The future of construction – challenging the status quo

Marks Barfield

Campbell Middleton
Laing O’Rourke Professor of Construction Engineering

crm11@cam.ac.uk

GLF Weimar – 5th June 2015
Trinity College

Isaac Newton
King’s College – founded in 1441 by King Henry VI

Maynard Keynes

Alan Turing
Francis Crick & James Watson – the Double Helix
Our future world: Utopia?
Our future world: reality?
Equitable and Sustainable Exploitation of Resources

• Energy
• Water
• Housing
• Transport
• Communications

QUALITY OF LIFE
(not just GDP growth)

Climate change
UK Construction 2025 - July 2013

Lower costs
33% reduction in the initial cost of construction and the whole life cost of built assets

Faster delivery
50% reduction in the overall time from inception to completion, for new build and refurbished assets

Lower emissions
50% reduction in greenhouse gas emissions in the built environment

Improvement in exports
50% reduction in the trade gap between total exports and total imports for construction products and materials

The global construction market is forecast to grow by over 70% by 2025.

Global Construction 2025: Global Construction Perspectives and Oxford Economics (July 2013)
Education

Vision
Leadership
Ambition

“Challenge the status quo”
Challenging the status quo

1. Procurement
2. Design
3. Construction
4. Operation & management
5. End-of-life
6. The future
Challenging the status quo

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Procurement – Bridge example

Images: www.steelconstruction.info

Image: Tata Steel

Image: ftp.dynatec.de
Procurement – Water industry example

- Alliance with contractor involvement from beginning
- Program not project based procurement
- Leads to rationalisation, standardisation and offsite manufacture
- Carbon reduction as business driver
Procurement

• Output and performance
  – incentivise lifetime performance NOT just lowest price

• Build up evidence base for procurement and design
  – cost & performance database

• Early contractor involvement – align objectives

• Genuinely include whole life performance and cost in tender evaluation
  – need historical data
  – residual life determination

“An effective procurement strategy is the key to success”
Challenging the status quo

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Design – Demand modelling (loading)

M1 Motorway (1959)
Today
Forth Road Bridge Traffic Growth 1966 - 2005

Source: A. Andrews, FETA
Traffic Demand on the Forth Road Bridge (1964)

- Design based on 22 ton lorries
- 38 tonne lorry introduced from 1983
- 44 tonne lorry introduced from 2001
- Traffic increase from 4 to 24 million per annum

Source: A. Andrews, FETA
Design Case Study: New maternity hospital, Addenbrooke’s Hospital, Cambridge

Slides and data from Prof. Stefan Scholtes, Judge Business School, Cambridge
Question: How big?

Birth Trend Predictions in delivery spells as projected by consulting company

No. of births

Year

Actual

Courtesy: Stefan Scholtes, JBS
Question: How big?

Birth Trend Predictions in delivery spells as projected by consulting company

No. of births

Year


0 1000 2000 3000 4000 5000 6000 7000 8000

Actual
Baseline prediction

Courtesy: Stefan Scholtes, JBS
Question: How big?

Birth Trend Predictions in delivery spells as projected by consulting company

Recommendation:
Build facility that can accommodate 7,500 births per annum
Getting a feel for the uncertainty: Inspect past forecast errors

If not available, construct your own forecasts

Generated past forecasts

- Historical data
- 1980 Projection

No. of births

Year


4000 4200 4400 4600 4800 5000 5200 5400 5600 5800 6000

Courtesy: Stefan Scholtes, JBS
Generated past forecasts

No. of births

Year

historical data
1980 Projection

Courtesy: Stefan Scholtes, JBS
Generated past forecasts of deliveries

No. of births

Year


1980
1985
1990
1995
2000
2005
2008

History: Stefan Scholtes, JBS
On the basis of past forecast accuracy the best we can do is this...

Scenarios of Future Birth Trends at Rosie

Year


No. of Births

3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000

historical birth trend
deterministic forecast
lower 95% CI
upper 95% CI
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5

Courtesy: Stefan Scholtes, JBS
Getting it wrong is very expensive for the client

Peterborough City Hospital's strain of PFI repayments

A hospital built under the private finance initiative (PFI) has saddled a health trust with crippling repayments, a report has found.

Peterborough City Hospital opened in 2010 to combine services on one site.

A National Audit Office (NAO) report found repayments - totalling £41.6m in 2011 - placed a "considerable strain" on Peterborough and Stamford NHS Trust.

The trust needs to cut spending by £64m by 2017. The union Unison said it wants a full inquiry into the project.

The report added that doubts over the trust's ability to meet repayments without services suffering had been raised but ignored before construction began in 2007.

Courtesy: Stefan Scholtes, JBS
The forecast is always wrong
Lisbon’s Tagus Bridge – how to design for flexibility?

