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Strategic intent and the management of infrastructure systems

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Abstract

Infrastructure forms an enduring and evolving system of services, assets, projects, and networks. This paper presents an overview of research into the misalignment between the strategic intent and the management of those systems. The research draws from experiences across infrastructure sectors and countries to frame the problem, then uses central and local government transportation organisations from New Zealand to explore the problem in more detail.

Although infrastructure does not often fail catastrophically, there is an inability to fully deliver appropriate and relevant infrastructure outcomes over the long term. This paper presents the cross-case analysis of three detailed studies which explored this issue through three different lenses by investigating three key lifecycle/organisational transitions at the system rather than at the project level. The research has identified a pressing need for 'system stewardship' to address the increased specialisation and siloed operation within current practice. This boundary spanning function/culture is needed to not only deliver 'joined up thinking', but also organisational learning, and the ongoing transformation of the complexed asset-service-organisational-contextual system in response to ongoing change.

Key words: system thinking, infrastructure, governance, management

Introduction

Although infrastructure does not often fail catastrophically during its design life, it also does not appear to be performing as well as it could be (e.g. Dobbs et al., 2013). However, this is not just about project selection, investment and delivery; a matter that has received much attention within both research and in practice (e.g. Flyvbjerg, 2009; OMEGA Centre, 2012). Rather, a currently overlooked challenge is the integration of individual projects, assets, and service initiatives, into existing infrastructure systems so that their impacts, benefits, and contribution to the whole system can be recognised, understood, and managed. So, even if questions of project delivery are fully addressed across all project stages prior to handover, there remains a wider systemic problem. This relates to the operational ability to deliver intended outcomes; not just of the project, but of the underpinning systemic strategic intent that firstly defined that project. It is this, less obvious underperformance that is the problem that interests this research.

Accordingly, the problems of interest here do not relate to whether project-level initiatives are being delivered across project stages, nor is this a matter of project procurement. Project-level matters, such as the follow-through of actions arising from environmental effects assessments, have already long been the subject of other investigations (e.g. Arts, Caldwell, & Morrison-Saunders, 2001; Blom,

1997, 2000). Rather, the point is that even if questions of project delivery are fully addressed across all project stages prior to handover, there remains a wider systemic problem. This relates to the operational ability to deliver intended outcomes, not just of the project, but of the underpinning systemic strategic intent that firstly defined that project. ***What is required is Systems Thinking for systems, not projects***.

So, while infrastructure rarely fails catastrophically, and may perform well in the short term or from a certain perspective, we need to address these problems of system level outcome delivery, which are insidious, complex, not widely articulated, and furthermore, less researched. Without systemic research we cannot be sure of whether the problems are material, and are left with unconnected anecdotes that are of limited value in improving the delivery of infrastructure outcomes.

However, the field of 'whole-of-systems working' is still emerging, and whilst now being advanced for public services such as health, there is little in the assets-as-service arena of the built public infrastructure sectors such as roads, rail, energy, and water. What is required is Systems Thinking for *systems*, not projects. Moreover, conventional, linear thinking is inadequate to deliver intended long-term infrastructure outcomes and a new paradigm is required; one that is both outwardly focused and system oriented. We need a different 'mental model' from the project- and asset-based conventions that dominate infrastructure practice at this time, and must address the question as to whether current infrastructure practice is capable of supporting system-level strategic intent.

Operational functioning

Jackson (2009) usefully contemplates Systems Thinking in relation to management and its place in contemporaneous operational research (terming this "*applied systems thinking*"). Whilst three strands to this are identified by Jackson, and highlight the evolution of applied system thinking, of particular relevance to this research is the commentary on a fourth tranche: described as 'recent developments'. In this, Jackson identifies two systems approaches that have been "*little discussed in the academic world but are having a considerable impact on practice*" (emphasis added):

> *'Whole Systems Working' has been influential in the field of health and social care. It is described by Hudson (2006) as the process of involving all stakeholders of a domain in a discussion about service change—all parties are encouraged to think about the way the whole service delivery system works, rather than focusing only upon their own service.*
>
> *Vanguard's system thinking combines aspects of systems thinking, lean thinking and intervention theory to deliver, it claims (Seddon, 2003):*

> *A method for...achieving the ideals many managers aspire to: a learning, improving, innovative, adaptive and energized organization. It provides the means to develop a customer-driven adaptive organization.*
>
> ***This approach is getting significant take-up in the public sector, where it offers a damning critique of existing ways of doing things as well as numerous examples of a better way*** *(Seddon, 2008).*
>
> *Both approaches provide an object lesson in how relatively simple (though not simplistic) combinations of systems ideas can have a huge impact on improving managerial practice and the efficiency and effectiveness of organizations (Jackson et al, 2008).*

Hudson's work describes an approach for integrated working at the system level (Hudson, 2006). However, the aspiration of Hudson's definition should not be construed as prerequisite criteria or a given method for approaching complex systems (i.e. it does not automatically stand that anything less than the involvement of all stakeholders cannot be classified as a whole system approach). Indeed, Hudson concludes that "*a whole system approach does not offer a single technique or a new big answer"*. Supporting this, Hudson identifies four case studies; each of which uses a different method. All four of the studies were in the health and social services, and paid "*more than a passing conceptual nod to what a whole system approach is really about*".

Hudson also notes that attempts to implement a whole system approach were "*few and far between*". This somewhat challenges Jackson's assertion that the approach has been influential in practice, but this may be more symptomatic of Jackson's observation that the area has attracted little in the way of academic discussion.

Public sector administration

Other germane literature includes the corpus which follows the development of 'New Public Management' in the public sector (which emphasises business-like performance management and stakeholder collaboration; Asquith (2016)). However, infrastructure-related literature in this area is also sparse; Almklov and Antonsen (2014, p. 1) providing one of the few examples. Significantly, they found that New Public Management "*renders essential aspects of operational work invisible — including practices that are known to be of importance for reliability*", particularly operational co-ordination and the retention of operational history. In this regard, Almklov and Antonsen observe that operational work has no clear beginning or end, and that this may be "*hard to prescribe, describe, and control*". They argue that this is at odds with the New Public Management model, and that there is very little research into the effects of New Public Management upon the practice of operating critical infrastructure.

It also transpires that the academic literature says relatively little directly or specifically about the relationship between the strategic intent and the management of public infrastructure systems:

> *Public service failure and turnaround are issues of pressing practical concern in most nations, yet theoretical and empirical research in this field is sparse.* (Boyne in Hartley, Donaldson, Skelcher, & Wallace, 2008, p. 249)

The few studies that are available focus on the delivery of services and therefore do not penetrate the technical realm of engineering for and within Public Administration. One of the inhibiting factors for any Public Administration research appears to be the very complexity of the systems in question, and how to meaningfully engage with this; despite fifty years of operational research, Jackson (2009), concludes this is still an emergent area.

Infrastructure administration

Much of the current built infrastructure literature examines issues through a project-centric lens which presupposes a conventional asset lifecycle of: plan–build–maintain–dispose (Figure 1). Implicit within this linear tradition is a presumption of delivering more projects, then optimising the maintenance and renewal of the hard assets.

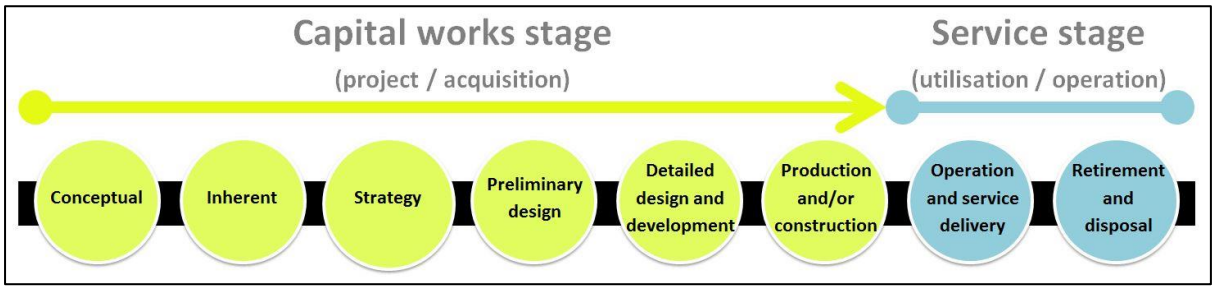


Figure 1: Conventional infrastructure lifecycle

Source: Adapted from Blom and Guthrie (2017b)

As there is an extensive body of literature aimed at improving (optimising) aspects of infrastructure management (e.g. project and asset management, strategy development, network function, benefit management, risk management), this research does not therefore include matters of project delivery. Instead it focuses on the integration of projects into the wider infrastructure system. This raises three points:

- Project delivery is a bounded system that is generally subject to controlled or managed changes in parameters within its boundaries. Project- and system-level matters are not mutually exclusive and should not be assumed to be one and the same.

