34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
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Systems Thinking: What Systems Engineers Need to Know

What I will be arguing?

According to **INCOSE-UK**, Systems Thinking is 'an essential skill for Systems Engineers … and provides a key intellectual underpinning for Systems Engineering'.

I want to argue that this is indeed the case. However, accepting Systems Thinking can require a radical reorientation of mindset on the part of some Systems Engineers.

I will develop this argument by explaining some key points about contemporary Systems Thinking.

What is Systems Thinking 1.

Systems Thinking is an approach used to address complex real-world problems in all domains. To do so, it must deal with different types of complexity.

Rescher, 2019, distinguishes:

- **'*Ontological complexity*' - the complexity that exists in the real-world**
    - **Quantity of elements**
    - **Variety of elements**
    - **Elaborateness of interrelationships**
- **'*Cognitive complexity*' - different ways the world is viewed**
    - **Cognitive limitations**
    - **Different beliefs and values**
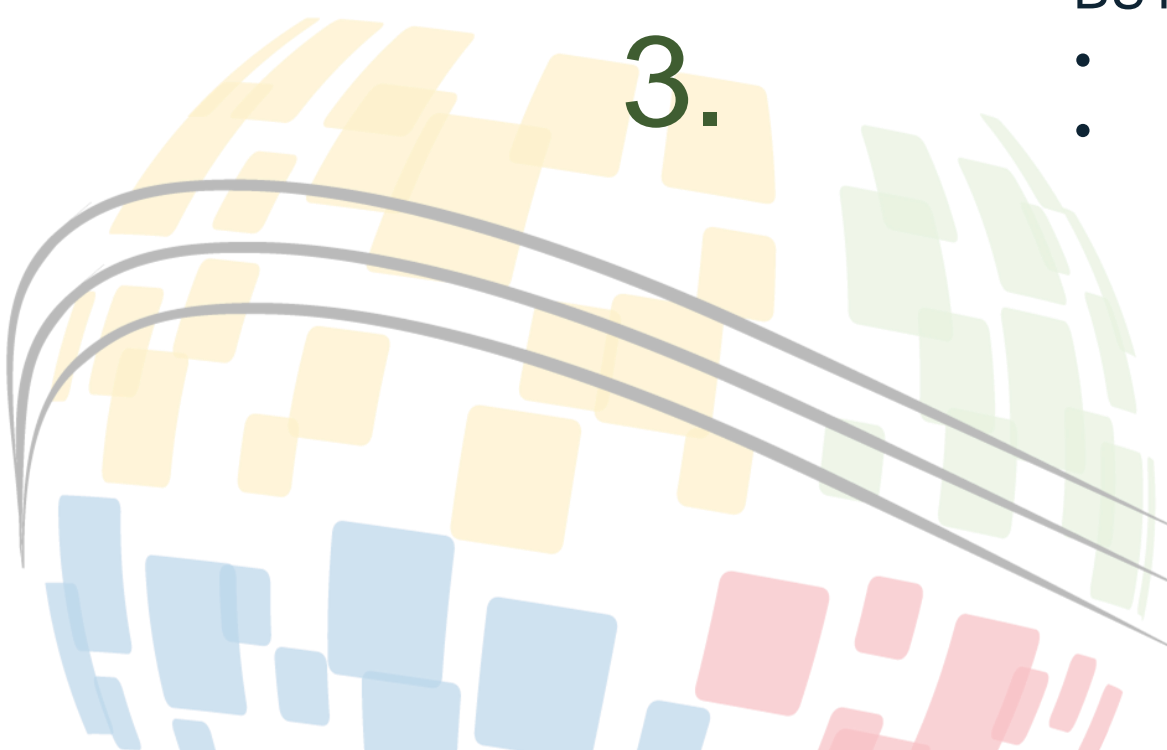   - **Conflict**

What is Systems Thinking 2.

How does Systems Thinking seek to engage with complexity?

Morin, 2008, suggests two possibilities:

- **'*restricted complexity*' – computational modelling techniques – remain 'within the epistemology of classical science'**
- **'*general complexity*' – resists universal truths; fundamental problem 'is epistemological, cognitive, paradigmatic'**

What is Systems Thinking 3.

Systems Thinking as a 'restricted complexity' approach:

Develop General Systems Principles to guide the application of SE processes:

'SE principles build on systems principles that are general for all kinds of systems and for all kinds of human activity systems' (Rousseau, 2018)

BUT

- Like 'waiting for Godot'

- As Boulding (1956) argued there are 'emergent properties' as we rise up the levels of complexity (machines, organisms, people, sociotechnical systems) that cannot be understood simply in terms of theoretical concepts employed successfully at lower levels….SE based on even the most sophisticated 'systems science' would continue to be blind to issues of indistinct boundaries, turbulence, divergent purposes, and politics and power

What is Systems Thinking 4.

