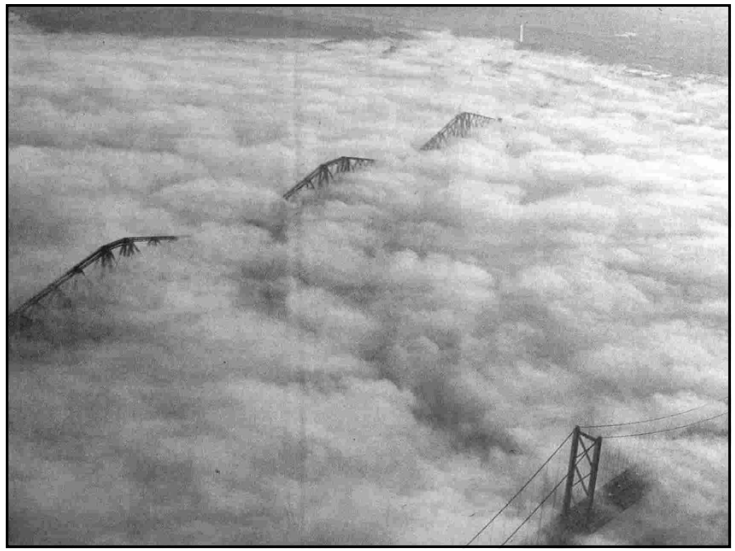


RETHINKING THE ENGINEER

Professor Paul W Jowitt

Heriot Watt University
and
The Scottish Institute of Sustainable Technology

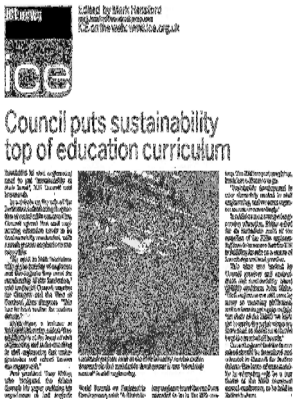
New Civil Engineer Jan 2003

Council puts sustainability top of education curriculum

"Sustainable Development is now absolutely central to Civil Engineering and we must organise ourselves accordingly"

ICE Council 17 December 2002

New Civil Engineer Jan 2003



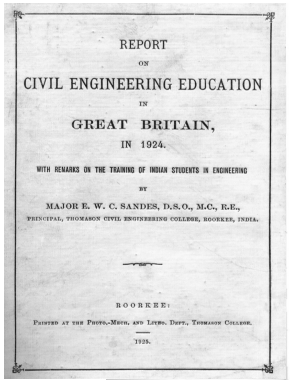
Council puts sustainability top of education curriculum

ICE Education and Training Task Group

Established by ICE Council in late 2002 to examine the implementation of sustainability principles into education, training and professional development…

1924

Not much on presentation and communication skills....
.... but lots of thermodynamics!



REPORT
ON
CIVIL ENGINEERING EDUCATION
IN
GREAT BRITAIN,
IN 1924.

WITH REMARKS ON THE TRAINING OF INDIAN STUDENTS IN ENGINEERING
BY
MAJOR E. W. C. SANDES, D.S.O., M.C., R.E.,
PRINCIPAL, THOMASON CIVIL ENGINEERING COLLEGE, ROORKEE, INDIA.

ROORKEE:
PRINTED AT THE PHOTO.-MECH. AND LITHO. DEPT., THOMASON COLLEGE.
1925.

CONTENTS.

2003

Engineering Education,
Sustainable Development and the Teaching and Learning Process?

- Content? **not shoving** more material into it… ??
- Process? but **pulling** relevant material into it!!

Engineering Education,
Sustainable Development and the Teaching and Learning Process?

- **Content**:
- **A**wareness/**A**ttitudes
- **S**kills
- **K**nowledge (broad and deep)

- ❖ **A**wareness/**A**ttitudes
  - An overarching approach to engineering problems in the context of environmental, economic and social issues.
- ❖ **S**kills
  - Ability to work with complex/-ill defined problems
  - Team work and communication skills
  - Ability to evaluate the merits and demerits of options
- ❖ **K**nowledge
  - Broad and Deep
  - Technical
  - Environmental
  - Social processes
  - Legal
  - Disciplined Body of General Knowledge

Engineering Education, Sustainable Development and the Teaching and Learning Process?

❖ **Process**:

- Use of Case Studies
- Studio Based
- Issue Driven
- Process Based
- Team Based
- Design/Delivery Focussed

Pulling relevant material into the curriculum,

not shoving more material into it…

This is an Apple Upside Down Cake

Could we do the same with the engineering curriculum?

Integrate rather than differentiate!

Engineering Education, Sustainable Development and the Teaching and Learning Process?

❖ **Process**:

- Use of Case Studies
- Studio Based
- Issue Driven
- Process Based
- Team Based
- Design/Delivery Focussed

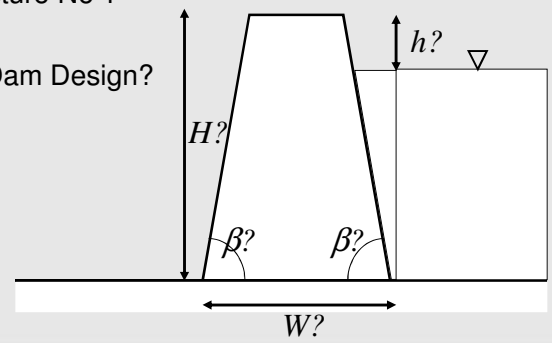
Pulling relevant material into the curriculum,

not shoving more material into it…

1st Year Lecture Course: Water Engineering/Structures 1970's

Lecture No 1

- Dam Design?