- Whilst infrastructure systems are dynamic, for those infrastructure types with the ongoing delivery of assets/projects/programmes, that state of flux and change is exacerbated. This is because, excluding most renewals, capital works or projects are ultimately designed to develop and change both the assets and function of the system.
- The lifecycle (and its key stages of strategy/planning, capital works, and operations/maintenance) is more than just a theoretical model, it can also reflect/dictate organisational structures, silos, and processes. It is notable that many organisations within the physical/built infrastructure sectors (i.e. roads, rail, energy, waters) are implicitly arranged to reflect this lifecycle.

Infrastructure exists as a 'project' for only a small proportion of its lifecycle before being absorbed into the system that the project was intended to transform. In this respect, infrastructure is 'chaordic' (Olmedo, 2010), as outcomes and feedback are inextricably linked with and change in the environment/context (i.e. playing the game, changes the game). The alternative, systems lifecycle developed by Blom (2014) which also re-orients practice to customer-oriented outcomes, reflects these dynamic, chaordic properties and so provides an underpinning conceptual model of the infrastructure system for this research (Figure 2).

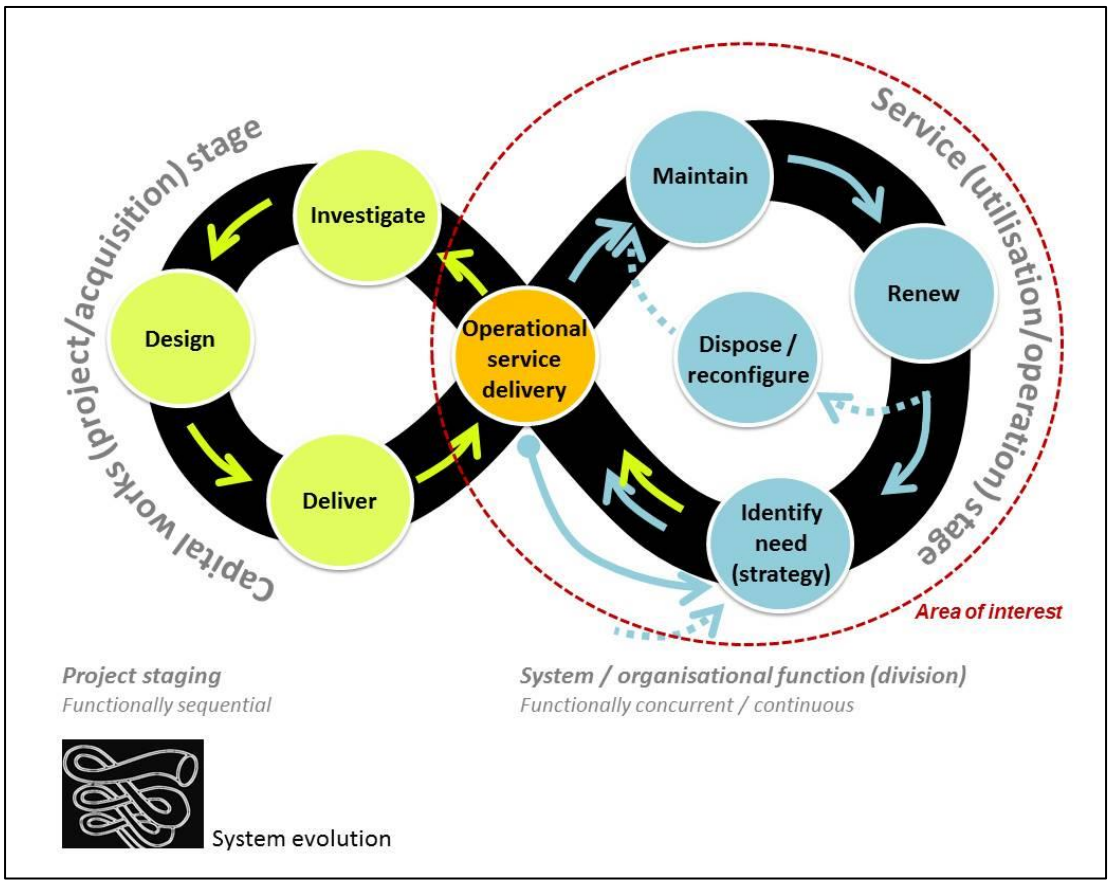


Figure 2: Infrastructure system lifecycle model

Source: Adapted from Blom (2014)

Key terms

Horwath (2009) is of the opinion that "*the "what" you're trying to achieve, whether it be a goal, an objective, or a long term vision, should never be confused with "how" you will achieve it, which is strategy".* This research concerned itself, not with the "*how*", but rather the strategic aspirations and outcomes which have been collectively referred to as the **strategic intent**. This emphasises the focus on outcomes and benefits rather than artefacts and features.

To this end, this research explores the nexus of public administration and services, engineering and technical practice, with infrastructure management and governance. **Public infrastructure** is that used by or within the public realm, and in New Zealand (the focus of the detailed studies), this is generally in some form of public ownership (New Zealand Government, 2011). It is acknowledged that, elsewhere, this might not always be the case; however, the focus here is upon the underlying infrastructure (engineering) management practice**. Infrastructure management**, here, means a hybrid of management, engineering, and other practice areas. As such, this distinguishes between the business acumen currently expected within the public sector and infrastructure organisations that exist as a commercial enterprise. In a similar vein, **infrastructure governance** refers to governance provided by a board of directors. Whilst political matters will be germane, they are outside the scope of this research; as one interviewee observed "*We can still have good governance if you've got bad politics*" [PR58].

Infrastructure systems, then, are an enduring complex of services, assets, projects, and networks — all at different stages of their lifecycles —dynamically affecting one another as they develop, then age. Moreover, assets in themselves are not sufficient for the delivery of outcomes, and so underline the importance of the service(s) delivered by built infrastructure. This is the very essence of what defines infrastructure, which is "*the basic physical and organisational structures and facilities (e.g. buildings, roads, power supplies)* ***needed for the operation of a society or enterprise****"* ("Oxford English Dictionary (online version)," 2014; emphasis added).

Research approach

In this context, the central hypothesis proposed that:

> *The strategic intent and the day-to-day management of infrastructure systems are often misaligned, with negative consequences for achieving the desired long-term infrastructure system outcomes.*

This was augmented by three underpinning propositions:

1. Individual infrastructure projects automatically, by their nature, become part of, embedded in, *and change*, a complex infrastructural system (e.g. interactions, feedback, emergent properties).

2. The governance and management of such systems will not be effective if focused on outputs at the level of projects, assets, or even subsystems. Governance and management needs to address the desired/intended strategic, externally-oriented outcomes and *aptitude* of the whole system. They also need to address the contributions of individual projects *and* of the day-to-day operations to that system.
3. No matter how well individual projects are designed and delivered, or strategic outcomes are initially defined, systems are dynamic. Accordingly, infrastructure administration needs to both accommodate and continually respond to this time dimension.

The challenge and level of uncertainty here is such that the hypothesis might be considered broad. However, this is the reality for those that are charged with addressing this in practice (Bazerman, 1994; Brugnach, Dewulf, Pahl-Wostl, & Taillieu, 2008; Snowden, 2005).

When faced with the scale, complexity, and goal-seeking (i.e. dynamic) nature of systems such as infrastructure, Ackoff (1994) and Snowden and Boone (2007) share the view that a probing approach is required. Not only does this 'sample' the system (recalling that there is no single solution to a complex problem or problem within a complex system); it can also assist in identifying and/or assessing 'points of leverage'. These are points at which a small intervention can result in a disproportionate change or system-level outcome (e.g. Bosch, Nguyen, Maeno, & Yasui, 2013; Hudson, 2006).

This philosophy is reflected in the staged methodology (Figure 3), which entailed preliminary research across infrastructure sectors and countries, before focusing on the New Zealand land transport sector for detailed study (but still drawing on the broader material; Blom and Guthrie (2017c)). Usefully, the New Zealand land transport sector is strongly centralised, and largely in public ownership. The New Zealand Transport Agency (NZTA) administers funding for land transport infrastructure and services through the National Land Transport Programme, in addition to performing its other functions (which includes the management of the national State highway network). Local land transport is largely managed by local government, and is partially funded through rates. Auckland Transport is the entity accountable for managing local-level land transport within New Zealand's largest city and most populated region, Auckland. Both organisations are charged with implementing a 'One Network' approach for the region.

The detailed studies looked at both organisations, and considered some of the interfaces between the two (e.g. overlapping performance measures, funding-related practice and requirements, common standards, and 'One Network' aspirations). Further detail for the three deep dives (detailed studies) is provided in Table 1.