Systems Thinking as a 'general complexity' approach:

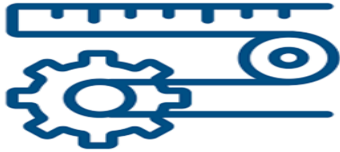Some Useful 'Systemic Perspectives' for Engaging with Complexity

'Successes of cognition', 'creative discoveries of generations' (Pepper, 1942); 'experiential gestalts' (Lakoff & Johnson, 1980); social theories

Mechanistic
Interrelationships
Organismic
Purposeful
Societal/Environmental

"The gears grind, the lights flicker, and the lenses distort. Nevertheless, we do seem to get some idea of our world from these vehicles, and without them we should have to walk pretty much in the dark" (Pepper, 1942)

What is Systems Thinking 5. – A multi-perspectival Mindset

- Mechanistic
- Interrelationships
- Organismic
- Purposeful
- Societal/ Environmental

What is Systems Thinking 6.

Systems Thinking as a 'general complexity' approach has a pragmatic orientation and uses a variety of proven 'systemic perspectives' to explore the complexity of Complex Sociotechnical Systems and intervene appropriately using related systems methodologies:

- Mechanistic – **SYSTEMS ENGINEERING** – efficiency, efficacy

- Interrelationships – **SYSTEM DYNAMICS** – important linkages which offer leverage points for achieving improvement and/or suggest possible unintended consequences of action

- Organismic – **VIABLE SYSTEM MODEL** – adaptability, agility, resilience, anti-fragility

- Purposeful – **SOFT SYSTEMS THINKING** – effectiveness, mutual understanding, accommodations, conflict

- Societal/Environmental – **CRITICAL SYSTEMS HEURISTICS** – marginalization, disadvantage, inequality, environmental issues, future generations

"In essence, a web of problems demands a web of solutions, involving a web of collaborators" (Brook, 2024)

Systems Engineering

Clarifying overall objectives and ensuring optimal integration of subsystems into a system to realise those objectives

Opportunities for SE: Supporting a 'Mission Economy' (Mazzucato, 'A Moonshot Guide', 2022)
- Taking inspiration from the Apollo Programme to manage the social and environmental challenges we face today
- Problems of inequality, ageing, new technologies, pollution, climate change, health, etc.
- A mission/project-oriented approach led by government and engaging public, private and third sectors, and civil society

Mazzucato argues that, nevertheless, significant changes are needed to the 'systems management' approach of Apollo to cope with the 'wicked problems' faced today, which encompass behavioural, social, economic, political, environmental as well as technical issues

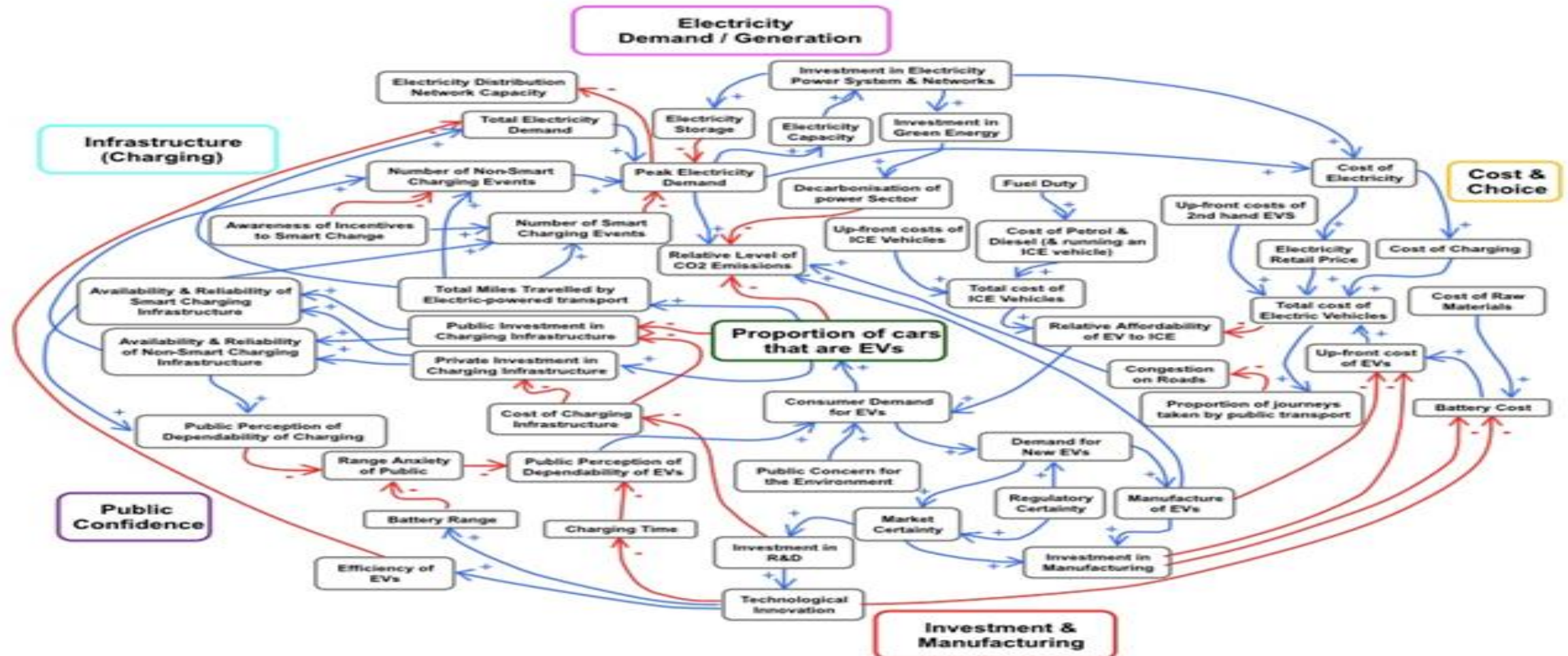ST 6b. Responding to issues raised by the interrelationships perspective