1st Year Lecture Course: Water Engineering – 21st Century

Lecture No 1

- Dams
- "West is West and East is East and ne'er the twain shall meet…" - Rudyard Kipling
- PROJECT BRIEFING

Monday, June 2, 2003 METRO

World's biggest dam swallows 1.5m homes

BY MARK CAPPER

IT WILL force 1.5million people from their homes and has sparked fears of major pollution – but the dam behind the world's largest and most controversial hydroelectric project started working yesterday.

China closed sluice gates to begin filling the reservoir of the £15billion Three Gorges Dam on the 3,955mile Yangtze River – the third longest in the world.

The 610ft high, 1.3mile wide dam – which has taken ten years to build – is needed to provide power for China's rising population, according to Communist Party leaders.

They hope it will help tame the river, whose annual floods killed 300,000 people in the last century.

Beijing held a live TV broadcast of the opening ceremony to show off the technical expertise behind its biggest building project since the Great Wall 2,000 years ago.

Critics say the dam, at Yichang in the central Hubei province, will bring ecological disaster. More than 265billion gallons of raw sewage are dumped into the Yangtze each year, most of which is flushed out to sea. But with the river dammed, there are fears it will back up in the 370mile long, 600ft deep, reservoir.

In addition, pollution will seep from the remains of 13 flooded cities, 140 towns, 1,300 villages and 1,600 factories.

More than 140,000 people have been resettled out of a total of 1.5million who must leave their homes. One farmer, Ke Changsu, 49, said he had been unable to find work since being relocated three years ago. They lied to us again," he said.

Big project: The Three Gorges Dam on the Yangtze

METRO Factfile

- In the past 2,000 years, the Yangtze has experienced 215 catastrophic floods.
- In 1998, flooding in the area to be covered by the dam left 4,000 dead, 14million homeless and cost £14billion.
- When it starts operating in 2009, the hydroelectric plant will produce the energy of 15 nuclear power plants.
- The dam contains twice the amount of concrete as the Itaipu project in Brazil, previously the world's biggest dam.
- It will join the Great Wall as one of the few man-made objects seen from the moon.
- Up to 1,300 archaeological sites will be lost under water and the Chinese river dolphin may be driven to extinction.

China's Three Gorges Dam

The Yangzi River is home to some of China's most spectacular natural scenery, a series of canyons known as the Three Gorges

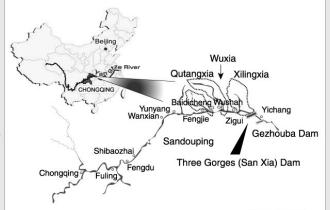
China's biggest construction project since the Great Wall generates controversy at home and abroad

By Bruce Kennedy
CNN Interactive

Sun Yatsen first proposed building a dam on the Yangtze River in 1919 for power generation

The idea resurfaced in 1963 as part of the new policies to build a "third front" of industry in SW China. But the Cultural Revolution erupted in 1966, and in 1969 the fear that the dam would be sabotaged by the Soviet Union, now an enemy, resulted in a construction delay.

Three Gorges (San Xia) Dam Construction Site



Ecologist Hou Xueyu was among the few who refused to sign the environmental report because it falsely hyped the environmental benefits provided by the dam, and failed to convey the real extent of environmental impact

After the Tiananmen Square massacre in June 1989, the government forbade public debate of the dam, accused foreign critics of ignorance or intent to undermine the regime, and imprisoned Dai Qing and other famous critics. Former Premier Li Peng crusaded for the dam and pushed it through the National People's Congress in April 1992 ….

Here are some of the Issues - Real or Spin?

METRO Factfile

- In the past 2,000 years, the Yangtze has experienced 215 catastrophic floods.
- In 1998, flooding in the area to be covered by the dam left 4,000 dead, 14million homeless and cost £14billion.
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- It will join the Great Wall as one of the few man-made objects seen from the moon.
- Up to 1,300 archaeological sites will be lost under water and the Chinese river dolphin may be driven to extinction.

26 hydropower turbines: 18.2 GW, 11% of China's output.

1st Year Lecture Course: Water Engineering

Questions and Issues to be resolved by next week

- How would you design the dam? (Structurally and in terms of Reservoir Yield/Power?)
- How would you assess the pre-existing Flood Risk?
- How would you estimate the impact of Water Quality/Effluent Discharges?
- Can you assess the effects of Sedimentation?
- How would you take into account the Social Consequences of Relocation?
- What are the Environmental Consequences and how would you balance these against Economic Benefits?

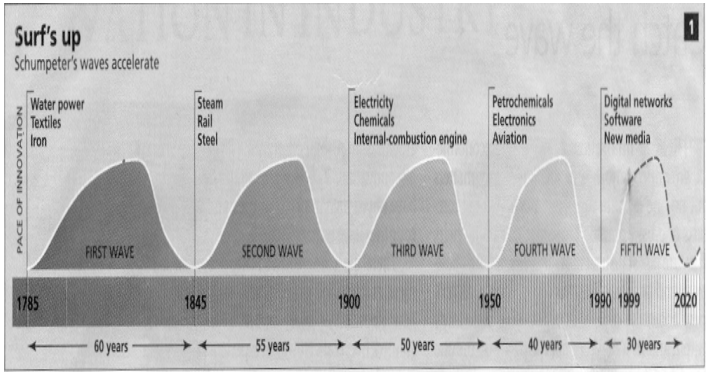
1st Year Lecture Course: Water Engineering

