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Abstract

In the absence of a clearly articulated, shared, collaboratively developed and mutually understood strategic vision of the desired outcomes we expect infrastructure to enable (PURPOSE), it is not possible to fully evaluate system PERFORMANCE gaps or assessment infrastructure NEED. This is significant for any country, region, city, town or community aiming to cost effectively improve the performance and resilience of its infrastructure systems. A systemic, collaborative, transparent, structured and flexible framework for infrastructure need assessment and decision making is proposed (Figure 1). The proposed Framework is systemic, built on a set of strategic need assessment principles, explicitly aligns need assessment with the desired outcomes infrastructure systems are expected to enable, prioritizes underlying systemic priorities, such as resilience, assesses infrastructure system performance and diagnoses infrastructure need from four perspectives, requires outcomes and needs to be neutrally framed, and prescribes transparent evaluation of options against clear defined systemic and outcome-aligned selection criteria.

1. Introduction

Achieving long-term value for money from infrastructure systems is a question of 'doing the systemically right thing right not the wrong thing better' (Beckford, 2013). The process of infrastructure needs assessment has a significant role to play in enabling this by (i) developing a systemic vision and clearly stating systemic priorities to underpin the identification of systemically right things and (ii) identifying systemic performance gaps (wrong things) to diagnose infrastructure need.

However, the credibility of recommendations made by any infrastructure needs assessment, is dependent upon the quality, transparency and inclusivity of the methodological approach used to perform the assessment. Therefore, infrastructure need assessment must be aligned with and driven by a clearly defined set of strategic need assessment principles, and be underpinned by transparent, systemic, structured, interconnected and flexible methodological framework. It must also generate a coherent narrative and audit trail to both record and justify all decisions made during, and all recommendations arising from, the need assessment process.

This methodological need is significant to any country, region, city, town or community grappling with the challenge of improving systemic infrastructure decision making processes. Furthermore, the development of an infrastructure need assessment process aligned with the desired societal outcomes infrastructure systems are expected to enable, has the potential to identify fit for purpose solutions, that are less likely to experience delays in the planning phase and are more likely to deliver stable returns over the investment lifecycle. Therefore, such a

process is of potential value to all involved with infrastructure system provision, funding, financing and operation.

Moreover, in the UK where a pipeline of future sector-specific infrastructure projects is regularly published (IPA, 2016a, 2016b) the National Infrastructure Commission (NIC) has a mandate to undertake a National Infrastructure Assessment (NIA) once per parliament (HM Treasury, 2017; NIC, 2017), 'better' infrastructure has been prioritised to support the delivery of Industrial Strategy objectives (HM Government, 2017) and HM Treasury have commissioned a special study into the resilience of economic infrastructure systems (NIC, 2018) this methodological need is particularly relevant.

The research presented in this paper develops a systemic, collaborative, transparent, structured and flexible framework for infrastructure need assessment and decision making in response to this methodological need (Figure 1). This Framework (Figure 1) is based on the identification of a set of strategic need assessment principles (orange boxes in Figure 1) and a nine stage infrastructure need assessment and decision making framework aligned with these principles (see blue boxes in Figure 1.)

The sections that follow, provide an overview of the context in which this research was developed; provide an overview of each Framework Stage (Figure 1), strategic need assessment principles (Figure 1) and the steps required to put the Framework into practise (Tables 1-9). The paper concludes by providing a summary of the unique features of the proposed Framework.

2. Supporting context

This research builds on earlier research undertaken on behalf of Infrastructure UK to develop a process for outcome-oriented performance indicators for infrastructure systems (Carhart et al., 2015, 2016; Dolan et al., 2016). Research developed in direct response to the launch of the National Infrastructure Commission and a consultation regarding NIA methodology (HM Treasury, 2016; Dolan, 2015a, 2016). Research to analyse infrastructure resilience as a system problem (Dolan, 2015b; Dolan and Cosgrave, 2016). Research to develop approaches to frame the societal outcomes we expect infrastructure systems to enable using solution, sector and technology neutral language (Dolan, In Press)

In particular, the need assessment and decision making framework proposed here and illustrated in Figure 1 is informed by a number of conclusions drawn from the above body of work, specifically:

The ability to perform a complete and systemic assessment of infrastructure need is significant for any country, region, city, town or community that aims to cost effectively improve the quality and resilience of its infrastructure systems and make fit for purpose infrastructure investments capable of enabling the societal outcomes expected.

