Drivers of Resilience

Systems Modelling for Understanding Manufacturing, Resilience and Sustainability in Bristol

Chris McMahon, Rachel Freeman, Patrick Godfrey
(University of Bristol)
Colston Hall, 14/10/2015
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Agenda Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:30 to 11:05</td>
<td>Introductory Speakers</td>
<td>Welcome: (Chris McMahon)</td>
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<td>Keynote: Sustainability and resilience in Bristol (Sarah Toy)</td>
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<td>Past and future presses on manufacturing in the UK, and how it affects regional resilience (James Simmie)</td>
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<td>Introduction to the project, the research framework, systems modelling method, and the modelling activities in the workshop (Patrick, Rachel)</td>
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<tr>
<td>10:05 to 11:35</td>
<td>First Modelling Session – Review and expand the strawman R-S model</td>
<td>1. What are the key casual influences between different types of sustainability and resilience trends in the region?</td>
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<td>2. What key disturbances have affected the city and its manufacturing sector in the past?</td>
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<tr>
<td>11:05 to 11:15</td>
<td>Refreshment Break</td>
<td>Tea/coffee</td>
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<tr>
<td>11:15 to 12:15</td>
<td>Second Modelling Session – Review and expand the strawman manufacturing model</td>
<td>1. What resilience characteristics does the city’s manufacturing sector have in the face of long-term and short-term disturbances?</td>
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<td>2. How resilient are different parts of the manufacturing sector (production, design, finance)?</td>
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<tr>
<td>12:15 to 12:45</td>
<td>Second Set of Speakers</td>
<td>Characteristics of resilient engineered systems (David Oxenham)</td>
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<td>Supply chain resilience (Alan Champneys)</td>
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<td>Implications of increasing environmental uncertainty for resiliency of production (Rich Pancost)</td>
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<tr>
<td>12:45 to 13:10</td>
<td>Lunch break</td>
<td>Tea/coffee/lunch</td>
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<tr>
<td>13:10 to 14:00</td>
<td>Third modelling session – add future pulses and presses and consider the role of RDM</td>
<td>1. Which pulses and presses are likely to be the most important to the city-region and its manufacturing sector in the coming decades?</td>
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<td>2. What are the possibilities for expanding re-distributed manufacturing in Bristol and how would it impact the sustainability and resilience of the region?</td>
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<tr>
<td>14:00 to 14:40</td>
<td>Wrap Up</td>
<td>A chance to wander round and comment on/add to other models</td>
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<td>Presentation of models from different groups to all Plenary discussion on what was learned</td>
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</table>
Overview of the Subject
# Resilience/Sustainability Types

**Sustainability:** system can run indefinitely

**Resilience:** system can withstand disturbances

<table>
<thead>
<tr>
<th>Resilience Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Sustainability</td>
<td>City-region can maintain a good quality of civic life for its citizens and support local businesses; citizens can be economically self-reliant</td>
</tr>
<tr>
<td>Environmental Sustainability</td>
<td>Natural environment can provide services such as drainage, productive soils, forests, good air quality; local and global environmental impacts such as carbon emissions are minimised</td>
</tr>
<tr>
<td>Short-term Resilience</td>
<td>Public/private agencies are able to establish normal services soon after short-term economic, social, political, or environmental shocks that disturb universal services</td>
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<tr>
<td>Long-term Resilience</td>
<td>Regional economy and society is able to evolve and adapt over time in response to a range of long-term stressors - ‘constant change rather than stability’ (Simmie &amp; Martin 2010)</td>
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</tbody>
</table>
The Research Framework

Pulses (identified risks)
- Extreme weather (floods/drought)
- Industrial accidents/environmental pollution
- Transport accidents/infrastructure failure
- Other infrastructure failures (ITC, water, waste, energy)
- Human and animal health crises
- Industrial action/public disorder
- Loss of access to finance/ability to import materials

