National Infrastructure Commission: Performance Measures

Final Report

22 May 2017

NATIONAL INFRASTRUCTURE COMMISSION

AN EXECUTIVE AGENCY OF HER MAJESTY'S TREASURY

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Revision History

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24 March 2017		Andrea Silberman, NIC
15 May 2017	Clarification of process and wording plus re-structuring of sections 5 and 6 to provide more outward facing document and removal of superfluous appendices	Andrea Silberman, NIC

Contract

This report describes work commissioned by the National Infrastructure Commission, by a letter dated 7 November 2016. The National Infrastructure Commission's representative for the contract was Andrea Silberman. Rachel Brisley, Alastair Dale, Paul Eccleston, Judith Stunell and Sam Wingfield of JBA Consulting; Simon Pringle, Scott Dickinson, Steve Hunter and Caitriona Lacy of SDG-Economic Development; Chris Fry, Erica Ward and Prabodh Mistry of the Temple Group and Eddie Murphy and James Saunby of GreySky Consulting carried out this work.

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Purpose

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JBA Consulting has no liability regarding the use of this report except to the National Infrastructure Commission.

Acknowledgements

We wish to thank Andrea Silberman, the National Infrastructure Commission contact who has provided support and advice throughout the duration of the project. In addition, we would like to convey our appreciation to the external infrastructure stakeholders that gave up their time to contribute to this study.

Carbon Footprint

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Executive summary

This report describes the results of a study commissioned by the National Infrastructure Commission to identify a set of quantitative performance measures that will be used to establish an understanding of the status and shortcomings of the UK's existing infrastructure assets and how this changes over time. The measures assess the Resilience, Quality, Cost and Environmental Quality of infrastructure for the following sectors: digital communications, energy, flood risk management, solid waste, transport, water and wastewater. The Study was led by JBA Consulting working with SDG-Economic Development, The Temple Group and GreySky Consulting.

The NIC needs infrastructure performance measures to inform the preparation of the National Infrastructure Assessment (NIA) and assess performance against government objectives to provide infrastructure that supports sustainable economic growth across all regions of the UK, improves competitiveness and improves quality of life. The proposed measures enable evaluation of the performance of infrastructure using the OECD's Pressure-State-Response model. Within this OECD framework, the performance measures are used to characterise the 'State' of national infrastructure and how it is affected by external pressures such as economic growth, population, technological change and climate change. This evaluation then provides evidence to inform the appropriate government responses to secure the required infrastructure performance standards over time. Assembly of performance measures for the respective sectors also facilitates evaluation of the interdependencies between the sectors with respect to their resilience and quality.

The study outputs comprise: this report, a spreadsheet containing the initial long-list of measures, a short-listed set of measures, and then the proposed measures that are recommended. The latter shows how these have been identified through an iterative process and a suite of six 'Sector Fiches' that summarise the process adopted to assemble inputs and present the final measures for each of the respective sectors. The intention is that the fiches provide the quickest and easiest means of accessing the outputs from the study.

The preparation of the study highlighted the following:

- There are a range of established performance measures particularly for sectors that had already been the focus of long-term government policy.
- The merit of preparing a concise set of measures for each sector, and the need to identify a number of new measures to achieve this.
- A requirement to recognise the variability in the drivers influencing the performance of infrastructure in different sectors and make allowance for this together with infrastructure performance when contemplating appropriate responses to address measured change.

The study's report recommends the need for future review and update of the proposed measures as within some sectors their 'shelf life' could be quite short. It is also recognised that there is a need to establish a more widely accepted definition of resilience, so that in future the potential ambiguities arising from the implicit degree of interpretation is reduced. Finally, following the study and the interest which it stimulated, it will be important that there is public promotion of NIC's proposed measures to act as the catalyst for a wider conversation about infrastructure performance.

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Abbreviations

ACP	UK Advisory Committee on Packaging
ASC	Adaptation Sub-Committee
BEIS	Department for Business, Energy and Industrial Strategy
CAA	Civil Aviation Authority
CCC	Committee on Climate Change
CCGT	Combined-Cycle Gas Turbine
CIWM	Chartered Institution of Wastes Management
Defra	Department for the Environment, Food and Rural Affairs
DfT	Department for Transport
EDoC	Electronic Duty of Care
EEA	European Environment Agency
ESA	Environmental Services Association
FCERM	Flood and Coastal Erosion Risk Management
FRM	Flood Risk Management
GHG	Greenhouse gases
GiA	Grant in Aid
IPA	Infrastructure and Projects Authority

ITRC	Infrastructure Transitions Research Consortium
OECD	Organisation of Economic Co-operation and Development
OS UPRM	Ordnance Survey Unique Property Reference Number
NIA	National Infrastructure Assessment
NIC	National Infrastructure Commission
NIP	National Infrastructure Plan
ORR	Office of Rail and Road
PRN	Packaging Recovery Note
RDF	Refuse Derived Fuel
R&W UK	Resources and Waste UK
WFD	Water Framework Directive

Working Definitions

Competitiveness	The ability and performance of a firm, sub-sector or country to sell and supply goods and services in a given market, in relation to the ability and performance of other firms, sub-sectors or countries in the same market.
Infrastructure	The basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise.
Interdependency	A mutual dependence that can be based on geography, information, economic, society or institutions.
Performance measure	The quantitative performance of infrastructure services provided in a sector regarding a specific desired outcome. A suitable performance measure will take on a different value to indicate a change in observed outcome.
Productivity	The efficiency of productive effort as measured in terms of the level of output per unit of input.
Quality	Capacity sufficient to meet current economic, environmental and social requirements and to future-proof new growth.
Resilience	The ability of infrastructure to maintain continuous supply/service under 'normal' and 'extreme' circumstances.

1 Introduction and context

The National Infrastructure Commission (NIC) was set up in October 2015 to 'provide the Government with impartial, expert advice on major long-term infrastructure challenges'.[1] The Government has set the following high-level objectives for the NIC:

- Support sustainable economic growth[2] across all regions of the UK
- Improve competitiveness
- Improve quality of life.

The NIC is committed to producing a National Infrastructure Assessment (NIA) during each Parliament that sets out an assessment of long-term infrastructure needs with recommendations to the Government. The NIC's key economic infrastructure sectors are transport, energy, water and waste water, digital communications, solid waste and flood risk management. The NIC's work and the scope of the NIA also need to take account of interdependencies between these key infrastructure sectors and their interaction with the built environment (e.g. the role of infrastructure in facilitating housing development). The NIA will be developed in two stages: Visions and Priorities to be published mid-2017 and then the NIA to be published in mid-2018. The NIC has stated that the NIA's recommendations[3] will be consistent with the UK's carbon and environmental commitments and will be:

- Open, transparent and consultative
- Independent, objective and rigorous
- Forward looking and challenging established thinking
- Comprehensive, taking a whole systems approach, understanding and studying interdependencies and feedback.

Analysing the current performance of, and constraints with, the UK's existing infrastructure, as well as planning for future performance, requires relevant, accurate and informative measures that can be used to assess performance over time. In response to this requirement, the NIC commissioned JBA Consulting (JBA), working with SDG Economic Development (SDG-ED), the Temple Group (Temple) and GreySky Consulting (GreySky), to identify measures by which the performance of each of the NIC's economic infrastructure sectors can be measured against the NIC's high-level objectives.

These performance measures will feed into the NIC's 'Visions and Priorities', and the formal NIA.

This report details the process that was undertaken to develop the proposed measures, including the work with external stakeholders to ensure the work was informed by latest expert thinking. It then sets out the recommended measures and provides suggestions regarding the future development and implementation of these.

This report is one of three study outputs; the others being an Excel workbook setting out the long-listed, short-listed and final proposed measures for each sector, and an explanatory fiche for each of the six economic infrastructure sectors. These fiches provide a commentary on the sources and processes used to gather and generate the measures for the sector in question, and present the proposed measures recommended to the NIC by which that infrastructure's progress might be tracked going forward.

[1] The National Infrastructure Commission Charter (2016) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/559269/NIC_charter_6_final.pdf

[2] The Commission intends to interpret the term 'sustainable' in its objectives ("…sustainable economic growth…") as meaning environmentally, economically and fiscally sustainable. The Commission will also remain mindful of the need to ensure its recommendations are compatible with legally binding environmental targets (such as the Climate Change Act 2008).

[3] https://www.gov.uk/government/publications/national-infrastructure-assessment-consultation-response

The target audience for this report is primarily the NIC as it will be used to support the formulation of the NIA process. However, the report, together with the sector fiches (that are intended to be more outward-facing) have been drafted to be shared with external infrastructure sector stakeholders to obtain their feedback.

The remainder of this report is structured as follows:

- Section 2 - study methodology
- Section 3 - organising framework for the development of the performance measures
- Section 4 - development of long-list measures
- Section 5 - selection of proposed measures
- Section 6 - cross-sectoral and interdependency issues within and across measures
- Section 7 - conclusions and recommendations.

2 Methodology

2.1 Introduction

This section sets out the methodology that was proposed prior to commencement of the Study, explains the main features of this and explains how the method was revised as the work was undertaken.

2.2 Proposed methodology and approach summary

The project methodology and timings proposed at the outset of the study are set out in Figure 2-1 below.

