5 simple rules for innovation in megaprojects

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Collaborators

- Professor Andrew Davies, UCL
- Professor David Gann, Imperial College
- Dr Sam MacAulay, University of Queensland
My motivation for working on megaprojects

• Major problem to be studied
• Opportunity to use knowledge in new field
• Practical application
• Work with great friends
Joseph Bazalgette 1819-1891
The research

The Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Project</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>HS1</td>
<td>£6.2b</td>
</tr>
<tr>
<td></td>
<td>Heathrow Terminal 5</td>
<td>£4.3b</td>
</tr>
<tr>
<td></td>
<td>London 2012 Olympics</td>
<td>£6.8b</td>
</tr>
<tr>
<td></td>
<td>Crossrail</td>
<td>£14.8b</td>
</tr>
<tr>
<td>2017</td>
<td>Tideway</td>
<td>£4.1b</td>
</tr>
</tbody>
</table>
Representative publications

Projects


Cities


Themes for today

• Megaprojects, complexity and uncertainty
• London’s megaprojects
• Five rules for innovation
• Megaprojects, complexity and uncertainty

• London’s megaprojects: innovation laboratory

• Rules for innovation
Megaprojects

- Strategic high-risk infrastructure projects $1bn or more (US dollars 2003)
- Investment in infrastructure $57 trillion 2012-2030 (McKinsey 2013)
- 90% are over budget (Flyvbjerg 2014), most are late and fail to achieve their targets
- The delivery model is broken
Megaprojects in cities are challenging

- Replace ageing infrastructure and build new systems
- Multiple stakeholders
- Projects in a “live” operational environment, adding to complexity, urgency and uncertainty
Delivery model: dealing with uncertainty

• Delivery model

- Project structure, process and contracting approach used to design, construct, integrate and handover infrastructure assets to an operator
- Shaped by assumptions about uncertainty – the information about the project’s goals, task and future conditions
- If uncertainties occur and are not addressed they can prevent the project from achieving its goals
Risk and uncertainty

Risk: measurable, can use probabilities

Uncertainty: unmeasureable, unknowable
Innovation required to deal with uncertainty

- James E. Webb head of NASA in 1960s Apollo Moon landing
  - 70-80% of complex projects can be foreseen
  - 20-30% are unforeseeable have to be addressed when the project is underway

- **Balanced needed**
  - ‘orderliness and stability’ (foreseen uncertainty)
  - ‘procedures to foster innovation’ (unforeseen uncertainty)
‘Foreseen uncertainty’
Fixed price contract, early design freeze, risk transferred to contractors, innovation avoided

‘Unforeseen uncertainty’
Flexible (incomplete) contracts, progressive design freeze, risk sharing/bearing, flexibility and innovation
Overview

- Megaprojects and new delivery models
- London’s megaprojects
- Rules for innovation
By early 2000s: UK delivery model was failing

- The client assumed uncertainty can be foreseen
  - Transfers risk to contractor (fixed-price contract)
  - Selects lowest price bid
  - Predefines all requirements (early design freeze)
  - Banishes innovation when the project is underway
  - Arms-length rather rather than collaborative relationships
  - (National Audit Office, Government Reviews, Industry reports)

1 year late 80% over budget
Channel Tunnel

4 years late 100% over budget
Wembley

6 years late 100% over budget
National Air Traffic Control Centre
London’s megaprojects

- Heathrow Terminal 5
- London 2012 Olympics construction
- Crossrail
Heathrow Terminal 5

- BA’s domestic and international passengers at Heathrow – annual capacity 30 million passengers
- 260 hectares – size of London’s Hyde Park
- 4-storey terminal building
- Satellite building
- 62 aircraft stands
- 4,000 space car park
- Hotel
- ATC tower
- Underground rail station – links to Heathrow Express and Piccadilly line of London Underground
The uncertainty facing BAA (British Airports Authority)

• T5 was a £4.3 billion megaproject
  – Financial risk for the client (BAA) – ‘could bankrupt the company’
  – Could not rely on government if cost escalation occurred
  – BAA had not undertaken a project of this size
  – UK construction industry poor track record

• Many uncertainties
  – New technology, rapidly changing airline industry (e.g. low budget airlines), security (9/11) etc
  – ‘We won’t be able to get it right the first time. We need to be realistic; change is a fact of life.’” (T5 Project Lawyer)*

*Quoted in N. Gil (California Management Review, 2009)
Preparing for T5

External learning

Using existing delivery model (fixed price and risk transfer) T5 would be:
- £1bn over budget
- 1 year late
- 6 deaths