Presses (mega-trends)
- Changing Demographics
- Globalisation, Future Markets
- Resource scarcity
- Climate change impacts and mitigation
- Dynamic Technology innovation
- Global knowledge society
- Mass customisation
- Sharing global responsibility

Local Manufacturing Environment
Biophysical Template
Structure – waterways, flood plains, hills/valleys, soil
Function – biomass productivity, physical access, drainage, rainfall, solar insolation

Economic/Social Template
Structure – local government & economy, business community, infrastructure networks, laws and regulation, workforce, subsidies
Function – employment, taxes, economic activity, generation of social capital, services (energy, water, sanitation, waste, transport, ITC, information), technology development

Local Manufacturing Template
Structure
Factories or other workspaces, supply chain, business models, equipment, material, branding,

Function
Production, design, creating value add locally, sales of goods, procurement of supplies, training, technology development, provide employment

Framework based on: Collins et al. (2011) Press-Pulse Dynamics framework that sets disturbances in context, in relation to an ecosystem and human systems within it

Pulses - Avon and Somerset Risk Register; Presses - European Factories of the Future Roadmap
Project Definition of Manufacturing

- Manufacturing is the creation (or repair, or remanufacture) of tangible artefacts from raw materials and/or parts
- This project will **not** consider the following sectors:
  - Service industry (e.g. healthcare)
  - Construction of buildings and infrastructure
  - Utilities (energy, water, sanitation, broadband, waste management)
  - Design (when not connected with manufacturing)
  - ITC and software
  - Mining and minerals
  - Agriculture
The Method for Today
Purpose of Today

- Developing an understanding of resilience and sustainability as characteristics of a system’s (city-region) dynamic behaviour
- Understanding the performance of the whole system by understanding the relationships between the parts
- Developing insights about resilience by identifying how things are connected (e.g. single point of failure)
- Creating simple models to represent our understanding of the key dynamic relationships related to the resilience and sustainability of a city and its manufacturing sectors
- Learning together
‘Systems thinking enables you to grasp and manage situations of complexity and uncertainty in which there are no simple answers’ (Open University 2012)

Systems thinking...recognises that the world is a set of highly interconnected technical and social entities which are hierarchically organised, producing emergent behaviour’ (INCOSEUK 2010)

Systems thinking is a framework for seeing interrelationships rather than things, for seeing patterns rather than static snapshots’ (Senge 1990)
Systems Modelling

- Systems modelling is a key method for systems thinkers to engage with real world problems
- We model problems, not systems – remembering purpose helps minimise confusion and unnecessary complication
- Models are not right or wrong, but useful representations of the system “as-is”
- Group Model Building is a way of creating models in collaborative groups by:
  - Surfacing and sharing our mental models to create a more comprehensive and robust model of the real world
  - Allowing divergent thinking (brainstorming, debate, non-censorious, fast, open…)

[Link to wiki source](https://en.wikisource.org/wiki/Cause,_Effect,_Efficiency_%26_Soft_Systems_Models)
Causal Loop Diagrams (CLDs)

- CLDs are “visual representations of the dynamic influences and inter-relationships that exist among a collection of variables” (Spector et al. 2001)

- The process of building CLDs can help to
  - capture dynamic hypotheses about the causes of system dynamics
  - elicit and capture the mental models of individuals or teams about the problem space
  - reveal and communicate important feedbacks

- Today we will be creating CLDs that represent your understanding of the key causal relationships between the resilience and sustainability of a city and its manufacturing sectors
## CLD Basics

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="A + B" /></td>
<td>Positive Causation/Influence: As A increases (or decreases) B increases (or decreases)</td>
</tr>
<tr>
<td><img src="image" alt="C - D" /></td>
<td>Negative Causation/Influence: As C increases (or decreases) D decreases (or increases)</td>
</tr>
<tr>
<td><img src="image" alt="E F" /></td>
<td>Causation/Influence with Delay: E causes an increase/decrease in F after some delay</td>
</tr>
<tr>
<td><img src="image" alt="B" /></td>
<td>Balancing Loop: goal seeking feedback that counteracts and limits change</td>
</tr>
<tr>
<td><img src="image" alt="R" /></td>
<td>Reinforcing Loop: amplification feedback that grows indefinitely until disturbed</td>
</tr>
</tbody>
</table>
Causation and Feedback

