ICIF & iBUILD

A Critique of Current Infrastructure Performance Indicators:

Towards Best Practice

MAY 2015

Executive Summary

This document is an interim summary of the findings of an ongoing collaborative research exercise between the ICIF and iBUILD projects. It sets out the current findings of these two projects regarding infrastructure performance indicators, and outlines a strategy to take this forward to develop a framework for the design and implementation of an innovative approach to infrastructure performance indicators.

The first section of the body of this summary report provides an overview of the UK's current infrastructure performance indicators as reported annually in the National Infrastructure Plan. The underlying data from which the indicators are compiled pose a number of relatively standard concerns which must be acknowledged. The underlying data is not recorded and gathered specifically for the purpose of providing national infrastructure performance indicators. There is no guarantee that any of these organisations will continue to collect this data, make it available in line with the indicators publication cycles, or make it available. Further to these points the critique highlights two significant issues: Firstly **the current performance indicator's purpose is unclear** and secondly, they **are largely disconnected from the wider context of the societal needs fulfilled by infrastructure**.

In addition to these there are issues relating to the appropriate **geographic scale**. The indicators are only reported at national level meaning underperforming regions requiring attention could be masked by those performing well. This relates to more general issues concerning the **aggregation of data** meaning that volatility and variance in other dimensions can also be missed.

The **normalisation of data** to 100, while allowing for comparisons between sectors, can reduce the overall transparency of the indicator but more problematic is that fact that the current indicators are **backwards looking to 2005**. Building on the lack of purpose and inherently backwards looking view, **there is no link between what is being measured and the future plans and visions for infrastructure.** The result of this is that **the value of the current indicators in informing strategic decision making is limited**.

The second section looks at the use and development of infrastructure performance indicators around the world. This concludes that the UK (along with others such as Australia and New Zealand) is at the forefront of reconsidering what indicators have the potential to deliver and how they can both inform effective strategies and help steer their realisation. The international developments complement findings elsewhere in this report – particularly in that **indicators should be: outcome-based, related to purpose, iterative and SMART**. In New Zealand in particular this has initiated a considerable process of stakeholder engagement in order to better understand the purposes of infrastructure systems, and how indicators could best help those tasked with managing them. The UK can draw-upon international evidence in principle, but must be mindful that UK infrastructure has a complex and challenging legacy and landscape which makes it unique.

The third section describes the findings of a stakeholder engagement exercise on the challenges of the current indicators and requirements of useful indicators. The point was strongly reiterated that **there is uncertainty over the purpose of the Indicators which stems from a lack of shared vision for national infrastructure.** It was also observed that the indicators **do not reveal the gap between what exists and what is desired**. Furthermore, they can be **difficult to interpret** and overly constrained in practice by regulatory time horizons. The national indicators are **not connected to adaptation**, and they are **not felt to be aligned with existing industry indicators**.

The third session of the workshop investigated the characteristics of innovative indicators. Section 4 of this report builds on the outputs of that session, along with a reflection on Sections 1 and 2 to produce a list of transferable requirements of good, innovative indicators. For example they need to:

- **Relate to public expectations and needs;**
- **Relate to controllable parameters;**
- **Take account of the dynamics of systems, including the behaviours of actors in the system;**
- **Identify Opportunities;**
- **Account for different audiences**
- **Have sufficient scope;**
- **Communicate uncertainty;**
- **Account for the whole system and whole lifecycle;**
- **Account for the wider context.**

The final section summarises the conclusions from each of the preceding sections setting out the challenges for the development of the indicators and how the development of a framework for infrastructure performance indicators could be taken forward to address these challenges and facilitate the development of indicators which better serve the needs of those making decisions about the future of the UK's infrastructure system.

It concludes that a complementary approach to infrastructure performance indicators is required in the UK to the existing methods through which performance is monitored. This approach must start with a long-term strategic vision for the UK's infrastructure based on stakeholder needs. Performance should be measured against the achievement of valued outcomes of infrastructure systems, in other words the ways in which infrastructure systems facilitate the achievement of stakeholder needs. It is likely that these outcomes will require the interaction of assets and services from multiple infrastructure sectors. It is therefore no longer sufficient to monitor performance solely on an infrastructure-by-infrastructure basis. Performance in one infrastructure can influence that in others, and the new indicators must be designed such that they recognise this. So, it will be necessary to trace interdependencies across infrastructures to provide clarity on the causality behind any given indicator.

Scale is also an important issue to consider in arriving at indicators that are of use nationally, regionally and locally. Current indicators sometimes fail to provide insights into performance at

the level of granularity necessary to support effective decision-making on the actions required for improvement.

In terms of next steps the report suggests:

- Obtaining an appropriate definition of the systems of interest and identifying the associated stakeholders and audience for the performance indicators.
- Working with the stakeholders to develop the strategic vision for future infrastructure needs with particular attention being paid to the outcomes desired.
- Obtain an appropriate understanding of the how the infrastructure systems interact as a complex whole to deliver the expected outcomes and performance, as well as an understanding of the wider context within which the systems exist.
- Obtain an understanding of the requirements of the intended performance indicators and what information would be of use for them to make the necessary strategic decisions related to achieving the required outcomes.
- Obtain an appropriate understanding of the interdependencies between the performance indicators themselves. Complex systems, or system-of-systems, require indicators which take account of the complexity of the systems they are attempting to monitor.
- Develop a reflective and adaptable process for indicator design is required to cope with the dynamic and uncertain context of required infrastructure outcomes, and therefore of infrastructure performance.
- Draw these strands together into a framework for a meaningful ‘system of indicators’ that captures these issues in a way which is practical, transferable and scalable.

Contents

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Introduction

This document is an interim summary of the findings of an ongoing collaborative research exercise between the ICIF and iBUILD projects. It sets out the current findings of these two projects regarding infrastructure performance indicators, and outlines a strategy to take this forward to develop a framework for the design and implementation of an innovative approach to infrastructure performance indicators.

The Purpose of Indicators

As will be seen through the body of this report understanding "purpose" is a very important concept, yet for infrastructure systems and infrastructure performance indicators it is largely underexplored and under-articulated.

There are two intrinsically linked elements to establishing useful indicators: (a) the purpose of the indicators themselves, and; (b) the purpose of the infrastructure systems they are monitoring.

It is not possible to establish a meaningful set of infrastructure performance indictors without knowing what form and level of performance is required and valued by the clients of the infrastructure systems through which the outcomes are delivered. It is in this sense that the purpose of the infrastructure systems being monitored must be understood. Furthermore, it is not possible to establish a meaningful set of performance indicators without knowing the audience for the indicators and how they intend to use them.

The UK's national infrastructure performance indicators are first presented in the 2011 National Infrastructure Plan [1]. Section 1.11 of this Plan states that its principles are "to maintain the overall performance of the UK's infrastructure over time" and "to address the UK's weaknesses and catch up with the best performers in the world". These principles provide an insight into why it was felt that an awareness of infrastructure performance might be useful. It is less clear how the actual indices were selected, and how these particular dimensions of performance are felt to be meaningful to the quality of infrastructure both in terms of societies use and its international competitiveness.