System Dynamics

- Causal loop diagrams/ computer simulations based on stock and flow diagrams

- Interactions/circular causality/feedback loops/lags/leverage points/unintended consequences

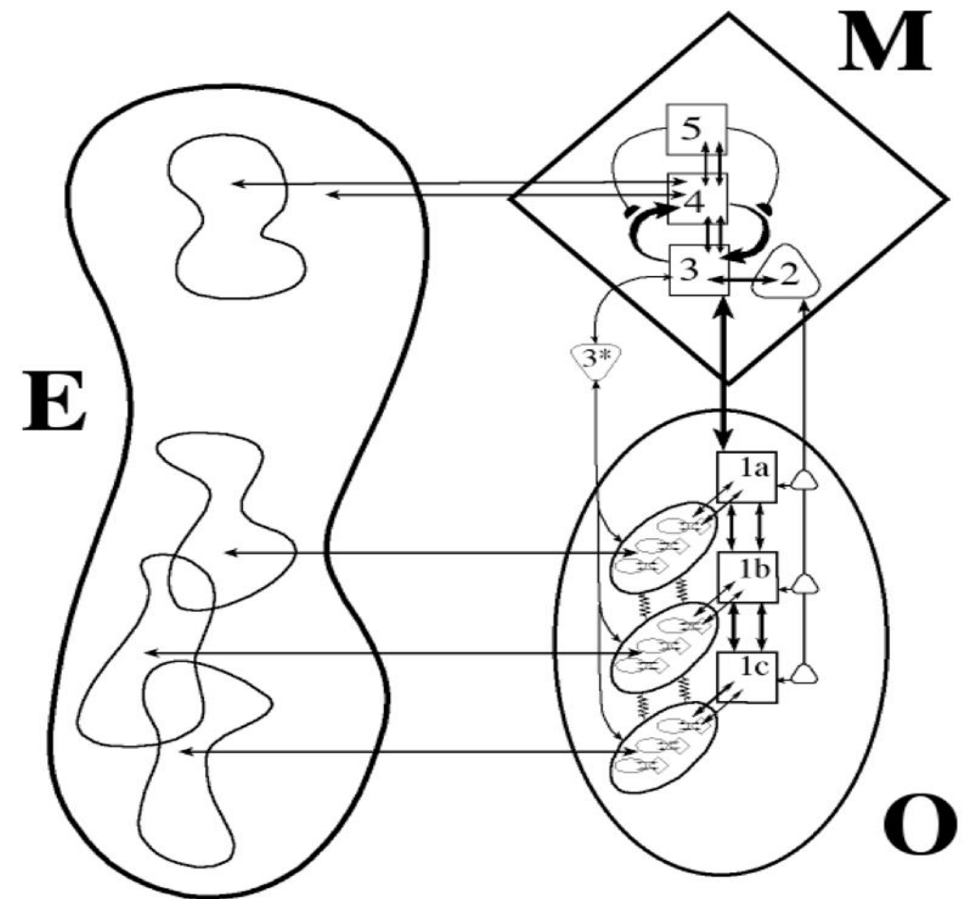# Figure 9: Example of a causal loop diagram showing interactions to consider in the roll out of electric vehicles
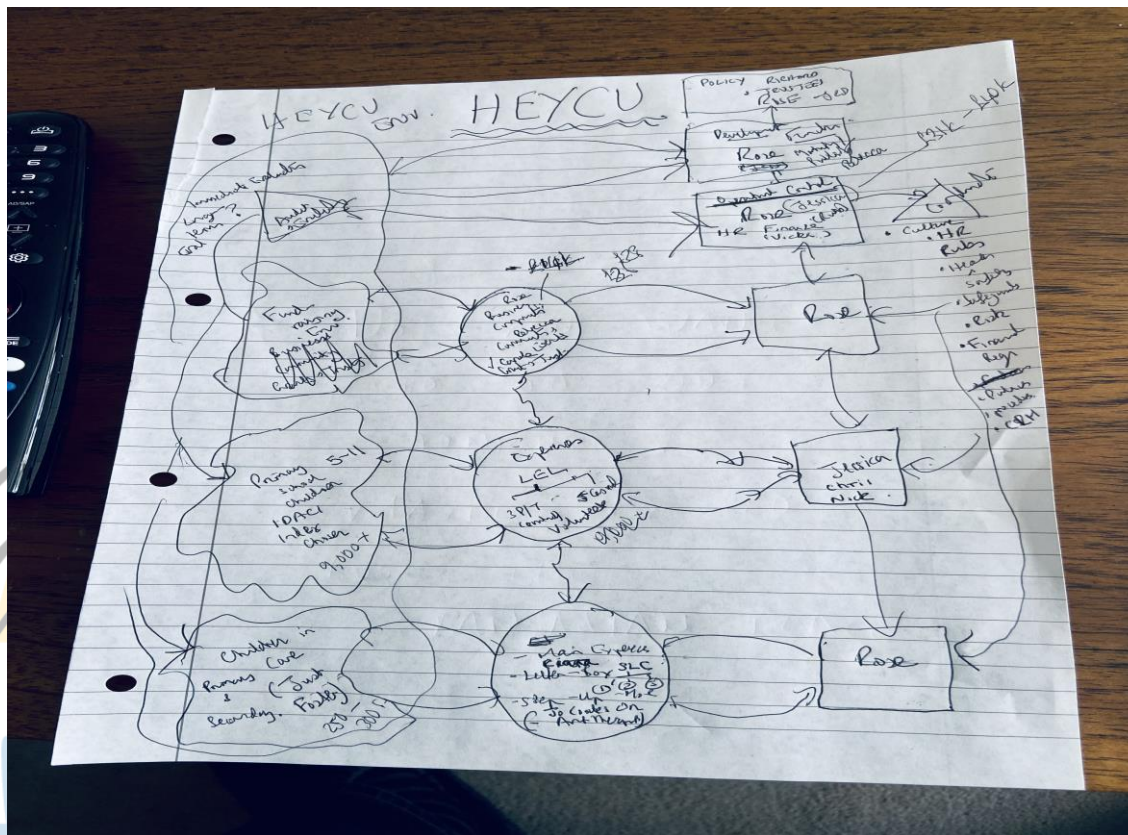
From the Net Zero Strategy.