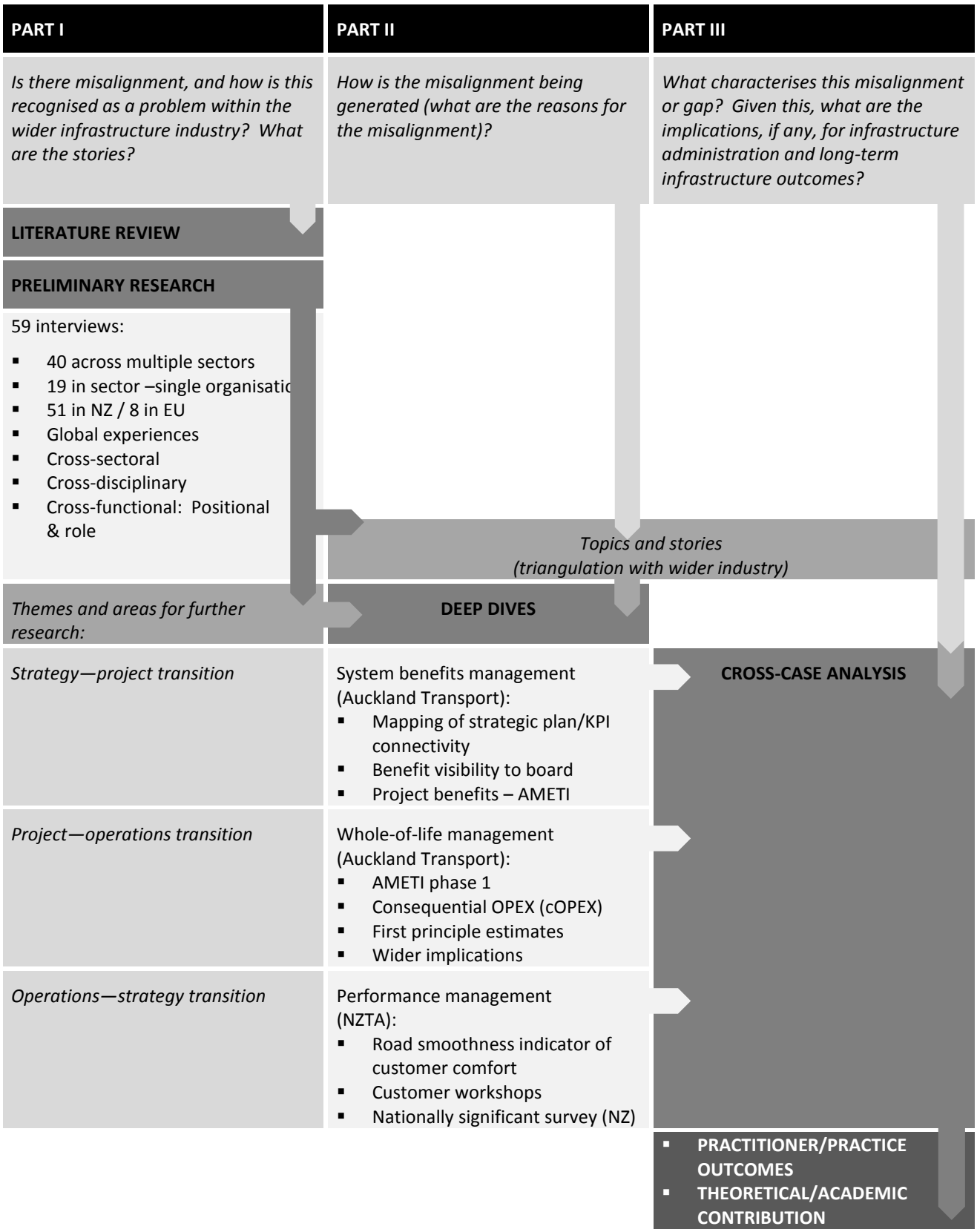


Figure 3: Overarching research methodology

Table 1: Summary of detailed study methodologies

LIFECYCLE INTERFACE	SUMMARY
Strategy/project interface	***Detailed study 1: System benefit management*** *See Blom and Guthrie (2017a)*
	Brief description: How strategic connectivity and benefit visibility at board level interrelates with projects.
	Organisation: Auckland Transport (local government organisation)
	Level: Strategic — ***Scale:*** Macro
	Methodology: Cross-sectional analysis through current practice, including analysis of: a) Connectivity of current organisational strategies and directives/how strategic intent transitions into strategy (mapping of 6 key strategic documents); b) Benefit visibility within board reporting/how strategic intent and benefits (outcomes) are reported and managed within the governance context (analysis of 765 board reports); c) How benefits have been managed and transition within the project context (site visit, review of 128 project documents). Plus a cross-analysis/synthesis of the implications for the strategy to project interface.
	Notes: ▪ Links to strategic intent via strategic plans and project objectives. ▪ Auckland Transport has recently melded best practice from across 1 regional and 7 local councils. ▪ No formal process in place (project-level benefit management under development). ▪ Links to wider land transport funding and strategic objectives as local government must demonstrate 'strategic fit' as part of NZTA funding applications (NZTA, 2013). ▪ Benefit delivery is of shared concern in wider New Zealand land transport organisations and across other infrastructure sectors (Blom & Guthrie, 2017c).
Project/operational interface	***Detailed study 2: Whole-of-life management*** *See Blom and Guthrie (2017b)*
	Brief description: Post project delivery, operational estimating of the cOPEX arising from new projects and programmes.
	Organisation: Auckland Transport (local government organisation)
	Level: Operational — ***Scale:*** Meso
	Methodology: Cross-sectional analysis through current practice, including: a) Analysis of project documentation to collate operational costs and trace how obligations have been managed and transition through the project development (site visit, review of 128 project documents); b) First principle development of cOPEX schedule and comparison against other current estimates (6 additional interviews, estimating workshop). c) Cross-analysis of the implications for the project to operations interface.

LIFECYCLE INTERFACE	SUMMARY
	Notes: ▪ Links to strategic intent via project objectives, operational budgets, and scope/levels of service. ▪ Auckland Transport has recently melded best practice from across 1 regional and 7 local councils. ▪ No formal process in place. Auckland Transport has recently completed an asset-based estimate of the first stage of a significant programme, enabling comparison across estimating techniques and approaches. ▪ Long-term costs are an identified issue for New Zealand local authorities in general (Controller and Auditor-General, 2014a). Whole-of-life costs were also identified as wider infrastructure issue (Blom & Guthrie, 2017c). ▪ Links to wider land transport funding as local government must calculate whole-of-life costs as part of NZTA funding applications (NZTA, 2013). Wider deliverables must also demonstrate strategic fit with overarching objectives.
Operational/strategy interface	***Detailed study 3: Performance management*** *See Blom, De Marco, and Guthrie (2015); Blom and Guthrie (2015)*
	Brief description: Road smoothness as an indicator of the strategic objective to improve customer comfort.
	Organisation: NZTA (central government organisation)
	Level: Tactical ***Scale*:** Micro
	Methodology: First principle reassessment of current practice, including: a) Workshops with infrastructure customers to canvas issues and to focus/pilot more comprehensive assessment (3 workshops across urban/rural New Zealand); b) National survey of customers (1,619 useable responses, 95% level of confidence); c) Assessment of the implications for the operations to strategy interface.
	Notes: ▪ Links to strategic intent as a performance indicator for a strategic objective. ▪ Road smoothness is a widely used national and international indicator. As well as being a measure of customer comfort by the NZTA (NZTA, 2011, 2014), it is a mandatory reporting measure for local government in New Zealand (Department of Internal Affairs, 2013). ▪ Performance management identified as a wider issue for New Zealand land transport organisations and across other infrastructure sector (Blom & Guthrie, 2017c).

For completeness and context, it is noted that the public administration of land transport in New Zealand is of international standing, particularly in areas such as asset management (Controller and Auditor-General, 2014b; Federal Highways Administration, 2005). This research was therefore aimed at providing an evidence base to encourage and support positive change in infrastructure administration beyond the subject organisations, sector, and country.

Overview of preceding research

Preliminary research

Given research in the area of whole-of-system working is emergent and lacking within the built infrastructure sectors, it was important to firstly understand what is actually believed or actually known within the infrastructure industry, for it does not automatically stand that:

- There is a systemic problem and that this is recognised (i.e. there is a problem that exists or is recognised beyond individual examples and stories);
- There is substantive evidence of the problem;
- The problem is material or its nature is understood; and
- Anything is being done about it.

Accordingly, the research firstly investigated industry perceptions in order to test and confirm the problem: the nub of which was found to be the inability to fully deliver appropriate and relevant infrastructure outcomes over the long term. In describing the overarching problem, many interviewees pointed to a misalignment between the intended strategic, or system-level, outcomes (or benefits) and the delivery, or management of those outcomes over the longer term. What was also clear was that there was no real understanding of the scale and scope of that misalignment, nor the significance of any implications, because system-level outcomes were not being given sufficient attention. It was found that whilst the primary issue might be simple to articulate, it is paradoxically complex. Accordingly, 'leverage points' were identified as the focus for further research at this time and the most advantageous points at which to 'deep dive'.