Incorrect

Ice cream sales ➔ + murder rate

Correct

Ice cream sales ➔ + average temperature ➔ + murder rate

Birth rate ➔ + population ➔ - death rate

Fractional birth rate ➔ + average lifetime ➔ -
Model Building

- Choose and add elements that seem the most important, to you, in causing system behaviour
- Name elements neutrally – “level of unemployment” rather than “reduction in unemployment”
- Variables can be “soft”, such as attitudes, behaviours, and perceptions (e.g. enthusiasm, willingness, beliefs)
- If polarity is difficult to agree upon:
  - There could be an element missing
  - It may not be possible to understand fully in the time available, then please mark with both a “+” and “-”
- Don’t be concerned about feedback loops – they will reveal themselves!
The Strawman R-S Model

- The strawman models are offered as a starting point, and you can:
  - Re-name any of the elements
  - Change the direction or connection of any of the causal links
  - Use the models and add to them
  - Disagree with them completely and start again!

- Each modelling session has a list of suggested system elements to add – please feel free to add any others
**R1:** Economic activity enables the city, its people and its businesses to:

- recover from short-term disturbances (e.g. floods, interruptions to supply networks)
- adapt in the face of long-term disturbances (e.g. climate change, scarcity of resources)

**B1:** Resources used to respond/adapt may reduce the total resources available

**B2:** Economic activity can negatively impact the local environment, such as through air pollution, ground pollution, and reductions in drainage (e.g. corn)
R2: Manufacturing health allows investment in resilience measures, which reduces impact form pulses

R3: manufacturing health improves the ability to learn and adapt to presses, reducing their impacts

R2 and R3 could run in two directions – continually decreasing (e.g. tobacco, chocolate) or increasing (e.g. aerospace) manufacturing sector health – depending on the strength of pulses and presses and the sector response
The Combined Strawman Model

This is offered for contestation/discussion. Please:

• Re-name any of the elements
• Change the direction or connection of any of the causal links
• Use this model and add to it
• Disagree with it completely and start again!
Modelling Sessions 1 and 2
### Sessions 1&2: Suggested Elements

<table>
<thead>
<tr>
<th>Characteristics of Resilient Systems</th>
<th>Additional Elements</th>
<th>Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptability; Response-ability; Awareness of future risks; Diversity; Self-organising</td>
<td>Workforce skills and education</td>
<td>Pandemics/changes in workforce</td>
</tr>
<tr>
<td>Levels of unemployment and inequality</td>
<td></td>
<td>Social unrest</td>
</tr>
<tr>
<td><strong>Technological</strong></td>
<td>Automation</td>
<td>Changes in availability and/or cost of materials or parts</td>
</tr>
<tr>
<td>Manufacturing technologies/machinery</td>
<td></td>
<td>Technology disruption</td>
</tr>
<tr>
<td><strong>Economic</strong></td>
<td>Demand for goods</td>
<td>Availability of investment capital</td>
</tr>
<tr>
<td>Costs of materials/parts/energy</td>
<td></td>
<td>Economic downturns/upturns</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Land use patterns</td>
<td>Extreme climatic events (e.g. floods)</td>
</tr>
<tr>
<td>Emissions (CO₂, NOₓ, SOₓ)</td>
<td></td>
<td>Shifts in weather patterns</td>
</tr>
<tr>
<td><strong>Political</strong></td>
<td>Rules on international trade</td>
<td>Sudden changes in political landscape</td>
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<tr>
<td>UK Government support for innovation</td>
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<td></td>
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<tr>
<td><strong>Legal</strong></td>
<td>Environmental laws</td>
<td>Changes in supply chain legislation</td>
</tr>
<tr>
<td>Employee legislation</td>
<td></td>
<td>Changes in business ownership</td>
</tr>
<tr>
<td><strong>Ethical</strong></td>
<td>Labour/environmental standards</td>
<td>Shocks that change ethical stances</td>
</tr>
<tr>
<td>Obligation to future generations</td>
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</table>
Session Two: Manufacturing Sector