Internal learning
Preparing for T5

Need a new delivery model for T5

External learning

Internal learning
BAA’s approach to risk and uncertainty*

**Traditional contracting**
Client ‘dumps risk’ on contractors
Adversarial relationships

**Under T5**
Client ‘bears the risk’
Works with ‘partners’

*BAA internal document*
“Conventional project logic seeks to redefine all requirements and banish change once the project has started. Yet flexibility and adaptability are key objectives for T5. Conventional processes and solutions are therefore not tenable. It will require flexibility of approach: flexibility of solutions; latest responsible decision making, etc. For this reason processes, practices and deliverables will be firmed up in stages”
Single digital model
T5 outcome

- Within £4.3bn budget
- On time, but disrupted opening
New practices and knowledge move from T5 to other megaprojects

• T5 offers a new delivery model to emulate
  – But not a one-size-fits-all approach
  – Each project has unique challenges and structures
  – Unlike T5, other projects have temporary clients

• New ideas, practices, knowledge and tools circulate between projects
Crossrail – London’s urban railway system

200 million passengers a year
Europe’s largest infrastructure project

- £14.8 billion funding
- 37 stations
- 9 new s/s stations
- 42 km new tunnels
- 19 boroughs
- 140 main works contracts
- 10,000 suppliers
- 10,000 site workforce
Crossrail: client and delivery partners

- **Sponsor**
  - DfT/TfL

- **Crossrail Ltd**
  - **Programme Partner**
    - CH2M
    - Aecom
    - Nichols
  - **Project Delivery Partner**
    - Bechtel
    - Halcrow
    - Systra

- **Integrated Programme Team**

- **Principal contractors**

- **Supply chain**
Tunnel Boring Machines

- 8 bespoke machines
- 148 m in length – equivalent to 14 London buses
- 1000 tonnes weight
- 100 m of tunnel build per week
Tunnel drives

Drive X

Drive Y

Drive G

Drive Z

Drive H

To Maidenhead and Heathrow

Paddington
Bond Street
Tottenham Court Road
Farringdon
Liverpool Street
Whitechapel
Canary Wharf
Custom House
Connaught Tunnel
Woolwich
To Abbey Wood
Tunnel cross-section
Crossrail Tunnels

All measurements are internal
Building Information Modelling
Carriers of new delivery model practices

• People, teams and organisations
  – Builds on lessons learnt on T5
  – Procurement team on the Olympics moves to Crossrail
  – Project Director on T5 becomes CEO of Crossrail
  – Crossrail programme director becomes CEO of Tideway

• Delivery partner
  – Laing O’Rourke and Mace ‘play the T5 card’ and become the delivery partner for the Olympics

• Universities
  – Imperial College involved in T5, London 2012 and Crossrail

• Government and institutions
  – Reports support innovation and promote the new collaborative approach
Overview

• Megaprojects and new delivery models

• London’s megaprojects: innovation laboratory

• Rules for innovation
Rules for innovation

• Innovation – generate and apply new ideas successfully to create value

• Innovation to address complexity and uncertainty

• ‘Simple rules’
  – High-level rules that guide organisational processes for dealing with opportunities and challenges
1. ‘Assess what’s worked before’

• **Rule**
  – Assess the uncertainty facing the project
  – Forecasts based on case studies, site visits and recruited expertise
  – Search for practices to deal with uncertainty

• **Examples**
  – BAA’s preparations for T5: learn from other projects and industries and learn from own experience
  – Learning and sharing knowledge between projects practiced on London 2012 and Crossrail
2. ‘Organise for the unforeseen’

• **Rule**
  – Flexible contracts required when it’s impossible to identify all conditions in advance or specify how to adapt to them
  – Collaborative teams incentivised to innovate and respond to emerging opportunities
  – ‘Psychological safety’ to take risks, learn and solve problems

• **Examples**
  – BAA’s T5 Agreement: Flexible (cost-reimbursable) contract and Integrated Project Team (client works collaboratively with contractors)
  – London 2012: risk sharing contracts and Integrated Project Teams
3. ‘Rehearse first’

• **Rule**
  – Test new technologies and practices are proven in ‘offsite’ trials, pilot studies and operational environments prior to their introduction
  – Rehearse on small scale in ‘live’ environment

• **Examples**
  – T5 roof, air traffic control tower and operational handover
  – London 2012 – complete one year early and test on live events
  – Heathrow Terminal 2 progressive operational handover
4. ‘Calibrate and apportion risk and uncertainty’

• **Rule**
  – Each element of uncertainty (foreseen and unforeseen) in the project has to be understood
  – Balance approach to target and mitigate different pieces of uncertainty over time
  – Design the right delivery model and contracts to deal with uncertainty