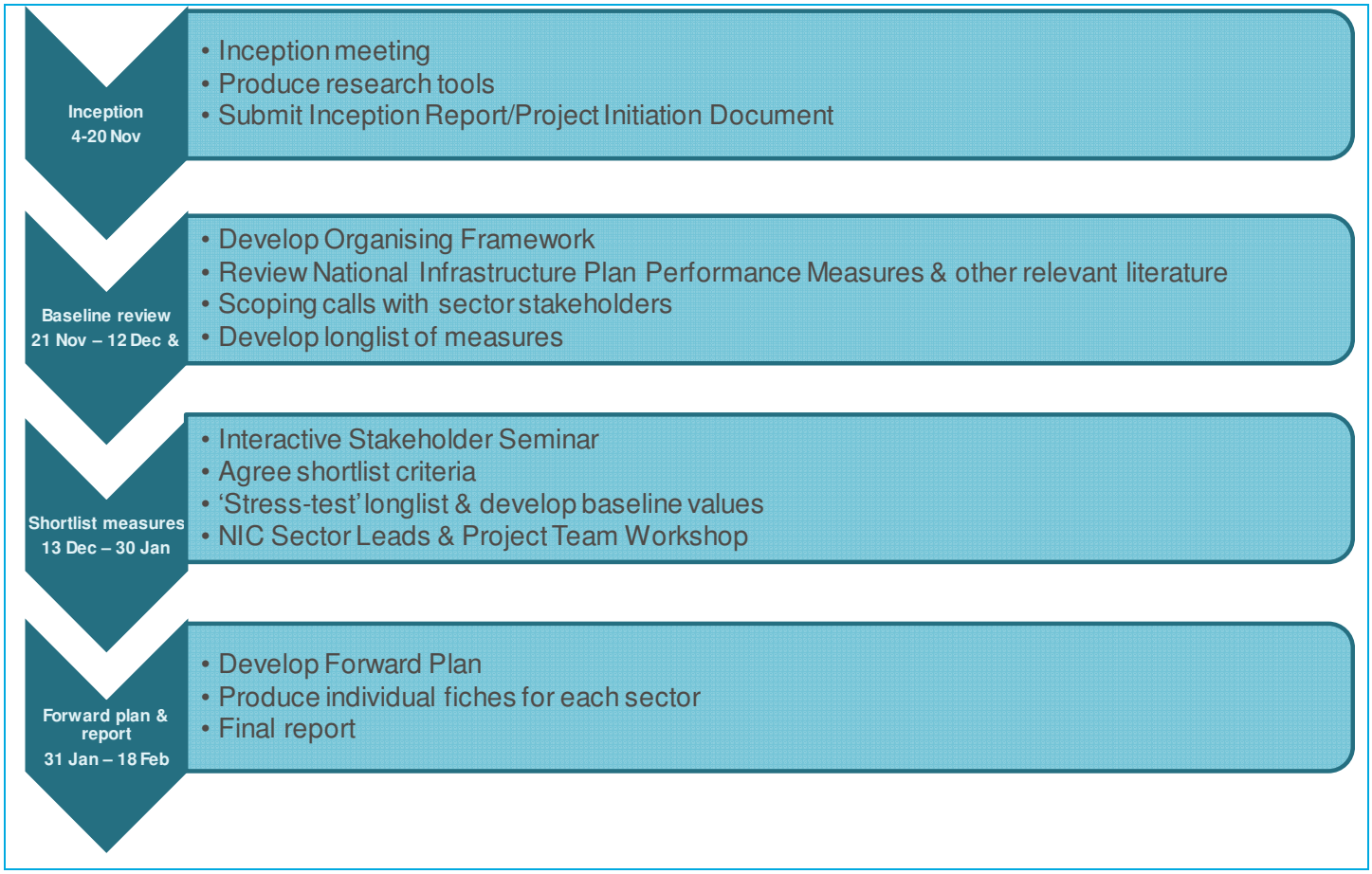

Figure 2-1: Overall project methodology

The methodology was intended to comprise a mix of primary and secondary research techniques involving stakeholder consultation, literature review and the development of performance measures on an iterative basis. After each stage, clear agreement was secured to 'lock down' specific aspects (for example, the organising framework) to ensure each part of the work was built on sound proceeding foundations. The method was revised, as described in 2.5. The study period extended beyond that originally anticipated due to additional stakeholder involvement.

2.3 Pragmatic and co-production approach

In developing the performance measures, the Study Team agreed with the NIC that the focus should be on identifying 'ideal' performance measures, but applying this intent pragmatically given the necessary reliance on publicly available information that is already collected. Where the ideal performance measures could not be populated with existing

data, these are identified as recommended future development measures to be implemented as/when such data become available.

The study involved a co-production approach with the Study Team working in close collaboration with the NIC, its sector leads and external stakeholders. The study team comprised a core management team (JBA and SDG) and a wider group of 'Infrastructure Leads' (digital communications – GreySky, flood risk management – JBA, energy – Temple, solid waste – Temple, transport – SDG-ED, water and wastewater – JBA). Whilst the study was managed by the core management team, Infrastructure Leads provided most input to the development of the performance measures. JBA, as lead contractor, worked closely with the study's Infrastructure Leads to secure a consistent approach to the selection of performance measures through weekly team briefings and the provision of standard templates and guidance.

2.4 Developing the evidence base

The evidence base for the development of the organising framework, through which measures were to be categorised, and the identification of the long-list of measures was informed by a comprehensive literature review and external stakeholder consultation.

2.4.1 Literature review

The first key task involved reviewing experience from elsewhere drawing on existing literature.

All Sector Leads reviewed the following documents:

- HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014: Performance Measures Annex
- HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.
- Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.
- Schwab, K. (2016) The Global Competitiveness Report 2016–2017.

In addition, a further 28 documents were reviewed in total across the six infrastructure sectors – some documents were relevant to more than one infrastructure sector, so were reviewed multiple times.

Each document review used the following structure:

- Challenges identified
- Responses to the challenges
- Methods identified
- Other research identified.

2.4.2 External stakeholder consultation

Extensive stakeholder consultation was not possible within the timing and financial confines of the study, but key external stakeholders were involved in three activities to gain their insights.

Scoping consultations

External stakeholders were consulted via telephone interviews in November 2016. These consultations focused on obtaining initial insights on potential performance measures and identifying existing performance measures used for other purposes e.g. the measures developed by the IPA in the 2014 National Infrastructure Plan and others developed by

regulatory bodies. 15 scoping consultations were undertaken with the following organisations:

- All sectors – Adaptation Sub-Committee of the Committee on Climate Change (ASC), IPA, Infrastructure Transitions Research Consortium (ITRC)
- Digital communications – Ofcom
- Energy – BEIS, Ofgem
- Flood risk management – Environment Agency
- Solid waste – Chartered Institution of Wastes Management (CIWM), Defra, Environmental Services Association (ESA), Resources and Waste UK (R&WUK)
- Transport – Civil Aviation Authority (CAA), DfT, Office of Rail and Road (ORR)
- Water and wastewater – Ofwat.

The consultations were undertaken using a pre-agreed aide memoire and written-up against the questions in this aide memoire. The consultations covered the following main areas:

- Challenges in developing performance measures for key infrastructure sectors
- Experience – personal and organisational - of developing performance measures
- Characteristics of successful performance measures
- Similar attempts at home or abroad to develop performance measures
- Immediate thoughts on potential measures and their strengths and weaknesses for the six infrastructure sectors
- Additional organisations that should be consulted or documents reviewed.

These conversations were useful in identifying different perspectives on how the work might be tackled, and the different approaches that could be adopted. These sessions were helpful in disseminating and embedding awareness of the study and all consultees were invited to participate in an interactive webinar.

Interactive check-and-challenge webinar

This was held in mid-December 2016. NIC's own sector leads and external representatives were invited to participate. The purpose of the webinar was to disseminate findings to date; obtain stakeholder views on interim findings and the performance measure short-list criteria, and set out how stakeholders could further assist with and advise on the study.

Ongoing consultation

Following the webinar, stakeholders (those who participated and those who were invited but could not participate) were sent the webinar presentation and asked to comment on the draft short-listing criteria with responses required in early January 2017. Short-listed measures were then circulated to stakeholders for comment later in the month.

Interactive workshop

This was held in January 2017, and attended by NIC's own sector leads together with NIC's Study Manager contact and representatives from the Study Team. The workshop comprised a presentation on progress and the status of the measures followed by break out groups by sector to discuss measures in more detail. A feedback note from the workshop is provided in Appendix C.

Ongoing dialogue with NIC Infrastructure leads

The proposed measures were selected through ongoing dialogue and iteration between the Study Team Sector Leads and the NIC's Sector Leads.

2.5 Overall method

The study was extended to allow more time for external stakeholder consultation, with the consequence that the draft final outputs were submitted to the NIC on 24 March 2017. In addition, a more iterative approach was conducted with greater involvement of NIC's Sector Leads than had been anticipated originally, helping to give added robustness to the proposed measures selected. The following graphic provides an overview of the final method.

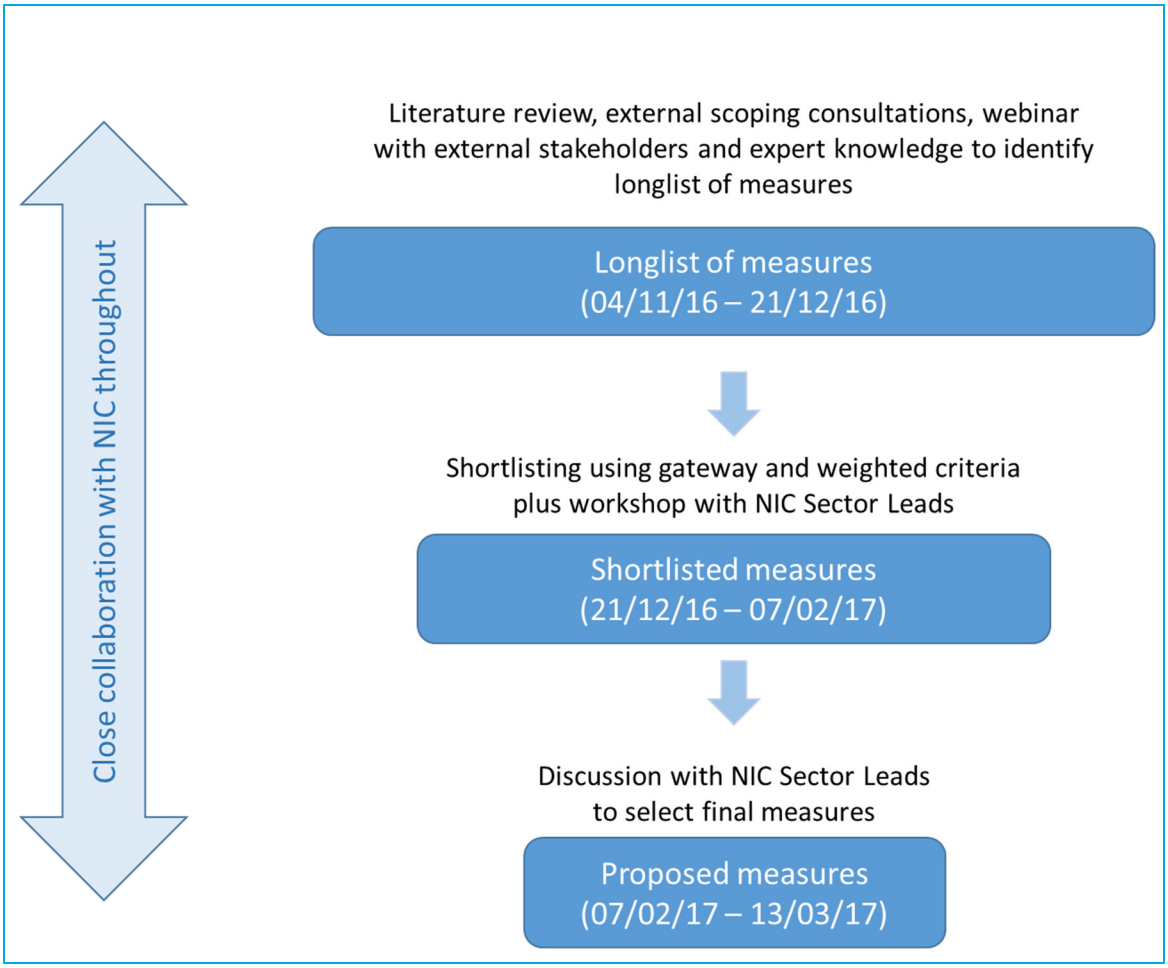

Figure 2-3: Measure development process

Section summary

A mixed method research approach was adopted comprising stakeholder consultation, literature review and the development of performance measures on an iterative basis.

