-operative working on BAA's smaller projects, such as the T4 International Arrivals Concourse and T1 Baggage Handling projects, provided a useful testing ground for T5 processes. The specific processes for delivering T5 – including lines of reporting, responsibilities and accountabilities – were written down in the "T5 Handbook", originally published in 1996 and revised to accommodate subsequent learning. The processes outlined in the handbook enabled BAA to develop the "T5 Agreement" – a legal document which assumed that the client would bear the risk on T5 and encouraged collaborative behaviour, designed to improve BAA and partners' working in integrated project teams.

While preparing for T5, BAA was involved in another large project that encountered an unforeseen event. The project was brought to a halt in October 1994 when one of the main tunnels collapsed after a period of heavy rain. At one point, the project was 24 months behind schedule. Unlike T5, the Heathrow Express project was a fixed-price contract. Balfour Beatty, the prime contractor, was accountable for the risk and solving any emergent problems. The automatic response would be to sue the contractor for breach of contract. However, as the joint project owner and client, Heathrow Express and BAA recognized that they were ultimately responsible for carrying the risk, since they would incur the loss of revenues and tarnished reputation associated with a heavily delayed service. Adopting improved project delivery processes – which BAA was developing at the time – could not resolve this problem. A more radical solution was required. The client decided to adopt a risk-bearing, cost-reimbursable contractual approach.

Before joining BAA, several senior managers involved in the Heathrow Express project, including Andrew Wolstenholme, the future T5 Project Manager, previously worked for design engineering firm Arup on a megaproject valued at £750m to build the pharmaceutical research facility for Glaxco (now GSK). The Glaxco project experienced major difficulties which were successfully resolved by adopting practices used on major oil and gas projects, including ownership of risk, co-located integrated project teams, and open-book cost-reimbursable contracts. Andrew Wolstenholme was instrumental in bringing the Glaxco risk-bearing experience and practices to the Heathrow Express project. Efforts to recover the tunnel and rescue the project enabled the Heathrow Express project to meet the tight target date for the project and it opened for service in June 1998. In the view of one senior manager, “Heathrow Express was proof of concept that the T5 Agreement could work” (Fugeman, 2006).

BAA’s decision to bear the risk on T5 was given added support by a systematic case study, undertaken between 2000 and 2002, of every major UK construction project over £1bn over the previous decade and every international airport opened over the past 15 years. The research discovered that the poor performance of megaprojects was associated with fixed-price contracts to transfer risk and responsibility to a prime contractor, such as the Channel Tunnel project. Such projects experience cost, time and quality overruns because of disputes and legal battles between clients and contractors over responsibility for scope changes. BAA's research found that no UK construction project had been delivered on time, within budget, and few projects had good safety records. Informed by a statistical analysis of airport projects, BAA predicted that without a radically different delivery strategy, the project would be £1bn over budget, one year late and result in two fatalities.

BAA's benchmark study identified poor systems delivery and integration (e.g. baggage handling) as one of the main reason why international airports failed to open on time. As Andrew Wolstenholme explained, the learning gleaned from other airport projects and programmes should have enabled BAA to avoid the risk of failure during the systems integration and commissioning stage:

> "we have a dozen benchmark programmes that we look at, and steal the lessons from them. We say look, airports don't open because that's what happened at Denver, that's what happened at Chek Lap Kok, and all the risks that happen in these programmes we know about, and we have documented, and we're putting in to our live, risk management process here" (Wolstenholme interview, 2006).

A more specific study of systems integration in megaprojects, conducted by Nick Gaines, BAA's Head of T5 Systems, found that projects involving a high technology component are less successful. The risks of cost and time overruns associated with integrating new technology were minimised on T5 by the decision to use existing technology and mature products. Where new technologies were introduced, they were first installed, tested and proven in trial or operational environments, such as one of BAA's smaller airports, before being taken to T5 (Gaines interview, 2006).

BAA's experience gained on the Heathrow Express project and its research on megaprojects demonstrated that despite efforts to transfer responsibility, the client ultimately must bear and pay for the risk when a megaproject runs into trouble. Under the T5 Agreement, BAA assumed full responsibility for the risk and worked in integrated project teams with first-tier suppliers. By removing the risk from the supply chain, the T5 Agreement was designed to reward high performing teams. This was the first time these twin principles were adopted on a UK onshore construction project (NAO, 2005).

