Systems thinking & systems engineering in rail

RTSA / Engineering New Zealand
Wellington, 24 August 2018
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CEO, Shoal Engineering Pty Ltd
Complex systems engineering firm

Former President, Systems Engineering Society of Australia (SESA)
Society of Engineers Australia focused on the engineering of complex systems
Chapter of International Council on Systems Engineering (INCOSE)

Career systems engineer
Aerospace, defence, communications, IT, transportation
National and international
30 years in technology & complex systems
20 years in large-scale system design & large projects
Drivers of change

Why are we talking about systems thinking today?
Anthony Foxx
US Secretary of Transportation
2013 – 2017
Obama Administration

APTA Annual Meeting in October 2015

Vision ... using public transportation to close opportunity gaps in modern society

“Transportation is a pillar of opportunity like education and health care”

“Addressing connectivity means embracing new technology“
Changes in **demography**

Smaller families moving closer in

“... between 2023 and 2029 couples without children will be the most common family type in Australia.” (ABS)

After ‘emptying out’ in the 1960s and 1970s, cities centres are becoming denser again
Changes in **public infrastructure**

Our vision is that in 2045 New Zealand’s infrastructure will be resilient and coordinated, and contribute to a strong economy and high living standards.
Changes in technology

‘Information to the edge’
Changes in connectivity

Seamless multi-modal

“Lyft and Amtrak now let passengers book rides to and from the train station”
Changes in societal expectation

Empowered consumer
So …

… how should or could we use investment in public transportation to close opportunity gaps in society?

… what design approaches will help us to deliver what’s needed?
Delivery challenges
Why are we talking about systems thinking today?
Holistic understanding needed

Of individual transportation systems
Systems of systems

The entire transport network
Complexity in relationships is often hidden. Inconsistencies result in problems.
Systems thinking
What is it?
What does it really mean?
Systems thinking – Two definitions

“Systems thinking is a management discipline that concerns an understanding of a system by examining the linkages and interactions between the components that comprise the entirety of that defined system.”

The Institute for Systemic Leadership

“Systems thinking is a world-view that provides the appreciative and reflective practice based on the ‘systems paradigm’ concepts, patterns, etc”

Professor Stephen Cook, Shoal Engineering
Systems methodologies

• Systems Engineering
• Project Management
• Asset Management
• Soft Systems Methodology
• User-Centred Design

• Strategic planning
• Holistic health practices
• Systems Dynamics Modelling
• Gestalt psychology
• ... and others ...
Systems thinking
Case studies
Queensland ‘New Gen’ trains

Media points:
• Queensland Rail asked for an exemption from Disability Discrimination Act with disability laws because of problematic trains
• Media fiasco around the Commonwealth Games (ratio: 8 out of 9 trains are needed to transport people for Games)
• The commission denied the exemption, which could put Queensland Rail at risk of lawsuits from people with disabilities
• The commission does not have the power to order the trains be removed

Key project facts:
• 75 New Generation Rail trains were ordered ($4.4billion worth)
• fleet ordered under previous government (half price of previous govt’s paid for rollingstock)
• commission questioned government decision to purchase “non-compliant” defective trains – not clear
• unclear why rectification work did not occur between procurement in 2013 and entry into service 2017
Queensland ‘New Gen’ trains

Key project issues:
- Breach of disability laws
- Late rollout
- Problems with braking, air-conditioning, ventilation (uncovered by on-track testing)
- Sightlines for train drivers compromised
- Problems with access paths and
- Unisex toilets being too small
- Testing failed: vision impaired people left waiting on train platform after never arrived

Systems Thinking principles relevant:
- Short Term vs Long Term – what are the short-term pressures being felt by the QLD Govt? What are the long-term consequences (both to the problem and to the govt’s organisational capacity and reputation) of this solution? How might these short-term solutions erode the long-term capacities for QLD Rail?
NSW train carriages

Media points:
• New fleet of trains promised to offer greater comfort and safety but an error means they can’t even operate properly
• train carriages are too wide to go through tunnels, could collide with walls on their way to Blue Mountains
• Transport bosses have insisted the trains will operate safely but conceded that, in places, rules will have to be broken
• relaxing rules will allow new fleet to operate and ensure “better long term operational outcomes” and “minimise heritage impacts through reduced tunnel lining modifications”
• tunnels needing modification for new trains is an embarrassment to Transport Minister

Key project facts:
• $2 billion worth of new trains on order being built in South Korea
• current trains are 2.9m wide – new trains (20cm wider) are 3.1m wide
• State opposition leader said the govt. needs to show guarantee for passenger safety
• TfNSW currently sets out “kinematic envelope” with min clearance around trains for sway and tilt – with 200mm distance between carriage and tunnel walls. new trains will infringe these min distances
• tunnels need to be “notched” in places involving gouging chunks almost 13cm deep
• almost 1/3 of total length of tunnels will have to be modified – taking two years with line close for periods
NSW train carriages