The 2011 NIP recognises the importance of the World Economic Forum and World Bank's global infrastructure rankings, but are critical of the subjective assessments on which they are based stating "It is important that views on UK infrastructure performance are based, so far as possible, on objective data, rather than anecdote." The 2011 NIP was the first time a set of performance indicators were established based on such objective data.

It is desirable to have robust indicators which can be reliably produced each year, but there is a danger than in designing these they overlook dramatic contextual changes. For example, if the nature of the demand for a particular infrastructure service changes completely, then an indicator that only monitors one aspect of supply may produce an insight of limited value.

The National Infrastructure Plan is often clear about what the purpose of the performance indicators is not. For example Section D of the 2012 National Infrastructure Plan [2] includes the caveats such as:

> "The assessment presented in this document is not meant to supersede or with the Ofcom's role as regulator and competition authority for the UK communications industries nor is it meant to provide any additional targets for the sector."

The 2013 National Infrastructure Plan [3] introduces a slightly different angle to the perceived purpose of the performance indicators. Paragraph 2.29 (p31) states that the indicators "will enable the government to better understand the impact of investment on the overall performance of the UK infrastructure system and networks". Thus there are at least three potential purposes of the current indicators:

1. To monitor whether infrastructure performance levels are, as a minimum, maintained over time;
2. To monitor infrastructure performance levels in relation to other countries;
3. To monitor the impacts of investment.

The 2014 National Infrastructure Plan [4], while not explicit on the issue, implies along the lines of the previous National Infrastructure Plan, that the indicators are related to delivering value for money. This also raises the potential opportunity for the national infrastructure performance indicators to play a larger role in informing the strategy and decisions regarding the future of national infrastructure and its delivery. Achieving this requires a consideration within the indicators of the desired outcomes from national infrastructure, and the sorts of performance that would deliver these outcomes. And although it is undoubtedly important, this goes beyond monitoring against past performance.

The wider literature on performance indicators has identified five general reasons for measuring performance [5]: where have we been; where are we now; where do we want to go; how are we going to get there, and; how will we know when we get there? A review by Behn [6] identifies eight different purposes of performance measurement (largely of individual rather than systems) in the public sector; to evaluate how well the agency is doing; to facilitate control; to budget; to motivate; to promote success; to celebrate success; to learn, and; to improve. Behn also references an earlier list by Hatry [7] which also includes responding to demands for accountability, building trust and supporting strategic planning. The general literature has also suggested such general purposes of performance indicators as "to enable everyone to focus on the key aspects of organizational performance that determine health and success" [8]. It has been suggested that sets of performance indicators are "not only aimed at providing the value of a few ratios, but also all the complementary elements (quality of the data, explanatory factors, context) which are needed in order to make appropriate decisions" [9].

The Organisation for Economic Co-Operation and Development (OECD) defines a Performance Indicator as: "A variable that allows the verification of changes in the development intervention or shows results relative to what was planned." [10], which is also reflected in the cross-

departmental guidance on performance indicators and performance measures from 2001 [11] which describes them as "measures of how well a service is performing against its objectives".

Elsewhere, the process of Performance Measurement is defined as: "A system for assessing performance of development interventions against stated goals" [12]. These definitions all reiterate the importance of understanding the purpose, goals and plans for the systems whose performance is being measured. Bossel's process for developing indicators [12] also highlights the pre-requisite of understanding the complex and dynamic workings of the system itself, the need for indicators to reflect on how well or not needs are being met and the need for wide stakeholder engagement. He refers to the fundamental stakeholder needs as "Orientors" which can include health, security and freedom.

The National Infrastructure Plan refers to the normalised values it reports as "Performance Indicators" and the underlying raw data are referred to as metrics. The implication of the NIP usage is that metrics reflect data specific to a system, while a performance indicator normalises that data to some degree such that it is comparable across very different systems. The indicators in the NIP are benchmarked to the performance levels of 2005, so while they allow for variations to be identified, they do not necessarily show results relative to plans and objectives unless the plans specifically relate to variation from 2005 performance as in (1) identified above for ensuring performance is maintained.

The body of this summary report looks further at infrastructure performance indicators in order to better understand the route towards developing a set which maximise the potential to better inform the future of the UK's infrastructure system, and ensure it continues to deliver the necessary outcomes.

Document Overview

The first section of the body of this summary report provides an overview of the UK's current infrastructure performance indicators as reported annually in the National Infrastructure Plan. It discusses the strengths of reporting these indicators as well as highlighting the identified issues and challenges they present.

The second section looks at the use and development of infrastructure performance indicators around the world, while the third section summarises the conclusions of a consultation with industry practitioners on the requirements of useful indicators.

These first three sections highlight the importance of understanding the purpose(s) of infrastructure performance indicators and also identify a number of attributes of indicators which are perceived to be fit for purpose. These are summarised in Section 4.

The final section summarises the conclusions from each of the preceding sections setting out the challenges for the development of the indicators in terms of a number of important themes, and how the development of a framework for infrastructure performance indicators could be taken forward to address these challenges and facilitate the development of indicators which better serve the needs of those making decisions about the future of the UK's infrastructure system.

Section 1 - National Infrastructure Plan Indicators

This section provides an overview of the current UK Infrastructure Performance Indicators as reported in the 2014 National Infrastructure Plan. It looks briefly at what they measure and how they are reported, before discussing some of the concerns over the underlying data and the challenges the indicators present in their current form.

Description of the Current Indicators

The current set of infrastructure performance indicators reported alongside the UK's National Infrastructure Plan are based on an underlying data-set of quantitative metrics identified from a number of different sources. These include regulatory authorities (Ofgem, Ofcom), the Office of National Statistics, the Environment Agency, the Department of Energy and Climate Change, National Grid and the Organisation for Economic Co-Operation and Development. The underlying data is not reported specifically for use in calculating the performance indicators.

Indicators are reported by sector for: Major Roads, Passenger Rail, Airports, Electricity, Gas, Communications, Waste and Flood Risk Management. For each of these sectors, and where applicable, the indicators attempt to report on performance in six areas: Capacity, access and availability; Asset or capacity utilisation; Service quality and reliability; Asset condition; Safety, and; Efficiency.

The raw data is combined to construct indicators such as 'motorway density in km/million licensed vehicles'. The available and meaningful data used to provide indicators for these areas varies between infrastructure sectors. For example "Service Quality and Reliability" for Passenger Rail is indicated by the "Proportion of trains arriving on time" while for the Gas sector it is indicated by the "Gas delivered by the gas transmission system as a proportion of gas demanded".

For each indicator this raw value is normalised, such that performance against any criteria in 2005 is base-lined to a value of 100. As of the 2014 NIP a value greater than 100 indicates an increase in the measure since 2005 while a value below 100 indicates a decrease in the measure in comparison to 2005. In previous years it was claimed that an increase in value represented an improvement in performance. This is not necessarily the case, and as such it is no longer claimed.

In total 65 performance indicators are calculated across all of the sectors. The indicators for each of the six areas of interest are combined within each sector to give a total index for that sector's performance.

