Five rules for managing large, complex projects

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100-character summary: Research reveals five lessons that can help executives manage big, complex projects more effectively.

500-character summary: Large-scale, long-term projects are notoriously difficult to manage. But recent research on megaprojects — defined as projects costing more than $1 billion — reveals five lessons that can help executives manage any big, complex project more effectively.

[rubric] Project Management

[head] Five Rules for Managing Large, Complex Projects

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The Leading Question: How can executives manage large, complex projects better?

Findings:

* Complex projects consist of both predictable, standardized tasks and innovative, novel procedures.

*Manage the two types of work differently, using fixed-price contracts for standardized work and more flexible ones for novel procedures.

*When introducing untested practices or technologies, find a way to rehearse first.

[main text] "Megaprojects" — defined as projects with budgets exceeding $1 billion — are important contributors to numerous sectors, including health care, defense, mining, telecommunications, transport, energy and water infrastructure, sporting events, science, and manufacturing. They represent a significant proportion of many nations' economic activity and profoundly affect productivity, social cohesion, and the environment.[1] Yet megaprojects have proved notoriously difficult to deliver on time and on budget; one estimate suggests 90 percent of them end up over budget.[2]

The Sydney Opera House was over 10 years late when it opened in 1973 and a staggering 1,400 percent over budget[3] and the "Big Dig" Central Artery/Tunnel Project in Boston, Massachusetts (original estimate $2.6 billion, actual cost $14.8 billion) are two prominent examples

Why are megaprojects so difficult to manage? The reasons include technical challenges, changes in design and operational requirements, increases in costs, disputes over responsibility, and new regulations. Complexity usually increases with project scale, and complexity can give rise to uncertainty and an inability to foresee the difficulties, changing conditions, and unanticipated opportunities that will be encountered once the project is underway. In this article, we argue that one way to manage the uncertainties is to innovate throughout the course of the project. What's more, we believe our suggestions are applicable to *all* large-scale, long-term projects — not just projects with billon-dollar budgets.

Specifically, we'll distill five rules for innovation in large high-risk projects, providing managers with guidance on how to modify their plans and processes when opportunities arise or conditions change. Our findings are based on more than 10 years of research into megaprojects. (See "About the Research.") The projects we studied included:

- High-Speed 1 (1998-2007), a high-speed, 109-kilometer railway from London to the Channel Tunnel, which cost £5.8 billion (roughly $7.5 billion at today's exchange rates)[4].

- Heathrow Terminal 5 (T5, 2002-2008), a new airport terminal, hotel, car park, subway line, and air traffic control tower, which cost £4.3 billion.
- Infrastructure for the London 2012 Olympics (2006-2012), which cost £6.8 billion.
- Crossrail (started in 2007, scheduled to open in 2018), an 18-kilometer railway across London that has a budget of £14.8 billion and includes 42 kilometers of new railway tunnels and including 10 new and 30 upgraded stations.
- Heathrow Terminal 2 (2009-2014), an airport terminal now serving 29 airlines that replaced an existing terminal and cost £2.5 billion.
- The Thames Tideway Tunnel project, begun in 2016, a 25-kilometer tunnel and an upgrade to London's sewer system; the project is expected to take up to seven years to complete, at a cost of £4.2 billion.

[A-head] Five Rules for Innovation

We follow the view that Donald Sull of the MIT Sloan School of Management and Kathleen M. Eisenhardt of Stanford's School of Engineering express in their book *Simple Rules: How to Thrive in a Complex World*: Management strategy in complex, uncertain circumstances is often best articulated as a series of simple rules.[5] Based on our experiences working on and studying megaprojects, here are our five rules for such projects.

[C-head] 1. Assess what's worked before. When Heathrow's Terminal 5 was being planned, the project team systematically studied every international airport opened in the previous 15 years and every U.K. construction project that cost more than £1 billion built during the previous 10 years.[6] One of the chief problems discovered was

the use of fixed-price contracts to transfer risks to suppliers, thereby creating adversarial relationships with contractors and — worse — freezing designs at an early stage of the project, limiting innovation. The planners of Terminal 5 calculated that if they used a fixed-price contract approach, the project would end up over budget and one year late. Endeavoring to learn from these accumulated lessons, the planners created a new delivery model based not on rigid fixed-price contracts but on a collaborative, innovative, and flexible process. Unfortunately, the public remembers the Terminal 5 project for its disastrous opening days, when more than 20,000 pieces of luggage were misplaced and several hundred flights were cancelled. [7] What's often overlooked, however, is that the Terminal 5 project was delivered on time and on budget, and a year after the opening was voted the world's best airport terminal by passengers. Furthermore, the problems with the Terminal 5 opening provided important lessons guiding key improvements in the megaprojects that would follow — improvements we'll outline in greater detail below.

[C-head] 2. Organize for the unforeseen. While fixed-price contracts may be adequate for dealing with predictable and stable conditions, more flexible contracts are required to deal with unexpected and rapidly changing circumstances. By using cost-plus or cost-reimbursable contracts, for example, the client and contractor enter into a relational agreement where there are incentives to build trust, form a collaborative culture, and share risks and opportunities.