When the decision to proceed with T5 construction was announced in March 2002, the budget of £4.3bn was a huge undertaking for a company with a market capitalization of around £8.5bn. BAA took out a £4bn insurance policy to cover such a large financial risk. It also negotiated with the Civil Aviation Authority, the UK regulatory body, to ensure that BAA was rewarded – or at least given some protection – for bearing the risks on T5 (Doherty, 2008: 20).

Design phase. The main design activity started in 1989, when Richard Rogers Partnership won a national competition to design a new high-profile, iconic building with a 156 metre single-span "wavy roof" and a glass façade. BAA and BA worked together with architects and designers in large integrated project team to present a coherent conceptual design to the planning inquiry. Work on the detailed design drawings continued into the construction phase of the project.

An approach called "progressive design fixity" was adopted in the knowledge that it would not be desirable to freeze the design too early on a project facing many uncertainties over a long gestation period, including with the outcome of the planning inquiry. For example, specifications had to be changed to cope with the Airbus A380, which was not fully developed when the original design was agreed. Progressive fixity was supported by the "last responsible moment" technique, which identified the latest date that a design decision could be taken (Dogherty, 2008: 78). Three different designs were developed to address unforeseen events that impacted on the project during the design phase, including changes to the roof, new safety legislation after a deadly fire at Kings Cross Tube station, and stringent airport security following the 9/11 terrorist attack.

During this phase, Norman Haste, T5's first Project Director, emphasized that many large projects fail because of insufficient investment in the design: "this is when you achieve your biggest wins. You're never going to achieve them during the construction phase." (Haste, 2006). A single model environment (SME) was developed to enable digital coordination of design as well as the integration and testing of components during the construction phase of the T5 project. The SME was a real-time, computer aided design system of digital prototyping and simulation to provide photorealistic representation as a "virtual walk through" of each final design. The SME supported "last responsible moment" decision making by identifying the latest time a design could be made before progressing to fabrication and construction.

Construction phase. Construction of T5 was broken down into two sub-phases: the construction of infrastructure and buildings, from July 2001 to March 2008, and the integration of systems and retail fit-out of the buildings, from January 2006 to March 2008. It was during construction when the "theory of the T5 Agreement was tested" (Egan, 2008).

A separate organization was set up to manage the T5 project, consisting of around 300 experienced and highly skilled staff led by a small team of senior BAA managers. As the overall systems integrator and project manager, BAA divided the construction phase into four main activities: Buildings, Rails and Tunnels, Infrastructure, and Systems. These groups were responsible for 16 major projects and 147 sub-projects, with the smallest valued at £1m ranging to larger projects, such as the £300m extension of the Heathrow Express underground rail station. The construction phase involved a large network of suppliers including 80 first-tier, 500 second-tier, 5,000 fourth-tier, and 15,000 fifth-tier suppliers.

Relationships between suppliers did not always run smoothly. In a team led by LOR, the design engineering firm Mott MacDonald had fallen behind in delivering design drawings. Facing the possibility of falling behind schedule, LOR turned to the client for advice. BAA instructed LOR to find a resolution within the “spirit of the T5 Agreement”. LOR and Mott MacDonald had to find a way of cooperating by communicating and reinforcing the importance of collaborative behaviours. After some initial resistance, they eventually succeeded in finding a solution using 3D modelling to produce digital prototype designs for the sub-assemblies.

Operational integration phase. A joint BAA and BA team worked over three years to ensure that systems, people and processes would be prepared for the opening. The “start-finish” team worked during six months of systems testing and operational trials prior to opening, including 72 proving trial openings, each involving 2,500 people, to prepare workers, processes, systems and facilities for the public opening at 4.00am on 27th March 2008.