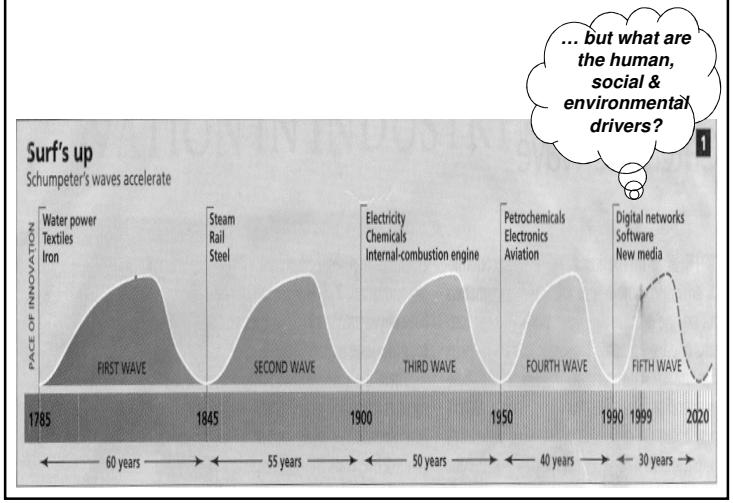
QUESTIONS?

And finally….

- How would you have done it differently?
- The crit sessions will be held next Friday and final reports to be filed electronically by the end of term…..
- *Some* Project data and references are available on the Department Intranet
- Assessment? Group mark based on final reports ….plus open book exam in the Spring diet…

Origins of our Present Condition – Part 1: Waves of Economic Growth/Innovation
(Austrian Economist Schumpeter)





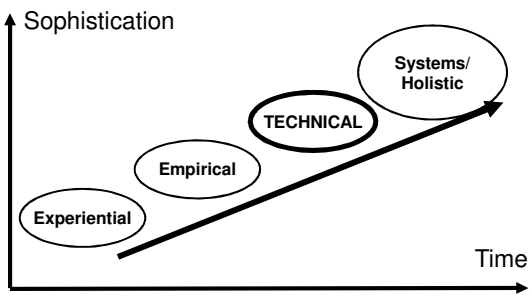
To what extent has Civil Engineering contributed to …..

- Public Health – clean water, safe wastewater disposal?
- Housing and Shelter?
- Improved transportation?
- GDP?
- **Sustainable Development?**

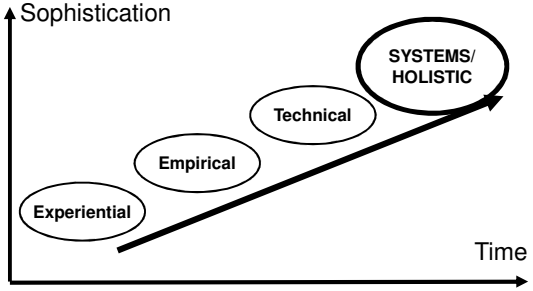
but also …

- CO2 emissions/Asthma?
- Depleted Water Courses?
- Inefficient Buildings?
- High Rise Buildings and Social Unrest?
- **Unsustainable Development?**

Phases of technology



Phases of technology



Systems and Sustainability?

We could spend hours debating this…..
But do we really need to?

Sustainable Development – will it last?

Why Sustainability?

Codswallop

When I looked at the *ICE News* piece in on sustainability (*NCE* 17/24 April) my first impression was of a page of meaningless jargon. This was confirmed by a second look.

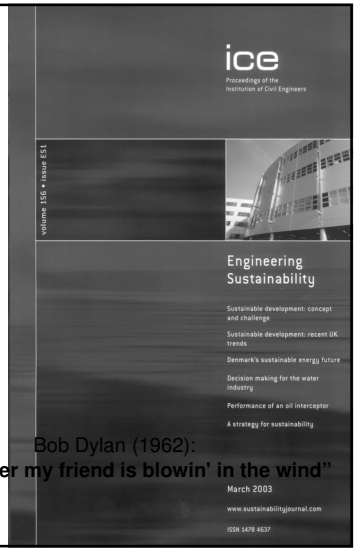
I may have missed something in the 10 years since I retired but I do not know what sustainability means or what a civil engineer can do to ensure it.

Does it mean do not build something that costs a lot but is no use – like the Dome? Or does it mean try very hard to scrape up the money when times are hard to build something that is very worthwhile – like Crossrail?

Either way the decision lies outside the field of the civil engineer.

NCE 1st May 2003

Bob Dylan (1962):
"The answer my friend is blowin' in the wind"



HRH The Prince of Wales,

ICE-Halcrow Lecture on Sustainability

Jan 2012

"But what has occupied me for a very long time is quite why, with all our technical knowledge, we find ourselves facing the threat of catastrophic climate change.

"I fear the answer lies in the very words in your Royal Charter"

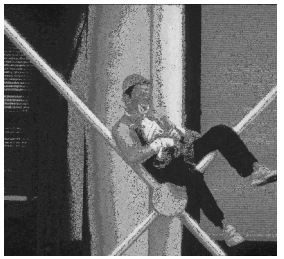
"We have been all too willing to direct and use the power of nature for our own ends, with scant regard for the long term consequences of our actions"

Thomas Tredgold's 19th c definition of Civil Engineering

Civil Engineering is the art of directing the great sources of Power in Nature for the use and convenience of man