In the absence of a clearly articulated, shared, collaboratively developed and mutually understood Strategic Vision comprised of a set of statements of the desired outcomes we expect infrastructure systems to enable, it is not possible to fully evaluate system performance. Specifically, it is not possible to identify systemic performance gaps where actual performance of the infrastructure system is not sufficiently aligned with the outcomes expected. From which

it follows, it is not possible to undertake a complete systemic assessment of underlying infrastructure system need (Dolan and Cosgrave, 2016)

Additionally, in the absence of strategic vision, there is a tendency to wrongly derive assumptions of infrastructure purpose from, and frame assessments of future infrastructure need, in terms of the technical characteristics of infrastructure assets already in operation. As a consequence, infrastructure need is often defined in sector, solution or technology specific terms rather than in terms of the outcomes the infrastructure system is expected to enable. Thus the solutions to infrastructure need are often assumed to be obvious, and the need for collaborative system-wide processes to enable the identification of common needs that span multiple sectors, and identify opportunities for innovative solutions are overlooked. Consequently, in the absence of strategic vision, the range of options considered in response to infrastructure need can be constrained to an unnecessary extent and innovative systemic approaches inhibited.

Infrastructure is a complex interdependent network of networks. It is, therefore, vulnerable to the emergence of systemic problems for example challenges associated with resilience, carbon mitigation, flood management, climate change preparedness, sustainability. These systemic problems emerge as a consequence of interdependent interactions within networks, between networks and between networks and the external political, social and economic contexts in which they are embedded. Systemic problems such as these are best managed collaboratively at the system level, using a portfolio of systemically targeted actions. Furthermore, system problems, if not prioritised, can jeopardise the achievement of all other

long-term strategic priorities. Therefore, infrastructure needs assessment and decision making must be systemic in scope, if systemic problems are to be managed as effectively as possible (Dolan et al., 2016; Dolan and Cosgrave, 2016; Dolan and Hiteva, 2017).

Infrastructure interdependence analysis(Boin and McConnell, 2007; Carhart and Rosenberg, 2016; Rinaldi et al., 2001; Rosenberg et al., 2014) has significant explanatory power, and is a substantially broader concept than mere dependence on the immediate inputs infrastructure systems require to function. Infrastructure systems are also interdependent with the dynamic external context (social, political, economic, financial, legal, environmental, regulatory, local, global, spatial and temporal) in which they operate. Therefore, understanding of interdependencies is needed to better understand, and improve, system performance. Furthermore, if interdependencies are well understood, an intentional change to any of the above contextual factors can theoretically be used as a strategy to improve system performance. However, we tend to focus predominantly on engineered solutions and overlook the significance of these other options. (Dolan and Hiteva, 2017).

To fully capitalise on the transformative opportunity created by the need for a regular National Infrastructure Assessment, a systemic collaborative, transparent, structured and flexible framework for infrastructure need assessment and decision making is needed (Dolan, 2015b, 2015a; Dolan and Cosgrave, 2016; Dolan and Hiteva, 2017).

3. Systemic need assessment guiding principles and framework

The infrastructure need assessment and decision making Framework (henceforth the Framework) in Figure 1 is based on the identification of a set of strategic need assessment

principles (orange boxes in Figure 1); and a nine stage infrastructure need assessment and decision making framework aligned with these principles (see blue boxes in Figure 1.)

This section is structured using the Framework Stages as subheadings and provides a brief overview of the how each Process Stage and Strategic Need Assessment Principle contributes to the Framework (Figure 1). Additionally, steps to implement each Process Stage are proposed and outlined (Tables 1-9).

