Infrastructure, Resilience and Sustainability

Strategic Approaches

Professor Peter Guthrie
What is Resilience?
A definition of resilience

‘The ability of a **system, community** or **society** exposed to hazards to **resist, absorb, accommodate** to and **recover** from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions’

(UNISDR, 2009, p.24)
Resilience

**Precision**: Resilience - an outcome, process or physical property. May relate to physical features, political strategies, organisations or community capacity.

**Circularity**: There can be an element of circular reasoning - is resilience a factor of, or the inverse of vulnerability?

**Context**: Resilience is influenced by scale and location, cultural context and timing in relation to crises.

**Completeness of knowledge**: Interpretation of resilience has led to competing views and uncertainty around how ‘resilience’ should be described and measured.
Resilience for a More Secure Future
Resilience Interpretations

(a) Kuhlicke, 2010
(b) Chang et al., 2014
(c) Milman and Short, 2008

MacAskill, K., Guthrie, P., 2014. Multiple Interpretations of Resilience in Disaster Risk Management. 4th International Conference on Building Resilience, 8-10 September, Salford Quays, United Kingdom. Elsevier BV
Three Scenarios Developed

[Diagram showing three scenarios: Self-Reliant Green City, Compact City, Smart-Networked City. The diagram is plotted against two axes: Change in land use & urban form (low to high) and Social values & institutions (market to cooperative).]
Smart Networked City

Higher economic growth
Increased urban density and new suburban development
Emphasis on ICT, communication and transportation

COMPACT CITY

The city as a site of intensive and efficient urban living
Moderate economic growth with strong local governance
Higher urban density
Mixed-use neighborhoods – increase in neighborhood infrastructure

SELF-RELIANT GREEN CITY

The city as a self-reliant bioregion, living in harmony with nature
Lower economic growth
Fall in urban densities
Cooperative and collective values underpin new models of shared ownership
Significant decrease in overall energy consumption
Re-localisation of production and consumption
Rise of urban agriculture

Green and blue space, local biomass and biodiversity are all harmonised and integrated into the city

Mend and strengthen culture – build on our strengths
Energy Efficiency in the Built Environment (EEBE) Research Programme

Scenarios

<table>
<thead>
<tr>
<th>Low Cost; High Availability of Energy</th>
<th>High Cost; Low Availability of Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positive Attitudes/Values</strong></td>
<td><strong>Negative Attitudes/Values</strong></td>
</tr>
<tr>
<td>Steady Progress</td>
<td>Transformational Change</td>
</tr>
<tr>
<td>Comfort Without Concern</td>
<td>Growing Divide</td>
</tr>
</tbody>
</table>
Knowledge Mapping for Future Proofing

Uncertainty of High Impact Future Trends and Drivers

- **Low**
  - **Straightforward**
    - Available knowledge to accommodate predictable future trends
  - **Innovation-oriented**
    - Need or new technologies, construction practices and optimum combination of established sustainability assessment methods

- **High**
  - **Uncertainty-oriented**
    - Need to prepare for a spectrum of plausible futures with the use of futures techniques
  - **Comprehensive**
    - Need for new technologies, construction practices and new generation future-oriented decision-support techniques