(Tredgold, 1828)

a 21st c definition of Civil Engineering



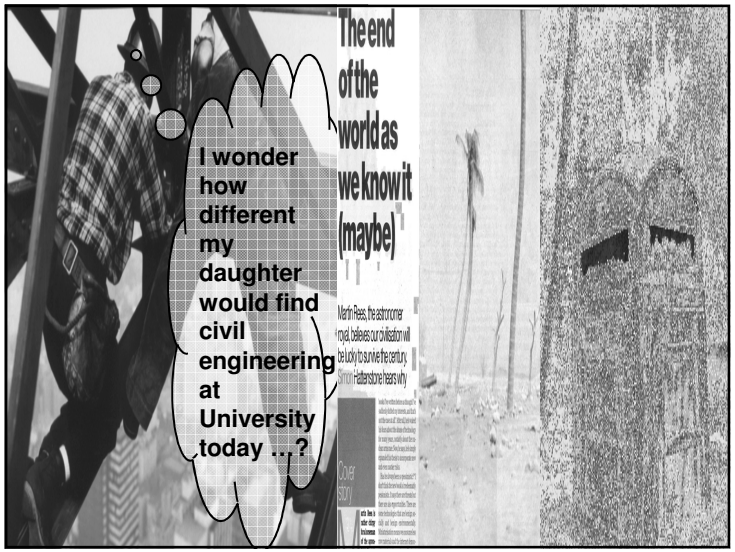
Civil Engineering is the art of working with the great sources of Power in Nature for the use and benefit of society

(Jowitt, 2003)

Time's Winged Chariots

- Water demand doubling every 21 years. 70% used for irrigation
- Limits on irrigation leads to limits on food production
- Limits on food production in poor countries leads to imports, higher prices and political instability
- Water tables are falling (caused by excessive pumping and leading to permanent damage to aquifers)
- Some rivers no longer reach the sea

David Thom (1998) – New Zealand Civil Engineer



2nd Year Lecture Course: Water Resources Engineering

- Welcome to Lecture No 1
- "Water is for fighting over" – Mark Twain
- PROJECT BRIEFING: The Middle East

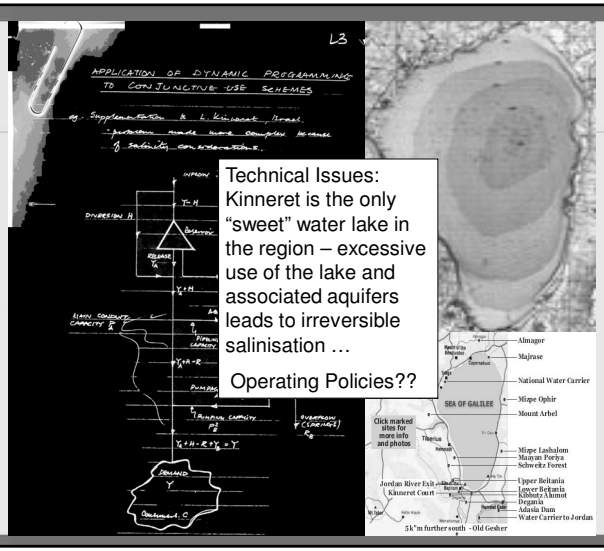
Case Study: Water Resources in the Middle East

Situation affected by:

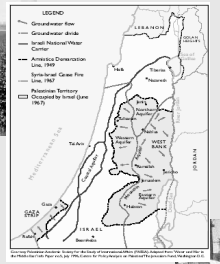
- 1967 Arab Israeli War – occupation of the Golan Heights
- Israeli-Jordan-Palestinian-Syrian Water Treaties
- Settlements in the West Bank
- Current conflicts and tensions

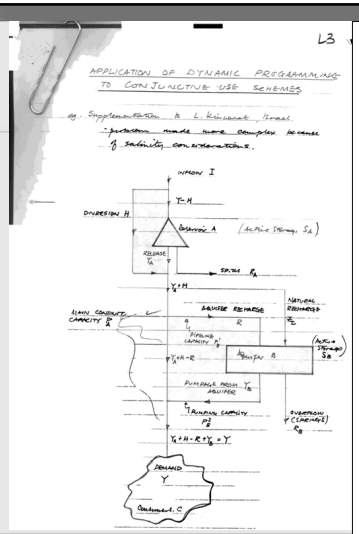
Reference:

"Water Agreements Between Israel and Its Neighbors" (Uri Shamir)



Optimal Allocation of Water Resources in Lake Kinneret – ….the Sea of Galilee…..





My lecture notes from a bygone age..

- well, circa 1980 –

.. for an MSc lecture course on Water Resources Management, Imperial College….

Strong on "hard" systems analysis and optimisation

<u>But what is missing?</u>

The Non Technical Context – the "soft" systems stuff!

The Sea of Galilee

Until 1967, Lake Kinneret and a small strip on the eastern shore of the lake served as the border between Israel and Syria.

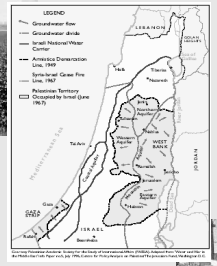
After the Six-Day War which resulted in Israel's occupation of the Golan Heights (east of Lake Kinneret), Lake Kinneret was no longer the border between Israel and Syria, and it is presently an inland lake of Israel.

Water Is the Root of Israeli-Palestinian Evil
JERUSALEM, April 2, 2002 (ENS)

Each side sees itself as the victim. The convoluted conflict which has its origin in Biblical times is created in part by the arid nature of the disputed lands.

Dwindling water resources increasingly affected by pollution, agricultural and industrial use and population growth, have elevated the strategic importance of water in the region. The water issue is at the root of the struggle over territory.

<u>Equitable</u> Allocation of Water Resources in Lake Kinneret – ….the Sea of Galilee…..



7 Work Groups,

7 Reports/Presentations by next Monday…..

Engineering Issues?
Ethical Issues?
Political Issues?
Environmental Issues?
Economic Issues?
Water Management Issues?
Social Issues?