3.1 Process Stage 1: Define system expectations and priorities

Stage 1 aligns with the Strategic Need Assessment Principle: *Meaningful decision making requires a clearly articulated systemic vision comprising sector, solution and technology neutral desired outcomes (statements of expectations).*

The development of a shared, collaborative and mutually understood statement of the desired outcomes an infrastructure system is expected to enable is essential for three main reasons. First, it provides the basis to articulate a systemic vision of infrastructure system purpose. Second, it provides a foundation for all subsequent stages of the proposed need assessment and decision making framework (Figure 1). Third, it creates an aspirational frame of reference against which all subsequent decisions, and evaluations of system performance, can be justified.

However, a systemic vision requires certain characteristics if it is to perform this function and support the need assessment framework in Figure 1. It must be (i) an accurate and inclusive representation of expectations; (ii) Comprised of a set of well structured, unambiguous, mutually understood and mutually accepted desired outcomes; (iii) Systemic in

scope and sector neutral, not aligned with a specific infrastructure sector; (iv) Solution neutral, not aligned with any specific solution or mode of delivery); (v) Technology neutral, not aligned with the incumbent or any other technology.

Significantly, consensus is not a necessary component of a systemic vision, provided the systemic vision is mutually understood and accepted. Steps 1.1 to 1.4 in Table 1 are proposed to ensure the systemic vision developed has these characteristics.

The sector, solution and technology neutral framing of desired outcomes is particularly significant because any bias or anchoring introduced at this stage, will similarly bias or anchor decisions made at all subsequent stages of the Framework (Figure 1).

3.2 Stage 2: Define systemic (system health) priorities

Stage 2 aligns with the Strategic Need Assessment Principle: *System Health priorities related to system problems must be identified and placed at the core of needs assessment processes*

Infrastructure is a complex interdependent network of networks. It is prone to the emergence of systemic problems for example challenges associated with resilience, carbon mitigation, flood management, climate change preparedness, sustainability. System problems are unplanned emergent properties, that emerge as a consequence of interdependent interactions within networks, between networks and between networks and the external political, social and economic contexts in which they are embedded. Significantly, system problems are not caused by any single infrastructure sector operating in isolation, and likewise cannot be resolved in isolation from the wider systemic context. Therefore, the root causes of system problems are most effectively diagnosed collaboratively at the system level, and are

best managed collaboratively at the system level, using a portfolio of systemically targeted actions that address systemic root causes rather than sectoral symptoms. (Dolan et al., 2016; Dolan and Cosgrave, 2016; Dolan and Hiteva, 2017).

Furthermore, system problems, if not prioritised, can jeopardise the achievement of all other long-term strategic priorities. Therefore, infrastructure needs assessment and decision making must be systemic in scope, if systemic problems are to be managed as effectively as possible. System Problems become Systemic (system health) Priorities when the system as currently configured and/or operated is vulnerable to a systemic problem which if not addressed has the potential to jeopardise the achievement of all other long-term priorities.

Therefore, any methodology for the assessment of infrastructure need, must include processes to identify systemic problems, improve understanding of these, and diagnose whether a system problem should be managed as a systemic priority. Furthermore, it is necessary to evaluate the impact of any recommended change to the infrastructure system on systemic priorities. Table 2 proposes 4 steps to put Stage 2 into practise.

3.3 Stage 3: Evaluate system performance

Stage 3 aligns with the Strategic Need Assessment Principle: *Whole system performance evaluation requires a suite of performance indicators (PI) covering Technical PI, Quantity PI, Outcome Oriented PI, System Health PI*

To fully understand system performance, it is necessary to evaluate performance from a range of different perspectives using a suite of Technical, Quantity, Outcome Oriented, System Health performance indicators (Dolan, In Press; Dolan et al., 2016). As a suite of performance

indicators, these four performance indicator types provide complementary insights and enable a meaningful assessment of whole system performance.

Indicators of Technical Performance (Technical PI): have the purpose of measuring and providing insight into real time performance, and are typically used at a tactical or operational level by infrastructure operators to inform real-time and short-term operating decisions and ensure an asset, component or process operates as efficiently (and effectively) as possible. Technical PI for a system component are typically fixed in line with technical specifications (typically those expected and/or designed for when the system component was commissioned) and typically remain constant, over the lifecycle of an infrastructure asset or system component.