The Viable System Model

- A living systems approach
 -Sensitivity to the environment
- Identity and cohesion
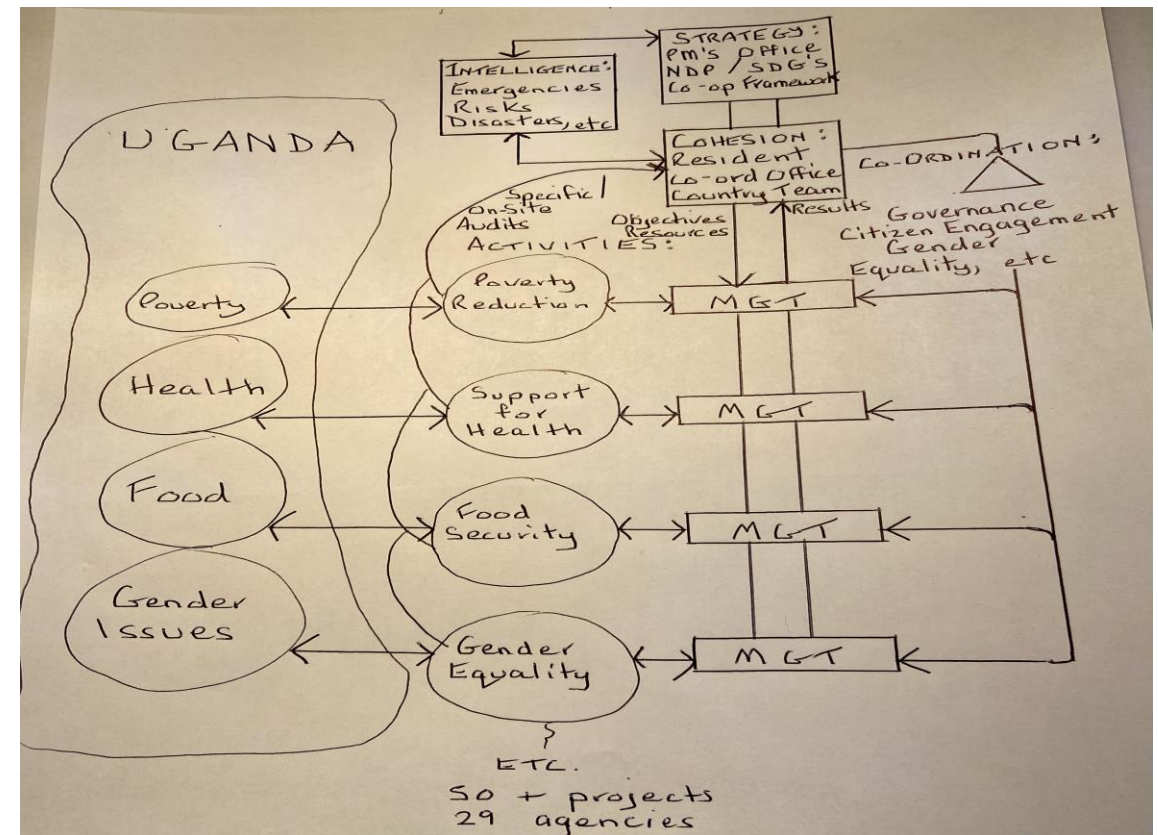- Appropriate decentralisation
- Viability, resilience, agility,