The method was revised, and the study period extended to allow more time for external stakeholder consultation.

3 Organising framework

3.1 Introduction

The approach to taking forward the study was focused on logic-model thinking, such that any performance measures developed flowed clearly and traceably from the government's high-level objectives for the NIC enabling the extent of progress to be evidenced. Importantly, the work was not about developing indicators by which the performance of the NIC itself could be judged, but rather understanding how six of the key economic infrastructures for which the NIC has oversight were performing.

3.2 Linkage between performance measures and high-level objectives

The NIA consultation document[4] that was consulted upon in summer 2016 highlights that the NIC intends to assess the performance of the UK's infrastructure recognising that there are inherent difficulties in measuring progress against such complex and multi-faceted high-level objectives. As such, a first task for this study involved working with the NIC to establish a common understanding of each of the organisation's high-level objectives, and then identifying the dimensions of these which needed to cascade down to the measures for individual economic infrastructures.

Following discussion with the NIC, the OECD's Pressure-State-Response model[5] was considered to provide a relevant platform for the study, in which:

- **Pressure** refers to external pressures on infrastructure, relating to demand and supply. The NIC has identified critical drivers (that link to the pressures) as:
  - demand pressures: economic growth and productivity, population and demography
  - supply pressures: technology and climate change and environment.
- **State** relates to the current state of infrastructure activity and performance and how this might change over time
- **Response** reflects government policy and investment responses leading to a change in pressures and state.

It was agreed with the NIC that the performance measures at the level of each of the key economic infrastructures were required to assess the **State,** to:

- Provide an indication of the current performance of UK infrastructure
- Enable monitoring of the change of performance over time to identify if the pressures are being addressed
- Show if responses are appropriate and inform how these may need to change.

The following summarises the study's interpretation of the NIC's high-level objectives:

1. Support sustainable economic growth across all regions of the UK
   - Economic growth (measured by productivity gains) in absolute terms
   - Balanced economic growth across the UK
   - Environmentally, economically and fiscally sustainable growth.
2. Improve competitiveness
   - Competitiveness is interpreted as export competitiveness with cost-competitiveness being a key element.

[4]

5 OECD (2003) OECD Environmental Indicators Development, Measurement and Use - https://www.oecd.org/env/indicators-modelling-outlooks/24993546.pdf

3. Improve quality of life

- Improving the standard of health, comfort and happiness[6] experienced by UK residents.

It was agreed with the NIC that 1 and 2 focus on infrastructure 'as a system', whilst 3. focuses on individuals' experience of using infrastructure or infrastructure services.

3.3 Definition of objective domains

The high-level objectives are broad so it was agreed that lower level domains should be identified enabling the grouping of performance measures into categories linked to the objectives. From discussion with the NIC, stakeholder consultations and the review of literature, the following domains were agreed upon:

- Resilience
  - The ability to anticipate, prepare for, and respond and adapt to everything from minor everyday events to acute shocks and chronic or incremental changes, now and in the future
- Quality
  - Optimise the capacity and performance of the current system, targeting both supply and demand and provide balanced access across the UK
  - Optimal user experience – users' experience meets/exceeds their expectations
- Sustainability
  - Economic and fiscal sustainability (value for money)
    - Economy: minimal cost
    - Efficiency: the unit costs of infrastructure
    - Effectiveness: extent to which infrastructure delivers what was intended of it
  - Environmental sustainability
    - De-carbonising infrastructure
    - Minimising other environment impacts e.g. air quality, biodiversity, conservation of culture and heritage (macro: large scale, micro: affecting individuals)
    - NB: climate change adaptation was considered under the resilience domain.

The initial long-listing of potential performance measures was conducted using the above domains and sub-domains. However, feedback on the measures received from NIC and external stakeholders resulted in environmental and economic sustainability being identified as separate discrete components as there can be an inherent tension between these with regards to some types of infrastructure construction and operation. In addition, the NIC was keen to maintain the economic focus on cost. During the long-listing and short-listing process it also became apparent that effectiveness was better captured under the quality domain. As a result, the short-listed measures and final measures were set out against the following domains and sub-domains:

[6] Oxford dictionary

- Resilience
  - Everyday resilience
  - Resilience to external shocks
- Quality
  - Optimise capacity and performance
  - Optimal user experience
- Cost
- Environmental sustainability
  - Decarbonisation
  - Minimise environmental impacts.

3.4 Objectives and domains

It was agreed with the NIC that not all identified domains and sub-domains were relevant to all the high-level objectives; the following table sets out how these map against each other.

Domains	Sub-domains	Objective 1: Support sustainable economic growth across all regions of the UK	Objective 2: Improve competitiveness	Objective 3: Improve quality of life
Resilience	**Everyday resilience**			X
	Resilience to external shocks	X	X	
Quality	**Optimise capacity and performance**	X	X	
	Optimal user experience			X
Cost		X	X	X
Environmental sustainability	**De- carbonisation**	X	X	X
	Minimising environmental impacts	X		X

Table 3-1: Objectives, domains and sub-domains

There are other performance measurement frameworks in use that adopt a similar but not identical organising framework and highlight different aspects. For example, the energy 'trilemma' of security of supply, affordability and decarbonisation is well known and discussions were held with ITRC representatives regarding a focus on quality (incorporating resilience), affordability and third party externalities focusing on environmental impacts.

Alternative approaches were considered, but in discussion with the NIC, it was agreed that the previously described framework was appropriate and relevant to ensure that performance against the three objectives could be measured by the identified set of domains and sub-domains.

Section summary

To ensure the work had a strong logical underpinning, an organising framework was designed to translate the NIC's high-level objectives into a set of organising domains within which the performance of the key infrastructures could be characterised. The design of this framework was informed by primary research with consultees, and messages from the literature review.

This approach gave rise to four domains – Resilience, Quality, Cost, and Environmental Sustainability. The Cost domain aside, these were then developed further to give rise to six more fine-grained sub-domains. These sub-domains were subsequently used as the devices through which appropriate measures of infrastructure performance were identified.

4 Development of long-list of measures

4.1 Introduction

This Section explains the process undertaken to identify the long-list of measures, as well as the key characteristics of the constituent measures. The process largely followed the methodology developed during the tender and inception stages of the project. The time and engagement confines of the study led to a focus on the identification and review of existing indicators, rather than the formulation of new measures and the outputs described in the accompanying measure spreadsheets reflect this bias.

4.2 Baseline evidence

The evidence from the baseline review (scoping consultations and literature review) was used to help inform the development of long-lists of measures by each of the Study Team Infrastructure Sector Study Leads.

4.2.1 Existing frameworks of performance measures

The original proposal for the work identified the key initial tasks in this stage being to:

- review the existing logic chain for activities and interventions
- review the existing framework and current basket of measures
- sift the existing framework for existing perspectives on the six key infrastructure sectors.

However, this assumed that the performance measures identified in the National Infrastructure Plan (NIP), 2011 and updated in 2014 provided the existing set of measures for the NIC. At the Inception Meeting, NIC representatives highlighted that the NIP was produced by the Infrastructure Projects Authority (IPA) that has quite a different remit to the NIC and therefore this should not be viewed as the existing framework, but rather as an input to the study.

4.2.2 Literature review

Findings from the literature review are summarised below, with more detail provided in Appendix A. Some of the documents reviewed addressed the issue of measuring infrastructure performance in general, whilst others discussed the issue in relation to a specific type of infrastructure and some dealt with performance measurement only tangentially. However, the Literature Review highlighted several common issues, including:

- How best to capture capacity, capability and performance.
- How best to measure performance in a rapidly evolving world.
- Limited potential for international comparisons due to the limited amount of comparable data available for all countries.
- Some indicators are open to a wide range of interpretation that limits their communicative capacity.
- Existing activity or stock indicators measure the level of activity and the quantity of infrastructure, but are not reflective of performance, and cannot be unambiguously interpreted in terms of welfare or living standards.
- Difficulties in capturing and interpreting the full range of user experiences effectively.
- How best to estimate a product/company/country's progress in making the transition from a linear to a circular mode of operation.
- Methodological differences between different parts of the UK in relation to some infrastructure types, e.g. solid waste management.

- How to capture variation between different geographies.
- How to take account of risk, so as not to restrict the scope for innovation.

The Study Team Sector Leads used information from the literature reviews relevant to their sectors to help inform the development of long-lists of potential measures. The general messages above were used to inform the overall approach, short-listing criteria and approaches to the construction and population of measures including data availability.

4.2.3 Scoping Consultations

Findings from the Scoping Consultations are summarised below, with more detail provided in Appendix B.

Challenges in developing performance measures

- Economist and system engineer audiences may have different perspectives. Typically, the 'economic system' approach views the world in terms of constrained economic resources, and how performance can be best fitted within this, whereas the 'systems engineering' approach puts resources to one side and understands how performance should be optimised to deliver a fully functioning system
- Consistency and comparability of data and definitions – within and between sectors
- Difficulties in connecting data with outcomes
- Measuring progress with the backdrop of medium to long-term uncertainties such as technological changes, economic performance, Brexit etc.
- Varying robustness in reporting across sectors and organisations
- Difficulties in managing resilience in terms of how this is interpreted and how it has differing impacts for different sectors.

Experience in developing performance measures

- Adaptation Sub-Committee (ASC) to the Committee on Climate Change (CCC) indicators
- Defra - Outcome Measures for flood and coastal risk management and National Indicator (NI)I 188: climate change adaptation
- ITRC work on interdependencies and performance measures
- Office of Road and Rail (ORR): Network Rail performance monitoring and resilience
- BEIS: energy sector indicators produced 2012-2015
- Ofwat: project on indicators due to report in March 2017.

Characteristics of successful performance measures

- Logical framework from overall goal to measurable outcomes then performance measures (Magenta Book referenced)
- Comprehensive
- High-level and pragmatic
- Simple – coherent and easily communicable
- Consideration of interplay: potential for trade-offs to avoid perverse incentives
- Data readily available and dependable
- Resilience could be measured by activity not outcome.

Development of performance measures elsewhere

- Most national organisations have their own performance measures some of which are sector wide e.g. ETR 138[7] (flood resilience standards for electricity sub-stations).
- Other measures include those established by Eurostat, the European Environment Agency (EEA), the European Commission (EC), OECD, International Energy Authority, US Homeland dept, World Bank, the i-Build programme[8] and the Beca Group Limited.

Cross-sectoral measures and addressing interdependencies

- Environmental/carbon measures and cost-benefit ratios
- Linkages between measures to address interdependencies.

4.3 Long-lists by sector

The Study Team Sector Leads assembled a long-list of measures using findings from the literature review, scoping consultations and webinar, together with their own expert knowledge. The characteristics of the long-lists and issues encountered in developing them are set out by sector below.