Deep dives

The organisational 'deep dive' is a diagnostic tool used to gauge strategic performance and cut through organisational practice in detail (e.g. Horwath, 2009; Yu & Bower, 2009). The deep dive is a particularly effective means of testing whether strategic intent has been organised into actions that will have meaning at multiple levels. Here, three primary lifecycle/organisational interfaces emerged as the key areas of interest and leverage at this time: strategy—project, project—operations, and operations—strategy. The detailed studies supported the findings of the preliminary research and showed there to be areas of systemic practice that are having a material effect upon long-term outcomes (Table 2). However, those effects were not often visible to the system itself; being acts of omission rather than commission.

Table 2: Summary of detailed study results

STRATEGY—PROJECT TRANSITION	PROJECT—OPERATIONS TRANSITION	OPERATIONS—STRATEGY TRANSITION
System benefits management (Auckland Transport): ▪ Mapping of strategic plans/KPIs ▪ Benefit visibility in board reporting ▪ Project benefits - AMETI	**Whole-of-life management** (Auckland Transport): ▪ AMETI phase 1 ▪ Consequential OPEX (cOPEX) ▪ First principle estimates ▪ Wider implications	**Performance management** (NZ Transport Agency): ▪ Road smoothness indicator of customer comfort ▪ Customer workshops ▪ Nationally significant survey (NZ)
How is the misalignment being generated (what are the reasons for the misalignment)?		
Strategic Mapping: ▪ Homogeneity: dominance by assets and projects ▪ Document (Strategy) order ▪ Poor iteration/change management ▪ New strategies/measures as a response to problems ▪ Ability to understand, connect and align all parts of the system.	**cOPEX estimating practice:** ▪ Actual cOPEX unknown – inhibits feed forward, learning, feedback ▪ No whole-of organisation approach. ▪ Whole-of-life may have different scope/meaning ▪ Dominated by familiar assets – services and multi-functional assets not well provided for (more often missing) ▪ Investment processes over-reach (e.g. long-term cOPEX missing including for major structures). Investment not operationally focused. ▪ Best for project can hide some costs ▪ No provision for change, events, adaptive management	**Workshops:** ▪ Terminology and the range of given issues often assumed - can be irrelevant/have different meaning to customers ▪ Focusing on technical issues too early curtails meaning/learning ▪ Embedded belief system inhibit inquiry ▪ Organisational, contract, and administrative boundaries are irrelevant to customers ▪ Monitoring inherently assumed to contribute to strategic intent ▪ Face-to-face customer interaction around needs rare
Benefit visibility: ▪ Dominance by features (outputs) ▪ Lack of system-level benefit visibility ▪ Disconnect between strategic intent and project benefits ▪ Reported follow-through and feedback non-existent ▪ Unclear how teams act on others/strategic intent		
Project-level benefit management: ▪ Under development/emergent ▪ Focused on project not system ▪ Dominated by tipping points from BCR (e.g. traffic) ▪ Lack of disbenefit management ▪ Deferred benefits – over-claimed system benefits ▪ No feedback, feed-forward, or follow-through	**Assessment of wider implications:** ▪ Dominated by project processes – best for project ▪ Embedded misalignment through institutional lock-in ▪ Information not accessible post-project nor prepared for operational needs ▪ Assumed accountability boundaries/belief that excluded matters are dealt with elsewhere ▪ Other costs/actions (e.g. project defects, compliance) not in budgets (absorbed/hidden) ▪ Known requirements not transferred – become unknown unknowns ▪ Deferred benefits – over-claimed system benefits in business cases	**Survey:** ▪ Don't usually ask potential/new customers ▪ Don't target all customers (reflect technical/mode bias) ▪ Don't survey beliefs or reflect the complexity of an issue ▪ Satisfaction is a sliding scale and does not necessarily enable change, correlation to conditions/context, enable the system to evolve/learn ▪ Customers have different needs in different contexts and over time – current approaches over simplify
Synthesis: ▪ Dynamics of system not managed ▪ Benefits not understood at multiple dimensions (scale, customer, function, timescale etc) ▪ Embedded misalignment through incremental change ▪ Wider corporate practice (e.g. HR/personal performance		

STRATEGY—PROJECT TRANSITION	PROJECT—OPERATIONS TRANSITION	OPERATIONS—STRATEGY TRANSITION
requirements) can also impede	▪ No feedback/forward ▪ Third party disconnects ▪ No programme staging reviews	
Effects		
▪ Absence of service-related strategy (and outcomes) ▪ Loss of connectivity and transparency ▪ Complicated framework – proliferation of requirements ▪ Unclear how individuals, teams etc contribute (counterproductive/silos) ▪ Loss of knowledge/reduced capacity for organisational learning ▪ Red-queen business with unknown progress/benefits not visible ▪ Loss of customer voice ▪ Loss of outcomes (simplification, homogeneity of customer/function/service) ▪ Movement of things misconstrued as movement of people (technical vs service outcomes) ▪ Does not support strategic intent	▪ Can have material impact upon total system OPEX – need to understand these are not from new but omitted requirements ▪ Overplays project benefits and underplays operational requirements ▪ Hidden system benefit loss through inadequate OPEX spend ▪ Omitted cOPEX equates to omitted actions/levels of service/outcomes – narrow asset-centric focus ▪ Does not support strategic intent ▪ Poor cOPEX estimating impacts on future budgets/opportunities /levels of service/outcomes ▪ Erodes services, multi-functional assets, mitigation, trans-organisational/departmental (wider) outcomes and long-term asset life/performance	▪ Does not provide for all/future/new customers ▪ Particularly does not provide for vulnerable customers ▪ Does not reflect multi-functional assets or the multiple services provided by those assets ▪ May address how customers feel using the asset – but does not consider how the asset serves their lives (confuses interaction with an asset with enabling societal outcomes) ▪ Many effects unknown/hidden as not measured ▪ Does not reflect the complexity of outcomes such as improved comfort ▪ Does not support strategic intent ▪ Does not enable meaning feedback/forward to strategy (or projects and operations)
Implications and interventions		
▪ Project-level benefit management is not enough – benefits must also be managed at system level ▪ System stewardship required: System-level synthesis/management of multiple benefits and multi-dimension benefits plus system dynamics ▪ Deferred benefits need to be understood and managed ▪ Corporate process (e.g. HR) also needs to align to outcomes ▪ Detailed interventions per specifics of case/organisation	▪ Change needed to cOPEX estimating practice, particularly for system transforming projects ▪ Need to follow project threads through organisation/system so fully integrated/embedded ▪ Whole-of-organisation approach to whole-of-life required ▪ Deferred benefits and adaptive capacity need to be understood and managed ▪ Corporate process (e.g. accounting/finance) also needs to align to outcomes ▪ Governance to reflect on true OPEX and drive ongoing system review	▪ Technical practice needs to evolve to reflect changes in context (e.g. society, technology) ▪ Care is needed so that all customers are heard; particularly the vulnerable ▪ Not all outcomes are equal – technical outcomes are not the same as system outcomes ▪ Changing KPIs alone insufficient-systemic change required ▪ Outcomes may not be enough – measures need to include system aptitudes ▪ Feedback needs to feed forward. Monitoring needs to generate information (not data) to enable the system to evolve.

Cross-case analysis

The third part of the research, and focus of this paper, comprised a cross-case analysis of the system-level implications arising from the deep dives. To deduce the overarching themes, the results and case-specific thematic outcomes from the detailed studies were revisited through a 'system-level' lens, categorised, and sorted alongside those from the preliminary research. This resulted in four interrelated themes, which are each discussed in turn below:

- Bounded influence, which is shaped by four aspects:
  - Organisational structure;
  - Strategic reach;
  - Transfer dimensions; and
  - Salience.
- Business practice;
- Feedback; and
- System stewardship.

It is these matters that contribute to, and characterise, the gap between the strategic intent and management of infrastructure systems.

Bounded influence

Each of the detailed studies explored an infrastructure lifecycle transition or interface. 'Handover disconnects' are a well-known problem, and current convention is that the transitions are unidirectional (Figure 1). Handover dysfunction is often seen as solvable by checklists and data transfer, and obviously this may work well in certain situations. However, the studies have shown that not only were all of the researched lifecycle interfaces complex and multi-directional, they were further complicated by layers of what will be termed 'bounded influence' (Bourne & Walker, 2005). Here, bounded influence refers to matters which limit influence and the ability to implement the change necessary to give effect to the intended outcomes. The willingness, capability, and/or capacity to effect that change is a separate matter. The four key aspects contributing to the observed bounded influence are discussed below.