True, flexible contracts can appear undesirable at first because of their higher up-front costs. But such contracts support coordination by mutual adjustment when project activities and schedules are modified in real time to address unforeseen

circumstances. The client creates incentives encouraging contractors working on the project to reveal problems, recover costs, achieve agreed-upon profit margins, exploit innovative possibilities, and build solutions. The “T5 Agreement” between the client and major contractors in the Terminal 5 megaproject formed the basis of a new flexible process for dealing with uncertainty — and was subsequently used as a model for the London 2012 Olympics and Crossrail megaprojects.

Another key to managing megaprojects is staffing project teams with innovative thinkers — and encouraging teams to remain flexible. After all, a megaproject comprises numerous smaller projects, each executed by a project team. When organized and incentivized effectively, people with different knowledge and skills can adapt and respond flexibly to rapidly changing conditions, unforeseen problems, and emergent opportunities. These teams treat existing knowledge and skills as bases from which to modify old routines and build new ones.

When it came to planning the London 2012 Olympics, the Olympic Delivery Authority exemplified the approach of using flexible project teams. One senior Olympic Delivery Authority manager told us that team dynamics depended on “having enough excellent people with a real attitude of rapid assessment and decision-making, to be able to see issues, discuss them, make decisions, and move on.” In addition to providing flexibility, well-organized team structures can also forge collaboration and overcome tensions that arise when companies with differing interests are expected to work together.

[C-head] 3. Rehearse first. The risks of cost and time overruns associated with the adoption of new technology and practices were minimized on the Terminal 5, Olympics, Crossrail, and Terminal 2 projects by reliance on established technologies and practices. Where new technologies and practices were introduced, they were first tested and proven in off-site trials, dry runs, and other operational environments such as smaller airport terminals.

For example, the "roof project" for the main terminal building was considered one of the most uncertain parts of the Terminal 5 project. There were concerns about erecting roof abutment structures with spans of more than 150 meters. The solution was erecting these structures in advance, at an off-site location. Through the off-site pilot, project leaders identified 140 lessons, each with a preemptive risk mitigation plan, enabling contractors to work more rapidly on-site.[8] As a result, the roof project was delivered three months earlier than planned.

In contrast, the first few days of operation of Heathrow's Terminal 5 infamously suffered from a lack of rehearsal. Having learned lessons from the problems associated with the opening of Terminal 5, the leaders of the Terminal 2 project established a new rehearsal-style process for Terminal 2: a "soft" opening. Importantly, the soft opening occurred *two years* prior to the official opening of Terminal 2 in June 2014. Terminal 2's soft opening was led by a dedicated "operational readiness" team. That team managed a gradual handover to operations, including 180 trials with 14,000 volunteers and 1,700 training sessions. The soft opening also included the creation of a mock-up "model terminal" to test check-in

software. In addition, there was a test with a live flight and a staged gateway process to move each airline into a live terminal building.

Terminal 2 wasn't the only project that learned lessons from the problem-plagued opening of Terminal 5. In its planning for the London 2012 Olympics, the Olympic Delivery Authority made a point of completing its construction program by July 2011 — providing *one whole year* of testing on live events in the run-up to the Olympic Games.

[C-head] 4. Calibrate and apportion risks appropriately. A megaproject contains a large proportion of predictable, standardized, and repetitive tasks that have been performed many times on previous projects — as well as novel and innovative procedures being applied for the first time. This combination requires a balancing act, and the concept of "targeted flexibility" provides a solution to it.[9] The idea is to break down a megaproject into distinct projects, structures, and processes, each of which addresses a different piece of the uncertainty.

A targeted flexibility approach creates different contracts and collaborative arrangements to address the varying challenges of individual projects within the program. A cost-plus contract, as we mentioned earlier, can be used when uncertainty is high; a fixed-price contract may be more appropriate when there's less uncertainty. The London 2012 Olympics megaproject used this approach to great success, relying on fixed-price contracts to deal with known conditions and risk-sharing, and target-cost contracts (including contracts based on a suite of what have been called "New Engineering Contracts" [10]) to deal with less predictable projects, such as the

construction of the London Aquatics Centre, the Velodrome, and the Olympic Stadium (now London Stadium).

Thanks in part to this approach, ISG plc, the contractor that built the Velodrome, came forward with the suggestion to switch from a steel roof to a cable net roof, resulting in significant reductions in time and cost.[11]

[C-head] 5. Harness innovation from start to finish. Formulating a coherent statement about innovation can help project leaders plan, coordinate, and communicate with research partners and other collaborators from start to finish.[12] We saw proof of this during the Crossrail megaproject, which introduced the idea of establishing an innovation strategy for the *construction* phase of the project.