Organismic – The Viable System Model
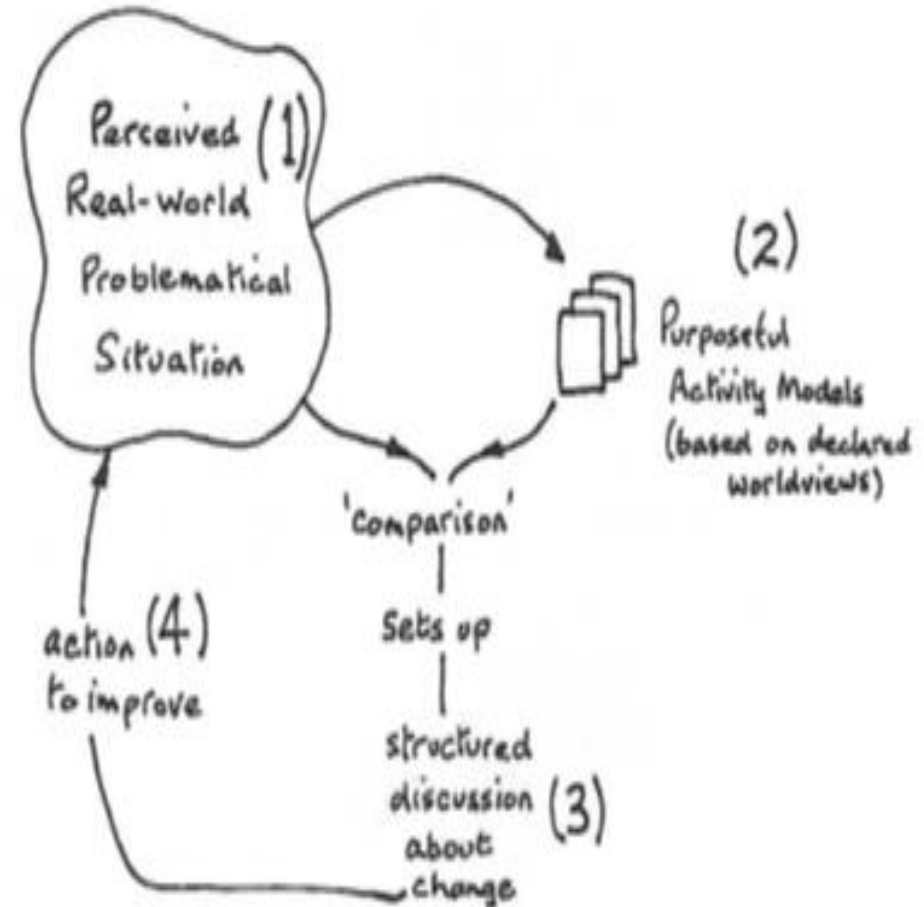
Hull and East Yorkshire Children's University

Evaluating UN Initiatives in Uganda

ST 6d. Responding to issues raised by the purposeful perspective
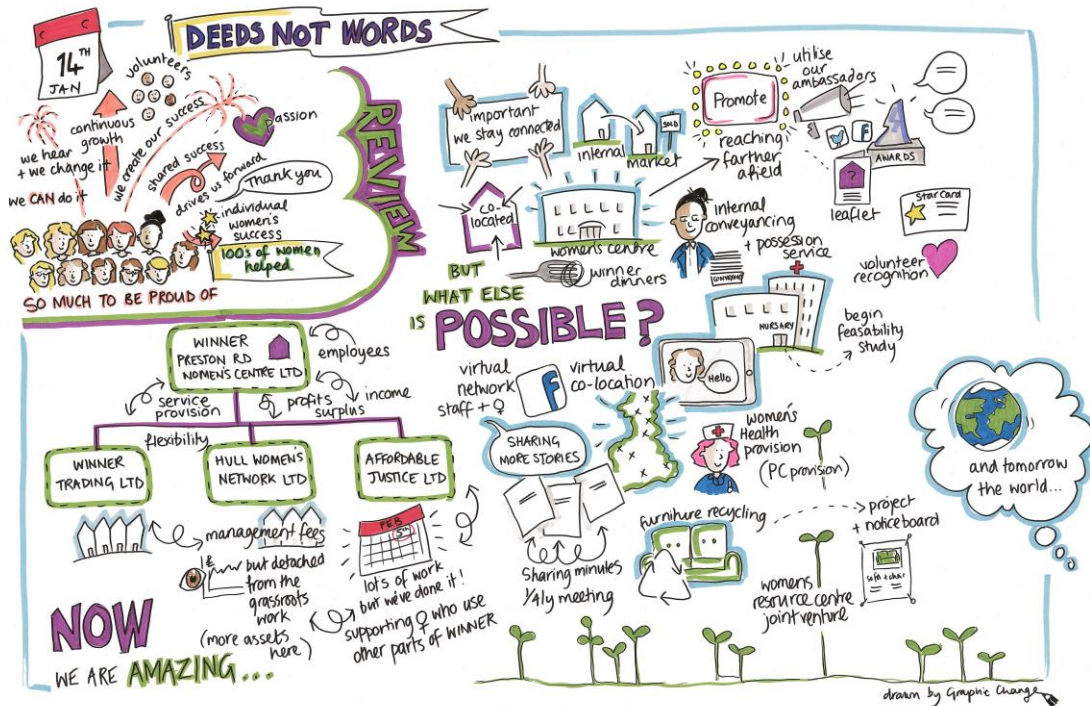
Soft Systems Methodology