Indicators of Quantity of Provision (Quantity PI): focus mainly on measuring either inputs or outputs. Quantity PI enable evaluation of whether current provision (supply) is sufficient to meet demand. Additionally, Quantity PI can be combined with projections of future demand to assess whether the current infrastructure capacity will be sufficient to meet future demand.

Outcome-oriented performance indicators (Outcome-oriented PI): are a form of strategic performance indicator directly aligned with one or more ‘desired outcome’ that infrastructure is expected to enable (Carhart et al., 2016; Dolan et al., 2016)

Indicators of systemic priorities (System health PI): are a form of outcome-oriented PI aligned not with desired outcomes but with system health priorities.

Table 3 proposes 4 steps to put Stage 3 into practise.

3.4 Stage 4: Assess performance gaps and diagnose infrastructure needs

Stage 4 aligns with the Strategic Need Assessment Principle: *Performance Gaps between expected and actual system performance can diagnose 4 types of infrastructure needs (maintenance/renewal, Quantity of provision, Alignment, System Health)*

An Infrastructure system is 'fit for purpose' if it enables all the desired outcomes expected of it, and operates without performance gaps. An infrastructure system need exists in any situation where there is a performance gap between actual and expected system performance. Infrastructure need can be diagnosed through analysis of performance gaps using the 4 performance indicator types introduced in Stage 3. A complete assessment of infrastructure need must include evaluation of 4 different types of infrastructure need:

Renewal or Maintenance Need – This need type can be diagnosed by identifying technical performance gaps. This need type arises where one or more component of an infrastructure asset or system is no longer performing in line with the initial technical specification of the component.

Quantity of Provision Need - This need type can be diagnosed by identifying quantity performance gaps. This need type arises where the demand (expectation) for an output or service supplied by the infrastructure system is greater than the supply capacity of the system (actual) for that output or service. Quantity Need can take two forms (i) Current - where current demand is greater than supply or (ii) Predicted Future - where future demand is predicted to exceed supply capacity in the future.

Outcome-oriented or alignment need – This need type can be diagnosed by identifying alignment performance gaps. This need type emerges where *actual* system performance is no longer aligned with the desired outcomes *expected* by society. In these cases, expected outcomes are not 100% satisfied because the infrastructure is not capable of enabling the desired outcomes as currently expressed.

System Health Need – This need type can be diagnosed by identifying system health performance gaps. This need type emerges when the system as currently configured and/or operated is vulnerable to an emergent system problem, which if not addressed has the potential to jeopardise the achievement of all other long-term priorities.

Table 4 proposes 4 steps to put Stage 4 into practise.

3.5 Stage 5: Frame infrastructure need as sector, solution and technology neutral

Stage 5 aligns with the Strategic Need Assessment Principle: *Need requires sector, solution and technology neutral framing.*

At stage 1, it was stated that a systemic vision requires certain characteristics if it is to support the infrastructure need assessment framework in Figure 1. Similarly, any statement of infrastructure need diagnosed through application of Figure 1 must be: (i) Sector neutral, not aligned with a specific infrastructure sector; (ii) Solution neutral, not aligned with any specific solution or mode of delivery); (iii) Technology neutral, not aligned with the incumbent or any other technology. Neutral framing of the strategic vision at Stage 1, aims to avoid bias or anchoring being introduced into the need assessment. Stage 5 is intended to provide quality

control to ensure this is the case for statements of infrastructure need diagnosed through application of Figure 1. Table 5 proposes 2 steps to put Stage 5 into practise.

3.6 Stage 6: Systemic exploration of potential options

Stage 6 aligns with the Strategic Need Assessment Principle: *A collaborative system-wide process is needed to identify options to address need (conversion of need into solution is non-trivial)*; and *Options can include any intentional change to any component of the dynamic context in which an infrastructure system operates.*

In an interdependent context, any intentional change to any of the contextual factors that characterise the broader external context within in which an infrastructure system is embedded (i.e. social, political, economic ,regulatory, financial, legal, environmental, local, global, spatial and temporal) can be used as a strategy to address an infrastructure need (Dolan and Hiteva, 2017). However, conventional approaches often focus primarily on implementing tried and tested sector level technical fixes (typically engineered solutions) in response to performance gaps observed at the sector level, with little reference to the possible systemic root causes of the performance gap observed.