Plus Mechanisms for Conflict Resolution?

So who will engineer
a sustainable future?

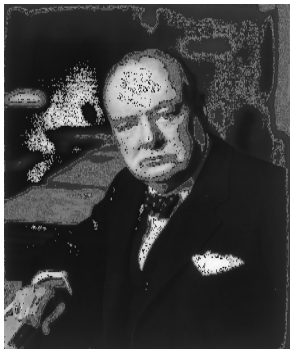
Engineers!

- The blind application of technology might have led to the unsustainable predicament of the present world.
- But one thing is for certain…..
- Engineers will play a key role – in partnership with others – in developing a sustainable future…..
- **The "Engineer of Responsibility"**

"We shape our buildings,

and afterwards our buildings shape us"

Winston Churchill



Infrastructure that inspires

Millau Viaduct, France

Eden Project, Cornwall

"Places where stuff works and people are happy"

Gateshead Millennium Footbridge

St Pancras International, London

The Shard?

"The Shard is a controversial building... looks impressive from afar, and awful close up.... unerringly like the Ministry of Truth on the opening page of Orwell's '1984'

Should the IStructE prick the bubble and say it's **<u>just a fully glazed lift shaft?</u>**

It is a tough call.."

David Fisk – CIBSE Past President

EPSRC's Sustainable Urban Environment (SUE) Programme

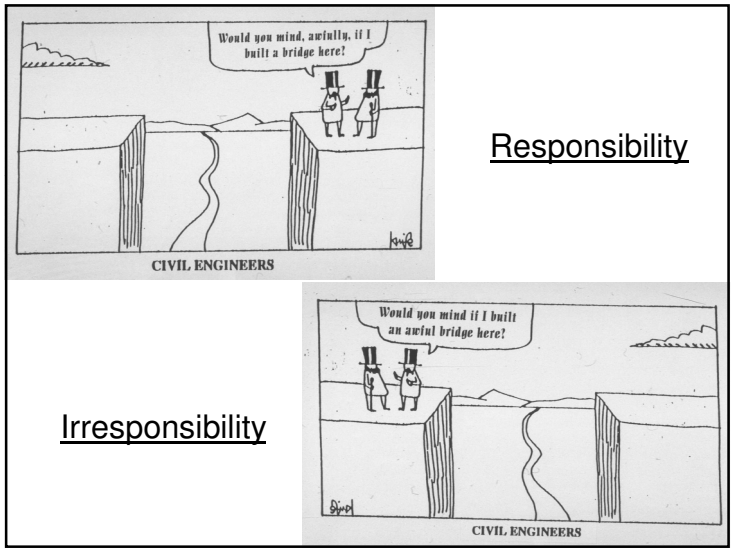
"Implementation Strategies for Sustainable Urban Environments" - *ISSUES*

www.urbansustainabilityexchange.org.uk

EPSRC
Engineering and Physical Sciences Research Council

The ISSUES Project

SUE
Sustainable Urban Environment

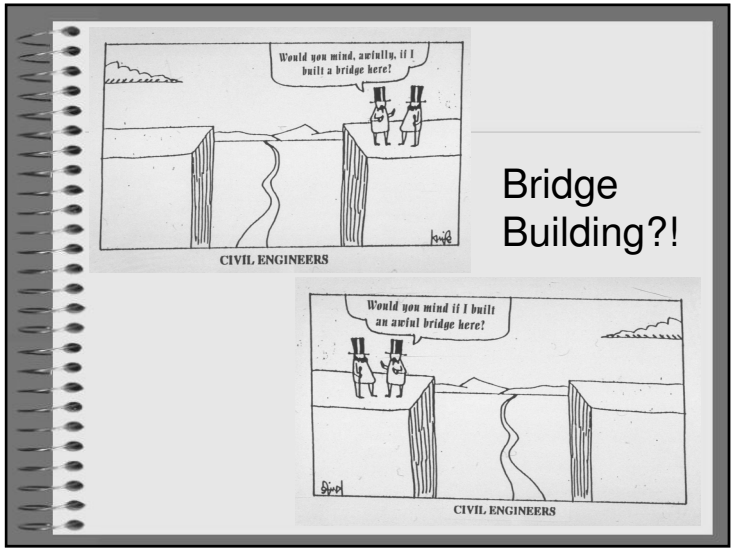


3rd Year Lecture Course:

Structures!

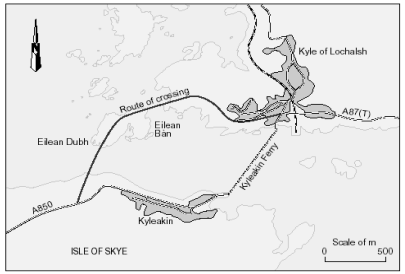
Bridge Design

- **Choice** (the design or decision options) and the exercise of **Preferences** over those choices
- **Function/Purpose?**
- **Benefit Cost Analysis**, and
- the **impact on Society** and diverse groups of **Stakeholders**…



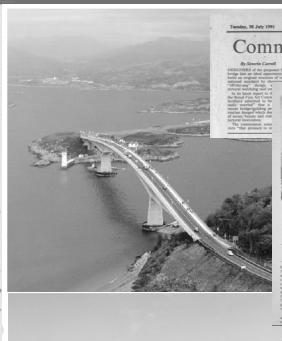
The Skye Bridge -

- the only bridge ever to divide two communities…???