- Aligning purposes
- Ensuring mutual understanding
- Encouraging creativity
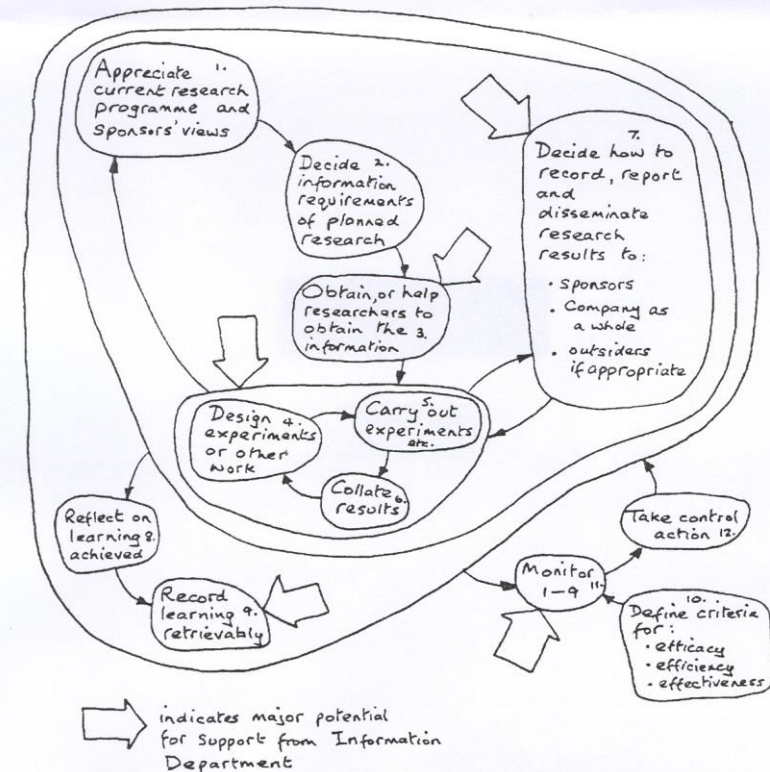- Facilitating debate
- Reaching accommodations
- Avoiding groupthink

Purposeful – Soft Systems Methodology

A Rich Picture – Preston Road Women's Centre

An Activity Model of a Research Support Department

ST 6e. Responding to issues raised by the societal/environmental perspective

Critical Systems Heuristics (marginalisation, empowerment, environmental considerations)