It follows, little if any attention is given to (i) understanding the performance gap as a symptom of a broader system-wide problem (ii) the identification of common needs that span multiple sectors, or (iii) the opportunity for innovative solutions to be sourced from outside of sector. Therefore, it is important to break the implicit connection between need and solution assumed in many conventional approaches to infrastructure decision making, and acknowledge that the potential option space is significantly broader than that traditionally considered.

Options to address a need can be based on: a portfolio of responses; targeted actions in other Infrastructure sectors; targeted change to any interdependent element of the broader system; adopting best practice approaches from elsewhere in the infrastructure system, or from outside the infrastructure system; innovative business models that deliver services in non-traditional ways; innovative solutions enabled by digital technologies, or problem avoidance based on understanding the root cause of the observed problem. Stage 6 complements step 1.3 of stage 1 (Table 1), and step 5.1 of Stage 5 (Table 5) on the neutral framing of desired outcomes and infrastructure needs, by explicitly focusing on processes to broaden the option space considered in response to statements of infrastructure need. Table 6 proposes 2 steps to put Stage 6 into practise.

3.7 Stage 7: Define and apply selection criteria

Stage 7 aligns with the Strategic Need Assessment Principle: *Clearly defined outcome-linked selection criteria and system health selection criteria are needed to evaluate the relative merits of different options*

Successful implementation of Stage 6 will increase the number and diversity of options proposed in response to any infrastructure need. A transparent set of methodologies to consistently evaluate the relative merits of different options against the desired outcomes and systemic priorities identified in stages 1 and 2 is required. It is proposed that to do this outcome-linked selection criteria are developed from the desired outcomes identified in the systemic vision (Table 1 steps 1.4 and 1.5) and systemic priority linked selection criteria are

developed from the system health priorities identified at Stage 2 (Table 2 step 2.3). Table 7 gives an overview of what is needed.

3.8 Stage 8: Publish to infrastructure project pipeline

Stage 8 aligns with the Strategic Need Assessment Principle: *Needs Assessment Outputs must be clearly linked to established plans.* Table 8 gives an overview of what is needed.

3.9 Stage 9: Regular review

Stage 9 aligns with the Strategic Need Assessment Principle: *Regular review of desired outcomes, and need assessment outputs, underpins the validity of the needs assessment*

4. Conclusions and recommendations

This Paper summarised the methodological need for and developed a systemic, collaborative, transparent, structured and flexible Framework for infrastructure need assessment and decision making (Figure 1). The Framework integrates a set of strategic need assessment principles into a 9 Stage infrastructure need assessment process (Figure 1). Steps to put each stage into practise were proposed in Tables 1-9.

This Framework (Figure 1) includes a number of features absent in other need assessment processes, specifically:

- To make the rationale underpinning each Stage transparent and defensible, the Framework is built on a set of strategic need assessment principles
- The Framework explicitly aligns infrastructure need assessment with the desired outcomes infrastructure systems are expected to enable

- The Framework explicitly incorporates underlying systemic priorities, such as resilience, which if not addressed can adversely affect system performance.
- The Framework prescribes evaluation of infrastructure system performance from four complementary perspectives, and the diagnosis of four different types of infrastructure need.
- All stages of the Framework are sector neutral. This supports a systemic need assessment capable of identifying needs that are common across multiple sectors, diagnosing the root causes of these needs, and selecting the systemically most effective options to treat underlying need at the system level rather than targeting need symptoms at sector level.
- All stages of the Framework are solution and technology neutral. The aim is to enable infrastructure need to be stated in terms independent of any specific solution or technology. Thus, supporting identification of potential options from a much broader option space than that traditionally considered
- The need assessment Framework requires explicit definition of outcome-linked and system priority-linked selection criteria as part of an objective process to evaluate of the relative merits of possible options against transparent selection-criteria.

