Infrastructure Interdependencies: Opportunities from Complexity

Valuing infrastructure conference

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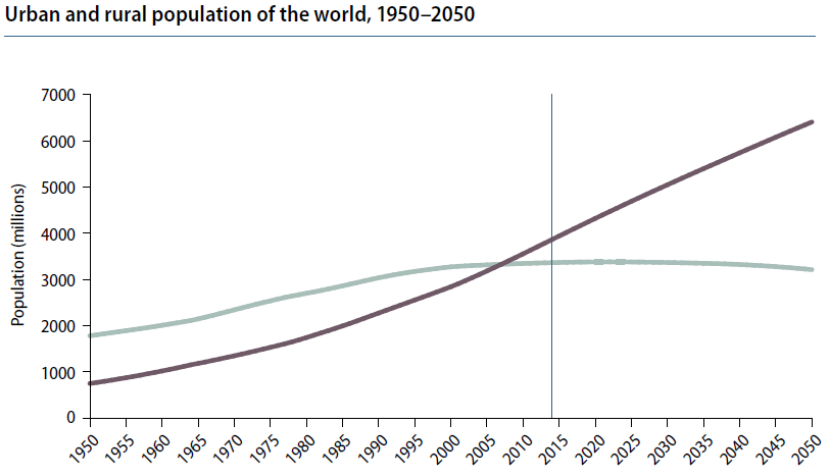
The prevalence of interdependency

- Vasubandhu (approx. 350–400 A.D.) a fourth-century Indian Buddhist logician raised the notion of **interdependence**
- Humans cannot realize all of the connections, let alone control them
- Risk taking and benefit sharing are not in isolation; they **create emerging value from infrastructure**: interdependency demands a new vocabulary and understanding



United Nations. World Urbanization Prospective: 2014 Revision, New York, 2014.

Two-faced interdependency

Unpicking interdependency notions

- ***Complexity*** describes an interdependent, dynamical, co-evolutionary state
- ***Interdependency*** suggests a lack of control with uncertain consequences of failure for a system whilst ***resilience*** is the ability of an entity or system to return to normal condition after the occurrence of an event that disrupts its state (Hosseini, 2016).
- Assumption: interdependencies increase **VULNERABILITIES**
- Contribution: use of interdependencies as **OPPORTUNITIES** to **increase system resilience and sustainability**

Hosseini, S., Barker, K., & Ramirez-Marquez, J. E. (2016). A review of definitions and measures of system resilience. *Reliability Engineering & System Safety*, *145*, 47–61. http://doi.org/http://dx.doi.org/10.1016/j.ress.2015.08.006

Flipped interdependency

Drivers and barriers of innovation

Factor	Vulnerability	Opportunity
technology	Carbon lock-in; duplication	Scale diversity; sharing
design principles	Conventional; just-in-time	CE, natural systems; redundancy
maintenance	Reactive, respond to fault	Pro-active, preventative
governance	Historic, rigid, silo'd	Adaptive
societal behaviour	Consumerism	Demand Side Response

Typology of increasing intensity of interdependency opportunities

From simple to integrative

- **Simple opportunities**
  - Process and knowledge exchange
  - Knowledge translation, improved practice
- **Geographical/physical opportunities**
  - Land, infrastructure, property sharing
  - Vehicle, cyber, space sharing
- **Integrative opportunities**
  - Variety and diversity, between scales
  - New services, autonomy, intelligence

Simple interdependency

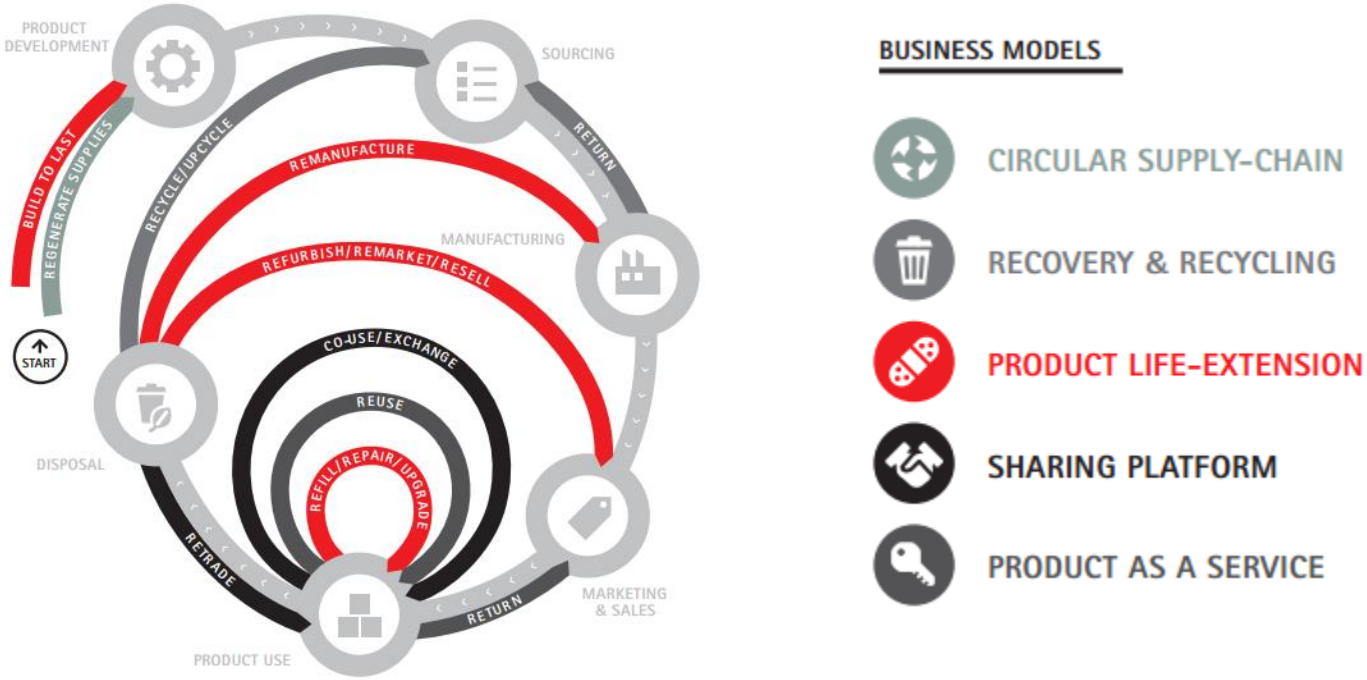
Intermittent, repeated, knowledge exchange