Skye Boat Song:

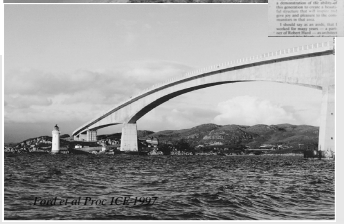
"Speed, bonnie boat, like a bird on the wing,
Onward! the sailors cry;
Carry the lad that's born to be King
Over the sea to Skye"



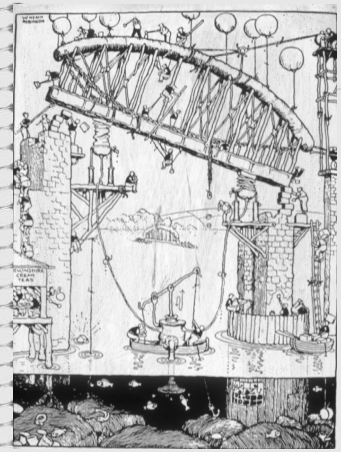
Home News

Commission criticises 'off-the peg' Skye bridge

Unfit for the Skye line



Role of PFI?
Design Quality?
Impacts:
- Social
- Environmental
- Economic



Tasks:
Find a better solution….
- Structural
- Economic
- Financial
- Social
- Environmental
- Aesthetic
- Process

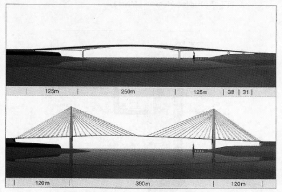


Fig. 6:
View of the free-cantilever-bridge (adopted design) and of the cable-stayed bridge (alternative proposal)

"EDUCATING THE REFLECTIVE PRACTITIONER"
by Donald A. Schon

- "In the varied topography of professional practice, there is a high, hard ground overlooking a swamp.
- On the high ground, manageable problems lend themselves to solution through the application of research-based theory and technique.
- In the swampy lowland, messy, confusing problems defy technical solution."

- "The irony is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, however great their technical interest may be....

  ..... while in the swamp lie the problems of greatest human concern.

The practitioner must choose.

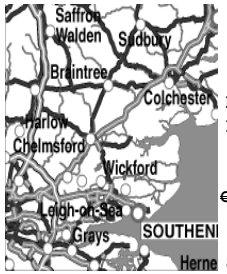
- Shall s/he remain on the high ground where s/he can solve relatively unimportant problems according to prevailing standards or rigor, or shall s/he descend to the swamp of important problems....?"

The 3rd London Aiport?

Roskill Commission (late 1960s early 70s)

Sir Colin Buchanan

Maplin Sands

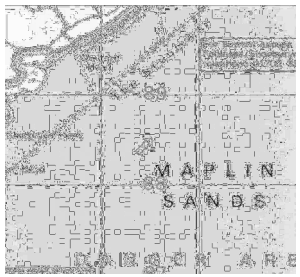


Brent Geese over Maplin & Foulness

~~**Cublington**~~

~~**Maplin**~~

Stansted!



PWJ: Origins of my research interests?

Roskill Commission; Sir Colin Buchanan

3rd Yr Option in "Systems and Mechanics"

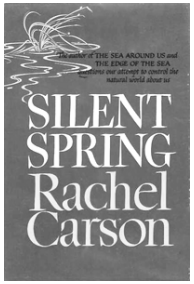
Optimisation Methods;
Risk and Probability;
von Neumann & Morgenstern's "Theory of Games and Economic Behaviour";
Decision Theory

PhD: "Decision-Making in Civil Engineering Systems"

Emerging/Background Issues

Carson (1962)
"Silent Spring"

Meadows, Meadows, Randers & Behrens (1972)
"The Limits to Growth"
A Report to The Club of Rome,



Impact on reputation/attractiveness of civil engineering as a profession…..

…. engineering perceived as part of the problem,
…. not part of the solution

The origins of our present condition – Part 2

… the world's economy has been built on the production, acquisition and disposal of consumer goods in an increasingly

material world…

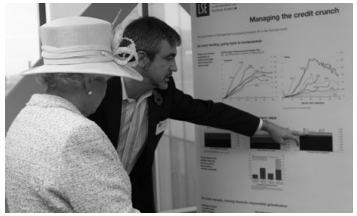
material world…

The credit crunch

HM The Queen:

"Why had nobody noticed it coming?"

LSE, November 2008



Response:

Professors Tim Besley and Peter Hennessy:

"Risk managers frequently lost sight of the ***bigger picture****."*

"A failure to understand the risks to the ***system as a whole"***

Systems level consequences

Systems level solutions

The engineers' ability to take a systems view at a range of temporal and spatial scales

Not just a shift to whole life costs

… but to whole life **values…**

What makes real life decisions more difficult?

- Discriminating between the **complexity** of the choices available and defining the decision-maker's preferences over them.
- Further exacerbated where there is **no single decision-maker** (or where a the decision maker(s) are **acting in some form of proxy** for others).

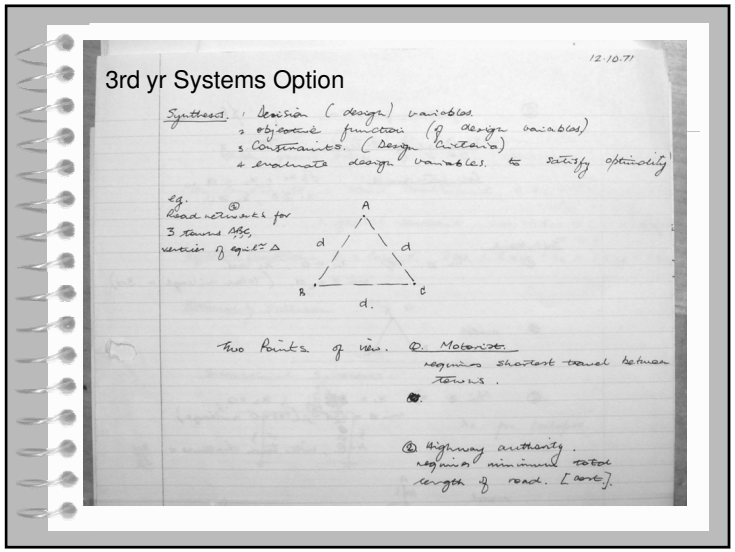
Multi-Stakeholder (Multi-Decision Maker) Decision Problems.