It is recommended that the Framework (Figure 1) be used for one of three purposes. (i) to conduct an infrastructure need assessment. (ii) to inform the design of infrastructure needs assessment methodology. (iii) to support critical evaluation, review and refinement of established need assessment methodologies.

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Table 1. Overview of proposed steps and actions to implement Stage 1

Step	Overview	Potential Benefit(s)
1.1. Identify Desired Outcomes (expectations)	A process to engage citizens, communities, industry, investors, government and other interested parties in identification of the desired outcomes, they expect infrastructure to play a role in enabling	An accurate and inclusive representation of expectations of infrastructure system
1.2. Clarify and Structure Desired Outcomes	A process to enable in-depth discussion, analysis, visualisation and structured mapping of the desired outcomes and to identified through 1.1.	A set of well structured, unambiguous, mutually understood and accepted desired outcomes.
1.3. Frame Desired Outcomes in Neutral Terms	A process to remove any sector, technology or solution specific terminology from the framing of desired outcomes.	Systemic, unbiased framing not anchored toward specific solutions or technologies
1.4. Set Systemic Vision	A process to convert the above into a shared systemic vision.	An aspirational direction of travel against which all subsequent decisions, and evaluations can be justified.
1.5 Define Outcome-linked Selection Criteria	See Step 7.1 in Table 7	See Step 7.1 in Table 7

Table 2. Overview of proposed steps and actions to implement Stage 2

Step	Overview	Potential Benefit(s)
2.1 Identify system Problems	A process to identify current system problems	Greater awareness of system problems
2.2 Analyse interdependent origins of system problems	A process to analyse system interdependencies with a view to understanding the origin of system problems	In-depth understanding of root causes of, and systemic resilience, to system problems
2.3 State Systemic (System Health) Priorities	Based on the above state systemic (system health) priorities that must be addressed or alleviated as part of needs assessment	A clearly framed set of priorities for infrastructure decision making
2.4 Define System Health Priority-Linked selection criteria	See 7.2	See 7.2

Table 3. Overview of proposed steps and actions to implement Stage 3

Step	Overview	Potential Benefit(s)
3.1. Select Indicators of Technical Performance (Technical PI)	Collaborate with infrastructure operators to identify available technical PI already in use, which can be employed for needs assessment purposes, and which elements of technical performance require additional indicators	A suite of performance indicators to inform analysis of actual system performance related to technical, quantity, alignment and system health. A foundation for the performance gap analysis proposed in stage 4
3.2 Select Indicators of Quantity of Provision (Quantity PI)	Develop a set of Quantity PI for national infrastructure to enable evaluation of whether current provision (supply) is sufficient to meet demand.	
3.3 Develop Outcome-oriented performance indicators (Alignment PI)	Apply the outcome-oriented performance indicator process proposed in (Carhart et al., 2016; Dolan et al., 2016) to develop a set of performance indicators identified in part 1.	
3.4 Develop Indicators of System Health (system health PI)	Refine the process used in 2.3 to create outcome-oriented performance indicators for the systemic (system health) priorities identified in part 1	

Table 4. Overview of proposed steps and actions to implement Stage 4

Step	Overview	Potential Benefit(s)
4.1 Identify Technical Performance Gaps	A process to identify components of an infrastructure asset or system that are not performing to the technical specifications they were designed to meet or to the technical specification expected by the operator (Technical Performance Gaps)	
4.2 Identify Current Quantity Performance Gaps	A process to identify any situation where the demand (expectation) for an output or service supplied by the infrastructure system is currently greater than the supply capacity of the system (actual) for that output or service.	
4.3 Identify Projected Future Quantity Performance Gaps	As above, but based on scenarios linked to drivers of changing demand, drivers of changes to current supply capacity, to identify under under what plausible future scenarios the demand (expectation) for an output or service supplied by the infrastructure system is projected to be greater than the supply capacity of the system (actual) for that output or service.	
4.4 Identify Outcome Oriented Performance Gaps	A process to identify any situation where actual system performance is no longer aligned with the desired outcomes expected by society. (Outcome-oriented performance gaps).	
4.5 Identify System Health Performance Gaps	A three parts process to: i) identify where the system as currently configured and/or operated system is vulnerable to System problems ii) Assess whether system problems identified in the previous assessment have changed in status iii) assess whether system problems or vulnerabilities will emerge as a consequence of planned changes to current patterns of system use, or change to external context (i.e. what system needs must we address if system failure is not to jeopardise the long term realisation of the outcomes we expect?	