Established in 2012, the Crossrail Innovation Strategy created a formal process for encouraging members of the project supply chain to submit ideas for innovation. In collaboration with Imperial College London, Crossrail's leaders created a small team for the express purpose of identifying, evaluating, and developing new ideas — ideas developed internally or originating with members of the project supply chain. Crossrail also developed an online digital platform called "Innovate18" to provide both insiders and outsiders with a mechanism to submit ideas, including an "Innovation Management System" to manage, track, and report on the progress of ideas. Innovations likely to benefit Crossrail thus had the chance to gain relevant sponsorship and commitment from interested parties well in advance of the actual construction. By summer 2015, the program had attracted more than 800 ideas ranging from the use of high-definition drone-mounted cameras for site inspections to

the repurposing of grout shafts to cool the train tunnels via geothermal heat production.

The success of the program made Crossrail's leaders recognize that there would be additional advantages in starting even earlier. So when Andy Mitchell, Crossrail's program director, became CEO of the Thames Tideway Tunnel megaproject in 2014, he decided to build upon the Innovate18 digital platform. He also recognized that it was important to involve the leaders who would manage the tunnel after construction was complete. The cost of operating a rail system, airport, or tunnel over a lifespan of several decades is much higher than the cost of designing and building it; those who will eventually maintain the asset can often identify and implement innovations during the front-end planning and design phase that will improve performance and reduce costs later on. Participants in Crossrail and Thames Tideway have developed this concept, creating an industry-wide program called i3P, which stands for Infrastructure Industry Innovation Platform. i3P has been rolled out to support innovation in a number of new megaprojects.[13]

[A-head] A More Flexible Approach

Despite the diversity of large high-risk projects, there are some simple rules that can help improve their performance. The five rules we have described encourage innovation to deal with uncertainty. They confer the flexibility to change while maintaining the stability required to deliver projects efficiently. And they help coordinate innovative action across multiple parties. These simple rules challenge traditional project management, which has pushed too far toward control and

prescription and been characterized by complicated, highly rigid contracts that stifle flexibility and innovation. These five rules might seem like common sense, but the marked failures of past megaprojects show the value of making such sense much more common.

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Exhibit 1: About the Research

We undertook our core research on three recent megaprojects in London — Heathrow Terminal 5, the London 2012 Olympics, and Crossrail — between 2005 and 2015. We also drew upon previous, adjacent, and continuing studies conducted by one or more of the authors, including studies of the first phase of High-Speed 1 in 2002 and 2003, of Heathrow Terminal 2 in 2014 and 2015, and of the Thames Tideway Tunnel from 2013 to 2016. Focusing on the strategic management of megaprojects, we engaged in long-term research collaborations with sponsors, clients, delivery partners, and major contractors.

Our methods included qualitative case studies, semistructured interviews, and ethnographic observations. We conducted more than 170 interviews with CEOs, project directors, project managers, directors, and project team members, mainly at the project head offices but also on-site with project managers engaged in daily activities. Although the form of research engagement varied, we produced an in-depth case study of each project's approach to innovation, which was checked and verified in meetings with our partners.

Our research activities on Heathrow Terminal 5 from 2005 to 2009 led to invitations to study the London 2012 Olympics project in 2010 and 2011 and the Crossrail project from 2011 to 2015. Since each project was completed around the time the next one began, we had a unique opportunity to observe how people, novel ideas, and practices move within and between projects. Distinct patterns of innovation emerged,

and we began to recognize how innovative capabilities and processes moved from one project to the next.

Our initial work on Heathrow Terminal and then the London 2012 Olympics involved observing and analyzing how innovation occurs in megaprojects. When we researched Crossrail, we continued with our observational approach, and we were also invited to help the client develop and implement an innovation strategy for the project, which drew upon lessons learned from previous projects. Our categorization of the five rules of innovation emerged during our engagement with the three projects. They were tested at numerous academic seminars at University of Pennsylvania, University College London, Imperial College London, University of Queensland, HafenCity Universität Hamburg, École Polytechnique, BI Norwegian Business School, and LUISS Business School.

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Exhibit 2: Five Innovation Rules for Large High-Risk Projects

The following five simple rules can help improve the performance of large high-risk projects. These five rules encourage innovation to deal with uncertainty and confer the flexibility to change — while maintaining the stability required to deliver projects efficiently.

Rule	Purpose	Practices
1. Assess what's worked before.	Learning from other projects sectors and research organizations Capturing own prior experience Evaluating risk and uncertainty	Case studies and site visits Recruitment of expertise
2. Organize for the unforeseen.	Flexibility and adaptability Changing behaviors Risk-sharing	Integrated client and contractor teams Flexible contracts Partnerships and collaboration
3. Rehearse first.	Exploring options Prototyping, proving, and improving Identifying and reducing uncertainty.	Off-site tryouts On-site tests and trials Simulations and models Solution development.
4. Calibrate and apportion risks appropriately.	Pairing stability and change Managing innovative components of the project differently from standardized and predictable aspects	Structured process to change the project plan Tailor contracts to address uncertainty in the project and subprojects Freeze the design progressively to deal with unexpected events

5. Harness innovation from start to finish.	Formalizing structures and processes for guiding, shaping, creating and using innovations	Explicit innovation strategy statement Establish innovation governance and leadership Develop, capture, and share innovations

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