A methodology which employs 'boundary critique' to expose the selective 'boundary judgments' influencing systems designs. A set of 12 questions is proposed which can lay bare their partiality. These questions are arranged according to four sources of influence on any design:
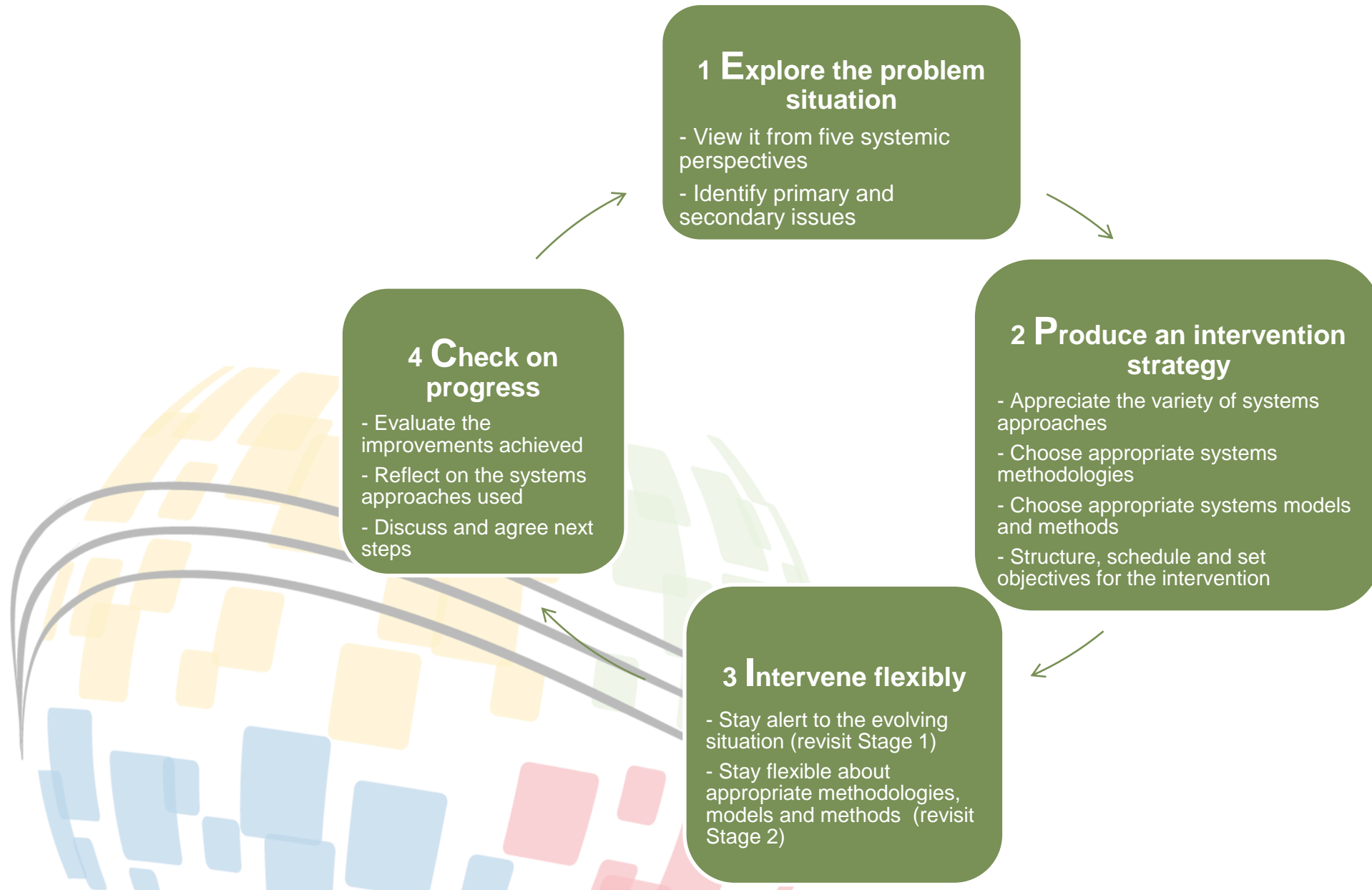

- **Who benefits?**
- **Who are the decision-makers?**
- **Who provides expertise?**
- **Who represents those affected but not involved?**

If the UK Post Office had listened to what Sub-Postmasters had to say about its Horizon computer system, it could have avoided committing what has been described as **'the most widespread miscarriage of justice in UK history' (Wallis)**.

'Commonsense should have led the Post Office to distrust the Horizon system. With systems thinking, it would have avoided causing suffering to thousands of Sub-postmasters and saved the country hundreds of millions (Hudgell).

What is Systems Thinking 7: Critical Systems Thinking and Practice

1 Explore the problem situation

- View it from five systemic perspectives

- Identify primary and secondary issues

2 Produce an intervention strategy

- Appreciate the variety of systems approaches

- Choose appropriate systems methodologies

- Choose appropriate systems models and methods

- Structure, schedule and set objectives for the intervention

3 Intervene flexibly

- Stay alert to the evolving situation (revisit Stage 1)

- Stay flexible about appropriate methodologies, models and methods (revisit Stage 2)