• **Examples**
  – London 2012 – menu of contracts to address uncertainties (e.g. fixed-price and flexible contracts)
  – London 2012 – change control process to identify uncertainty/opportunity and deal with it (e.g. cable net roof)
5. ‘Harness innovation from start to finish’

• **Rule**
  - Establish formal innovation structures and processes to achieve the project’s goal
  - Incentives and rewards encouraging operators, contractors, suppliers, users and other stakeholders to innovate

• **Examples**
  - Crossrail Innovation Programme to develop and implement new technologies, materials, practices and tools to improve performance
  - Thames Tideway Tunnel and other projects
Innovation programme

Innovation online digital portal: Innovate 18
Innovation team
Innovation management system
Funds for projects
INNOVATION

PREFABRICATED SCALLOPED FORMWORK

Innovation #
Innovation Title: Prefabricated Scalloped Formwork
Innovator / Team: Daniel Frett
Site / Directorate: Liverpool Street
Contract:
Parent Company: Laing O'Rourke
TelephoneNumber: 07920 410 260
Contact Email: dpfrett@laingorourke.com
Site Champion: Brian Curran

Motivation
Prefabricated Scalloped Formwork is an innovative method of building guide walls for large diameter piles on a congested worksite.

Innovative Solution
To maintain programme effectiveness in terms of time, cost and safety, a solution was sought that exceeded the standard methods of construction.

This technique delivered 60 linear metres of guide walls whilst reducing delivery time by five days.

Prefabricated formwork realised net savings of £8500 against traditional construction methods and reduced storage requirements on a congested site, whilst reducing hazards of slips, trips, falls and logistical issues.

Site safety is also enhanced by adoption of these preformed shutters, resulting from the reduction of temporary works activities, operative’s exposure to HAVS, elimination of polystyrene formers and eradication of manual handling due to integrated eyelets.

Benefits to Crossrail

Programme - Building the formwork, laying the reinforcement and pouring the concrete would have usually taken two weeks
Safety - This improved safety by eliminating the need for manual handling
Cost - Net Savings against traditional methods
Quality - Improved control over setting out whilst supporting the ‘Right first time’ aspirations of the project. Prefabricated scalloped formwork delivered a product which meets Crossrails expectations

Crossrail values realised by adopting innovation

<table>
<thead>
<tr>
<th>SAFETY</th>
<th>INSPIRATION</th>
<th>COLLABORATION</th>
<th>INTEGRITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Exposure to HAVS and Manual Handling reduction</td>
<td>Improved Productivity, reduced labour, net cost reduction and Improved quality control</td>
<td>Technique previously used by LO’R and shared with CRL as a possible solution</td>
<td>Reusable shuttering reduces wastage and improves sustainability</td>
</tr>
</tbody>
</table>

In collaboration with:

Laing O’Rourke
Unit 4 South Road Industrial Estate
Alnwick
Northumberland
NE66 2NN

INSPIRE your colleagues and spread the word

MOVING LONDON FORWARD
INNOVATION
DUST SUPPRESSION USING CHEMICAL MEMBRANE

Innovation# INV0032
Innovation Title: Dust Suppression using Chemical Membrane
Innovator / Team: C315 Innovation Team
Site / Directorate: Connaught Tunnel
Contract: Bechtel
Parent Company: 07841 647623
Innovation Manager: Joshua Baker
Contact email: JoshuaBaker@crossrail.co.uk
Site Champion:

Search Criteria
Particulates; Stakeholder; Construction; Environment

Motivation
During the Olympics, C315 had a large 'bare earth' site adjacent to the ExCel & DLR. Concern was raised by London 2012 organisers regarding the potential for dust or particulates being generated from the Connaught Tunnel site during this particularly sensitive event.

Innovative Solution
Dustbuster is an environmentally safe, powerful polymer emulsion that produces effective control of dust and erosion, using conventional methods of applications including water bowser and hoses.

This membrane remains active on most particulates, is long lasting and will cope with heavy traffic included tracked vehicles. The product is insoluble, will not track off site, whilst effective for extended periods without the need for reapplication.

Saving time and money whilst maintaining excellent stakeholder relationships and protecting the environment, this product has potential for use across Crossrail, where airborne particulates are of concern.