Availability of Product and Process Innovation

- **Available**
  - Straightforward
  - Innovation-oriented

- **Unavailable**
  - Uncertainty-oriented
  - Comprehensive

## Categorisation of Future-Proofed Design Approaches

<table>
<thead>
<tr>
<th>X-axis: Coverage of SD Issues</th>
<th>Y-axis: Adopting Lifecycle Thinking</th>
<th>Z-axis: Accommodating Risks and Uncertainties</th>
</tr>
</thead>
</table>
| **X₁:** Financial considerations | Y₁: Operational energy performance  
  - Y₁a: Predictive studies  
  - Y₁b: Post-Construction Audit/Post-Occupancy Evaluation | Z₁: Steady-state modelling |
|  - X₁a: Capital cost assessment  
  - X₁b: Cost-Effectiveness Analysis  
  - X₁c: Financial incentives | **Y₂:** Embodied energy and carbon  
  - Y₂a: Design for ‘cradle-to-gate’  
  - Y₂b: Design for ‘cradle-to-grave’  
  - Y₂c: Design for ‘cradle-to-cradle’ | Z₂: Adoption of standards beyond statutory minima |
| **X₂:** Environmental considerations  
  Hierarchical approach to low-energy design | **Y₃:** Lifecycle Assessment  
  - Y₃a: Building material and/or construction component scale  
  - Y₃b: Building scale  
  - Y₃c: District scale | Z₃: Design for adaptive capacity  
  - Z₃a: Design for resilience to overheating  
  - Z₃b: Design for flexibility |
| **X₃:** Socio-economic considerations  
  - X₃a: Sustainability information and education  
  - X₃b: Demand-side management strategies  
  - X₃c: Assessment of energy-related social impacts | **Y₄:** Lifecycle Costing | **Z₄:** Advanced future-oriented analysis  
  - Z₄a: Dynamic building performance evaluation  
  - Z₄b: Stochastic modelling of future overheating risk  
  - Z₄c: Use of futures techniques |
Future-Proofed Design of Low-Energy Housing Developments: Conceptual Framework and Case Studies from the UK and Sweden

Maria Christina Georgiadou
PhD Thesis October 2013

Diagram:
- Z-axis: Accommodating Risks and Uncertainties
- X-axis: Coverage of SD issues
- Y-axis: Adopting Lifecycle Thinking
- Comprehensive Future-Proofing
- Straightforward
- Uncertainty-oriented
- SD-oriented
- Lifecycle-oriented
Agent Based Modelling (ABM)
Scenarios can be tested
Civil Infrastructure

• The framework upon which society can function
• Providing connectivity
• The building blocks of an integrated society
• Operationally interdependent but functionally separated
Civil Infrastructure Characteristics

• Long life
• High initial investment
• Geographically widespread
• Compatibility with existing systems
Civil Infrastructure

- Building on historic decisions and embedding them (railways)
- Reinforcing existing systems (roads and railways)
- Enshrining distinctiveness
- Resulting obsolescence (canals)
WEF Global Risks 2017

• Decision makers may see the provision of infrastructure as unlikely and of limited impact

• Risks of extreme event may cause infrastructure failure

• Infrastructure failure through system collapse would lead to societal breakdown
Catastrophic Risks GAC at WEF:
3 of top 4 for Impact:
- Extreme Weather
- Natural Disasters
- Water Crises
Failure of Critical Infrastructure comes 25th
Resilience

Inversely proportional to economic development

Developing economies are excellent at absorbing shocks - elastic

Sophisticated societies are strong and highly resistant - but brittle
Currently

- Total Assurance of Non Failure
- Assumption that Failure is Catastrophic
- Risk Allocation is Confined
- All Resource Use Now is Allowable

Potentially

- Design for Failure to Occur
- Design for Graceful Failure
- Risk is Shared More Widely
- Resource Use Now Balanced against Future Impacts
Sustainability in Infrastructure

• Designed from response to need
• Sustainability is retrofitted to the design

But …

• Sustainability Goals should be the Starting Point
• Infrastructure designed to meet these aims
Sustainability in Infrastructure

Sustainable Infrastructure is Infrastructure that is Determined by Sustainable Development Goals
Design Infrastructure in Response to Need

Determine Engineering

Retrofit Sustainable Development Aspects
Design Infrastructure in Response to Need

Determine Engineering

Re抵制 Sustainable Development Aspects
Set Sustainable Development Vision

Introduce Societal Aspects

Design Sustainable Infrastructure
Figure 5: Map of shortlisted schemes

- **B3**: Brean Down to Lavernock Point Barrage
- **B4**: Shoots Barrage
- **B5**: Beachley Barrage
- **L2**: Welsh Grounds Lagoon
- **L3d**: Bridgwater Bay Lagoon
Resilience for a More Secure Future
Thank you

Peter Guthrie  pmg31@cam.ac.uk