Potential Challenges with Data Underlying Current Indicators

The underlying data from which the indicators are compiled pose a number of relatively standard concerns which must be acknowledged. The underlying data is not recorded and gathered by IUK, and as mentioned above is not collated specifically for the purpose of providing national infrastructure performance indicators. In some instances the data relies on the efforts of third-parties within the relevant industries, beyond those listed above. There is no guarantee that any of these organisations will continue to collect this data or make it available.

There is a risk that the way in which the data is collected and reported may change, while the timing of the data's publication is beyond the control of IUK. This could affect the ability to report consistent indicators to accompany the National Infrastructure Plan in line with its publication cycle.

Gathering and reporting the underlying data is a significant task, and the organisations undertaking this presumably do so because they see value in their efforts. While it would not be possible to mandate the collection of this data for specific use in the NIP (and even if it were this may send out the wrong message regarding the purpose of the indicators) it should be possible to demonstrate the value of the data if the indicators themselves are fit for purpose and provide value to infrastructure stakeholders. This could provide confidence in the continuing availability of the data.

Critique of Current Indicators

In addition to the general issues regarding the underlying data, there are a number of further challenges relating to the structure of the indicators themselves, both individually and collectively. There are two broad and interrelated issues which cut across all of the indicators:

- **The current performance indicator's purpose is unclear**.
  As discussed in the introduction the current indicators do not have a clearly articulated purpose or purposes. Despite the statements in the early National Infrastructure Plans, it is not evident how the performance indicators are intended to inform the actions of any stakeholders. Performance indicators may be used to identify issues with the state of the current systems and direct resources, to measure progress in achieving a goal, to attract investment, to demonstrate success or enforce penalties. Data collected for one purpose is not necessarily appropriate for other purposes. Understanding what performance information infrastructure stakeholders require for the decisions they make is central to moving towards an improved set of indicators.

- **The current performance indicators are largely disconnected from the wider context of the societal needs fulfilled by infrastructure**.
  The current indicators and the values and requirements of society in general are at best loosely coupled. While in some instances it is implied, for the vast majority of the indicators there is no clear link between the data and the direct experienced outcomes of those relying on the infrastructure systems they measure. This may stem from collective uncertainty over these societal needs and how they relate to the infrastructure systems which facilitate their fulfilment. Understanding societal, environmental and economic needs and wants is also important for developing an improved set of indicators.

These points are fundamental as they underpin why the indicators exist. Further to these are a number of structural issues with the indictors which are also of importance to their use and value.

Firstly, there are issues relating to the appropriate **geographic scale**. The indicators are only reported at national level meaning underperforming regions requiring attention could be masked by those performing well. Spatial data and associated local causal factors are lost as the data is aggregated. Reporting at this level affects the degree to which the indicators can be used to

make specific decisions about infrastructure strategy. This relates to more general issues concerning the **aggregation of data**. The aggregation of the data means that volatility and variance in other dimensions can also be missed. This could mean poor performance at certain times or to specific groups could be overlooked.

The **normalisation of data** to 100, while allowing for comparisons between sectors, can reduce the overall transparency of the indicator. A percentage change in some indicators may be more significant than in others. Related to this is the fact that the current indicators are **backwards looking to 2005**. There is no obvious reason why 2005 is the benchmark year against which current performance is judged other than the fact that this was the earliest year that all of the underlying data was available for. The normalisation to 100 masks whether the actual performance in 2005 was adequate, good or poor. Most importantly, placing emphasis on 2005 suggests the infrastructure performance requirements that were relevant then remain relevant today. Such benchmarking to the past only makes sense if all other variables remain constant. In a complex system, with multiple interacting factors, it is not appropriate for all of the indicators, particularly those based on objective measurements, to be benchmarked in this way. There is no guarantee that economic or social requirements of infrastructure haven't outpaced the observed performance. In addition to the disconnect from societal needs then, the **exogenous drivers are not explicit or not taken into account at all**.

The disconnect from the wider context, from societal needs and from exogenous drivers of performance means that **the underlying logic of the indicators is not always clear**. Decisions have to be made about the presentation of the data, and a balance is required between complexity and usability, but this does not preclude the consideration of the fundamental causal systems which sit underneath the indicators. It is necessary to understand the complex systems being monitored in order to appropriately assess performance. Overlooking the complex relationships in the system to produce overly-simplified indicators creates a **risk of perverse incentives**. This can also be mitigated with a clear understanding of the indicators purpose.

Building on the lack of purpose and inherently backwards looking view, **there is no link between what is being measured and the future plans and visions for infrastructure.** There is no obvious articulation of what this vision is, what the future expected requirements are, and therefore whether performance is heading towards or away from these requirements. This is of course linked to an understanding of the societal and economic requirements, and the infrastructure performance levels that would fulfil them.

The result of this is that **the value of the current indicators in informing strategic decision making is limited**. This is a missed opportunity as the wealth of data available could provide evidence to inform investment and planning decisions in such a way as to enhance the efficiency and effectiveness of infrastructure projects, better meeting the needs of society, and as a result improving both societal welfare and economic performance.

Section 2 - International Best Practise

This section looks at some of the efforts around the globe to monitor infrastructure performance. It begins with a consideration of benchmarking for international comparison before looking at the way in which those involved in the governance of infrastructure within individual nations recently have attempted to develop the ways in which they measure its performance. A slightly expanded version of this review can be found in Appendix A.

International Benchmarking

The World Economic Forum (WEF) produces a ranking of countries based on a 'Global Competitiveness Index'. The most recent assessment, which focuses on transport, electricity and telephony infrastructure, ranks the UK 10th for Infrastructure out of 144 countries [13]. Data is taken from a number of sources, including subjective assessments coming from the WEF's annual Executive Opinion Survey. The assessment of perceived quality is arguably aligned with socio-economic requirements, but are a snapshot of the present and do not reveal trends or help inform planning for future states, nor can perceptions between countries be compared in a meaningful way. Similarly, The World Bank produce a global ranking based on their Logistics Performance Index [14]. This focuses on international trade, and in doing so attempts to assess the physical and service components of trade related infrastructures. It is based on a survey of logistics professionals and provides a view of those within the country and of the global community. In 2014 the UK was ranked 4th overall, but 6th in terms of the quality and cost of physical infrastructure associated with trade (roads, ports, airports etc.).

While these rankings are important, they give very broad overviews of the UK's international position and the measures on which the success of its infrastructure is judged from an internationally perspective and provide little guidance on how the UK can improve its infrastructure, effectively, sustainably and efficiently. The degree to which they should influence the formation of national indicators is limited and would depend on the purpose of the indicator, for example a different set of indicators would be necessary to improve perception compared with attracting investment.

National Infrastructure Performance Indicators

Those tasked with the governance of national infrastructure systems around the world are investigating the ways in which the sort of information that is increasingly available can be best structured and used in order to improve the state of their infrastructure, and ensure it continues to meet economic and societal needs. The rest of this section provides an overview of these studies and activities. Among other things, these provide an insight into the characteristics and structure of useful indicators.