Final Year Lecture Course –
or should this be First Year?!

Systems:
Decision Making/Conflict Resolution?

Elements of a Decision?

- **Choice** (ie in the design or decision options) and the exercise of
- **Preferences** over those choices, and
- **Uncertainty/Risk** over the actual outcomes
- Plus many **Stakeholders**…

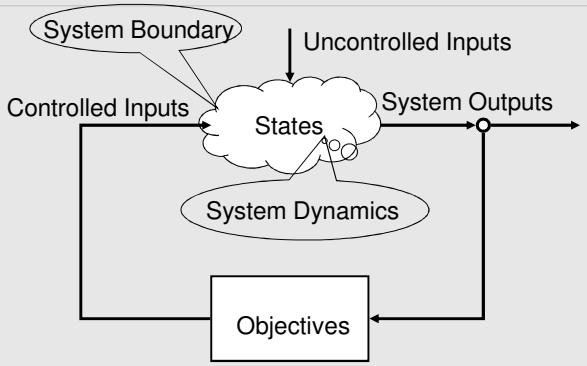


The Concept of a "System"

Landmark "Systems" concepts:

- A systems boundary;
- A set of state variables within this boundary that characterise the state of the system;
- A set of external inputs and system outputs;
- A set of system/state equations which define the interaction of the external inputs and state variables and which describe how the system will evolve;
- A performance measure reflecting the stakeholders' objectives….

A "System"



Systems and Duality

"Equilibrium"
The Relationship between external "forces" and internal "stresses"

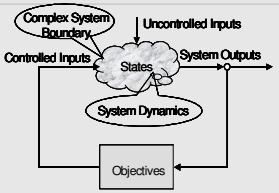
$\underline{\mathbf{A}}.\underline{\mathbf{q}} = \underline{\mathbf{D}}$

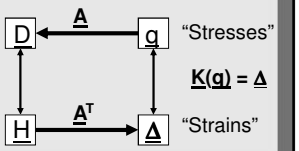
"Compatibility"
The Relationship between internal "strains" and external "displacements"

$\underline{\mathbf{A}}^T.\underline{\mathbf{H}} = \underline{\Delta}$

"Stress-Strain Law"
The Relationship between internal "stresses" and internal "strains"

$\underline{\mathbf{K}}(\underline{\mathbf{q}}) = \underline{\Delta}$





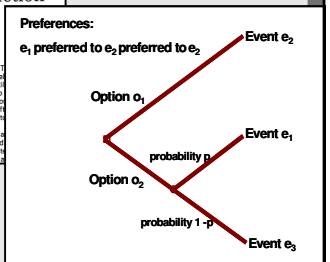
Multiattribute Utility (Value) Theory

A Von Neumann–Morgenstern interpretation of the weighting factors in a valuewise-independent utility function

P. W. Jowitt*

The possible eventualities in decision problems are often multi-attributed. T task of assigning utility functions to such eventualities can be considera simplified if the property of valuewise-independence extends over the uti field or can be assumed to do so. This allows component utility functions to constructed and the composite utility function assembled from these co ponents with appropriate scaling. The component utility functions are of scaled between zero and unity and weighting factors attached to each to rest the correct scaling.

The interpretation of these weighting factors has often been misleading a the various methods suggested for their determination have not been related the fundamental notions of utility theory, the Von Neumann–Morgenst axioms. The object of this paper is to demonstrate that the determination

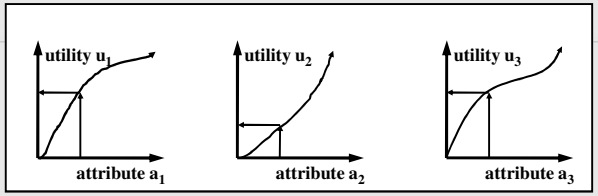


valuewise-independent, so that the utility of any eventuality can be written:

$$u(e_j) = \sum_{i=1}^{m} u_i(x_i) \qquad (1)$$

where $u_i(x_i)$ is a component utility function of the ith attribute.

Multiattribute Utility (Value) Theory



Total Utility = $w_1.u_1 + w_2.u_2 + w_3.u_3$

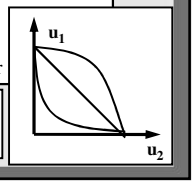
BEWARE! Limitations:

Practical: eg achieving consistency

Theoretical: eg the utility function might not be linear

"milk ***or*** juice"

"bread ***and*** butter"



Engineering Decision Making?

Involves:

Resolving Conflicting Objectives

Resolving Conflicting Opinions

... Engineering is not an apolitical activity

Civil Engineering Issues for the 21st Century?