4.3.1 Digital Communications

The full digital communications long-list comprises a total of 64 measures of which 33 are concerned with resilience, 29 with quality, one with cost and one with environmental sustainability. The key aspects of performance were associated with coverage, speed of provision and providing a continuous service.

Several challenges were encountered in identifying the initial long-list; these are summarised below:

- Digital communications infrastructure is changing at a breath-taking pace – for instance residential broadband speeds can now be 200 times what they were in 2003. This implies a need to be forward looking in the choice of indicators.
- The data available from Ofcom are much richer and much more reliable than data from most other national sources; this limits the possibility of international comparison.
- There are multiple generations of technology operating in parallel. Therefore, deciding which are the most important was a key consideration. For example, some technologies such as 2G mobile are still heavily relied upon.
- Related to the above, understanding what represents a 'failure in infrastructure' was crucially important. For example, counting one or two second gaps in service may give a big output number suggesting failure, but the actual outcome in the real world is negligible because there is minimal impact.
- It is important that measures collected are relevant to the ultimate consumer experience of the service. It is easy to put a very strong emphasis on easily measured items such as headline download speed, but sometimes these only have a tenuous link to the customer experience. As an example, if a consumer clicks on a page in an on-line newspaper, what is downloaded is an assembly of information from up to 150 different sources, each sitting on servers of differing business and capacity. These can also download scripts that may run or crash. These things

7 Energy Networks Association (2016) Engineering Technical Report 138 – Resilience to Flooding of Grid and Primary Sub-stations - http://www.naturalsols.co.uk/Ducts/Energy%20Networks%20Association%20%28ENA%29%20Substation%20Resilience%20to%20Flooding%20report.pdf

8 EPSRC funded programme that aims to become an internationally leading centre for innovation and research excellence in infrastructure business models run by a consortium from Newcastle University, the University of Leeds and the University of Birmingham - https://research.ncl.ac.uk/ibuild/researchprogramme/

have a much greater impact on how the user perceives the service than the raw download speed.

- In mobile, the coverage maps issued by the operators are tuned towards a receiver which is a high-quality radio receiver (usually a Nokia). Most smartphones are much poorer radio devices so coverage at the margins of availability is often overstated by the operators compared to the consumer experience.
- Highly technical measures such as packet loss[9], jitter[10] and latency[11] can have very little impact on the consumer experience although they are supported by engineers.

4.3.2 Energy

The energy long-list consists of 68 measures in total that are split within the domains as follows: 33 resilience, 15 quality, 9 cost and 11 environmental sustainability. Key performance aspects of energy infrastructure are security of supply, affordability and the decarbonisation of supply and use.

Energy sector statistics are well established as a government responsibility with long-term time series for some datasets. Measures rarely cease to be used unless they are very obscure, although some of the indicators published with accompanying explanations in the "Energy Sector Indicators" series[12] were discontinued after 2015. User experience measures (via attitude-tracking surveys) have wide uncertainty/confidence levels. Energy measures become more specific when they are dealing with specific issues such as the roll out of a technology.

Specific challenges encountered in selecting appropriate measures for Energy were as follows:

- Ofgem works towards the three objectives of promoting value for money, security of supply and sustainability[13] but these are not always internally compatible. Data availability now and in the future, was also identified as an issue - for example, if competition policy and regulation change, data may not be collected for that purpose any more.
- The energy sector is large and diverse in terms of energy sources, imports, transmission and distribution, users and uses. Some parts of the energy system have less coverage than others but it was recognised that the identification of measures should not be constrained by the current availability of data.
- Energy is not generated and managed on a single country basis so there are issues concerning the boundary of the UK energy system.
- The public policy environment for energy changes regularly with implications for what is measured and whether previous indicator datasets are still being maintained by BEIS.
- There are numerous internationally comparable indicators for energy, particularly via the International Energy Association, but few relate to the issues most pertinent to the overall performance of the UK's infrastructure system.
- Emerging elements of the energy system as it moves towards a smarter and more decentralised system, such as electricity storage, do not yet have accepted measures for tracking performance.

9 Packet loss occurs when one or more packets of data travelling across a computer network fail to reach their destination usually as a result of network congestion.
10 Jitter is defined as the short-term variations of a digital signal's significant instants from their ideal positions in time. Essentially it describes timing errors within a system that can lead to data errors.
11 Latency refers to time interval or delay when a system component is waiting for another system component to do something. This duration of time is called latency.
12 UK Energy Sector indicators - https://www.gov.uk/government/collections/uk-energy-sector-indicators
13 https://www.ofgem.gov.uk/about-us/how-we-work

4.3.3 Flood Risk Management

A total of 78 measures were identified for tracking the performance of flood risk management (FRM) infrastructure. These are split between the domains as follows: 17 resilience, 23 quality, 29 cost and 9 sustainability. The key role of flood risk management infrastructure is to protect lives and livelihoods. The Environment Agency collects and reports on an extensive dataset related to properties at flood risk, properties protected and the investment planned in new schemes and their anticipated outcomes.

The Environment Agency's main outcome measures[14] for flood risk management relate to achieving better flood and coastal erosion protection for people and property. New assets and maintenance can increase the overall Standard of Protection. The Environment Agency's Corporate Scorecard has performance measures concerned with increasing the resilience of people, property and businesses to the risks of flooding and coastal erosion, protecting and improving water, land and biodiversity, improving the way we work as a regulator to protect people and the environment and support sustainable growth, working together and with others to create better places and ensuring that we are fit for the future.

Outcome Measures are also identified in relation to the Flood and Coastal Erosion Risk Management (FCERM) Programme (formerly the Medium-Term Plan) used to select FCERM projects for investment. The outcome measures cover cost-benefit, number of households moved to a lower flood probability category, households with a reduced risk of coastal erosion.

Homes better protected in terms of moving properties between risk bands and assessing economic benefits are relatively straightforward to collect; asset condition and the probability of an asset failing is more of a subjective assessment that normally depends on an asset inspector's judgement[15].

4.3.4 Solid Waste

A total of 103 measures were identified in the solid waste infrastructure long-list; these comprise: 33 resilience measures, 22 quality measures, 22 cost measures and 26 environmental sustainability measures. The number of measures identified for solid waste reflects the number of indicators for which data are currently available and that these are collected separately for different waste streams. The key performance elements of waste infrastructure concern waste collection and management. Some internal conflicts exist in that waste management facilities (e.g. Energy from Waste plants) require a minimal quality (e.g. calorific value) of waste to operate effectively yet there is a policy imperative to minimise waste generation.

Waste management is heavily influenced by policy (e.g. on organic waste collection, recycling and reduction to landfill) that then influences the data that is collected.

Datasets for household waste are extensive whilst those for commercial and industrial wastes are patchy, although it should be recognised that the quality and uncertainties associated with both sets of data can be very variable. In addition, there are uncertainties in waste generation and waste management data, partly due to exemptions of small scale plants (considered to have low environmental impact, but which can manage significant quantities of waste individually and in aggregate). Data on re-use is also sparse.

The extent of, or spend on, waste infrastructure was considered to be of key importance. The type of waste infrastructure is also important; for instance, a local dedicated recycling facility for a specific waste stream would help to circularise production. Efforts and benefits of waste prevention are difficult to measure.

14 Chapter 1 of: Calculate Grant in Aid funding for flood and coastal erosion risk management projects Guidance for risk management authorities Version 1 updated February 2014, Environment Agency - https://www.gov.uk/government/publications/calculate-grant-in-aid-funding-flood-risk-management-authorities

15 Asset performance tools – asset inspection guidance Report – SC110008/R2, July 2014, Environment Agency

Weight based data are probably not the most appropriate as these could mask efforts higher up the waste hierarchy and the carbon intensity of products. Local authorities are faced with key obligations to divert waste from landfill and to reduce carbon emissions. Weight-based performance data (e.g. wt% or tonnes recycled) do not align with emissions based performance; for example, local authorities can avoid landfill by generating energy from waste but this could remove materials that could be recycled, which would have higher GHG saving potential. Therefore, a focus on weight alone could drive the performance in the wrong direction.

It is also possible that some recycling targets and facilities could cause unintended consequences, for instance, the example of Packaging Recovery Notes (PRNs). PRNs are designed so that packaging producers from across the UK can provide evidence that they are contributing or paying towards packaging recycling. Scotland is considering changing the scheme to focus on its own targets but may have insufficient packaging to meet these. This could lead to importing of waste from England that could then impact on England's ability to meet its recycling obligations.

It is worth noting that the PRN system is currently being scrutinized by the UK Advisory Committee on Packaging (ACP)[16] that covers the whole UK.

In the last seven years, there has been a significant increase in export of Refuse Derived Fuel (RDF) to European countries[17]. Such RDF is often just baled waste that has been taken through primary separation stages taking out metals, bulky items and some of the wet organic waste. The export of RDF is driven by a market pull of the European waste to energy plants which would otherwise run with much reduced capacity. A recent study by Eunomia[18] shows that the gap between residual waste arisings and available treatment capacity in the UK has reduced from 12.9 million tonnes to 10.2 million tonnes as more treatment plants come online (e.g. Ferrybridge Multifuel facility in West Yorkshire, Wheelabrator's Kemsley Mill facility and Viridor's Avonmouth plant). This is positive as the UK's decision to leave the European Union creates uncertainty over this export of RDF.

4.3.5 Transport

183 measures are identified in the transport infrastructure long-list. These are sub-divided across the identified domains as follows: 30 resilience, 98 quality, 45 cost and 10 environmental sustainability. The transport sector collects and analyses an extensive dataset to assess the performance of its infrastructure in relation to reliability, safety, cost and decarbonisation. The complex and separate regulatory environments for transport sub-sectors provide a rich source of performance measures. In addition, the transport sector is proficient in appraising Value for Money and environmental impacts.

Specific challenges in identifying long-list measures for transport were:

- Quality deteriorates as demand by users using that transport mode/service nears capacity (due to congestion/crowding). Measures need to be cognisant of this effect.
- The relationship between demand and capacity varies by location and time (/day/season) such that any 'straight' average measure (e.g. comparison of UK annual demand with capacity) is not a useful representation.
- Differences in approach/level of detail around the globe limit the extent to which measures can usefully be compared beyond the UK.
- On robustness, certain transport data currently require significant validation efforts to match up different sources (e.g. from Ports/shipway agents).