4 Check on progress

- Evaluate the improvements achieved

- Reflect on the systems approaches used

- Discuss and agree next steps
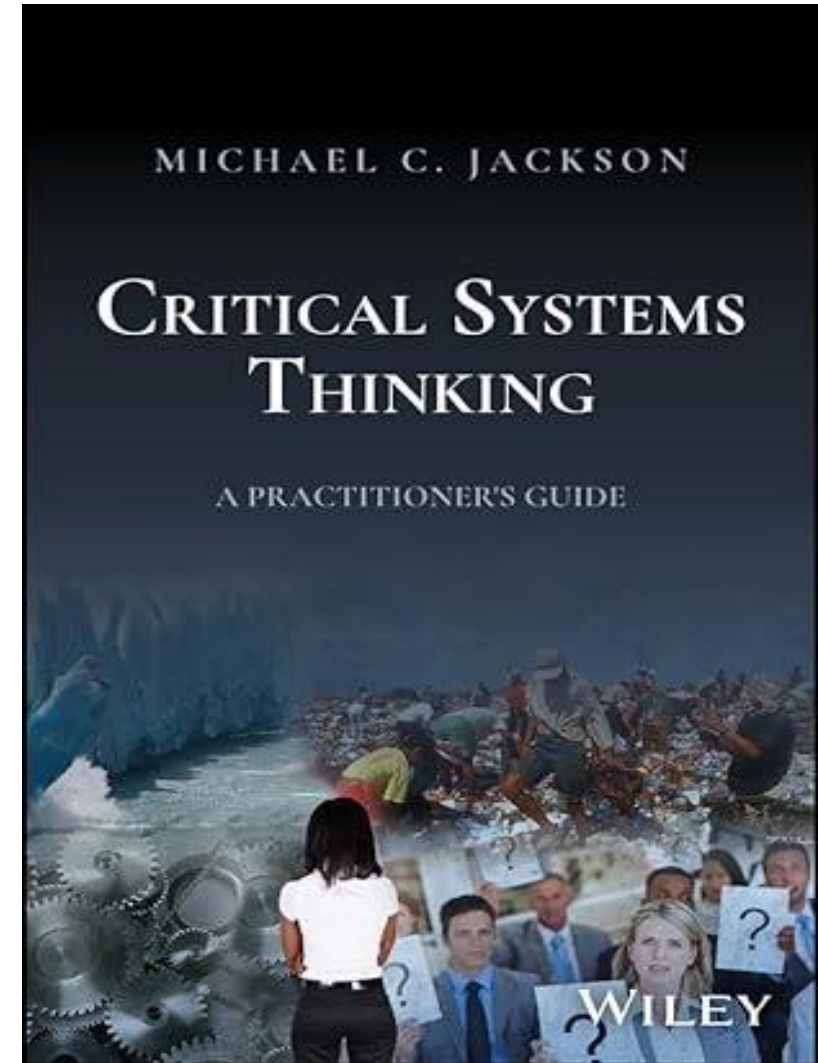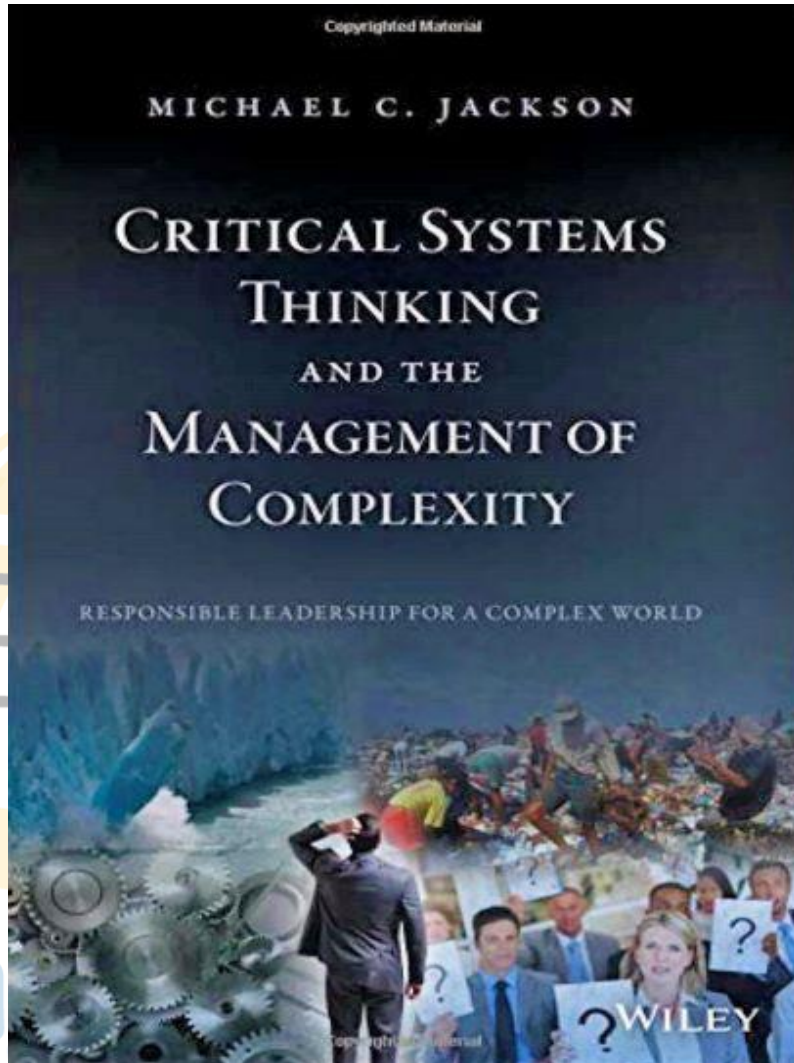
How Can Systems Thinking be of Use to SE?

If SE embraced Systems Thinking, it would be:

- **More capable of addressing major challenges in a broader range of application domains (industry sectors, societal and environmental issues)**

- **More capable of engineering solutions for a better (more 'balanced') world**

- **Better supported by a more encompassing foundation of theory and sophisticated methodologies and model-based tools**

- **More able to enhance its educational infrastructure to equip future Systems Engineers prepare for the challenges they will face**

(SE Visions 2025/35)

Critical Systems Thinking and Practice

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www.incose.org/symp2024
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