Benefits to Crossrail
Environment - Biodegradable, Non-Hazardous, Non-Combustible
Safety - Reduces airborne particulates
Cost - Save on labour and equipment, Less maintenance
Quality - Cleaner worksites particularly in sensitive locations promotes Crossrail's World-class delivery aspirations

Crossrail values realised by adopting innovation

<table>
<thead>
<tr>
<th>COLLABORATION</th>
<th>INTEGRITY</th>
<th>RESPECT</th>
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<tbody>
<tr>
<td>Tier 1 and supply chain delivered bespoke and effective solution to a period during which intense scrutiny was targeted at this location</td>
<td>This promotes Crossrail's image as a responsible developer that is keen to engage with our neighbours and address their concerns</td>
<td>Being close to a large population, this solution reduced the adverse impacts of noise inconveniences associated with traditional dampening operations</td>
</tr>
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In collaboration with:
Dustbusters division of NTM Sales & Marketing Ltd
P.O. Box 2, Summerbridge
Harrogate, North Yorkshire, HG3 4XN

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MOVING LONDON FORWARD
INNOVATION
LARGE QR CODE

INNOVATION REF: INV0007
INNOVATION TITLE: Large format hoarding QR Code
INNOVATOR / TEAM: Rob McCarthy
SITE / DIRECTORATE: Liverpool Street
PARENT COMPANY: Laing O'Rourke
CONTACT EMAIL: rmccarthy@laingorourke.com
SPONSORING CHAMPION: Brian Curran

SEARCH CRITERIA
Keywords / metadata: QR code; hoarding; stakeholder; interface

CONTEXT / ISSUES / OPPORTUNITY / MOTIVATION
Site hoardings are an important factor in promoting Crossrail as one of the most public facing elements of the project. There is a desire to share the progress behind each hoarding, however physical 'windows' in site hoardings aren't always possible due to geographical, security or safety

INNOVATIVE SOLUTION
'Digital windows' for Crossrail sites via large scale QR codes installed on hoardings.

At Liverpool Street, Blomfield Box (C502), the site hoarding extends over the Eastern footpath of Blomfield Road to the highway edge. Concerns over the safety of members of the public who were crossing the road to read hoarding information whilst standing in the highway were raised. To reduce this risk, all site information was removed, however a bare site hoarding is unable to engage with our stakeholders.

The Laing O'Rourke Site team collaborated with the Crossrail team to develop a solution that provides engaging content, whilst ensuring the safety of the public.

The idea of a digital window was trialled using a large scale, hoarding mounted, QR code. This was successfully scanned using smartphones and tablets from the safety of the opposite footpath. These findings were passed to the Crossrail external communications team to incorporate the design into their new corporate hoarding design. Now installed at Tottenham Court Road, the QR code directs the public to the Crossrail website using smartphone technology.

At Liverpool Street, their hoarding will shortly be given the new branding treatment with the addition of a unique QR code that links to the Crossrail Liverpool Street webpages. This allows Laing O'Rourke to provide content for external communications to upload specifically related to their site and programme of works. The public now has safe access to news, images and video of the C502 site via this 'digital window'.

BENEFITS TO CROSSRAIL
Transparency - Public have access to site photographs and the latest information regarding the works.
Safety - Reduce the safety risk of the public by avoiding the need to cross the road.
Digital / Physical integration - The concept of a QR interface delivers against the theme innovation of Digital Physical Interface.
Long life and low maintenance - URL linked web content can be updated without need to re-print a QR code or change the hoarding design.

QR CODES - VITAL STATISTICS
QR: an abbreviation of Quick Response Code, is a 2-dimensional barcode. Approximately 14 million QR codes were scanned worldwide in 2011 and this number is rising rapidly with the phenomenal uptake in app-enabled, internet connected, smartphone technology.

SUPPORTING ELEMENTS

INSPiRE your colleagues and spread the word

MOVING LONDON FORWARD
Ultra Low Carbon Concrete
Collaboration with VINCI

Sprayed Concrete Lining Digital Image Correlation
Collaboration with NPL

Safety Glove Messages
Collaboration with Costain
Investing in innovation

Light weight Aggregate
Collaboration with © Nustone Limited and

Automated Near Miss Reporting / Observation
Collaboration with

Layar App Trials
Collaboration with
Industry initiative for Digital Railway
From Research to Rules

The Research

2001

The Projects

2017

HS1

Heathrow Terminal 5

London 2012 Olympics

Crossrail

Tideway

Innovative elements of delivery model

- Collaboration
- Risk bearing contract
- Integrated Project Team
- Flexibility
- Digital model

- Delivery Partner
- Risk sharing contracts
- Innovation Programme Innovation

Rules for innovation

1. Assess what’s worked before
2. Organize for the unforeseen
3. Rehearse first
4. Calibrate and apportion risk and uncertainty
5. Harness innovation from start to finish
Conclusion

• London’s ‘megaproject laboratory’: complex, uncertain and successful

• New ideas, practices, and knowledge circulate between projects

• Carriers of ideas: individuals, project teams, firms and organizations – a ‘social movement’

• Develops a growing base of capabilities to bring innovation into megaprojects

• Virtue of simple rules for complex problems
Thank you!

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