Key project issues:
• Discrepancy in carriage width could have big impact (big risk, huge consequences)
• NSW Govt (TfNSW) devised a plan to relax safety standards – current regulations watered down so wider trains can operate
• Existing tunnels (10 of them) will be partially modified to allow the new trains to run - expensive
• Additional measures such as widening parts of track, speed restrictions, varied track maintenance and timetabling also need to be implemented in some instances
• Total cost of remediation is unknown and not available – tunnel modifications alone are at $2.3 billion

Systems Thinking principles relevant:
• Tendency to focus on the symptom vs. the problem – do the solutions proposed address the actual problem, or possibly create new problems? How would we know if this issue is a symptom of the problem rather than the root cause of the problem
The ‘Big Dig’ in Boston

Media points:
• Program was complicated by fact it was staged as a fast-track program
• Big dig was not always on schedule or budget, but delivered one of most complex, inner city tunnelling efforts in the world
• Changing needs of the program over time – criticised but susceptible to the political and economic influence
• Huge risks: enormous level of uncertainty from all facets (govt. political economic etc.), and potential for catastrophic loss

Key project facts:
• Largest, most complex and technically challenging highway initiative in US history – almost 30 years in making (shovels from early 1990s and completed in 2007)
• More than 132 major work projects, 54 major design packages, thousands of subbies, more than 9,000 processes / procedures, & 5,000 workers
• Deepest underwater connection and largest slurry wall application in North America
• World’s widest cable stayed bridge
• Largest tunnel ventilation system in the world
• Systems engineering was used to integrate various components of the 135 major projects in the program and provide a holistic view to systems and requirements
• Important role of SE was analysis of safety failure modes for all critical infrastructure projects
The ‘Big Dig’ in Boston

Key project issues:
• Complex governance structure that unfolded over a long period of time... cost blowouts and delays experienced over the lifecycle
• Complex stakeholder environment
• Though integration of teams, sponsors and stakeholders was supported and recognised as a credible solution later on – it was also criticised for compromising the independence of govt as a ‘watchdog’

Systems Thinking principles relevant:
• Structure drives behaviour – what about process (rules, policy etc.) caused a delayed integration of project organisations right from the start and early in the planning phase.. What aspects of government and changing political culture might be affecting and constraining performance for such a large and complex project?
What is it?
What is **Systems Engineering**?

“A transdisciplinary approach that applies to systems principles and concepts to enable the successful realization and use of engineered systems and whole-system solutions.”

INCOSE Fellows

Focuses on defining customer needs and required functionality early in the development cycle, capturing requirements, then proceeding with design synthesis and system validation while considering the complete problem:

- Operations
- Cost & schedule
- Performance
- Training & support
- Test
- Manufacturing
- Disposal
**Key concept – Lifecycle**

A mechanism for handling risk and change

Large complex projects may take many years before they are operational

<table>
<thead>
<tr>
<th>Phase 0</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
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<tbody>
<tr>
<td>Long Range 20 Yr Needs (Program/Programmatic)</td>
<td>Project Profile, Master Plan, Concept of Operations &amp; User Requirements</td>
<td>Prelim Design</td>
<td>Final Design</td>
<td>Construction/Implementation</td>
<td>Operations &amp; Maintenance</td>
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Validation: Did we build the right system?  
Verification: Did we build the system right?
Key concept – Early-stage design

Capital Project Process Model: A Systems-Engineering Approach to Project Delivery

Image courtesy New York City Transit
UK rail value-for-money study

Whole-of-life, whole-of-system approach

Savings in capital cost of 6-18%
Reduced overspend of 17-30%

Upper Savings Range vs. Phase

Upper and Lower Overrun Avoidance vs. Phase

Lower Savings Range vs. Phase


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Related approaches

How else do we design and manage complex systems?
User-Centred Design

A systems methodology

The design is based upon an explicit understanding of users, tasks and environments.

Users are involved throughout design and development.

The design is driven and refined by user-centred evaluation.

The process is iterative.

The design addresses the whole user experience.

The design team includes multidisciplinary skills and perspectives.
Asset Management
How do systems thinking & engineering relate?
SE the AM change mechanism

Organizational Strategic Plan

Customers
Legislation
Investors
Commercial Environment

Scope of Asset Management

Organization & People
Strategy & Planning
Asset Management Decision Making
Asset Information

Lifecycle Delivery
- Technical Standards & Legislation
- Asset Creation & Acquisition
- **Systems Engineering**
- Configuration Management
- Maintenance Delivery
- Reliability engineering
- Asset Operations
- Resource Management
- Shutdown & Outage response
- Fault & Incident Response
- Asset Decommissioning & Disposal
SE fit in an **Enterprise AM context**

- **Support organisational objectives**
- **Portfolio return on investment, compliance & sustainability**
- **System performance, cost & risk control**
- **Life Cycle Activities: efficiency & effectiveness**

- **Corporate/ Organisation Management**
- **Manage Asset Portfolio**
- **Manage Asset Systems/Networks**
- **Manage individual Assets over their Life Cycles**

**Enterprise Systems Engineering**

**Project Systems Engineering**
Systems thinking – Another view

“Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing ‘patterns of change’ rather than static ‘snapshots.’”

Peter Senge, MIT
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