16 http://www.recycle-pak.co.uk/News/News_37.htm
17 RDF Export: Analysis of the Legal, Economic and Environmental Rationales; report for RDF Export Industry Group, prepared by Eunomia; August 2015 - http://www.eunomia.co.uk/reports-tools/rdf-export-industry-group-report/
18 http://www.letsrecycle.com/news/latest-news/eunomia-examines-impact-of-brexit-on-rdf-market/

- It is difficult to identify standard measures for transport resilience - recovery is very dependent on the scale of the incident and has multiple potential causes.
- Specific to airlines is the interplay between different airports i.e. connectivity (where can fly to) rather than accessibility (closest airport). Capacity in the air can be an issue and - like performance - can be constrained by factors beyond the UK, e.g. Scandinavia to Spain flights routing through UK airspace during a French Strike. Potential measures range from objective (e.g. environmental impact) to subjective (passenger quality).
- Route based analysis can be used for rail. However, this brings with it the challenge of whether to assess a steady state or a growing market (in comparison, the digital sector has big technological shifts that one market size can support). Longitudinal analysis can be more helpful, rather than comparisons between routes.
- For roads, there is the challenge of maintenance versus customer experience i.e. investment leads to short-term pain (applies to rail too). The commercial imperative of Private Finance Initiatives (PFI) makes comparisons difficult with non-PFI schemes, but it appears to work. Consumer surveys show that road measures are mostly in the 'right' broad areas.

4.3.6 Water and Wastewater

For the water and wastewater sector, 57 measures were identified in the long-list split across the four domains as follows: 21 resilience, 11 quality, 11 cost and 14 environmental sustainability. There is no shortage of existing measures as the UK water sector is highly regulated, however, the sector is heterogeneous and therefore generic measures are hard to identify. Key areas of importance that reflect Ofwat's priorities are: asset health, water resources, sewer flooding, impacts of wastewater on the environment and social/economic aspects.

The sector has moved to a much higher use of Performance Commitments[19] that are individual for each company. Ofwat requires companies to develop such commitments and consult with their customers on these. As these are individual to each company, whilst the range of measures has expanded, the ability to compare these across regions, and to collate national data, has reduced.

For international comparisons, the challenge is to derive measures that compare the UK to other advanced economies. For example, a measure of % of population with a wholesome water supply isn't going to show much differentiation between the UK and other European countries.

[19] OfWAT (2015) Monitoring and Assuring Delivery. Accessed online at http://www.ofwat.gov.uk/wp-content/uploads/2015/10/pap_pos20151015monitor.pdf on 09/05/2017.
OfWAT (2016) Outcomes, performance commitments and outcome delivery incentives 2015-16. Accessed online at http://www.ofwat.gov.uk/publication/outcomes-performance-commitments-outcome-delivery-incentives-2015-16/ on 09/05/2017

Section summary

There is a rich body of experience regarding the issues and challenges faced in developing performance indicators for infrastructures. To the greatest extent possible, this learning experience was fed back into our approach in developing measures for the study.

Across the six infrastructure sectors, over 550 potential measures of performance were identified, with the greatest number identified for transport infrastructure. Across the infrastructure sectors, those which have been the focus of policy and action for longer tended to be characterised more fully in terms of numbers of measures than the more recent ones.

Infrastructure comparisons across national jurisdictions varies significantly for the six infrastructure sectors in view. Self-evidently, this reflects the extent to which infrastructures interface across different countries (e.g. energy comparisons are strong, flooding ones are weaker), and the extent to which infrastructure communities are engaging with one another across national boundaries.

5 Selection of proposed measures

5.1 Introduction

The individual sector long-lists were reduced to a more manageable number of measures through a short-listing process using criteria that had been informed by the previous tasks including the stakeholder webinar. Once short-lists had been produced, baselining information was provided in terms of the construction of measures and the data required to populate them. The final stage in the process involved close collaboration with the NIC, its sector leads and external stakeholders to select and agree the proposed measures.

5.2 Short-listing criteria

The criteria developed to short-list performance measures were applied in two ways; some of these were for characterisation purposes, whilst others were used to rule specific measures 'in' or 'out'. These criteria were reviewed by stakeholders and the NIC and their comments incorporated prior to use.

The literature review and Scoping Consultations highlighted the following general challenges to the formulation of performance measures:

- Challenges that were highlighted most frequently and on a cross-sectoral basis covered: linking measures to objectives, how to sensibly measure performance in a rapidly evolving world and data availability, consistency and comparability.
- Sectors differ in the maturity of existing performance measures: some sectors have well-defined national performance measures that may need tweaking or refining such as waste, energy and water whilst others need a more fundamental assessment e.g. digital communications.
- Measures should be high-level, straightforward to populate, understand and interpret. This does not suggest a lack of sophistication for example, ratios of inputs to outputs and identifying ranges of performance rather than averages.
- Different types of measures may be appropriate for different domains, for example, activity to assess resilience and outcome to measure quality.
- Measures need to capture the gap between what exists and what is desired.
- Avoid measures that fail to incentivise innovation.

In addition, the design characteristics of successful performance measures were considered. These included:

- Set within a 'logical framework' from overall goal to measurable outcomes then performance measures (Magenta Book referenced)
- Comprehensive
- High-level and pragmatic
- Simple – coherent and easily communicable
- Considerate of interplay, recognising the potential for trade-offs to avoid perverse incentives
- Data readily available and dependable.

The above considerations led to confirmation of the following broad criteria for moving from long-listed measures to short-listed ones:

Content criteria - intended to characterise measures, but not part of the short-listing assessment. These covered the definition of the measure, the identification source (for example, existing measure already in use, suggested by stakeholder or suggested by Study Team Infrastructure Lead), existing data source (if an existing measure), type of measure (activity, output or outcome) and current frequency of collection or publication (again, if an existing measure).

Gateway criteria were used as 'knock out' criteria. If the answer was negative for any of the criteria, then the measure should not be short-listed unless there was a very good reason to do so.

- Attributable to relevant infrastructure – is the measure persuasively linked to the relevant type of infrastructure?
- Clarity of definition – is the measure concise and to the point?
- Reliability of source – has the measure been suggested by a recognised authority or advocacy group, stakeholder, expert judgement or an idea?
- Statistically valid – is the data that will be used to populate the measure drawn from a robust dataset i.e. covering a large sample rather than a small sample or proxy data?

Weighted criteria (these were scored to help prioritise shortlisted measures)

- Easily comprehensible – can the measure be easily understood?
- Unambiguous – are the implications of a change in the measure (increase or decrease) likely to be universally understood?
- Comparison between different parts of the UK – can the measure be populated at sub-national levels?
- International comparisons - is the measure common to members of OECD, World Economic Forum etc.?
- Cost-effective - is the measure cost-effective to collect i.e. is it readily available and already collected or can it be developed from existing sources or would the data need to be collected from scratch?
- Multiple sectors – could the measure apply to more than one sector?

5.3 Short-listing and measure development process

Short-listed measures were identified using the process set out above and considered at a workshop with the NIC's Sector Leads in January 2017. This led to several changes and additions to the short-lists. The NIC also requested at this point that the measures should be presented against domains but not objectives to achieve greater clarity and that the economic sustainability sub-domains should be replaced with the heading of 'Cost'. Following the workshop, further iteration of the measures was undertaken in conjunction with the NIC to provide the final set of proposed measures.

5.4 Baseline measures

As a second step, the short-listed headline measures above were subsequently characterised in terms of the types of data that would be required to populate them, and populated with actual data where this was available. It was assumed that all data are or would be collected on an annual basis and the study team's Sector Leads were asked to provide an explicit comment if data should be collected on a less frequent basis. The following headings were added to the short-listed measures tab in the supporting spreadsheet.

- Composition – specifying what the measure comprises e.g. average number of minutes lost per electricity customer.
- Metric – unit of measure to be used e.g. minutes.
- Value – actual value if data are available e.g. 45.
- Date collected – the date point for which the most recent data are available e.g. 2014/15.
- Positive progress source – explanation of whether an increase (or decrease) is evidence of positive progress for the infrastructure concerned.

- Data source – source from which data can currently be obtained, or for new measures, where it should be available from e.g. Ofgem.

5.5 Proposed measures

The final selection of proposed measures was made in close collaboration with NIC Sector leads, and are described for each infrastructure sector, together with the justification for their selection and highlighting issues likely to be encountered with their construction, population and use.

5.5.1 Digital communications

Key characteristics of the performance measures identified

Ten measures have been identified split across all domains and sub-domains other than sustainability – minimise environmental impacts. The measures focus on the quality of the service available (including, resilience, coverage and performance) and the cost of the service to the end user. An environmental measure of carbon emissions has been proposed as there appears to be little monitoring of the sector in this respect.

Two measures have been identified for the capacity and performance element of the quality domain covering download and upload speeds for broadband and mobile networks, whilst the user experience sub-domain comprises four measures with mobile broadband coverage split into 4G and 2G/3G due to the number of users that are not provided with 4G coverage.

Four new measures have been identified (that is, measures that are not currently used or collected), the construction and population of which will require further development. These cover: service downtime (everyday resilience), rate of service restoration after significant event (resilience to external shocks), agreed % of sold speed experienced by customers (user experience) and CO_2 emissions (decarbonisation). The resilience and decarbonisation measures, together with the cost measure (average cost (£) per GB of traffic) are cross-cutting measures that also apply to other infrastructure measures.

Setting out the baseline

Ofcom publishes a wide variety of indicators on the Digital Communications sector and most of the final measures can be populated from information regularly published by them, with most data available for 2016. Ofcom holds very detailed data on most aspects of the communications infrastructure. Much of it is held at OS UPRN (Ordinance Survey Unique Property Reference Number) level, allowing any desired level of aggregation (country, region, city, local authority area, etc.) to be extracted. Ofcom is currently looking at ways in which this data can be made more readily available. However, the four new measures identified are not currently reported by Ofcom. It will be worth exploring these with Ofcom to see if the required data is held in-house or whether some new data gathering will be required.

Issues relating to the accuracy, reliability and integrity of the proposed measures

Aside from the requirement to find new data as described above, some consideration will need to be put in to the precise definitions behind some of the new performance indicators. Care will need to be taken to define the precise terms of 'service downtime' across a whole public network and how this will be measured. Care will also need to be taken in defining what is a major disruptive incident, how it is triggered and when the transition to normal operation happens. Such considerations will need to be made in the light of the available detailed information.