Table 5. Overview of proposed steps and actions to implement Stage 5

Step	Overview	Potential Benefit(s)
5.1 Frame Performance Gaps identified as option, sector, technology neutral needs	A process to collate performance gaps and ensure framing is sector, solution and technology neutral terms, and reframe need wherever necessary	Framing need in neutral terms enables (i) the identification of common needs that span multiple sectors, and (ii) the opportunity for innovative solutions to be considered
5.2 Root Cause Analysis	A process to analyse and diagnose the root causes of the performance gaps identified, and to analyse whether performance gaps can be clustered as 'symptoms' of a shared systemic common cause.	Develop deeper understanding of the systemic causes of performance gaps

Table 6. Overview of proposed steps and actions to implement Stage 6

Step	Overview	Potential Benefit(s)
6.1 Publish list of neutrally framed infrastructure needs (infrastructure need pipeline)	Regularly publishing the neutrally framed statements of infrastructure needs identified at Stage 5 (Table 5 step 5.1). Promote this to create transparency and clearly signal the infrastructure needs where action is required.	Broadening the option space, creates a marketplace to engage with possible solution providers, greatly increasing the potential for innovative options to be identified
6.2 Invite Option Proposals	Invite the proposal of options aligned to the infrastructure needs published in 6.1. Make the process accessible to non-traditional actors and invite cross sectoral solutions,	
6.3 Cross Sectoral and Public Engagement	Develop a suite of processes to drive engagement around the list of infrastructure needs pipeline (step 6.1) and support the submission of option proposals.	

Table 7. Overview of proposed steps and actions to implement Stage 7

Step	Overview	Potential Benefit(s)
7.1. Define Outcome-linked Selection Criteria	A process to convert the desired outcomes identified in step 1.3 (Table 1) into a set of sector, solution, technology neutral outcome-linked selection criteria suitable for use as i) guidance for those proposing options in stage 6 and ii) for evaluation of Options identified in stage 6	Establishing a clear link between the systemic vision, system priorities and decisions making processes in this way enables transparent defensible decision making to enable expectations and manage systemic priorities. It also provides Needs Assessment recommendations with credibility
7.2 Define System Health Priority-Linked selection criteria	A process to convert the systemic (system health) priorities identified in stage 2 (step 2.3, Table 2) into a set of systemic priority linked selection criteria	
7.3 Publish Selection Criteria	Publish the decision criteria identified in 7.1 and 7.2 alongside the infrastructure need pipeline in step 6.1.	
7.3 Apply Selection Criteria	A process to apply the selection criteria identified in steps 7.1 and 7.2 to evaluate which of the options identified in stage 6 are most fit for purpose.	

Table 8. Overview of proposed steps and actions to implement Stage 8

Step	Overview	Potential Benefit(s)
8.1 Publish the Decisions made in step 7.3 (Table 7)	A process to link needs assessment decisions to the established portfolio of planned actions, and delivery plans	Create certainty for investors and other infrastructure practitioners

Table 9. Overview of proposed steps and actions to implement Stage 9

Step	Overview	Potential Benefit(s)
9.1 Repeat stages 1-8 every 5 years	Follow stages 1-8 of this process for every subsequent National Infrastructure Assessment (NIA). Do not skip steps 1 or 2	Regular review ensures the credibility of recommendations from the need assessment process.
9.2 Review Needs Pipeline every 5 years	A process to review whether a Need put into the pipeline 4.1 at the previous NIA remains fit for purpose	Regular review of pipeline needs and pipeline projects is needed to ensure that need and projects remain fit for purpose in the period between recommendation and implementation.
9.3 Review Projects in Pipeline every 10 years	A process to review whether a project added to the project pipeline over 10 years ago remains fit for purpose.	

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Figure 1. A systemic, collaborative, transparent, structured and flexible framework for infrastructure need assessment and decision making