OECD

The OECD [15] developed a framework for characterising infrastructure performance indicators based on model of the *pressures* exerted on a system that affect its quality or *state*, and the *responses* of society to this. This model highlights cause and effect relationships, benefits from being easy to understand, neutral as to whether changes are positive or negative, and flexible.

A more recent study compared options for benchmarking infrastructure performance: based on growth contributions, performance by cost-benefit analysis of new projects and social efficiency of service provision.

New Zealand

New Zealand's National Infrastructure Unit are developing a framework for infrastructure performance indicators [16] that is motivated by a vision that "*by 2030 New Zealand's infrastructure is resilient and coordinated and contributes to increased economic growth and better quality of life*". This is to be achieved through two objectives: (i) better use of existing infrastructure and (ii) better allocation of new investment (parallel to Infrastructure UK's objective to co-ordinate the planning and prioritisation of investment in infrastructure in order to achieve greater value). The report advises that, "*investment in new infrastructure, as with the management of existing assets, must focus on delivering services and outcomes rather than just building assets*" hence relating to the welfare emergent from infrastructure (drawing upon the New Zealand Treasury Living Standards Framework which uses capital stocks (financial & physical, human, social and natural) and welfare flows (e.g. income, employment, freedom, amenities)).

The framework sets out two types of infrastructure indicator: *Activity/Stock Indicators* - these highlight the current situation and forecasted future need, but do not relate directly to emergent welfare and may be ambiguous over whether more is better; *Performance Indicators* - these measure productivity and efficiency and are more closely linked to welfare. In addition to these two types, it also adopts the Pressure-State-Response (PSR) model for classifying indicators set out in the OECD's conceptual framework (see above) and outline generic examples of pressure indicators applicable to all infrastructure sectors, e.g. demand – population growth rates; supply – climate change.

The framework also sets out a list of criteria for selecting infrastructure performance indicators: usefulness and balance, ease of calculation, data availability, proportionate representation of different viewpoints, alignment with government objectives, policy relevance, industry relevance, comparability across sectors, comparability across jurisdictions, cost effectiveness and international practice. The report also stresses that it is important to consider whether the indicators are best measured relative to others rather than as absolute or single data points, and to aim where possible for consistence in reference units. A further lesson from this framework is that scale and location are important, and nationally aggregated indicators could obscure issues.

Australia

Sharpe et al [17] considered the potential role for infrastructure performance indicators in light of the "*increasing complexity in investment decision making, and increased challenges in prioritising that investment*' and the reality that '*infrastructure systems serving modern economies are highly complex, highly interconnected, and often highly interactive*." This work, therefore, is highly relevant because its purpose is similar to that of Infrastructure UK, and its starting point is infrastructure as a complex adaptive system.

A distinction between four indicator types is proposed: (i) inputs (e.g. level of capital investment) (ii) outputs (infrastructure built) (iii) outcomes (the stated reasons for the output) (iv) impacts (factors occurring as an indirect result of the ii and iii). They argue that service performance is critical, if agencies are to be better equipped to prioritise investment and understand how the outcomes of that investment are valued by the consumer. Therefore performance indicator sets should be designed to measure outcomes: ***Reliability:*** the ability of the infrastructure to meet normal or current demand (e.g. proportion of trains running on time, road congestion in response to normal traffic demand); ***Stability:*** the consistency of the infrastructure service provided (e.g. drops in water pressure, surges in electricity); ***Safety:*** the safeness of the infrastructure for those who use it (e.g. microbial levels in water, frequency of road accidents); ***Resilience:*** the ability of the infrastructure to respond in the event of unusual demand (e.g. road congestion in response to unusual event, internet download speeds).

Furthermore, this work proposes performance indicators should be SMART: specific: unambiguous, and a direct measure of performance that cannot be confounded by other factors; measurable: a quantitative (not qualitative) measure of performance, that is ideally already collected (and public); attributable: measures performance that is, ideally, directly attributable to the specific infrastructure network; results-oriented: measures infrastructure outcomes, not inputs or outputs; trackable: can be expected to change over time as performance improves or worsens.

USA

A 1995 report from the US National Research Council [18] entitled "*Measuring and Improving Infrastructure Performance*" sets out a large number of indicators in three categories: efficiency, effectiveness and cost and defines infrastructure as proving goods and services that '*support other economic and social activities, a safe and healthful environment, and a sustainably high quality of life'.* The study found that single measures of performance were inadequate, instead multiple measures are required to reflect the multiple "community-objectives" fulfilled by infrastructure systems; objectives they note, which may be in contradiction with one another. Furthermore, performance measurements should be taken "in the context of social objectives and the multiplicity of stakeholders who use and are affected by infrastructure systems". Oswald et al [19] describe the US Chamber of Commerce's development of a national performance index which uses the Analytical Hierarchy Process to compare performance indicator across different infrastructure types. The research uses the Analytical Hierarchy Process (AHP) to compare performance indicator across different infrastructure types. Their method is based on publically available quantitative data sources, and draws on earlier work on indicators for sustainable development. There is a rigorous and robust framework for selecting and managing the data, but it only looks at the current performance and compares it to the past.

Sector Performance Indicators

As well as international benchmarking and national level performance indicators, individual infrastructure sectors are pursuing frameworks though which to better design and use performance data.

ACI 2012 Guide to Airport Performance Measures

The Airports Council International (ACI) Guide [20] to airport performance measures highlights the important distinction between (i) internal/self-benchmarking (where an airport compares its

performance with itself over time); and (ii) external/peer benchmarking (where an airport compares its performance against other airports). This applies more generally to any infrastructure context and highlights the need to state the purpose of performance indicators before designing them because, purpose influences what data you collect. The report illustrates a step wise approach whereby key performance areas are firstly identified for the infrastructure in question, secondly at least one performance indicator (PI) is defined within each KPA thirdly the PIs are used to evaluate and improve performance and finally KPAs and PIs are iterated through consultations with users and other interested parties.

Conclusions from International Best Practice

It can be concluded that the UK (along with others such as Australia and New Zealand) is making advances in terms of reconsidering what indicators have the potential to deliver and how they can both inform effective strategies and help steer their realisation. Although other countries looked at different aspects and contexts for deriving infrastructure performance indicators lessons can also be learned from developments within individual infrastructure sectors such as airports and railways. These developments complement findings elsewhere in this report – particularly in that indicators should be: outcome-based, related to purpose, iterative and smart. In New Zealand in particular this has initiated a considerable process of stakeholder engagement in order to better understand the purposes of infrastructure systems, and how indicators could best help those tasked with managing them. The UK can draw-upon international evidence in principle, but must be mindful that UK infrastructure has a complex and challenging legacy and landscape which makes it unique.

Section 3 - Practitioner Consultation

The Infrastructure Performance Indicators reported each year in the UK National Infrastructure Plan are intended to provide a source of information for infrastructure users, planners, policy-makers and investors. There is a perceived need to establish whether these Infrastructure Performance Indicators are fit for purpose, and in particular whether they offer value to the relevant stakeholders in terms of their decision making about the future of UK infrastructure.