Organisational structure

The effect of organisational silos is also well recognised, and often focused upon the project–operations interface. However, study 2 in particular, challenged this by highlighting disconnects created by the relative ease at which the primary functions are, in fact, identifiable silos. To this end, whilst the capital development part of the study organisation was complex, 'the project' was typically a known or identifiable team. However, in reality, 'operations' was not as neatly

identifiable as it comprises multiple functions within the organisation. This raises a number of fundamental questions:

- Who or where within the organisation was 'the project' to be handed to, and who was accountable for the outcomes (including co-ordination and integration with other newly delivered capital works)?
- Who was accountable for that process? Was this capital development given the tendency to close a project shortly after close of contract, and/or was there an individual in operations (given the need to follow the 'threads' through the organisation)? 'Threads' refers to strands of logic, requirements, and/or actions that might affect or need to be embedded within other parts of the organisation (e.g. strategy, benefits, compliance or other requirements, levels of service, standards).
- Who subsequently 'owns' those threads, where they are stored, and what value they are given over time (or when they are lost)?
- Who, then, was responsible for providing integrated operational feedback to those developing strategy, or was the customer/user voice on a project?

To date, many of these issues have been managed through tools such as an asset management database. However, as complexity increases and infrastructure is re-purposed, such tools are no longer adequate on their own, have become a proxy for decision-making, and enable the abrogation of responsibilities. After all, "*to codify method is to impede thinking*" (Seddon, 2008). This was visible in all three studies, but was particularly demonstrated by the limitations of current cOPEX estimating practice and the use of an overly simplified performance measure (road smoothness) as an indicator for strategic intent (improved customer outcomes; customer comfort).

Furthermore, such a simplified view of operations is problematic in large organisations, where 'operations' consists of multiple departments and functions including multi-modal services. In this regard, detailed studies 1 and 2 also demonstrated that effective change or ongoing implementation was not simply a matter for the asset management team and that delineation according to organisational structure, system tools, and/or processes does not account for all requirements. Instead, the 'threads' need to be firstly defined and understood and then followed through the organisation to their logical conclusion. This is inclusive of any consequences (secondary threads) generated by that process. Moreover, because public infrastructure organisations can best be viewed as a complex adaptive system, this is (necessarily) an ongoing and evolving process.

Infrastructure only exists as a project for a very short period of its lifespan. Post-delivery, it disperses across and is absorbed by the physical and organisational system. The transition is

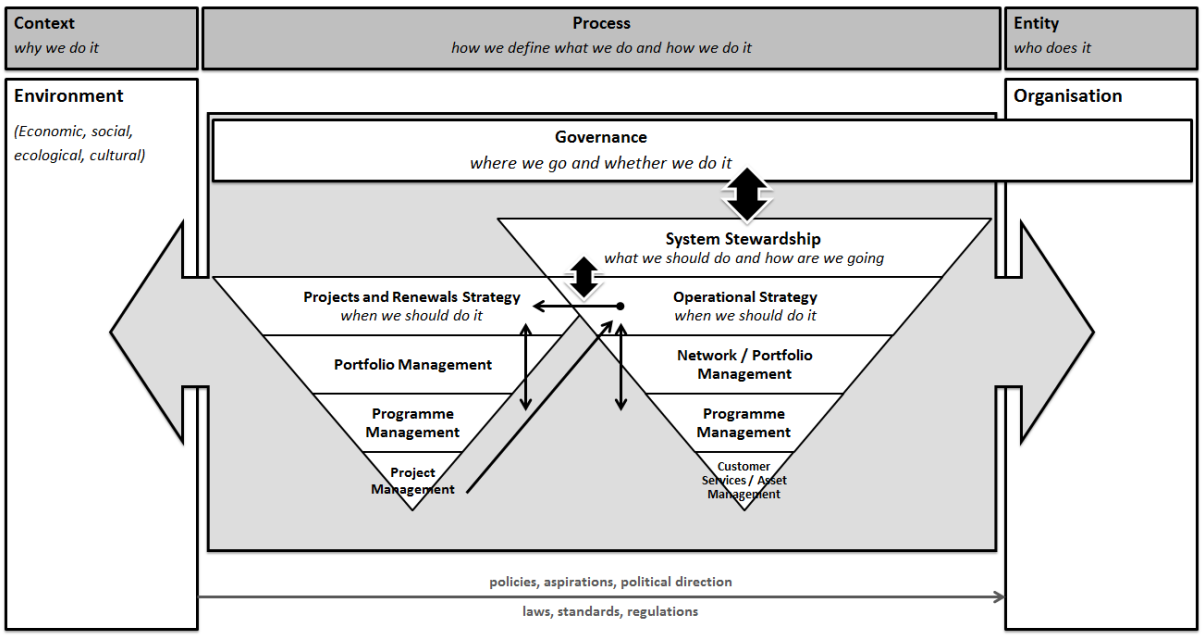
perhaps less about project to operations, than project to system. This is where the notion of system stewardship developed within study 1 has merit (see inset). As one interviewee observed:

> *We're bringing together…literally dozens of disparate systems that have not been designed to…work together or invested in, as a coherent collection of networks. So we are having to get to grips with…different pieces of infrastructure, not necessarily aligning nicely with…the way the network is operated…we're still probably adding operating costs that we would be better to avoid. And…I'm not being critical of what we're doing… …[but] we've got quite a bit more…to achieve.* [PR19]

✓ **Proposition 1***: Individual infrastructure projects automatically, by their nature, become part of, embedded in, and change, a complex infrastructural system (e.g. interactions, feedback, emergent properties).*

SYSTEM STEWARDSHIP

Zimmerman and Sparrow (1997) describe stewardship as "*a collective sense of ownership or accountability*". Here, system stewardship is envisaged as an 'ecosystem orchestrator' to ensure ongoing system fitness. Ultimately, system stewardship might evolve into a cultural norm. Until then, it may require the establishment of a specific role or organisational function to enable its development and implementation (much the same as health and safety or sustainability). The figure below indicates where this function might sit within a generic infrastructure administration structure (potentially introducing the role of 'system steward' to better define accountabilities). This is further described in Blom and Guthrie (2017a).



Strategic reach

Currie and Proctor (in Walshe, Harvey, & Jas, 2010, p. 251) advise that:

> *Although the public sector literature is giving increased attention to strategy, there have so far been few explanations about how public sector managers develop and implement new strategic approaches.*

Whilst study 3 investigates the implementation of a new, customer-oriented strategy (NZTA, 2014), it was study 1 which charted the development of the strategic framework of a newly formed infrastructure organisation, through to project delivery, and, through study 2, to operational implementation. This showed that the effectiveness and overall 'reach' of strategies was being curtailed from their formation.

As one delved deeper into the organisation and wider industry, the impediments to the delivery of strategy kept building. Study 2 demonstrated the significant role played by handover omissions and other systemic disconnects. All studies found that, in general, outcomes relating to existing organisational processes or tools were more likely to be retained than:

- Complex/non-standard assets (e.g. architectural features);
- Long-term requirements (e.g. maintenance for long-design-life structures);
- Those relating to:
  - How the infrastructure enabled society (e.g. provision for local place-making, customer comfort); or
  - Its context (e.g. environmental mitigation or enhancement).

There was a sense of society working around its infrastructure, despite the strategic intent expressed by the infrastructure organisations responsible for its management.

Whilst the subject organisations showed a broad awareness of their overarching strategic direction, generic strategic justifications in organisational processes and documents also led to disconnects, or strategies being reinterpreted by different parts of the business. This led to the partitioning of outcomes by functional area and compounded the barriers to the organisation as a whole aligning with its strategic intent. Certain strategies appeared to be favoured over others because they might have sustained a convention or 'belief-system'. Others have also encountered this. For example, in relation to study 3:

> *NZTA has a detailed set of technical levels of service and overarching performance targets and measures for maintenance and renewal work. But it was unclear how these levels of service were determined, or what they mean for road users… …NZTA's overarching levels of service for pavement maintenance were inherited…and have been*

> *in place for many years… …It told us that these…are comparable with those of overseas roading authorities…*(Controller and Auditor-General, 2010, p. 36)

Accordingly, this also serves in underlining the importance of the deep dive from first principles (Dobbs, Manyika, & Woetzel, 2015).

Study 1 found that the organisation was well-connected to some strategies whilst others had been completely omitted without documented justification: strategic connectivity by preference, not plan. This raises the issue of who decides which factors are most important, and what is to be omitted, particularly where there are democratic and statutory processes that call for transparency and invite public participation in the decision-making. This, in turn, affected board reporting, leading to study 1 asking "*If not the board, then who is responsible for closing the system-level strategic loop?*" (Blom & Guthrie, 2017a).

Detailed studies 1 and 3 highlighted the importance outcome-oriented performance plays in affecting strategic reach. However, not all outcomes are equal. This point was made in study 3, whereby outcomes need to be directed at two levels:

- How an individual interacts with the asset (e.g. they have a pleasant experience, and don't feel unsafe or vulnerable); and
- How the infrastructure enables that individual's life/business (they can do what they want to, when they want to).