Proposed performance measures

The distribution and definition of the performance measures for this key infrastructure, plus any issues likely to be encountered in their population or use are set out in the following table.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Resilience	Everyday resilience	Service Downtime	**Source:** to be determined **Construction:** to be determined	New measure for which data will need to be identified. Precise definition will need to consider the data available or identify the data that should be made available.
	Resilience to external shocks	Rate of service restoration after significant event	**Source:** to be determined **Construction:** to be determined	New measure for which data will need to be identified. Precise definition will need to consider the data available or identify the data that should be made available.
Quality	Optimise capacity and performance	Average download and upload speed for the fixed broadband networks	**Source:** Ofcom: Connected Nations Report 2016 - https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016 **Construction:** data transfer rate in megabit per second (Mbit/s)	Download speed (experienced by customers) is the headline measure that is used when selling broadband services to customers. It is an important indicator of the overall capability of broadband infrastructure. Upload speed is increasingly important as more people and businesses use cloud computing and generate their own content to share.
		Average download and upload speed for the mobile networks (3G and 4G)	**Source:** Ofcom - Smartphone cities: Measuring mobile broadband and voice performance, 2016 - https://www.ofcom.org.uk/research-and-data/broadband-research/smartphone-cities/smartphone-cities-dec16 Ofcom - Measuring mobile broadband in the UK 4G and 3G network performance - **https://www.ofcom.org.uk/research-and-data/broadband-research/mobile-broadband-performance** **Construction:** data transfer rate in megabit per second (Mbit/s)	Similar justification to the above for download and upload speed. 3G is an intermediate technology that will shortly be superseded by 4G. Therefore, it is unlikely that information collected for this will be of great value.
	Optimal user experience	Average % of sold speed experienced by customers	**Source:** to be determined **Construction:** to be determined	New measure for which data will need to be identified in consultation with OOKLA and Ofcom. Precise definition will need to consider the data available or identify the data that should be made available.
		Fixed broadband coverage	**Source:** Ofcom: Connected Nations Report 2016 - https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016 **Construction:** Proportion of premises with no access to fixed broadband at 10Mbit/s or more - %	This is a fundamental indicator for the 'less easy to serve' areas where cable and fibre networks do not exist and local loop lengths are long. The new broadband Universal Service Obligation is expected to require service at 10Mbit/s.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
		2G/3G coverage	**Source:** Ofcom: Connected Nations Report 2016 - https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016 **Construction:** Proportion of premises without any mobile coverage (2G/3G) - %	Coverage of older networks is important, particularly 2G networks for voice coverage. 3G coverage is still of interest while 4G networks are rolling out but is likely to become less important as 4G coverage becomes more extensive.
		4G coverage	**Source:** Ofcom: Connected Nations Report 2016 - https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2016 **Construction:** Proportion of premises without any mobile coverage (4G) - %	It is important to have a focus on the roll-out of the latest generation of mobile networks. Once 5G is launched and rolling out, it may be appropriate to focus on 5G here and move 4G to the older networks section.
Cost		Average cost (£) per GB of traffic	**Source:** Ofcom: Communications Market Report, 2016 https://www.ofcom.org.uk/research-and-data/cmr/cmr16 and Connected Nations, 2015 - https://www.ofcom.org.uk/research-and-data/infrastructure-research/connected-nations-2015 **Construction**: £ per GB of traffic	Calculated indicator based on average monthly revenue per subscriber and average monthly data download per fixed broadband customer.
Sustainability	**Decarbonisation**	CO_2 emissions ($MtCO_2$)	**Source:** to be determined **Construction:** to be determined	This is not currently calculated for the whole sector. CO_2 emissions expressed as an absolute rather than a rate (CO_2 emissions per GB of traffic) because the rate would show unrealistic positive progress due to the rate at which traffic is growing. Measuring carbon emissions for the whole sector is a better measurement of performance for the sector.
	Minimise environmental impacts	N/A	N/A	N/A

Table 5-1: Proposed digital communications performance measures

5.5.2 Energy

Key characteristics of the performance measures identified

A total of six measures are identified covering the four categories (resilience, quality, cost, and environmental sustainability). The measures cover six distinct aspects of the energy infrastructure system. These are required to provide appropriate coverage across the main types of energy sources/types (e.g. electricity as well as gas).

In many cases, the measures are derived ultimately from data recorded against individual pieces of infrastructure (e.g. power stations, interconnectors, meters) and so would be available to be disaggregated to the sub-national level or other scales. Whilst none are adopted from known internationally reported indicator sets, some measures may be comparable with international measures, for example the International Energy Agency has similar measures for the chosen aspects including diversity of supply and carbon emissions.

Cross-cutting measures that apply to other sectors are as follows:

- Everyday resilience – service downtime
- Resilience to external shocks – rate of service restoration after significant event
- Cost - £ per KWh generated
- Environmental sustainability: decarbonisation – total CO_2 emissions from energy generation.

Setting out the baseline

Four out of the six main aspects that the performance measures cover have been previously reported by Government or the regulator Ofgem in this form with baseline data available up to 2013, 2014 or 2015. The proportion of smart meters does not appear to be reported in this form but it should be relatively straightforward to derive from data already collected. Average energy efficiency of buildings may require further work to define based on existing and feasible data sources. The remaining measures are variants for different sources/types/uses of energy and whilst some of the data inputs required for the measures are collected, work is required to bring the data together into a combined index across a range of sources.

Issues relating to the accuracy, reliability and integrity of the proposed performance measures

In general, the measures selected are not contradictory in the long term so it should be possible for progress to be made across all measures over decades. In the short term, however, there will be tensions between prices and decarbonisation as it is inevitable that newer, cleaner technologies and the industries that support them take time to achieve scale and optimise costs/output. The measures are also largely agnostic to the energy sources, particularly across the array of electricity generation options, and should therefore remain relevant and robust as technologies emerge and the mix changes.

The proposed measure for diversity (of electricity and gas sources) raises two considerations. First, is the question of how diversified the UK energy system needs to be to be resilient and appropriate in other respects. The system may be less diverse and self-sufficient than is desirable now but a drive for diversity beyond a certain level may work against optimising in cost (or carbon) terms and may not be appropriate for the UK socio-economically and environmentally. Second, is whether the Shannon-Wiener measure is the most robust and sophisticated metric over time as there is debate and research in this area that could result in new preferred measures for energy supply diversity emerging in time.

An overall issue that has been considered throughout the study is the difference between the UK's energy system today and how fast it evolves to a different new decentralised,

smarter system. The pace of change in some areas may be rapid (e.g. recent changes in solar PV production costs and the future roll out of electric vehicles) and the changes may give rise to the need for additional or different headline measures even at the macro scale of the UK energy infrastructure system. One of the short-listed performance measures is particularly focused on the changing system (% smart meters) but this measure's usefulness may in fact be relatively short-lived and it could therefore be used as a supplementary measure rather than a headline one. Others associated with the changing system may be relevant to consider further as potential headline measures in time (e.g. storage related measures).

Proposed Performance Measures

The distribution and definition of the performance measures for this key infrastructure, plus any issues likely to be encountered in their population or use are set out in the following table.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Resilience	Everyday resilience	Service downtime for electricity	**Source:** Ofgem data portal https://www.ofgem.gov.uk/data-portal/network-indicators **Construction:** Unplanned (supply) minutes lost per electricity customer	Measuring the unplanned minutes lost per customer is a good measure of resilience as it focuses on the recovery time and end user experience rather than the incidents themselves which may have many different causes.
	Resilience to external shocks	Diversity of power generated from different fuels/sources	**Source:** BEIS statistics as published for electricity in DECC's Energy Sector Indicators 2015 https://www.gov.uk/government/statistics/uk-energy-sector-indicators-2015 Diversity of gas sources is not currently reported so a measure will need to be constructed and data recorded to populate this. **Construction:** Diversity of electricity generated from different fuels and gas from different sources, Shannon-Wiener measure = The market share multiplied by the natural log of the market share for each fuel in the market summed together	The Shannon-Wiener measure of diversity has been chosen because it places weight on the contributions of smaller participants in various fuel markets as they provide the options for future fuel switching. This is done by multiplying the market share by the natural log of the market share, which diminishes the impact of larger participants. However, it is recognised that there are shortcomings in using only one indicator to represent a concept as complicated as diversity. (Source: DECC, Energy Sector Indicators 2015)
		Rate of service restoration after significant event	**Source:** to be determined **Construction:** to be determined	New measure for which data will need to be identified. Precise definition will need to consider the data available or identify the data that should be made available.
Quality	Optimise capacity and performance	Energy efficiency of buildings	**Source:** to be determined **Construction:** to be determined	New measure for which data will need to be identified. Precise definition will need to consider the data available or identify the data that should be made available.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
		Number of smart electricity and gas meters in operation (% of total meters)	**Source:** BEIS smart meters' statistics https://www.gov.uk/government/collections/smart-meters-statistics **Construction:** % of domestic meters in operation that are smart meters; % of non-domestic meters in operation that are smart meters	Data is currently reported for the large energy suppliers and so the performance measure may be limited to that scope initially.
	Optimal user experience	N/A	N/A	N/A
Cost		**Cost per KWh**	**Source:** to be determined. Potentially could use the Levelised Cost of Electricity Generation which is the discounted lifetime cost of ownership of using a generation asset converted into an equivalent unit of cost of generation in £/MWh. **Construction:** Cost per Kilowatt hour for electricity and gas	This measure provides an overall cost for all users and uses of electricity and gas and could be shown separately or jointly for those energy types.
Environmental Sustainability	Decarbonisation	**Carbon emissions**	**Source:** Reported in the National Infrastructure Plan Performance Indicators 2014 – https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/431762/NIP_annex_performance_indicators_030615.pdf Based on BEIS data i.e. UK greenhouse gas emissions national statistics- https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics **Construction: C**arbon intensity of electricity generation - CO_2 emissions tonnes per KWh (Kilowatt hour)	This measure provides an assessment of the carbon emissions associated with electricity generation, but there is no equivalent measure for gas – this would need to be developed.
	Minimise environmental impacts	**N/A**	N/A	N/A

Table 5-2: Proposed energy performance measures

5.5.3 Flood risk management

Key characteristics of the performance measures identified

A total of seven measures are identified covering the four categories (resilience, quality, cost and environmental sustainability).

Within resilience there are two sub-domains with performance measures to show how the UK is managing with 'everyday' flood events and how this may increase under different climate change scenarios. The everyday resilience measure will be based on real data of properties flooded, but resilience to external shocks will be theoretical and based on national flood modelling.

The quality domain is concerned with the performance and quality of existing and new flood risk management infrastructure. There are two measures within the two sub-domains. The performance sub-domain measure will focus on the properties 'at risk' of flooding and if this number is decreasing due to improved infrastructure. The quality measure is based on the design quality and if the infrastructure is delivering the benefits.

There are two cost measures. These focus on the average Flood and Coastal Resilience Management Grant in Aid (FCRM GiA) investment per property protected and the average cost-benefit ratio achieved from schemes supported by the programme.

The environmental sustainability domain has one measure based on the area of habitat created or improved from flood risk management works; this contributes towards meeting the requirements of the Water Framework Directive.

All these measures can be captured at subnational level based on local authority boundaries. Some of the measures are already reported on at this level but some will need some simple GIS analysis to get sub-national consistency.

The only cross-cutting measures that also applies to other sectors is the unit cost measure: £ per property protected.

Setting out the baseline

The Environment Agency collects a large amount of data on new flood risk management schemes in its Flood and Coastal Erosion Risk Management (FCERM) Programme. This information is useful and can help populate the baseline for some of the measures, but this data is primarily focussed on new schemes. The measures proposed focus on the state of all flood risk management infrastructure, existing and future. The Environment Agency reports back to Defra on this information but it is not yet known if this data can be adapted to the proposed performance measures and how much effort it will take to populate the measures at sub-national level. The main source of baseline data for properties at risk is the Environment Agency's FCERM Long-term investment scenarios (LTIS) 2014.