This report records the output of a workshop held on **Monday 2nd of March 2015** at University College London. The purpose of this workshop was to improve the collective understanding of what infrastructure stakeholders need from performance indicators in order to make decisions about the future of infrastructure.

The workshop was attended by 29 infrastructure stakeholders from industry and academia, including those involved in financing, delivery, operation and regulation. The road, rail, ports, construction and energy sectors were represented along with experts in economic, climate and sustainability issues affecting infrastructure systems.

The workshop was split into four discussion sessions, interspersed with relevant talks by infrastructure experts. The first of the discussion sessions looked at understanding the value of infrastructure from the end-user perspective. This led to the identification of 12 broad variables thought to be valued by end-users: communications, anonymity and un-invasiveness, availability, safety, reliability, sustainability, inclusivity, flexibility, low-impact, affordability, comfort, and choice. These all need to be interpreted in the context of a multitude of individual and societal purposes.

The second session enquired about the current usage of infrastructure performance indicators and identified several challenges. It was strongly felt that **there is uncertainty over the purpose of the Indicators which stems from a lack of shared vision for national infrastructure.**

In addition to this the Indicators are seen as a **backwards looking statement of observable fact, which can limit innovation** whereas there is a **need for the indicators to look forwards**. Related to this was the observation that they **do not reveal the gap between what exists and what is desired**. Furthermore, the indicators can be **difficult to interpret** and overly constrained in practice by regulatory time horizons. The national indicators are **not connected to adaptation**, and they are **not felt to be aligned with existing industry indicators**.

Furthermore **the presentation of the data, its granulation, aggregation and normalisation, may limit its benefits** and little consideration has been given to the **perverse incentives** they may cause.

The third session investigated the characteristics of innovative indicators, suggesting that they need to:

- **Relate to public expectations and needs;**
- **Relate to controllable parameters;**
- **Take account of the dynamics of systems, including the behaviours of actors in the system;**
- **Acknowledge different types of indicators, the influence of standards and their origins;**
- **Allow for intelligent design;**
- **Identify Opportunities;**
- **Have purpose and vision;**
- **Account for different audiences**
- **Have sufficient scope;**
- **Communicate uncertainty;**
- **Account for the whole system and whole lifecycle;**
- **Account for the wider context.**

Additionally, good indicators need to be:

- **Joined-Up;**
- **Transparent;**
- **Flexible;**
- **Forward Looking;**
- **Outcome Focused.**

The final session looked at indicators from the perspective of the whole infrastructure system, asking whether there were performance indicators from one sector that would be valuable to another, or whether there were performance indicators that only make sense at the whole system level, as opposed to individual sectors. This revealed several additional factors which are important when considering the design of national infrastructure performance indicators. The **level of the system** is important, as is the **temporal** and **geographic scale** of the data.

It is important to take into account the **audience for the data** and **purpose of sharing the information**. A lack of shared understanding of purpose causes confusion. For example, sharing data can be very important in event recovery. It is also useful for **understanding wider benefits and impacts** of decisions and actions taken with the whole infrastructure system.

Section 4 - The Requirements of Useful Indicators

This section synthesises the critique of current infrastructure indicators (Section 1), the review of best practise (Section 2) and the findings from the stakeholder engagement (Section 3) to present a general list of requirements which meaningful performance indicators for infrastructure should be designed to meet (Table 1).

Table 1 - The Requirements of Useful Indicators

Characteristic	Description
Meaningful	Indicators should be easy to interpret and unambiguous
Purposeful	Designed for an explicitly stated purpose
Strategic	Designed to provide meaningful feedback on progress toward strategic outcomes
Outcome-focused	Be more than indicators of stock/activity or technical performance, provide meaningful feedback on progress toward strategic outcomes. (Strategic outcomes should be linked to welfare as well as economic growth)
Future-focused	Designed to measure elements of performance relevant to the future of the infrastructure system in question
Systemic	The purpose of indicators needs to be clearly linked to the system they are measuring, which may cross sector boundaries. Each performance indicator should be part of a meaningful multi-dimensional set that collectively gives a view of system performance. Indicators should not be used in isolation for the purpose of optimising individual system elements.
Transparent	The underlying data source(s) for any indicator need to be declared as do methods and justifications for any calculation/aggregation/normalisation performed to create the indicator. Where an indicator is aggregated from multiple data sources, it should be published alongside the indicators that comprise it.
Relevant Presentation	Relevant information can be hidden by average or normalised values. A range of formats should be considered for publishing indicators such that the indicator meaningful communicates behaviour linked to its strategic purpose.
Geographical Scale	Indicators should be presented on a geographical scale relevant to decision makers. Where national data is published, appropriate regional data should be made available.
Reviewed Frequently	Indicators should be frequently reviewed in terms of whether they remain fit for purpose, and aligned with strategic outcomes. Indicators no longer aligned with these elements should be removed or adapted to ensure the indicator remains meaningful
Unconstrained by Data	Strategic elements of performance or outcomes that need to be measured should be identified before issues of data availability are considered. Where data is unavailable clear justification for the use of alternative metrics should be provided.
Objective and Neutral	Indicators should not create lock-in to particular infrastructure solutions or technologies
Encourage Innovation	Send clear signals to infrastructure industries by being consistent with strategic outcomes
Reflect Decision-Maker's Needs	The performance indicators should provide relevant information to stakeholder groups who may use them.
Capture Multiple Stakeholder Perspectives	Indicators should provide measures of performance relevant to a range of infrastructure stakeholder perspectives

Conclusions & Next Steps

A new approach to infrastructure performance indicators is required in the UK. Many of the current indicators remain firmly embedded in their infrastructure 'silos', and fail to help address performance assessment at the system-of-systems level. They report across eight principal infrastructure sectors with values normalised to a 2005 baseline, which allows changes in performance to be monitored historically, but is of limited use when it comes to steering the future direction of infrastructure. There is a missed opportunity which a complementary set of indicators could address.

Comparisons in performance between different infrastructure systems are difficult to make using the current indicators; there is some commonality around reporting themes such as capacity available, capacity utilisation and service reliability, but as might be expected, the underlying data used to calculate the metric varies depending on the infrastructure concerned. And there are issues over data collection, quality and long-term availability. Collection is a significant task; any mandatory requirements would likely be seen as onerous by industry, and have the potential wrongly to focus companies on particular aspects of their businesses. As for quality, methods of collection may change over time, thereby adversely affecting consistency of metrics.

A new approach to indicators must start with a long-term strategic vision for the UK's infrastructure based on stakeholder needs. Without this, and the identification of the principal steps required to achieve it, any attempt to create a new family of indicators will lack the necessary focus. An important precursor to developing the vision will be to determine the boundary of the infrastructure system-of-systems, and identify the associated stakeholders. Involving stakeholders early on in the development process for the new indicators will be an important determinant of success, both in terms of the value provided to the country as a whole, and the benefits available to individual stakeholders.