BAA’s research on previous airport projects and programs recognized that the opening could be disrupted by a “passive operator who will just stand back”, rather than one who “gets in early, operates early, steals this off you, takes all the learning, does final commission, and witnesses all the testing” (Wolstenholme, 2006). Despite being fully aware of the possible risks that could occur during opening, the BAA-BA team were unable to prevent the major difficulties arising when it opened for service on 27th March 2008. In the five days after opening, BA misplaced 20,000 bags and cancelled 501 flights, incurring costs of around $31m. The terminal achieved the first full schedule of operations 12 days after opening. A Government report concluded that the chaotic opening could have been avoided through “better preparation and more effective joint working” between BAA and BA (House of Commons Transport Committee, 2008). A major cause of the problem was BA’s decision to press ahead with the opening in the knowledge that its staff had insufficient training and familiarity with the terminal’s facilities and baggage handling system (Done, 2008; Williams and Done, 2008).

Although the project experienced problems when it opened for service, the project achieved its goals of designing and building a high-quality facility on exactly on schedule, within budget and with a satisfactory safety record.

DISCUSSION

A megaproject is an organizational response to extreme risk and uncertainty. At the outset, there may be a recognizable need for a project, but uncertainty about what ought to be done. In resolving this uncertainty, risks are identified and strategic decisions are made about how to proceed, including defining the overall project goals, governance structure and strategy for project delivery.

The design, construction and operational delivery of a megaproject involve a combination of routine and innovative tasks and processes. Risks can be reduced through the preparation of routines in anticipation of known uncertainties, such as the well-known overruns on megaprojects and specific airport problems (e.g. problems of installing baggage handling systems disrupting openings). However, uncertainty reduction through innovation is required when unexpected happenings occur on a project, ranging from major events (e.g. a tunnel collapse, unexpected outcome from a planning inquiry, or extreme events such as 9/11) to smaller-scale emergent problems encountered on sub-projects.

We now provide a discussion of the T5 case to examine the influence of the contractual framework required to address the risk-uncertainty and routine-innovation dimensions of this and other megaprojects.

Managing Risk and Uncertainty

The decisions and learned behaviours that allow risk and uncertainty to be managed in projects are formed in the context of formal contracts.

While planning for T5, BAA recognized that a new approach was required to cope with the scale and complexity of the project and long-gestation period for approval to proceed. Many uncertainties could not be predetermined. It appreciated a standard commercial contract would not be effective. BAA had to develop a contractual approach which fostered a routine-driven culture and mindset necessary to identify, isolate and tackle risks, while providing flexible space for innovation and problem-solving when unusual happenings or unpredictable events occurred.

BAA's systematic research on construction and airport megaprojects found that major project overruns were associated with the use of a fixed-price contract. BAA was fully aware of the importance of distinguishing between risk and uncertainty. Under this contractual approach, the client issues an invitation to tender, receives several competitive bids, selects a bidder and develops a contract. The contract consists of a high-level description of the desired outcome and large volumes of pages outlining what happens if and when changes in scope occur or the project fails. The contract specifies how the client and contractors must address "known risks" that may emerge during project execution. Rather than seek to understand uncertainties, each bidder concentrates on the known risks and outbidding competitors by producing a low-cost submission.

BAA identified an unresolved assumption of zero-sum thinking in commercial contractual contracting, which assumes that there will be a "winner and loser" on each project (Douglas, 2005). As Tony Douglas explained, "if these risks are so predictable, why did they keep replicating them from project to project, which takes you back to the same fundamental flaw in the game: somebody sees that they've got to win and somebody sees that they've got to lose" (Douglas, 2005). BAA's research found due to the high-level of uncertainty inherent in megaprojects "the bidder can't possibly know until you're further down the line what the solution could remotely be like" (Douglas, 2005).

BAA concluded that the only way to achieve a desired outcome on T5 was to "change the rules of the game" by creating a new type of agreement based on two fundamental principles: the client bears the risk and works collaboratively with contractors in integrated project teams. BAA had to take responsibility for risks and uncertainties, whilst creating "an environment within which our suppliers can actually find solutions" (Wolstenholme, 2005).