Many of the performance 'outcomes' encountered during this research were focused on the first of these. This might provide valuable information on maintenance and asset performance, but is ultimately introspective and may not necessarily align with community expectation or need. Rather, technical requirements are system-level outputs, not outcomes. This touches on two further matters that bound, or limit, influence: transfer dimensions and salience.

Transfer dimensions

In study 3, analysis of all the workshop material showed effecting change was a matter of:

- **Needs**: What is delivered and how it is delivered;
- **Precepts**: What customers believe or expect to be delivered;
- **Choices**: Whether the choices are appropriate, purposeful, and that compromises have been understood;
- **Aptitudes**: Whether there is the ability to change both reactively and proactively;
- **Process/technical requirements**; and
- **Institutions/entities/functions**.

The first four of these had been firstly identified as 'problem dimensions' within the preliminary research, and were subsequently found to affect how problems were being understood by the organisation within study 1.

It emerged from study 3 that whilst attending to 'needs' might be obvious and relatively straightforward, this was likely to curtail the effectiveness of the project–system transfer and amalgamation. This was due to the disproportionate influence of secondary areas such as 'precepts' and 'aptitude', and pointed to the importance of addressing such matters if change was to be effective.

By contrast, study 2 identified a slightly different range of factors and proposed a whole-of-life change matrix as a result. Although aimed at effecting change across the infrastructure lifecycle ('**lifecycle change**'), and also to account for **organisation change** requirements, there was nonetheless overlap with the preliminary research and the other detailed studies (e.g. process, organisational belief, structure, function). Furthermore, all the dimensions/factors encountered across the research programme were found to reinforce disconnects with strategic intent through omission, organisational inertia, and factors such as redirection/reinterpretation. Therefore, to effectively transfer a project into an operational infrastructure system, whilst retaining the intended outcomes across the infrastructure lifecycle, change processes need to address the organisational, lifecycle, and wider contextual outcomes that are the imperative of infrastructure ('**contextual change'**). These terms appear as dimensions of change within Figure 5, to be discussed later.

Salience

Salience is "*who and to what managers actually pay attention*" (Mitchell, Agle, & Wood, 1997). Similarly, Ramsden and Spoonley (1993) ask who defines what is important. The detailed studies highlighted a range of salience-related factors, for example:

- The ability of customers to be 'heard' over technical and funding considerations;
- The voice of the vulnerable customer;
- Relative performance and levels of service between areas and modes;
- 'Best for project' over operational and system-level considerations;
- Control, responsibility, culture, and familiarity/convention;
- Perceived personal relevance/interest (e.g. introspective outcomes, disciplinary background);
- The relative level of attention given to tasks related to performance measures; and
- Visibility of an issue.

It is the first two of these matters that are perhaps of the greatest importance due to the meaning of infrastructure and public administration. Whilst study 3 explored this matter directly and in the most detail, the issue of stakeholder, community, or customer salience was a recurring theme

throughout all detailed studies and the preliminary research interviews. Worryingly, the inclusion of customers as active participants is deemed 'unorthodox' for industry (Moodley, 2015).

Bonsall, Beale, Paulley, and Pedler (2005) note that few customer surveys and studies considered customer beliefs. Study 1 picked up this theme by recommending the inclusion of a belief-oriented performance measure to assist the development and assessment of customer-oriented outcomes. The study also highlighted the lack of customer voice during the operational phase to protect or argue for the retention of outcomes or levels of service. Given the requirement for community participation in the study context, this was not so much about higher-order community consultation, but where or who within this amorphous area of 'operations' was the proxy for the customer voice (and which customers were being 'heard' the most).

Business practice

Failure to account for the lifecycle and context dimensions of infrastructure was shown to impact on the ability to deliver appropriate outcomes in all three of the detailed studies. Accounting convention (study 2) was particularly problematic with issues ranging from the over-reaching of investment assessment tools (e.g. use of BCR parameters or discounting in the assessment of long-term requirements and costs), through to budgetary horizons, and the management of non-standard/complex assets/services. Hussein and Hafseld (2016) too, describe a range of organisational influences encountered by a governmental project in Norway. Many of the issues raised, such as culture, human resources frameworks, change management, and user involvement are issues-in-common with this research, which found these can create a form of 'running interference'.

The point is improved co-ordination, incremental improvement/establishment of best practice is unlikely to be sufficient and may result in perverse outcomes. Just as engineering and other technical processes may need to change mental models and orthodoxy to provide better alignment with customer- and system-level outcomes (i.e. efficacy), business practices do too. This is an area for further research and development for the relevant sectors.

Feedback

The wider industry interviews and subsequent detailed studies found that benefits (infrastructure outcomes) are:

- Often being deferred or are not being followed through during project delivery;
  Note that the 'follow-through of benefits is not just a matter of completing a project checklist. This is also a matter of (for example) resolving conflicts, delivering consequential actions/requirements, and ensuring services and operational matters are provided for and handed over.

- Rarely followed up and reassessed post-project delivery;
- Frequently not following on within the wider operational system; and
- Mistaken for technical and/or administrative measures during both operations and project delivery.

This affects organisational memory as the information is not available to feed forward into the incremental development and the evolution of strategy (Thiry & Deguire, 2007). Ackoff (1971, p. 665) has observed that if a goal-seeking system has memory, then "*it can increase its efficiency over time in producing the outcome that is its goal*".

Where feedback was encountered in this research, it was generally found to be in the realm of incremental improvement. Such feedback is introspective —little more than a lessons-learned exercise aimed at the project level —useful, but not all that is required from a system perspective. The reduced scope and project-level specificity reinforced retrospection and a perceived or actual reduction in wider applicability:

- Because an infrastructure system consists of assets, projects, and networks at various stages in their lifecycle, an end-of-pipe expectation of feedback is neither practicable, nor likely to happen, because:
  - Of the time scales involved;
  - Of the existence of silos, not only within the infrastructure organisation itself, but within its consultant teams, who may specialise in one particular stage of infrastructure management (e.g. scheme assessment and consenting versus detailed design or construction supervision);
  - Infrastructure is a chaordic system (Olmedo, 2010); and
  - There is not, in fact, an end to the process as a project may be one of many that are simultaneously acting on an infrastructure system (Figure 2).
- Not only is there a need to feed back between lifecycle phases, but there is also the need to do so between the organisational levels of strategy, operations and tactical management.

This is where the depiction of feedback processes, can be problematic as they do not incorporate the ongoing change to a system that occurs independently of any transformative feedback (e.g. Figure 4). This is not just a matter of graphics. Rather, this was found to be more indicative of how feedback was both being thought of, and thence managed, in practice. Whilst Figure 4 shows two additional levels of feedback and learning, there is yet another (complementary) way to look at this. This is that, quite simply —but paradoxically —when viewed as a dynamic and evolving system, feedback actually feeds-forward and contributes to systemic change. This includes enhancing organisational learning; as study 3 found, this is vital given the changing technology and complexity of infrastructure.

At face value, this might seem at odds with calls to improve foresighting practice (Snowden & Boone, 2007). But feedback/feed forward is not the same as foresight, and both need to be accommodated and reconciled; for unless feed forward occurs, strategies are at risk of redundancy without this necessarily being immediately clear. As discussed earlier, this is particularly so, given the chaordic nature of the system. Accordingly, infrastructure administration needs to be re-oriented to system-level matters.

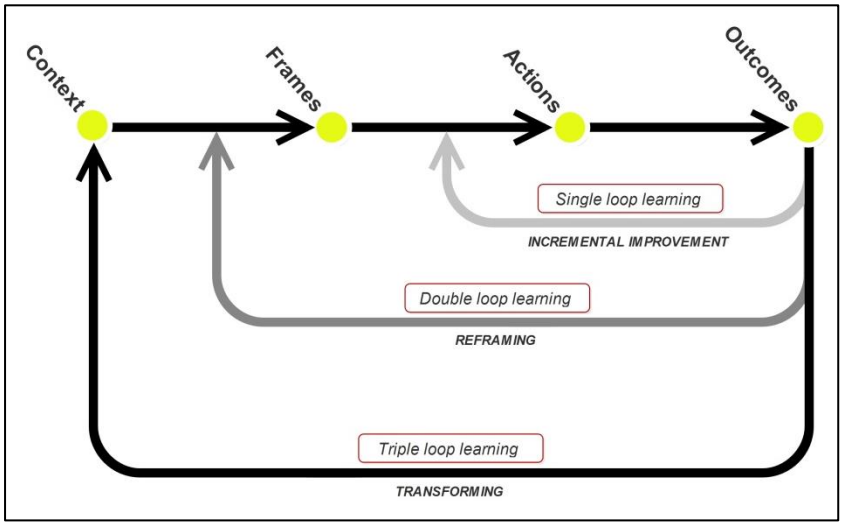


Figure 4: Feedback as a sequence of learning cycles

Source: Pahl-Wostl (2009)

✓ **Proposition 2:** *The governance and management of such systems will not be effective if focused on outputs at the level of projects, assets, or even subsystems. Governance and management needs to address the desired/intended strategic, externally-oriented outcomes and aptitude of the whole system. They also need to address the contributions of individual projects and of the day-to-day operations to that system.*

System stewardship

The 'better use of existing assets', as a first step towards improved infrastructure outcomes, is not just a matter of asset management. It is enabled by both managing the transfer and system assimilation of new projects/renewals and services (studies 2 and 3), and the ongoing stewardship of customer-oriented benefits over the long term in a continually changing system and its interrelated context (all studies).