Building on the vision and the steps to get there, a decision needs to be made at an early stage about what the indicators are for; in other words, what sort of infrastructure outcomes they will be measuring. Performance should be measured against the achievement of valued outcomes. It is important to make a distinction here between outcomes and outputs: outcomes are in effect goals and objectives that meet the needs of society and that in a system-of-systems like infrastructure are likely to require the interaction of multiple infrastructure assets and services from several sectors; whereas, outputs are narrow measures, generally focused on a specific part of a specific infrastructure system. Focusing on indicators that are related to the delivery of outcomes from infrastructure systems, and fulfilment of the stakeholder needs which form the basis for the infrastructure vision, as shown in Figure 1, also has the advantage of avoiding technological lock-in by being solution neutral.

Industries and sectors already measure and report the condition and performance of individual infrastructure assets and services within the infrastructure systems. These are valuable for managing the systems over certain time horizons, but could be complemented be indicators which involve interdependency between the systems to deliver outcomes. This could include

dimensions such as affordability, customer experience and resilience beyond those related to specific assets.

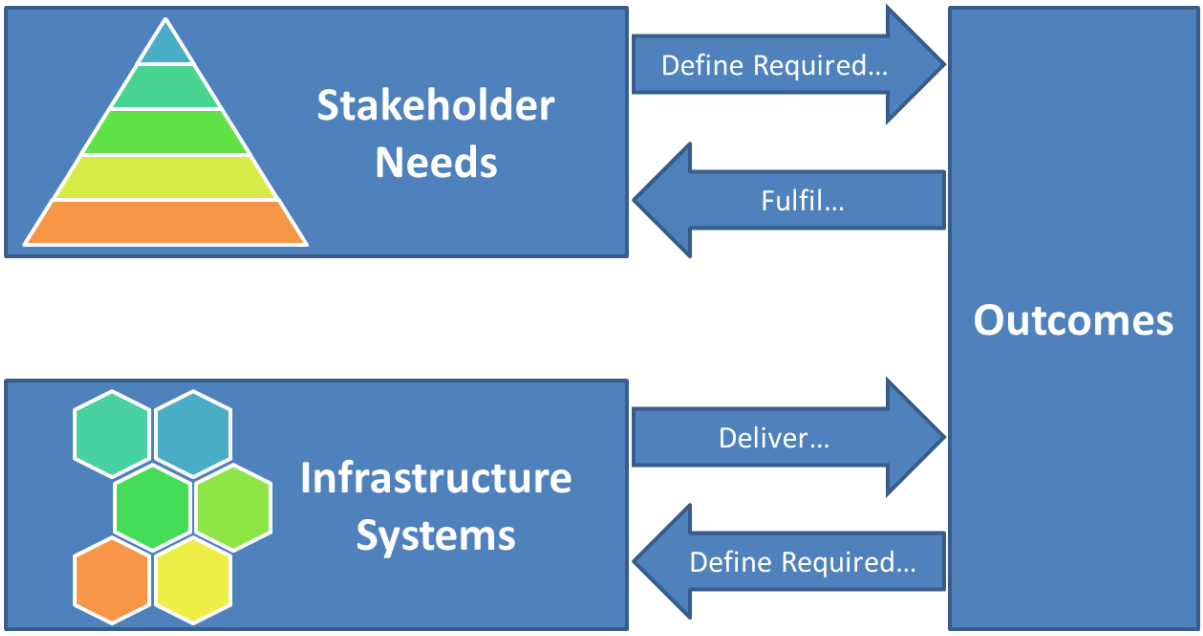

Figure 1 - Delivery of Outcomes

It is no longer sufficient to monitor performance solely on an infrastructure-by-infrastructure basis. Performance in one infrastructure can influence that in others, and the new indicators must be designed such that they recognise this. So, it will be necessary to trace interdependencies across infrastructures to provide clarity on the causality behind any given indicator. Despite presenting advantages, existing balanced-scorecard approaches are unlikely to be sufficient to achieve this, because while they take a holistic approach to indicator identification, they do not account for the interdependencies between them.

Mapping models of the infrastructure system-of-systems to outcomes allows for a better picture of the capability of the whole system, including new opportunities and gaps which require further investment.

In a similar vein, scale will also be an important issue to consider in arriving at indicators that are of use nationally, regionally and locally. Current indicators sometimes fail to provide insights into performance at the level of granularity necessary to support effective decision-making on the actions required for improvement. The indicators must offer the flexibility to assess performance across the whole of what might be termed the 'infrastructure solution space': in other words, the space that contains the full range of existing, and future, combinations of infrastructure.

The indicators selected must be 'SMART'. This is not to say that the process of selection must follow this particular piece of management theory generally attributed to Peter Drucker's 'management by objectives' concept. Instead, the point is to recognise that having identified outcomes and the indicators to measure them, some sort of 'feasibility check' is required to give confidence that the indicators will actually work. Testing new indicators for 'smartness' should

help do this. It will involve assessing indicators against a number of criteria including, but not limited to:

Specific: clear and focused to avoid misinterpretation, including assumptions and definitions.
Measurable: quantified and comparable to other data, allowing for meaningful statistical analysis.
Attainable: achievable, reasonable, and credible under conditions expected.
Realistic: fits into the organisation's constraints and is cost-effective.
Timely: doable within the time frame given.

And finally, care must be taken to ensure that the new indicators do not drive what might be seen as undesirable behaviours. The very act of flagging a particular suite of indicators risks suggesting to infrastructure operators that these are the issues they should be focusing on; whereas, it is likely they will be part of a much more complicated, integrated approach to assessment. Failure to make this clear could result in operators resorting to micro-management of individual indicators and the limitation of innovation.

Next Steps

The first necessary step is to appropriately define the system to be considered, before identifying the associated stakeholders. The most important step is to work with these stakeholders to develop the strategic vision for future infrastructure and the mission for future indicators, with particular attention being paid to the outcomes desired. The nature of the valued and required outcomes of the present and the future may not be the same as they were in the past, therefore it may not be meaningful to benchmark current or future performance against the same indicators that were used in the past. The vision and purpose of infrastructure systems must be articulated, and the indicators selected to reflect these.

Furthermore, the valued and required outcomes may be a product of the interaction of infrastructure systems from several different sectors (as they have been defined in the past). This necessitates an understanding of the how the infrastructure systems interact as a complex whole to deliver the expected performance, as well as an understanding of the wider context within which the systems exist. . There must be an adequate understanding of how these infrastructure systems interact as complex socio-technical systems to meet the necessary outcomes.

In parallel with this, research is required into the interdependencies between the performance indicators themselves. Complex systems, or system-of-systems, require indicators which take account of the complexity of the systems they are attempting to monitor. To be effective, the new indicators must take account of the fact that a decision to increase output in one area may well have adverse effects in other areas. There has already been research in the rail sector into hierarchies of indicators, but this needs to be repeated in other sectors, and extended to cover relationships between sectors. A reflective and adaptable process for indicator design is required to cope with the dynamic and uncertain context of required infrastructure outcomes, and therefore of infrastructure performance.