- Opened August 1966, 4 lanes
- 1990: middle guardrail removed and fifth, reversible lane created
- 1998 side walls extended and reinforced to make space for a sixth lanes.
- 1999: lower platform included to carry two railroad tracks [planned expansion, carried out by the original builder American Bridge Company]

Courtesy: Stefan Scholtes, JBS
More on the theme
Rethinking structural computational analysis

Ref: Dr Andrew Jackson
Advanced failure analysis

Upper bound analysis
Lower bound analysis

Ref: Dr Andrew Jackson
Challenging the status quo - BIM

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Digital Engineering – BIM

Overarching Digital Asset Information Model Framework
Digital Engineering - 3D structure generation

Prof. Roberto Cipolla
3D Reconstruction & Object Recognition

Courtesy of Dr Ioannis Brilakis
Inspection

Augmented reality (AR) visualisation tool with fast image matching

1. Image acquired on tablet computer

2. Registration to GIS database, user is geolocated

3. Changes with time viewed
Digital Engineering

Virtual reality – a simulated world

Penn State – Synthetic Environment Applications Lab
The future for digital modelling?
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Process - Insitu Reinforced Concrete construction
Design - Individual design of short span bridges
“LEGO-isation” of construction e.g. bridges
Laing O’Rourke Explore Industrial Park (EIP) - Steetley
USA: “ABC”  Accelerated Bridge Construction

- FHWA ABC Manuals  
  [www.fhwa.dot.gov](http://www.fhwa.dot.gov)

Slides on ABC courtesy of Michael P. Culmo, P.E.  
CME Associates, Inc., East Hartford, CT, USA
Pre-Cast Deck Slab Connection Details

Courtesy of Michael P. Culmo
Precast Piers - Holyoke Project

 Courtesy of Michael P. Culmo
Integral Abutment Project

- Charlemont, MA

Courtesy of Michael P. Culmo
Modular components - Details

- Grouted Reinforcing Splice Couplers
  - Emulates a reinforcing steel lap splice
  - No special design required
  - Multiple companies
    - non-proprietary
  - Used in
    - parking garages
    - stadiums
    - bridges
  - Favoured by North Eastern States

- Seismic design

Courtesy of Michael P. Culmo
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“If a car can be made smart enough to spot when the oil is low or a brake light has failed, why not do the same for bridges, tunnels and buildings?”
Smarter structures

Source: The Economist, Dec 2010
Modelling behaviour

Leadenhall Building
Measuring response

Leadenhall Building
Key technologies

1. FO - Fibre Optics
2. WSN - Wireless Sensor Networks
3. MEMS - MicroElectroMechanical Systems
4. Computer Vision
5. Data Analytics
Brillouin Optical Time-Domain Reflectometry (BOTDR)

Distributed versus point strain measurement

The frequency shift of the Brillouin scattered light is proportional to the strain.
Field demonstrations
Crossrail shaft
30m diameter
40m deep
52m deep walls
Fibre optic sensors for strain
Addenbrookes Bridge - Cambridge
Wireless sensor networks

Welcome to the Humber Bridge Structural Health Monitoring page. This page has been developed as part of an EPSRC funded collaboration between the University of Cambridge and Imperial College London as well as critical infrastructure partners including the Humber Bridge Board.

Available health monitoring systems:
- Hessle Anchorage environmental monitoring
- Ferriby Road Bridge support bearings (to be installed)
Humber Bridge Anchorage

Steel wire strands
Connection to concrete block
Concrete foundation block
Mote location - Piers

- Displacement
- Inclination
- Strain
- Temperature
- RH
MEMS sensors

MEMS sensor

Piezoresistive sensor
End-of-life

Low Carbon Materials Processing group – Julian Allwood

http://www.lcmp.eng.cam.ac.uk/wellmet2/publications
Future technologies

1. New materials
   a) aerogels
   b) UHPC
   c) graphene
   d) carbon nanotubes

2. 3D printing

3. DNA Memory storage

4. Quantum Computing
New materials - Aerogels aka “Frozen Smoke”

http://www.youtube.com/watch?v=kHnen2nSmDY&feature=player_embedded
Supersonic laser deposition (SLD) / Laser cutting
Ultra High Performance Concrete
Ultra High Performance Concrete (UHPC) - FHWA
Graphene?
Carbon Nanotubes
Printing 3D buildings & bridges?
DNA Memory storage
Quantum Computing

Atomic layer of iron

Photo: R.Wiesendanger (University of Hamburg)
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1. Procurement – outcomes & whole-life performance
2. Design – flexibility for changing demands
3. Construction – standardisation & offsite manufacture
4. Operation & management – “smart” structures
5. End-of-life – reuse, reduce, extend
6. The future – embrace new technologies

“The industry is looking for leadership, vision & ambition”