Risk bearing: The T5 Agreement is a form of cost-plus incentive contract, in which the client reimburses the costs incurred by the contractor plus pays a profit margin for exception performance. Unlike other forms of cost-incentive contracts where the risks are shared between the client and contractors, under the T5 Agreement BAA assumed full responsibility for the risk. Norman Haste, T5's first Project Director, was primarily responsible for persuading BAA to hold the risk:

> "I persuaded BAA that they had to accept all the risk all the time. Given what was going on with the Public Inquiry – nobody knew what the outcome was going to be and the conditions imposed by the Inspector or Secretary of State – you could not pass the risk to the design teams or contractors" (Haste, 2006).

Faced with such uncertainty at an early stage, the risk could not be transferred in a traditional contractual way because BAA could not possibly know what the solution would ultimately look like. It was decided that risks of not achieving a successful T5 would rest entirely with BAA.

Around 75% of the £4.3bn total cost was procured using the T5 Agreement with its 80 first-tier suppliers. By removing the risk from first-tier suppliers, the contract was designed to avoid damaging adversarial practices associated with fixed-price contracts. Instead the T5 Agreement provided incentives to encourage teams to work collaboratively to create innovative solutions when problems were encountered, rather than seek additional payments or enter into legal disputes about scope changes.

The T5 Agreement was a legal framework comprised of project execution and commercial principles. The execution principles for delivering the overall programme were laid down in the "Project Delivery Handbook" as repertoire of routines - predefined systems, and processes and collaborative behaviours.

The commercial principles ensured that suppliers were repaid all the costs on a cost transparent “open-book” basis and incentivized to improve their performance and innovate by bonuses for exceeding previously agreed “target costs” and completion dates. If the performance of a project exceeds target costs, the profits are shared among team members. This contractual approach was underpinned by routines to expose and manage risks rather than transfer or bury them and offered incentives for innovation and problem solving.

Integrated project teams. BAA’s approach to risk and uncertainty was underpinned by a collaborative organizational approach mandated by contractual form. Integrated project teams were formed at the start of the planning inquiry to develop the overall design of the facility. The construction of T5 was conceived as a series of customer products delivered by teams. The aim was to create a “virtually integrated” supply chain composed of integrated project teams led by BAA staff or individuals from the consultants, contractor and other organizations. The T5 Agreement did not specify the work to be undertaken by first-tier suppliers. Rather it was a commitment from suppliers to provide capability when and where it was required on the project. This mechanism enabled BAA to select talented individuals with the competencies and experience to perform the specific tasks, irrespective of the needs of their parent company.

The creation of virtual teams undermined any thoughts that risks could be transferred to an individual supplier and made it impossible to hold an individual supplier responsible for failure to achieve a project’s objectives. The teams were expected to work cooperatively towards achieving project goals by solving problems and acting on any learning gained, rather than “allocating blame or exploiting the failure or difficulties of others for commercial advantage” (Wolstenholme, 2008: 12). They were motivated by Richardson’s (1972) cooperation rather than Williamson’s (1975) “self-seeking with guile”. The success of each team was measured by the ability of individual members to work cooperatively to achieve high-levels of performance and manage unforeseen events.

Given the UK construction industry’s poor track record in managing large projects, the challenge of building T5 led by an inexperienced client and an untested supply chain was a huge risk for BAA. A core team was recruited or selected internally for their experience on other large UK and international projects. For example, senior BAA staff including three T5 project directors (Norman Haste, Tony Douglas and Andrew Wolstenholme) were headhunted by BAA because “they had a track record for completing projects and thrive on the cross-sharing of capability from best practices found in other industries” (Milford, 2006).

Balancing Routines and Innovation

As the case of T5 shows, risk and uncertainty in megaprojects can never be eliminated, but can be kept to a minimum by planning in advance and following carefully-prepared routines to reduce the possibility of predicted outcomes from occurring. However, when megaprojects encounter unknown problems or emergent events – as they invariably always do – a well-rehearsed, automatic or pre-programmed response is not always sufficient. Novel or unique solutions must be found to overcome obstacles to progress. Therefore, managing risk and uncertainty in megaprojects involves finding a judicious balance between performing routines and promoting innovation (Nelson and Winter, 1982). In the literature on organizational learning this is expressed as a trade-off between developing the capability to exploit repetitive processes to cope with risks, whilst being able to explore and implement customized solutions when unexpected happenings occur (March, 1991).