Change management in the context of an infrastructure system has been discussed already as has the importance of feedback as a feed-forward mechanism. The latter was highlighted by studies 1 and 3 and in particular the role community engagement and collaboration played in that feedback/feed-forward flow. However, providing an integrated operational response can be

challenging when 'operations' is, by contrast to a project's delivery, a diverse group of autonomous functions.

During the preliminary research interviews, it was observed that roles such as that of the borough engineer (who had oversight of the infrastructure of an area) no longer exists. As the system increased in complexity, this has, through necessity, increased specialisation. So as a consequence, this specialism created a barrier to systems-thinking. The 'glue' within the organisation and/or the system had been lost, and any connection to "*social advancement or social improvement*" had also gone missing [PR51].

Whilst all studies highlighted the need for silo-spanning roles, the effect of silos and specialisation was particularly noticeable in both studies 2 and 3 where benefits were being eroded by, for example, falling between decision-making boundaries, functions, or management processes and tools, or between management and governance. To respond to the issues raised within study 1, a model for system stewardship was proposed to reintroduce this system overview.

Accordingly, the three dimensions of lifecycle, organisational and context-oriented change, have been integrated with the notion of system stewardship and centred on externally-oriented outcomes (i.e. the customer). The aim is to provide a framework for how the project-system transition and other system-level change might be improved (Figure 5), and to enable learning and adaptive capacity.

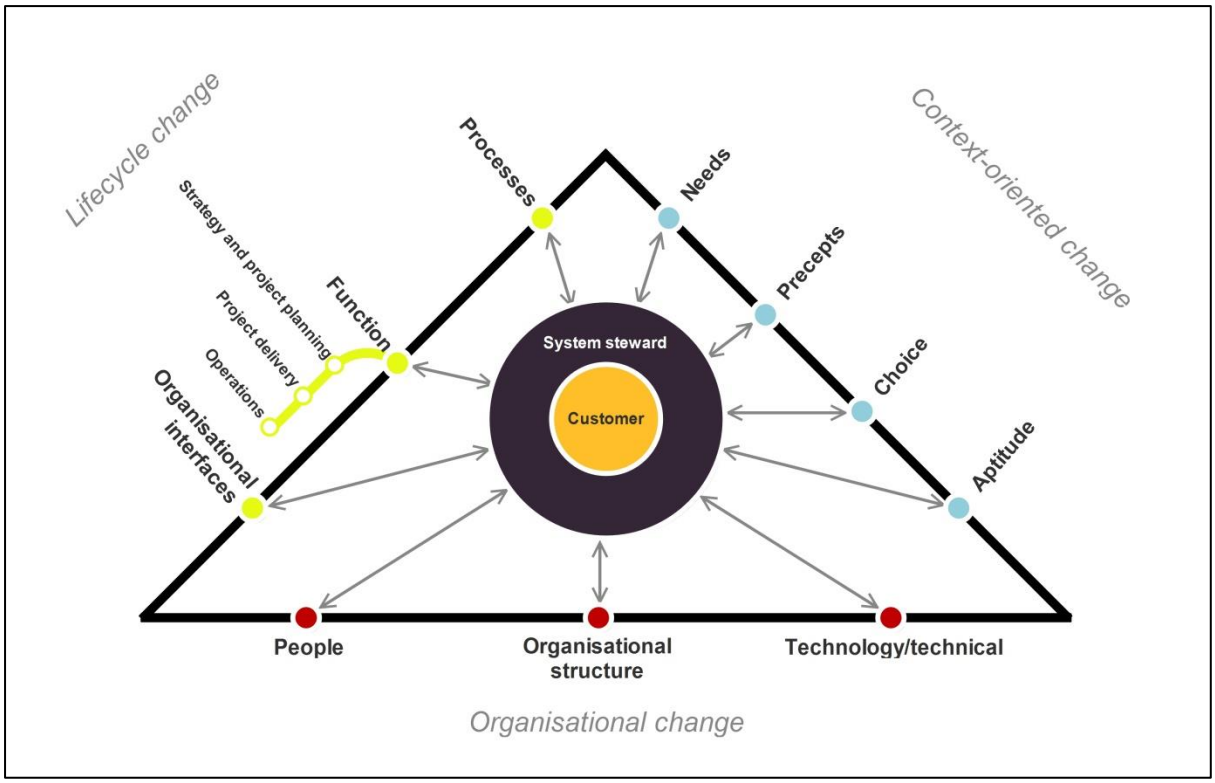


Figure 5: Infrastructure system change management framework

This integration is important, but will inevitably require the balancing and management of requirements, or 'threads' through the system —and over time. This is not a unidirectional framework, but provides for iteration and feedback/feed-forward. As such, this aims to give voice and visibility to customer-oriented outcomes (and synaptic-like system connectivity).

The framework also provides a forum for reconciling and managing all the dimensions of change and system dynamics/evolution that appear, from the research, to be necessary to effect strategic intent. This research has shown that these integrated aspects are missing from current practice with a resultant adverse effect upon long-term infrastructure outcomes.

✓ **Proposition 3:** *No matter how well individual projects are designed and delivered, or strategic outcomes are initially defined, systems are dynamic. Accordingly, infrastructure administration needs to both accommodate and continually respond to this time dimension.*

Implications for long-term infrastructure outcomes

The long-term implications arising from the management of infrastructure systems being unable to connect with, fulfil, or align with strategic intent are complex and interwoven with the four themes just discussed. Just as study 3 highlighted two levels of outcomes (inward and outward looking), and all studies two levels of response ('corrective action' and ongoing system evolution and adaptation) there are implications for infrastructure organisations and their environment.

By exploring the lifecycle interfaces (which provides a longitudinal profile and also explores organisational boundaries in this context), it is clear that strategic intent is not supported from the outset. Directives, objectives, and other statements of intent dissipate or become disconnected by strategy development. This is exacerbated across the project interface and project delivery where strategic intent can be adversely affected by project management drivers and 'best for project' thinking/behaviour. Then, even if projects are able to fully develop and deliver upon the strategic outcomes being sought, there are subsequent milestone or key processes within the lifecycle of that infrastructure which inhibit its ability to:

- Deliver upon the strategic intent; and
- Fully integrate and transform the system (as was inherently the intent of the capital works in the first place).

Many of the effects or implications of this arise from an insidious issue of omission and unrealised potential rather than acts of commission. Furthermore, many of the negative implications are unlikely to be observable within the current conventions of an infrastructure organisation and therefore may appear as a 'latent failure' to that organisation. For example:

- **Asset life:** In the preliminary research, several 'legacy' issues were identified as arising from past infrastructure-related decisions and management choices. However, every example referred to infrastructure that was less than a century old and therefore notionally within its design life. Examples included operational changes with unintended/unknown consequences (such as might be made to a water treatment plant) through to planned/purposeful deferred maintenance that knowingly reduces asset life. Whether purposeful or not, both are 'active failures' but may become absorbed or latent over time as that system knowledge is lost.

  Study 2 detailed this further, showing a suite of active failures that included (amongst other matters) omissions and eroded levels of service. However, because the loss of asset life may not be known, or able to be tracked back to this root cause through organisational processes, a loss in asset life becomes a latent effect upon community levels of service (and potentially on rates or other levies). In other words, a latent social, environmental, and/or economic impact. Furthermore, all the studies suggest that even if the design life were achieved, the infrastructure may not necessarily have fulfilled its potential or delivered the intended benefits.

- **Social exclusion:** Study 3 showed how parts of the community such as certain modes, sectors (e.g. rural), or user groups (in particular the vulnerable) are excluded or compromised by technical and organisational decision-making and processes. Furthermore, whilst organisational salience and other factors may have led to this, the disparity or absence may not be visible to the organisation if those affected do not have a strong community voice to start with (social, cultural impact). This was underscored in study 2 through the apparent lack of clear ownership for long-term operational matters, due in part to the diversity operational functions and therefore structure.
- **Environmental impacts:** Study 2 showed matters of compliance including environmental mitigation and social outcomes were not being incorporated into cOPEX assessments. Should any adverse effects result, then these would not be seen by the subject organisation in this instance as there were no internal checks and balances at the time the study was undertaken (environment, social, cultural, economic impact). This was also seen in study 1 with the weighting and preference given to traffic related benefits rather than to wider environmental and other aspects.
- **System fitness:** The preliminary research interviews highlighted resilience and related factors as top of mind for many infrastructure organisations. Study 2 also highlighted the omission of factors that might affect system 'fitness' (being aspects such as resilience, adaptive capacity, enabling future value). These will likely only be observable to the organisation in retrospect, including after a major event such as a natural disaster (environment, social, cultural, economic impact).