Large Scale/Systems Scale Problems

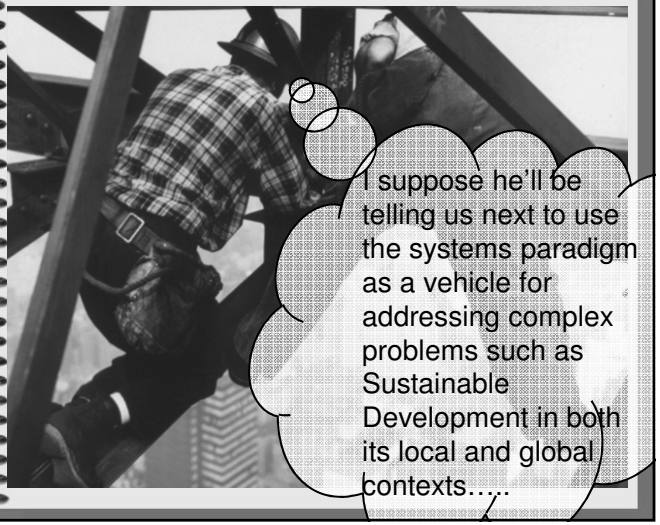
– Basin Scale Water Resources Management
– Large Scale Urban Regeneration
– Asset Management/Infrastructure Integrity
– International Development/UN MDGs
– Climate Change/Energy

The whole Construction Process

Risk/Safety/Health

Waste Min/Resource Management

Sustainable Development



Sustainability?

- It's time we moved on!
- It's now about sustainability at the "systems level", not just the "within-project level".
  - Best practice should automatically be about sensible use of resources, environmental protection, SUDS, low carbon solutions etc.
- Sustainability at the systems level requires something far more strategic....

... and involves the assessment of the economic, social and environmental impacts at a range of scales –

... physical and temporal...

Systems Level Solutions?

- What are the systems boundaries – and who sets them?
- Transparency – how transparent is the information upon which the decisions are made?
- What are the decision criteria?
  - CBA, the Treasury Green Book, profit, whim, or something more visionary, consequential - and consensual?

Accounting for the Future?

- How do we deal with the future?
  - Economic Discounting?
    - Does not cope adequately with the future value (and consequences) of impacts which cannot be easily monetised.
    - By definition, it discounts the future!
  - **You can discount future carbon prices, but you can't discount the impact of future CO2 emissions....**

"Forty Years on!"

~1973

- APT - British Rail's Advanced Passenger Train
- Roskill Commission – 3rd London Airport
- Victoria Tubeline in London
- The Buchanan Report – "Traffic in Towns" – Planning
- Channel Tunnel
- Severn Barrage
- Concorde

~2013

- HS2 – High Speed Rail from London to ???
- Davies Commission on London's Airport Capacity
- Crossrail
- The Armitt Report - Long Term Infrastructure Planning
- The Thames Tideway
- Severn Barrage (again!)
- Elon Musk's "Hyperloop" Train

Decisions by incoming UK Coalition Government after 2010 General Election

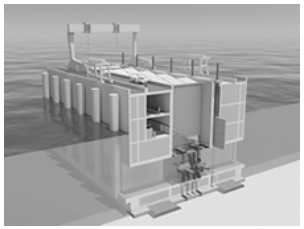
- Cancelled the Severn Tidal Energy Barrage
- Backed the construction of of the High Speed Rail link (HS2) from London to Birmingham

And the rationale for these decisions?

... the search goes on ....

The Severn Barrage?

What next?



Corlan Hafren (Arup, Halcrow, KPMG) has morphed into Hafren Power and is looking at a revised scheme....

The Armitt Review

An independent review of long term infrastructure planning commissioned for Labour's Policy Review

High Speed Rail?

Evidence-based Policy Making?
or
Policy-based Evidence Making?

- ...might be useful if the evidence was made transparent before the decisions are made rather than developed in the heat of controversy afterwards....

HS2 plans a “game-changer” says Birmingham Chamber CEO

“HS2 is a ‘giant folly’ and should be scrapped” warns influential Institute of Directors

“HS2 to boost UK economy by £15bn a year” says report

“HS2 costs spiralling and benefits dwindling” MPs warn

High Speed Rail across Europe

The Route...

High Speed Rail:

"Rural unrest grows: Clive Aslet visits the Warwickshire village of Wormleighton, close to which the proposed HSR rail link will run...."
(from the Daily Telegraph)

"HS2 to Anywhere?"

Risk and Uncertainty?

– When, from where, and where to?

The Economics?

– What are the benefits, to whom, and where?
– And the economic impacts on the rest of the UK?

"The ~~20.25~~ 2025 HST to Edinburgh due to depart from Platform $9^{3}/_{4}$ has been delayed...."

How <u>should</u> we decide on large infrastructure projects?

"The ~~20.25~~ 2025 HST to Scotland has been postponed"

A far cry from W H Auden's "The Night Mail"…..

NIGHT MAIL by W.H. Auden

This is the Night Mail crossing the Border,
Bringing the cheque and the postal order,

Letters for the rich, letters for the poor, the shop at the corner, ...

... Down towards Glasgow she descends...
... All Scotland waits for her

Letters of thanks, letters from banks....

In Glasgow, Edinburgh, and Aberdeen, they continue their dreams ....
... but shall wake soon...

Who can bear to feel themself forgotten?

Will we be disappointed?

The **H**igh **S**ustainability **T**rain?
The End? – or just the Start

A Brief Encounter – or a Long Haul?

"The 2025 High Sustainability Train to Edinburgh due to depart from Platform 9¾ will be cancelled.... unless we challenge the economic arguments"

Rethinking the Engineer?

- Holistic Approach
  - Need to deal with Complexity
- Clear Vision of System Functioning
  - Criteria to assess quality
- Appropriate Attitude, Skills and Knowledge
- Awareness/Exposure to Significant Issues
- Ability to relate to/understand beyond immediate specialism

- **An organising principle to bring it all together**

A student's mind is not a vessel to be filled ….

…. but a fire to be kindled