Issues relating to the accuracy, reliability and integrity of the proposed performance measures

The 'everyday resilience' and 'cost' measures will use real data of actual properties flooded and costs. This will show more variation on a year to year basis than theoretical data but could be misleading if taken as the changing state of FRM infrastructure on a year to year basis rather than longer term patterns.

For 'resilience to external shocks' it has been assumed that national mapping is available that shows the variation in risk across different climate change scenarios. This has not yet been confirmed.

The 'optimise user experience' measure is based on post implementation benefits being available on schemes that have been completed. It is not yet known if this is available or if it is consistently measured across all schemes.

Proposed Performance Measures

The distribution and definition of the performance measures for this key infrastructure, plus any issues likely to be encountered in their population or use are set out in the following table.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Resilience	Everyday resilience	Proportion of 'at risk' properties that flooded in the last year	**Source:** Environment Agency (this is not a publicly available figure, but the Environment Agency reports these figures to Defra each year so should be able to access them) **Construction**: Can be collected for each source of flooding: • % properties at 1% chance of annual flooding from rivers that flooded last year • % properties at 0.5% chance of annual flooding from the sea that flooded last year • % properties at X% chance of annual flooding from surface water that flooded last year	This measure indicates the degree to which infrastructure is protecting properties that are identified as being at risk based on accepted risk levels set by the Environment Agency. However, if extreme events occur, such as with storms Desmond, Eva and Frank in winter 2014/15, the numbers flooded are likely to be higher than in other years due to the low probability/high consequence of such events. This needs to be accounted for when reporting on this measure.
	Resilience to external shocks	Variance in number of properties at risk under different climate scenarios	**Source:** New measure, to be determined **Construction:** Number of properties at risk under a range of climate scenarios.	This indicates the degree to which infrastructure is protecting commercial and residential properties against climate change; this is likely to have significant impact on flood risk in the future. The LTIS estimates properties based on different **investment** scenarios in the future, not climate change alone. The CCC has also done a study on this, but the numbers do not align with LTIS (https://www.theccc.org.uk/wp-content/uploads/2015/10/CCRA-Future-Flooding-Main-Report-Final-06Oct2015.pdf.pdf)
Quality	Optimise capacity and performance	Total number of properties at risk from flooding	**Source:** Environment Agency, FCERM Long-term investment scenarios (LTIS) 2014 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381939/FCRM_Long_term_investment_scenarios.pdf **Construction:** Number of residential and non-residential properties at risk from river/sea and surface water.	The total number/ of properties at risk of flooding should reduce with appropriate and high quality flood management measures in place.
	Optimal user experience	Measure of design quality for FRM assets	**Source**: new measures, to be determined **Construction:** new measure, to be determined	No measure has been identified for this, but it is an important area to be investigated to ensure the safety and security of communities.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Cost		£ per property protected	**Source:** Environment Agency, Flood and Coastal Erosion Risk Management (FCERM) Programme (2015/16 – 2020/21) - https://www.gov.uk/government/publications/programme-of-flood-and-coastal-erosion-risk-management-schemes **Construction**: £ invested in properties protected by flood risk management schemes supported in the last year	This provides an indication of the amount of investment in flood risk management schemes. The data is not produced annually as this is a multi-year programme. The programme also includes coastal erosion schemes that would need to be considered separately.
		Cost benefit ratio of FRM measures	**Source**: Defra: Flood and Coastal Erosion Outcome Measures - https://www.gov.uk/government/statistics/flood-and-coastal-erosion-risk-management-outcome-measures **Construction:** Outcome Measure 1 - the ratio of the whole life present value benefits (Pvb) to the whole life present value costs (Pvc) from projects in the Flood Risk Management Grant in Aid capital investment programme	Provides the average cost benefit ratio for all schemes in the programme. Not reported regularly – most recent reporting is from 2014.
Environmental Sustainability	Decarbonisation	N/A	N/A	N/A
	Minimise environmental impacts	Net area of habitat improved or created	**Source:** Defra: Flood and Coastal Erosion Outcome Measures - https://www.gov.uk/government/statistics/flood-and-coastal-erosion-risk-management-outcome-measures **Construction:** Outcome Measure 4 – meeting the Framework Directive • Hectares of water dependent habitat improved or created • Hectares of intertidal habitat created	This measure provides evidence of how flood risk management schemes can make a positive contribution to the environment by increasing and protecting habitats and helping to meet the requirements of the Water Framework Directive.

Table 5-3: Proposed flood risk management performance measures

5.5.4 Solid waste

Key characteristics of the performance measures identified

A total of seven measures are identified covering the four domains (Resilience, quality, cost and environmental sustainability). One measure is identified for resilience; this covers the utilisation of the current capacity available and the degree to which the technologies will need replacing within five years thus highlighting where capacity issues arise that could impact on resilience. Two measures are identified in relation to quality – optimising capacity and performance - that focus on the recycling rate that has been achieved and the value of residual waste. One relates to the cost of solid waste management and three to broader environmental sustainability.

These measures are available at England as well as UK level, but generally can be disaggregated to individual countries. Household waste can be disaggregated down to the local authority level. Most of these measures can also be compared to those of the EU15 countries, as required.

Cross-cutting measures are included that also apply to other infrastructure sectors; these are:

- Cost - £ per tonne of waste collected/treated/disposed
- Environmental sustainability: decarbonisation – carbon emissions from solid waste management per year.

Setting out the baseline

Any baseline data need to be judged against the increasing drive towards waste minimisation, as a back drop and the changing socio-economic factors that influence the quantities and composition of waste streams. Waste minimisation is difficult to measure as any data on minimisation/re-use of materials is sparse. In the medium to long term, businesses need to be encouraged to use the Electronic Duty of Care System[20]. As well as reducing burdens on business of the current paper-based system, it will significantly enhance the ability to extract good quality data for businesses, regulators and the NIC. To measure the resilience of solid waste infrastructure it is important to measure the state of current waste management facilities and their usage plus their capacity/ability to meet future solid waste challenges. For this, it will be important to examine the Environment Agency's records once again (last done in 2010) to determine rated capacity of facilities as well as their current utilisation.

At present, a great deal of the household waste data are collected (annual returns from local authorities, using Defra's Waste Data Flow database) and, to a lesser extent, the commercial and industrial waste. This provides a good starting point for the data required for the proposed measures. Construction waste in the UK is recycled to a very high degree (consistently greater than 85%, compared to the 70% EU target) and is not included in the final high level measures.

Issues relating to the accuracy, reliability and integrity of the proposed performance measures

The measures selected are complementary and it will be possible to take each of them individually or simultaneously. Of course, there are several more detailed measures (and data) that sit underneath these and it is advised these are viewed alongside the high-level measures. Other issues to note are:

- Extensive datasets exist for household waste, as each local authority report their activities using Waste Data Flow. There is much less data on commercial and industrial waste management that often uses household waste processing, recycling

[20] An on-line system (https://www.edoconline.co.uk) that is designed to help businesses record what happens to their waste and thereby doing away with the physical records of 'waste transfer notes'.

and disposal facilities.

- There is a degree of uncertainty around solid waste quantities as some waste is taken to small scale plants that are exempt from the normal regulatory and reporting requirements.
- To understand waste minimisation activities, several parameters will need to be assessed, simultaneously. These may include gross value added by the waste management industry and composition of commercial and industrial waste plus quantities of its constituent parts. In recent years, a lower paper recycling rate has been observed because of reduced quantities of waste paper, driven by increasing use of digital storage in offices and use of on-line information and news media.
- Innovative work is underway in waste minimisation and re-use that will provide better, faster and cheaper methods to separate and recover materials; e.g. peeling off different layers of packaging materials into constituent parts to enable recycling. At present, such measures are still rather disparate and localised and therefore difficult to monitor nationally.

Proposed Performance Measures

The distribution and definition of the performance measures for this key infrastructure, plus any issues likely to be encountered in their population or use are set out in the following table.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Resilience	Everyday resilience	N/A	N/A	N/A
	Resilience to external shocks	% utilisation of active facilities by technology	**Source:** Unpublished, but can be obtained from the Environment Agency: https://test.data.gov.uk/dataset/waste-infrastructure-data-tables-afa223 **Construction:** This requires analysing capacity of 'active' facilities of each type and relating them to throughput, on an annual or five-year basis. It would be possible to combine this into a single % utilisation value.	This measure will need to be viewed with caution as owners/managers of high capital intensity facilities tend to work these assets well beyond their normal life. This is driven by operational economics and regulatory requirements, which for old plants may be less stringent, having been issued much earlier so the definition of 'Best Available Technique' may differ (note: a cycle of identifying need, then planning and implementation of energy from waste plants can take up to 5 years).
Quality	Optimise capacity and performance	Recycling rate	**Source:** Defra Digest of Waste and Resource Statistics, 2016 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567502/Digest_waste_resource_2016_rev4.pdf **Construction:** proportion of household, commercial and industrial waste recycled - %	This is based on household waste to report recycling rates under the Waste Framework Directive (2008/98/EC). Can be derived for each source of waste or a composite measure be developed.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
		Energy recovery from waste	**Source:** Defra Digest of Waste and Resource Statistics, 2016 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567502/Digest_waste_resource_2016_rev4.pdf **Construction:** Net export of energy from waste measured by Gigawatt hours per year. This measure includes all aspects of energy recovery from waste including anaerobic digestion and biogas.	Latest data is from 2014 covering energy from waste and anaerobic digestion.
	Optimal user experience	N/A	N/A	N/A
Cost		£ per tonne of waste collected and disposed/ treated	**Source:** ONS UK Environmental Accounts: 2015 - https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/ukenvironmentalaccounts/2015-07-09 **Construction:** Average cost of solid waste management - £/tonne. This is a high-level cost measure covering the costs of all aspects of waste management, collection, disposal and treatment divided by the total household and C&I waste tonnage. NB: this is a gross cost – it does not take account of energy produced.	This measure provides an assessment of unit cost; this is also applied to other sectors.
Environmental Sustainability	Decarbonisation	Carbon emissions from solid waste management	**Source:** Defra: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567502/Digest_waste_resource_2016_rev4.pdf **Construction:** Emissions are measured by tonnes of carbon dioxide equivalent per year	This measure demonstrates the sector's positive contribution to reducing the quantity of emissions through re-use of materials, recycling and energy recovery.
	Minimise environmental impacts	Waste generated per capita	**Source:** Defra Digest of Waste and Resource Statistics, 2016 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567502/Digest_waste_resource_2016_rev4.pdf **Construction:** Waste generated per capita is measured by kilograms per person per year	Based on household, commercial and industrial waste.