Since sectors differ in their characteristics, for the manufacturing part of the CLD each table can pick a sector to model – depending on your experience, interest, knowledge, etc.

<table>
<thead>
<tr>
<th>Suggested Sectors</th>
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<tbody>
<tr>
<td>Defence and Aerospace</td>
</tr>
<tr>
<td>Textiles and furnishings</td>
</tr>
<tr>
<td>Vehicles</td>
</tr>
<tr>
<td>Chemicals</td>
</tr>
<tr>
<td>Building materials</td>
</tr>
<tr>
<td>Industrial supplies</td>
</tr>
<tr>
<td>Food and beverage products</td>
</tr>
<tr>
<td>Household products</td>
</tr>
<tr>
<td>Makers and crafts</td>
</tr>
<tr>
<td>Paper and packaging</td>
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</tbody>
</table>
Redistributed Manufacturing (RDM)

- **SolidWool**: A new material for furniture making, made of low-cost wool and resin, bringing jobs to a Devon village.
- **Thomas Ware and Sons**: traditional leather tannery in Bristol making quality leather goods; a modernisation programme including computer aided cutting machines and CAD/CAM ensured future success.

Evolution in where and how design and manufacture is done to achieve:
- The most appropriate mix of capability and employment
- Minimised environmental impacts
- Improved product specialisation to markets
- Improved resilience of provision under megatrends

Trade Globalisation

- Economies of scale
- Operational flexibility
- Risk sharing
- Access to new markets

- Loss of manufacturing jobs
- Loss of core capabilities
- Increased risks of supply disruption
- Increased environmental impacts

Redistributed Manufacturing

Adaptable manufacturing processes and techniques capable of operating at small scales.
# Session Three: Suggested Elements

<table>
<thead>
<tr>
<th>Megatrends (Presses)</th>
<th>Changing Demographics; Globalisation and future markets; Scarcity of resources; Climate change; Dynamic technology and innovation; Global knowledge society; Mass customisation; Sharing global responsibility</th>
</tr>
</thead>
</table>
| Social               | Jobs for different levels of skills  
Pride in locally produced products                                                                                                                                                                                                                                                                                                           |
| Technological        | Appropriateness of technologies to the region  
Use of local materials/resources  
Local technological knowledge and skills                                                                                                                                                                                                                                                                                                           |
| Economic             | Local economic development  
Ability to compete globally (e.g. reshoring)  
Profits reinvested in local economy                                                                                                                                                                                                                                                                                                            |
| Environmental        | Embedded impacts of products used in Bristol  
Environmental impacts from manufacturing                                                                                                                                                                                                                                                                                                         |
| Political            | Support for local government  
Citizen engagement                                                                                                                                                                                                                                                                                                                           |
| Legal                | Patents/Local IP                                                                                                                                                                                                                                                                                                                         |
| Ethical              | Local worker conditions  
Distribution of profits                                                                                                                                                                                                                                                                                                                     |
Wrap Up

- **Questions to consider:**
  - What overarching themes have arisen from the exercise?
  - What was *not* captured by the modelling?
  - Has the workshop helped you to understand resilience, sustainability and manufacturing in relation to your own key interests?

- **Review of Purpose:**
  - Developing an understanding of resilience and sustainability as characteristics of a system’s (city-region) dynamic behaviour
  - Creating simple models to represent our understanding of the key dynamic relationships related to the resilience and sustainability of a city and its manufacturing sectors

**Thank you for your participation!**