Following from these tasks, an exercise is required to develop a framework for a meaningful ‘system of indicators’ that captures these issues in a way which is practical, transferable and scalable.

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Appendix A – International Best Practice

This section considers international best practice in infrastructure performance measurement in greater detail, expanding on the sources summarised in Section 2. National infrastructure performance is measured for international comparison by the World Economic Forum (WEF) and The World Bank. While not necessarily indicative of best practice or a suitable for the needs of infrastructure decision makers within the UK, they represent a sensible starting place as they allow for international comparisons.

World Economic Forum

WEF produces a ranking of countries based on a 'Global Competitiveness Index'. The most recent assessment ranks the UK 10th for Infrastructure out of 144 countries. This focuses on transport, electricity and telephony as shown in the table below. Data is taken from a number of sources, with subjective assessments coming from the WEF's annual Executive Opinion Survey. Participants are asked questions such as: "How would you assess passenger air transport infrastructure in your country? (1 = extremely underdeveloped, 7 = extensive and efficient by international standards)".

Indicator	Global Rank (out of 144)	Value (or rating out of 7)
Infrastructure (overall)	10th	6.0
Transport Infrastructure	14th	5.6
Quality of Overall [Transport] Infrastructure	27th	5,.3
Quality of Roads	20th	5.2
Quality of Railroad Infrastructure	16th	4.9
Quality of Port Infrastructure	16th	5.6
Quality of Air Transport Infrastructure	28th	5.5
Available Airline Seat km (million seat km/week)	3rd	6725.3
Electricity & Telephony Infrastructure	6th	6.4
Quality of Electricity Supply	12th	6.6
Mobile Telephone Subscriptions (no./100 pop)	51st	123.8
Fixed Telephone Lines (no./100 pop)	8th	52.9

ICT use is reported separately in terms of technological readiness rather than infrastructure.

Indicator	Global Ranking (out of 144)	Value (or rating out of 7)
ICT Use	2nd	6.8
Internet Users (% of Population)	9th	89.8
Fixed Broadband Internet Subscriptions (no./100 pop)	7th	35.7
Internet Bandwidth (kb/s/user)	7th	352583.1
Active Mobile Broadband Subscriptions (no./100 pop)	12th	87.2

In terms of the WEF method it is worth noting that the assessment of perceived quality, while somewhat subjective, is arguably aligned with a tacit consideration of the socio-economic requirements of those completing the assessment. It is however also a snapshot of current performance, does not help reveal trends or expose the underlying causality or structure of the systems in question. These indicators are therefore of limited value for the level of decision making required to plan and implement a strategy for the future of national infrastructure. The measurements of the asset base are even less obviously aligned with the desired outcomes of a society. The links between 'airline seat km' or 'fixed telephone lines' and the economy or well-being of the stakeholders, for example, are less clear.

While these rankings are important in terms of international perception and the influence this has, the method behind these indicators is of limited use in the formation of national indicators. While the purpose of national performance indicators is not necessarily clear, it is evident that these do not provide sufficient detail to inform the sorts of decisions that national infrastructure stakeholders would need to make.

World Bank

The World Bank produce a global ranking based on their Logistics Performance Index along similar lines to the WEF. This Index focuses on international trade, and in doing so attempts to assess the physical and service components of trade related infrastructures. It is based on a survey of logistics professionals (1000 people across 143 countries), and provides a view of those within the country and of the global community. In 2014 the UK was ranked 4th overall, but 6th in terms of the quality and cost of physical infrastructure associated with trade (roads, ports, airports etc.).

These give very broad overviews of the UK's internationally position and the measures on which the success of its infrastructure is judged from an internationally perspective. However, as with the WEF index, they provide little guidance on the detail of how the UK can improve its infrastructure, effectively, sustainably and efficiently.

The sorts of indicators reported in the National Infrastructure Plan can help inform those making planning and investment decisions which will shape the future of the UK's infrastructure systems. Technological advances mean that there is an increasing amount of data available on which to base these decisions, and new innovative ways of exploring it.

In addition to indices for international comparison, those involved in the operation and governance of infrastructures at a national level are investigating the ways in which this data and information can be best structured and used in order to improve the state of their infrastructure, and ensure it continues to meet economic and societal needs. This section provides an overview of these studies and activities. Among other things, these provide an insight into the characteristics and structure of useful indicators.

New Zealand

New Zealand's National Infrastructure Unit is involved in the process of developing a framework for infrastructure performance indicators. This has involved work by Becca and Covec [16]. Implicit throughout the development of this framework is a focus on "welfare obtained from infrastructure" as well as the infrastructure itself.

The framework is motivated by a vision that "by 2030 New Zealand's infrastructure is resilient and coordinated and contributes to increased economic growth and better quality of life". This is achieved through two objectives:

1. Better use of existing infrastructure
2. Better allocation of new investment

The second of these could draws parallels to Infrastructure UK's objective to co-ordinate the planning and prioritisation of investment in infrastructure in order to achieve greater value.

The report from Becca and Covec advises that "Investment in new infrastructure, as with the management of existing assets, must focus on delivering services and outcomes rather than just building assets" hence relating to the welfare emergent from infrastructure. They note (Section 2.4.6) that the output of infrastructure sectors are used by others to produce beneficial services, or by consumers in combination with other output to create benefits. Therefore caution is required when measuring the scale of an output. Electricity is used to facilitate a benefit (e.g. warmth), but an increase in consumption does not unambiguously mean an increase in the derived benefit. This focus on emergent welfare draws on the New Zealand Treasury Living Standards Framework which uses capital stocks and welfare flows (e.g. income, employment, freedom, amenities). It sets out four types of capital: financial & physical (e.g. financial wealth, housing), human (e.g. skills), social (e.g. trust) and natural (e.g. biodiversity). These facilitate the flow of activities, and it is from this that welfare is generated.

The performance indicator framework sets out two types of infrastructure indicator:

Activity/Stock Indicators: These highlight the current situation and forecasted future need, but do not relate directly to emergent welfare and may be ambiguous over whether more is better.

Performance Indicators: These measure productivity and efficiency and are more closely linked to welfare.

They suggest that while activity measures have a place, performance measures more closely related to emergent benefits and welfare are a generally more useful form of indicator.

In addition to these two types, it also adopts the Pressure-State-Response (PSR) model for classifying indicators set out in the OECD's conceptual framework for core environmental indicators [2]:

Pressure Indicators: Indicators measuring external pressures on the infrastructure system that have an impact on the welfare derived from it (e.g. demand)

State Indicators: Indicators of the systems current conditions or activities that contribute to societal welfare

Response Indicators: Indicators of societal responses (e.g. policy and investment, expenditure on new infrastructure, operating expenses to provide new services with the same assets, expenditure on maintenance of assets).