Routines. The scale, frequency and predictability of activities performed on a megaproject provide opportunities to develop repetitive and stable project and operational processes. These are routines that are structured in a controlled sequence, simplified into core repetitive tasks, based on standardized designs modules and components, and frequently repeated processes (Davies et al., 2009).

Routines must be devised to deal with fundamental risks that could hamper the progress of an entire project. Taking out an insurance policy, ensuring a favourable regulatory settlement to recover large fixed costs, and estimating future demand and revenues, are examples of high-level, standardized and routine responses that can be enacted and repeated during the planning phase of any megaproject.

Routines are also required to deal with the well known risks and uncertainties during the design and integration of a high complexity "system of systems" or array project (Shenhar and Dvir, 2007). BAA adopted two routines to minimize the such risks during project delivery. First, it recognized that the overall conceptual design could not be frozen until the outcome of the planning inquiry was known. The longer the project gestation, the more unpredictable and vulnerable was the project to emergent events. Supported by the SME, the concept of progressive design fixity was introduced to freeze the design at the earliest possible moment, while maintaining the flexibility to make adjustments as circumstances changed. Second, informed by its own research on megaprojects, BAA was fully aware that introducing new and unproven technologies on a complex project often results in significant cost, schedule and quality overruns. This "technological uncertainty" (Shenhar, 1992) was addressed by creating pilot and trial processes to test new technologies in other operational environments, such smaller airport or BAA's off-site testing facility at Heathrow (Gaines, 2006).

Most routines are developed to perform the many stable and repetitive tasks involved in mitigating risks regularly encountered in day-to-day operations. BAA's CIPP process and T5 Delivery Handbook are codified and replicable processes for project and programme delivery. BAA invested in the advanced visualization technologies based on the SME and complementary project management software to identify, diagnose, isolate and manage the risks involved in performing closely interdependent design, integration, fabrication and construction tasks on individual projects and across the whole T5 programme. Pre-assembly, pre-fabrication and Just-In-Time techniques are examples of high-volume production routines used on T5.

Even when organizations have identified the risks and understood a range of possible uncertainties that could be harmful to the progress of a project, they may not be able to avoid them. BAA was fully cognisant of the possibility that the opening of the airport terminal could be disrupted by the failure to follow carefully planned procedures and well-rehearsed routines. Despite identifying the systems, processes and trials required to prepare for the opening, BAA and BA failed to heed the lessons learnt from their study of unsuccessful airport projects. When the airport opened, BA's staff lack of familiarity and preparedness caused huge disruption to service. In this example, the solution did not require innovation. The problem was eventually resolved by BAA and BA's joint efforts to identify the causes of the problem and reinstate the routines necessary to achieve a full schedule of services.

Innovation. In many cases, however, unexpected problems and opportunities to improve performance cannot be resolved by falling back on an existing repertoire of routines. These situations are so unexpected or unusual that they require new and innovative ways of solving them to achieve or exceed their performance targets. Our research identified two levels of organizational flexibility and innovative capability in response to uncertainty: the overall project (or programme) and sub-project levels.

First, a major uncertainty or emergent event, which can threaten to hinder the progress of the project as a whole, requires a response from the senior members of the project and client organization. For example, when the Heathrow Express project came to a standstill after the tunnel collapse a solution was possible because the client's project directors and managers had the freedom to implement and adapt the cost-reimbursable approach based on their experience of the Glaxco research facility and other megaprojects (Murray, 2005). This expert team of senior managers brought the intuitive judgement, experience and decision-making skills – which Leonard and Swap

(2005) call “deep smarts” – required to solve an immediate crisis and prepare for the future.

Second, a megaproject is often executed as a programme broken down into major projects and sub-projects. As we illustrated by the example of the team comprised of LOR and Mott MacDonald, managers responsible for an individual project – within a larger programme – need the autonomy and freedom required to find solutions to problems or events that they encounter. Our research identified several other examples of integrated project teams working innovatively around problems that hindered their chances of success on specific sub-projects within the overall T5 programme, such as the use of digital modelling and construction of buildings and facilities, including air traffic control tower, airside road tunnel and main terminal roof. When organizations generate innovations to problems in this way, they tend to repeat them until they have become standardized and replicable routines for use within and across other projects.