- Sharing of knowledge across network gaps to inform and improve good practice through exposure to new perspectives and procedures
- **Opportunity to increase the efficiency and resilience** of systems by establishing lines of effective communication and collaboration between managers, designers and operators that cross traditional departmental or industry boundaries
- Start with a learning event or sharing of ideas (e.g. eco-system services, alternative methods of governance), establishing a transactional pathway for the recurring transfer of knowledge between system operators
- Flows will be **intermittent**, but repeated
- All consequences of knowledge adoption/adaption are unknowable

Case study: simple interdependency

Knowledge of innovation across infrastructure and more

- Circular economy vs linear economy (Lacy & Rutqvist, 2015 Waste to Wealth, Palgrave**); EMF** knowledge hub
- CE business models and the digital economy



Geographical/physical interdependency

Coupling based on co-location and/or physical sharing

- Expansion of within sector infrastructure sharing concepts to sharing across **multiple networks and sectors**
- Use of domestic, commercial and industrial buildings as an extension to infrastructure to operate technologies at point of use
- **Opportunity to increase resilience** through technology diversity at different scales
- **Opportunities for cost-saving and increasing system efficiency** from the sharing of physically co-located systems and associated risks
- Beneficial couplings can extend to land sharing (e.g. for location of other sector assets), moveable asset sharing (e.g. truck utilization) and cyber sharing (e.g. VPN) across systems at a localised scale

Case study: Geographical/physical interdependency

- **Green and blue infrastructure**

- Using design principles of green and blue infrastructure, linear parks manage excess fluvial and surface water, provide flood water storage and slowing down the spread of water, improving resilience
- Other benefits include
  - recreational facilities improving quality of life, health and well-being
  - ecological resources, habitats
  - attractive settings for development on boundaries

Varga, L. (2016). Milton Keynes 2050 Water Sustainability Report, Milton Keynes Council, Feb 2016

Integrative interdependency

Using advantages of one network to manage another

- Integrative interdependency opportunities are defined by a synergy and **extensive functional interconnection between multiple infrastructure systems at multiple points**, representing shared risk as well as significant **benefits to the effective functioning of all coupled systems**
- Creating **opportunities for increasing resilience** by using the advantages of one network for the management of another
- Assets, materials, data and information are gathered, distributed and used to **actively and efficiently manage decisions and flows** in networks in real time
- Exploiting complex systems design principles: loose coupling, redundancy, adaptive capability to create opportunities for **improving the delivery of existing services and/or making entirely new services possible**
- Variously integrated, complex infrastructure systems are our future (and present) and have potential for transformative outcomes and benefits sharing

Case study: MK Smart

Integrative opportunities

- ‘Motion Map’ service involves the rollout of sensors across the city to track traffic flows and congestion in car parks and bus routes
  - Information will be pooled and distributed to local travellers via a mobile app, enabling **informed decision-making and intelligent routing**
  - Sensors will be mounted largely on existing lampposts, **making use not only of pre-existing structures but the electrical supplies already present**
- ZTE’s ‘BluePillar’ systems combining **street lamps, electric vehicle (EV) charging points and base transceiver stations** provide an example of fully integrated design

http://www.mksmart.org/

Key messages – interdependency and opportunity

- Complex systems thinking, embracing complexity, is a key enabler of infrastructure innovation
- Interdependencies vary in intensity and opportunity
- Risk and benefit sharing need a new vocabulary for infrastructure interdependency
- Resilience can improve through interdependency innovation

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Thank you

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