In discussing these three types of indicator Becca/Covec comment:

> "When measuring pressure, there is a question of whether measures of activity or volume (e.g. GWh of energy production [...]) are appropriate pressure indicators [...] in our view such indicators must be interpreted carefully, as an increase in the quantity of electricity consumed could correspond to an increase in demand driven by increased population (which is a true pressure), or a response in demand driven to a fall in price induced by an increase in supply (which is not a pressure but a change in state)"

They outline generic examples of pressure indicators applicable to all infrastructure sectors. Examples of Demand Pressure Indicators include 'Population Growth Rates' and 'Outlook for Key Commodities'. Supply Pressure Indicators include such values as 'Cost Indexes for

Infrastructure Construction', 'Climate Change' and 'Human Resources in Particular Key Skill Shortages'. The framework also sets out a list of criteria for selecting infrastructure performance indicators:

- Usefulness and balance
- Ease of calculation
- Data availability
- Proportionate representation of different viewpoints
- Alignment with government objectives
- Policy relevance
- Industry relevance
- Comparability across sectors
- Comparability across jurisdictions
- Cost effectiveness
- International practice

In addition to these it is also important to consider whether the indicators are best measured relative to others rather than as absolute or single data points, and to aim where possible for consistence in reference units. A further lesson from this framework is that scale and location are important, and nationally aggregated indicators could obscure issues.

From these elements of the New Zealand Treasury Living Standards Framework, the division of stock/performance indicators, OECD framework and criteria, a number of potential example indicators are derived.

Australia

Sharpe et al [17] have described an approach developed in recognition of the potential role for infrastructure performance indicators in light of the 'increasing complexity in investment decision making, and increased challenges in prioritising that investment' and the reality that 'infrastructure systems serving modern economies are highly complex, highly interconnected, and often highly interactive.' This work, therefore, is highly relevant because its purpose is similar to that of I-UK needs and its starting point is infrastructure as a complex adaptive system.

A distinction between four indicator types is proposed, these are (i) Inputs (for example, the level of capital investment) (ii) Outputs (the specific infrastructure built) (iii) Outcomes (the stated reasons for the output) (iv) Impacts (factors occurring as an indirect result of the ii and iii). They argue that service performance is critical, if agencies are to be better equipped to prioritise investment and understand how the outcomes of that investment are valued by the consumer. Therefore performance indicator sets should be designed to measure Outcomes. Specifically, they identify outcomes connected to… as particular important to all elements of any infrastructure system.

> ***Reliability****:* the ability of the infrastructure to meet normal or current demand (eg. proportion of trains running on time, road congestion in response to normal traffic demand)

***Stability**:* the consistency of the infrastructure service provided (eg. drops in water pressure, surges in electricity)

***Safety**:* the safeness of the infrastructure for those who use it (eg. microbial levels in water, frequency of road accidents)

***Resilience**:* the ability of the infrastructure to respond in the event of unusual demand (eg. road congestion in response to unusual event, internet download speeds)

This is very similar to ACI 2012 Guide to Airport Performance Measures work that identify safety, quality of service, productivity and cost effectiveness as candidates for key performance areas in which performance indicators should be defined. (see below)

Furthermore, this work proposes performance indicators should be SMART. - (This may be interesting to compare to our workshop framework!)

- Specific: unambiguous, and a direct measure of performance that cannot be confounded by other factors
- Measurable: a quantitative (not qualitative) measure of performance, that is ideally already collected (and public)
- Attributable: measures performance that is, ideally, directly attributable to the specific infrastructure network
- Results-oriented: measures infrastructure outcomes, not inputs or outputs
- Trackable: can be expected to change over time as performance improves or worsens.

ACI 2012 Guide to Airport Performance Measures

The ACI Guide (2012) to airport performance measures highlights the important distinction between (i) internal/self-benchmarking (where an airport compares its performance with itself over time); and (ii) external/peer benchmarking (where an airport compares its performance against other airports). This applies more generally to any infrastructure context and highlights the need to state the purpose of performance indicators before designing them because, purpose influences what data you collect. The report illustrates a step wise approach whereby key performance areas are firstly identified for the infrastructure in question, secondly at least one performance indicator (PI) is defined within each KPA thirdly the PIs are used to evaluate and improve performance and finally KPAs and PIs are iterated through consultations with users and other interested parties.

US Chamber of Commerce

The efforts of the US Chamber of Commerce to develop a national infrastructure performance index are reported in Oswald et al. [19]. The research uses the Analytical Hierarchy Process (AHP) to compare performance indicator across different infrastructure types.

Their method is based on publically available quantitative data sources, and draws on earlier work on indicators for sustainable development [12] that sets out a four-step process, and a subsequent [21], expanded 7 step processes:

1. Define infrastructure sectors
2. Identify representative samples based on geography and economy
3. Create hierarchy models for each sector
4. Identify indicators for each sector
5. Explore data sources and collect indicator data
6. Weigh the indicators using AHP pairwise comparisons
7. Compute the index based on normalised indicators, relative weighting, and economic relevance

The sectors are identified before each sector is then decomposed based on geographical and economic classification (for example infrastructure in large cities may be differentiated from rural infrastructure). They are then further broken down by mode or function before then being finally decomposed into performance type (supply, quality of service, utilization and efficiency). Existing data is then selected to fulfil each of these performance type measures

While a rigorous and robust framework for selecting and managing the data, it only looks at the current performance and compares it to past performance.

US National Research Council

A 1995 report from the US National Research Council entitled "Measuring and Improving Infrastructure Performance" [18] sets out a large number of indicators in three categories: efficiency, effectiveness and cost. It defines infrastructure performance thusly:

> "Generally, performance is the carrying out of a task or fulfilment of some promise or claim, and for infrastructure this means providing or enabling movement of goods and people, clean water supplies, waste disposal, and a variety of other services that support other economic and social activities, a safe and healthful environment, and a sustainably high quality of life. Infrastructure is a means to other ends, and the effectiveness, efficiency, and reliability of its contribution to these other ends must ultimately be the measures of infrastructure performance." (p5)

OECD

The OECD developed a framework for characterising performance indicators based on model of the pressures exerted on a system that affect its quality or state, and the responses of society to this. This model highlights cause and effect relationships, benefits from being easy to understand, neutral as to whether changes are positive or negative, and flexible [22].

A more recent study compared options for benchmarking infrastructure performance [15]. These include:

- Benchmarking based on growth contributions (the impact of infrastructure capital stock on growth)
- Benchmarking performance by cost-benefit analysis (CBA) of new projects;
    - They suggest "Net socio-economic benefit" is the sum of "change in consumer surplus + revenues for the infrastructure operator – operating costs of

infrastructure services + change in welfare because of externalities + effect on government budget”
    - They discuss the use of shadow prices for including externalities in the CBA.
- Benchmarking performance based on the social efficiency of service provision
    - Including ‘distance functions’ and ‘data envelopment analysis’ (DEA)

In conclusion, along with New Zealand and Australia the UK is making progress in reconsidering what indicators have the potential to deliver and how they can both inform effective strategies and help steer their realisation. There are commonalities in terms of the focus on explicitly linking infrastructure performance indicators to the values and requirements of the stakeholders the infrastructure serves. In New Zealand in particular this has initiated a considerable process of stakeholder engagement. There are also important national differences which will have an impact in the framework for indicators. In particular the UK has more legacy infrastructure, and more of its infrastructure assets are densely located.