CONCLUSION

Megaprojects are typified by low innovation and high risk, yet their success depends on increasing the former and decreasing the latter. A balance needs to be struck between routine and innovation based on clear identification of risks and uncertainties. Too great a focus on routine eliminates responsiveness to the inevitably unforeseen; too much focus on innovation leads to chaos.

Our concern has been to examine the consequences of the contractual framework at T5 on the balance of innovation and routines. Lawyers and economists would adopt different perspectives, but our interest lies not with legal construction and interpretation nor economic consequences and choices. We are interested in understanding from the perspective of strategy and organization how innovation and routines managed to mitigate risks and uncertainties. A number of factors are influential. For example, the use of proven technology and visualization techniques aided the project’s success.

Learning from past experiences proved hugely valuable, and when this did not occur in the final operational stage, problems ensued.

We have found that the contractual framework is critical to finding an appropriate balance between innovation and routines. Megaprojects require routines to address risks and create a space for innovation to cope with uncertainty. Routines create a consistency of approach – such as the CIPP, T5 Project Delivery Handbook, and progressive design fixity – to address risks identified prior to project execution. However, pre-specified and programmed routines are insufficient to cope with unusual events or happenings not previously identified during the planning phase. A megaproject must retain scope for variation and innovation in response to such uncertainty. In the T5 case the contract provided a framework for a deliberative process and negotiated resolution to problems with and between suppliers to address unforeseen problems. Managers and organizations responsible for the overall project and sub-projects had the autonomy, flexibility and space to search, experiment and implement unique solutions to unexpected problems encountered during project execution.

Appendix: Interviews on T5

	Date	Interviewee	Affiliation	Job title
1	11/10/05	Simon Murray	ex BAA	ex T5 Project Director
2	22/10/05	Tony Douglas	BAA	Managing Director T5 (now MD HAL)
3	29/11/05	Nigel Harper	LOR	Director Performance Improvement
4	10/01/06	Andrew Wolstenholme	BAA	T5 Project Manager & Project Director
5	18/01/06	Mike Robins	LOR	Group Business Leader
6	10/02/06	Ian Fugeman	BAA	Head Rail and Tunnels T5
7	13/02/06	Bill Frankland	LOR	Head of Roof Project, T5
8	15/02/06	Timm Wellens	LOR	Phase 2 Production Leader
9	15/02/06	Nigel Harris	LOR	Digital Prototyping
10	15/02/06	Tony Blackler	LOR	Senior Construction Manager
11	15/02/06	Gavin Milligan	LOR	3D Modeller
12	15/02/06	Matthew Prentice	LOR	Production manager
13	15/02/06	Damian Leydon	LOR	Construction Manager
14	27/02/06	Steve Nuttall	LOR	CTRL project leader
15	27/02/06	Spiros Tsakonas	LOR (CORBER)	Production Leader, C105 St Pancras Station CTRL
16	27/02/06	Andrew Williams	LOR	CTRL
17	03/03/06	Phil Wilbraham	BAA	Head Design, Building Projects
18	10/03/06	Rob Stewart	BAA	Head Infrastructure projects T5
19	21/03/06	Colin Croft	ex British Airways	ex BA T5 Project Director
20	29/03/06	John Milford	BAA	Head Buildings Projects T5
21	04/04/06	Nick Gaines	BAA	Head Systems Integration Projects T5
22	10/04/06	Liz Daily	LOR	Head of Business Improvement Team
23	10/04/06	Robert Hicks	LOR	3D/4D/5D and nD modelling
24	10/04/06	Matt Blackwell	LOR	3D/4D/5D and nD modelling
25	10/04/06	Ray O’Rourke	LOR	Owner
26	05/05/06	Roy Adams	LOR	Head of R@DD
27	05/05/06	Jim Dennis	LOR	Brighton Marina Project
28	05/05/06	Jacqui Radford	LOR	
29	22/05/06	John Harris	BAA	3D modelling
30	14/06/06	Norman Haste	ex BAA, now LOR	ex T5 Project Director

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