Study 1 showed that it was not the strategic intent to exclude any of the above matters, in fact for the subject organisation, quite the opposite. Yet that study showed that in order for long-term infrastructure benefits to be realised, more than a project-oriented benefit realisation process is required, that this requires the stewardship of our infrastructure systems; the feedback, feed-forward, and follow through at all levels of the organisation. Moreover it requires not just the delivery of outcomes, but outcomes that are customer-oriented, and enable the goal-seeking behaviours of the complex, adaptive system that is infrastructure.

✓ **Hypothesis:** *The strategic intent and the day-to-day management of infrastructure systems are often misaligned, with negative consequences for achieving the desired long-term infrastructure system outcomes.*

Implications for infrastructure administration in practice

In simple terms this research is applicable at multiple levels and scales, but has the potential to enable change to underlying belief-systems and mental models (Figure 6). This speaks to the nested nature of complex systems and that of system aptitude (which is both the attributes and the inherent or acquired ability and inclination of the system to respond and adapt to its evolving context). Ultimately, the applicability of the research will depend on the willingness and the ability of an organisation/sector/industry to respond to the issues and opportunities that have been raised. The research does, however, provide evidence and recommend several interventions to support both specific and general change.

The nature of that change will be context-dependent, and several 'influencing change' workshops have already started the process within the two study organisations. However, although change is clearly intended, it was not within the scope of this research to either implement that change or to monitor its effectiveness. That is a future opportunity. But given the complexity of the system, the point is that the effects of any change should not be completely discernible/separable, and that by effecting any change, the system itself has evolved.

Also, in challenging from first principles, whilst arguably necessary for purposefully 'disruptive thinking' (Dobbs et al., 2015), the concepts still needs to be socialised, understood, and that takes time. This is particularly so at the levels of organisational-, sector-, and general infrastructure-practice considered here. However, this research contributes to that 'socialising' process by providing evidence within the detailed studies to raise awareness and develop understanding. Readers are referred to the separate papers for that evidence and further detail (see Blom (2014); Blom et al. (2015); Blom and Guthrie (2015, 2017a, 2017b)).

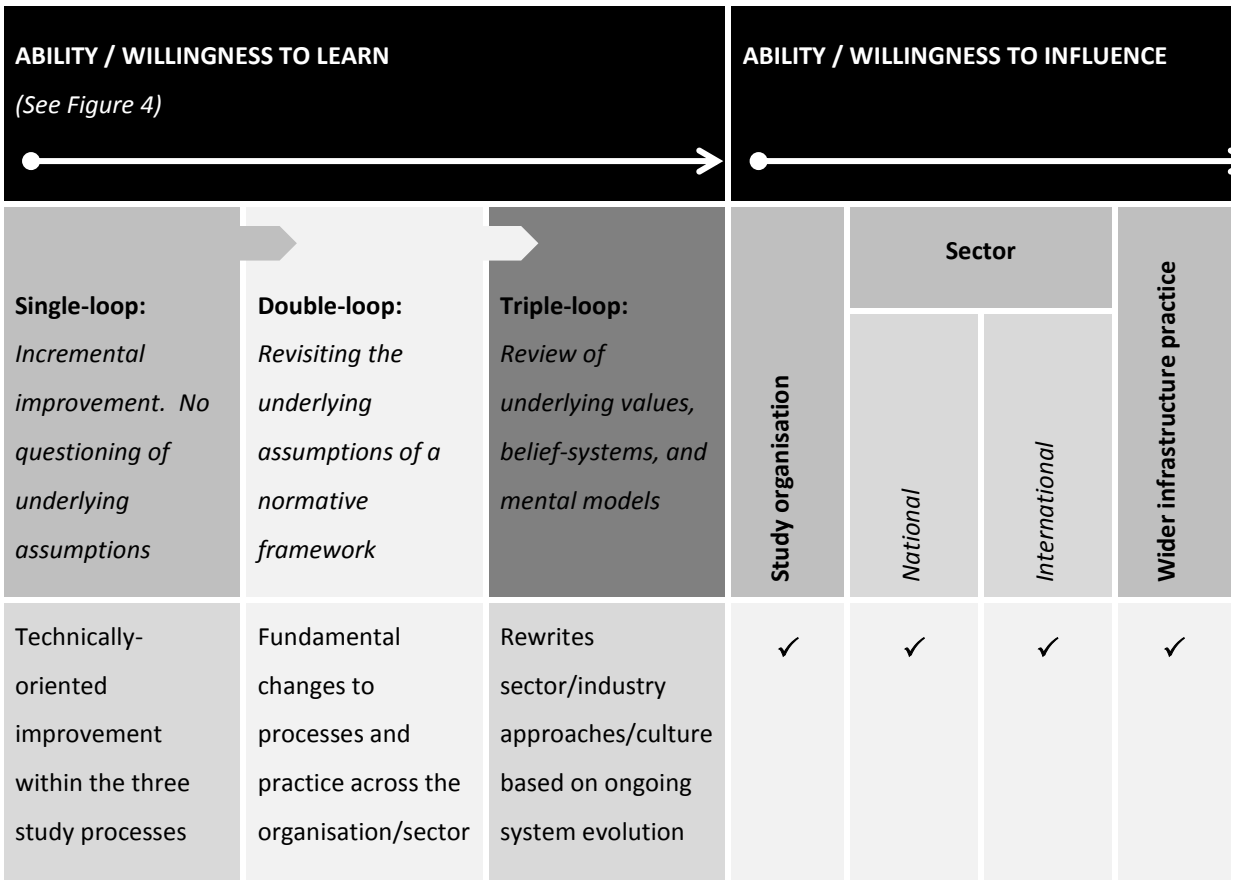


Figure 6: Applicability of this research

In addition, the research has identified a pressing need for 'system stewardship' to address the increased specialisation and siloed operation within current practice. This boundary-spanning function and mind-set is needed to not only deliver 'joined up thinking', but also organisational learning, and the ongoing transformation of the complexed asset-service-organisational-contextual system in response to ongoing change. The other sense-making models described in the detailed studies (Blom, 2014; Blom & Guthrie, 2015, 2017a, 2017b) support the function/notion of system stewardship and should therefore assist sense-making both within and across the system. They should also assist in orienting practice towards adaptive practice and customer-oriented outcomes.

Conclusions

The linear view of infrastructure may have been appropriate in the establishment of 'new world' economies or in response to specific events such as post-world war or disaster recovery. However, this 'pipeline' view of infrastructure does not necessarily assist (as best it might), with managing the complexities of less tangible objectives and the messy, non-linear reality of day to day service-led infrastructure management. Edkins and Zerjav (2014) contend the asset-based and service or provision-based typologies need to be broadened, and Snowden and Boone (2007) that the application of simple solutions or approaches can fail when applied to a complex situation or system.

In short, conventional, linear thinking goes only so far in delivering intended long-term infrastructure outcomes. A new 'philosophy' is required, and needs to be both systems-oriented and focused on outwardly-looking outcomes. As such, this requires a move beyond the immediacy of projects and programmes (Blom & Guthrie, 2016).

The benefits of public infrastructure to society is a central theme drawn from the definition of infrastructure itself. This research shows that it is not enough to be focused on technical outcomes. Infrastructure needs to move beyond how society interacts with an asset, to the outcomes that reflect the needs, beliefs, and choices of society as well as its ability to respond to change (aptitude). In short, so that society no longer has to work around its infrastructure. To this end, the research has increased our understanding of the ways in which the misalignment between strategic intent and the management of infrastructure systems can occur, and the consequences this has for achieving the desired long-term outcomes. It found those consequences were material, and frequently not visible within the sub-system accountable for the delivery of those outcomes. However, although the research has confirmed its hypothesis and three supporting propositions, the research does not purport to offer '*the* solution'. Any corrective interventions will not 'solve' the issues to hand. This is because single solutions do not exist to address the challenges facing a complex adaptive system such as infrastructure.

There is still considerable scope for further research here. This includes use of the methodological approach, matters of detail arising from the individual detailed studies (e.g. in relation to the vesting of assets; detailed studies 2 and 3), and the development of system-level themes.

Public infrastructure exists, not in its own right, but to benefit society. It also endures and changes in a way that is akin to the metaphorical grandfather's axe. As the metaphor goes, the axe has an inherent value as an heirloom (even if the axe-head and handle are replaced over time). For infrastructure, this equates to the notion of 'future value'. However, in order for our infrastructure to be valued in the future, we perhaps need to start thinking of it as 'our grand*children*'s axe'.

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