Table 5-4: Proposed solid waste performance measures

5.5.5 Transport

Key characteristics of the performance measures identified

The five headline Transport Sector performance measures represent the overall quality of connectivity each against a 'crow fly' distance approach, traveller-km for person trips and tonne-km for freight. Two types of measure are included: journey speed (that is, 'crow fly' distance over travel time); and cost per km. Separate measures could be derived for each transport mode for personal and freight travel as needed.

For the Resilience domain, the headline 'everyday resilience' measure represents the range of variability in speed and cost/km of a journey in typical conditions, as experienced by an individual or freight operator. A demand-weighted construction of typical traveller and freight journeys is specified to combine the attributes of journeys on different parts of the network and at varying times of the day. With consistent application of the demand weighting, the measure can be populated at any sub-national level. However, for the same reasons, it is expected to be of limited value for comparison to pre-existing measures internationally. No suitable headline measure was identified for 'Resilience to external shocks' given the uniqueness of any incident on the transport network, for example including the extent to which alternative routes/modes are available and the flexibility of travellers to temporarily change their behaviour to reduce the inconvenience.

For the Quality domain, the headline measure for 'Optimise capacity and performance' represents the latent performance of the network, that is the speed in 'free-flow' (uncongested) conditions, a function of the directness and capability (for example the speed limit) of the infrastructure. A demand-weighted construction of uncongested traveller and freight journeys is specified to combine the attributes of journeys on different parts of the network. With consistent application of the demand weighting, the measure can be populated at any sub-national level. However, for the same reasons, it is expected to be of limited value for comparison to pre-existing measures internationally. No proportionate headline measure was identified for 'User experience'.

For the Cost domain, the headline measure represents the costs that any journey imposes on the traveller and on others, including on Government, in terms of subsidy and tax receipts, and other network users, as the costs of increased congestion and of accidents.

Finally, for the Sustainability domain, the shortlisted measures represent the marginal contribution of each km travelled/hauled (by each sub-sector) to the costs imposed on different groups. For the 'Decarbonisation' sub-domain, the measure describes the Carbon Dioxide (CO_2) emissions resulting from each traveller/tonne km on the network. For the 'Minimise environmental impact' sub-domain, the measure should cover the impact that each traveller/tonne km imposes on vulnerable areas/groups in terms of local air quality and noise emissions.

The cost (£ per passenger/ tonne/km derived for different transport modes) and carbon emission (CO_2 per km travelled derived for different transport modes) also apply to other sectors (cross-cutting measures).

Setting out the baseline

Considerable data are already readily available describing the connectivity of the UK transport network in uncongested and typical conditions. While there are also considerable data that can be used to develop the required demand-weighting approach to combining the data into a baseline measure, it is noted that this step is fundamental to the usefulness of the measure and is expected to require additional thought and developmental analysis. For the 'Minimise environmental impact' sub-sector, a consistent approach to defining and keeping up-to-date areas that are particularly vulnerable to local air quality and noise emissions and of relating these to infrastructure performance requires further development.

Issues relating to the accuracy, reliability and integrity of the proposed performance measures

In general, the measures selected for the respective objectives and domains do not give rise to conflicting assessment of performance; it should be possible for progress to be made in all measures simultaneously. However, it should be noted that journey cost and speed may change at different rates and, in some circumstances, in opposing directions. There are also of course trade-offs, in common with other sectors, between improving transport infrastructure – which results in increased demand to travel – and environmental sustainability measures.

Proposed Performance Measures

The distribution and definition of the performance measures for this key infrastructure, plus any issues likely to be encountered in their population or use are set out in the following table.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
Resilience	Everyday resilience	Variance in 'typical' speed	**Source:** Traffic Master/other GPS, and smart/mobile phone data for speeds/times; GIS software for distances **Construction:** Typical speed is based on demand weighted average across time conditions rather than a comparison of peak and free flow journey times. This will be recorded separately for different modes of transport.	Resilience is captured in terms of the range of variation around the typical speed achieved by travellers across a range of conditions. This allows for differences in peak times/durations across the country and for longer trips that may only be in peak conditions for part of that journey. Considerable data on how long journeys take (allowing the calculation of speed) at different times/on different days is now readily available. The variance this indicator records includes differences between times of day, days of the week, and across the year and reflects journey time reliability as experienced by travellers. There is a body of evidence supporting that unreliability of journey times is more of an annoyance for users than duration. For example, if the peak journey time was predictably more than the free-flow this is less of a problem for travellers.
	Resilience to external shocks	N/A	N/A	No measure is included due to the uniqueness of any incident. Evidence from transport research shows that there is more flexibility in the system than typically recognised. For example, in terms of the availability of alternative routes or modes of travel or in the ability for travellers to vary their travel plans to limit the impact of disruption which they experience.
Quality	Optimise capacity and performance	Fastest average speed	**Source:** Traffic Master/other GPS, and smart/mobile phone data for speeds/times; GIS software for distances **Construction:** Fastest average time is constructed from the distance over time in free-flow/uncongested conditions. This will be recorded separately for	Quality is captured in terms of the best (free-flow) speed which can be achieved by travellers, representing the capability of the network.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment
			different modes of transport.	
	Optimal user experience	N/A	N/A	Developing a comparable and statistically significant typical measure of user satisfaction by mode over time, would require a significant quantity of data to adjust for the influence of variations across: geographies; times of day; journey purposes; and more. Such a data collection exercise would come at considerable cost and would provide limited explanatory power in terms of the link between infrastructure and user experience. It is therefore not considered to be proportionate to define a user experience measure.
Cost		£ per passenger/ tonne/km derived for different transport modes	**Source:** DfT **Construction:** calculation of the cost per passenger-km or per freight tonne km travelled for each different transport mode. This dataset is available as a future time series that considers issues such as changes in fuel costs. DfT updates the information in its WebTAG data book annually (and sometimes more often) updating some but not all of the underlying parameters each time	Each trip made has costs beyond the financial impact on the individual or organisation travelling (for example vehicle operating costs, parking charges or fares). Those affected include the Government (in terms of subsidy and tax impacts) and wider society (including other travellers on the road for example in terms of congestion and accident costs).
Environmental Sustainability	**Decarbonisation**	Carbon emissions (CO2 per km travelled) derived for different transport modes	**Source:** DfT **Construction:** calculation of the carbon impact of travel in terms of CO_2 emission per passenger-km or per freight tonne km travelled for each different transport mode	Transport carbon emissions are a primarily a function of the number of vehicle km travelled, with the carbon per passenger-km or freight tonne-km also being affected by the 'load' carried by each vehicle. On the highway network the carbon emissions are also influenced by the level of congestion.
	Minimise environmental impacts	• Air quality measure • Noise measure	**Source**: new measure, to be determined **Construction:** new measure, to be determined.	This measure could be based on emissions in 'vulnerable locations' – EIA/transport appraisal guidance could be used to identify such locations. Measures do exist, but those set out in WebTAG and EIA guidance (for example) are arguably too precise – being specified at a local rather than national scale. For example, considering noise impacts or air quality at individual residential properties. It will be important to engage air quality and noise experts in advising on the construction of the measures.

Table 5-5: Proposed transport performance measures

5.5.6 Water and wastewater

Key characteristics of the performance measures identified

A total of ten measures are identified covering the four categories (resilience, quality, cost, and environmental sustainability). In three sub-domains, two measures are required to represent performance in both water and wastewater; for example, everyday resilience is measured by the most severe types of failures for water (loss of water supply) and wastewater (sewer flooding), resilience to external shocks is assessed through the frequency of expected drought permit orders and the rate of restoration of services following a significant event. The Service Incentive Mechanisms (SIM), used to measure user experience, is an industry-developed composite measure that assesses customer service performance.

Environmental sustainability performance is measured through carbon emissions (of construction/operations) per litre abstracted/treated and through the status of rivers according to the Water Framework Directive, which specifies EU requirements for the quality of water in our rivers and lakes.

In all cases, the measures are available disaggregated to the sub-national level of individual water and sewerage company supply regions (or to water-only company regions). Some measures are directly comparable with international measures, for example the percentage of rivers at good or better status is comparable with all EU and European Economic Area members.

Cross-cutting measures that apply to other sectors are as follows:

- Every day resilience – service downtime
- Resilience to external shocks – rate of service restoration after significant event
- Cost - £ per litre provided or abstracted/treated
- Environmental sustainability: decarbonisation – total CO_2 emissions from water and wastewater.

Setting out the baseline

The performance measures identified are largely existing measures with baseline data available for most to 2015/16 on the discoverwater.co.uk dashboard for England and Wales. Several of the measures have also been recorded for several years, so trends over the recent past can be analysed.

Equivalent measures are available in most cases for Scotland and Northern Ireland, although there will need to be an exercise undertaken to directly map these and to check for differences in data collation or interpretation.

Two measures (Rate of service restoration after significant event and Total water abstraction) are new proposed measures and will require further development to construct and populate these.

Issues relating to the accuracy, reliability and integrity of the proposed performance measures

In general, the measures selected are not contradictory, that is it should be possible for progress to be made in all measures simultaneously. There are significant challenges to achieving this, for example the drive towards achieving Good Status or Potential for all watercourses is increasing the use of more energy-intensive wastewater treatment, which in turn can drive up carbon emissions. The industry is, however, seeking to increase the use of low-carbon alternatives for example through catchment management measures.

It could be argued that there is a contradiction between measures that address resilience, quality and sustainability with cost measures. The water and wastewater sector is experienced at addressing the trade-offs between costs and service, for example through the customer engagement and "willingness-to-pay" studies used to help shape water

company business plans. Furthermore, whilst addressing sustainability, quality and resilience may lead to increases in direct costs (water bills), failure to address these measures may lead to greater indirect costs to customers and society, for example more frequent drought orders, or missed opportunities, such as where water quality improvements are a component of urban regeneration.

Some measures are subject to annual fluctuations due to weather conditions, most notably sewer flooding, but also greenhouse gas emissions may rise in a wet year due to increased pumping of surface water and infiltration in sewers. This could be addressed by tracking measure both on an annual and on a three-yearly rolling basis.

Proposed Performance Measures

The distribution of the performance measures for this key infrastructure by the four domains of Resilience, Quality, Cost, and Sustainability, together with appropriate baseline measures, is provided below.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment and justification
Resilience	Everyday resilience	Service downtime (loss of water supply)	**Source**: Water UK, 2016 - http://www.discoverwater.co.uk/loss-of-supply Construction: the average minutes lost per property, per year	Continuous water supply is key aim of infrastructure so any loss represents a reduction in everyday resilience.
		Sewer flooding - internal and external	**Source:** CCWater and Water UK, 2016 - http://www.discoverwater.co.uk/sewer-flooding **Construction:** the number of all properties (residential, commercial etc.) flooded internally and externally from sewers	Represents failure of infrastructure providing day to day service. The figures for external and internal flooding should be kept separate as the numbers for external are far greater and would mask the internal flooding measure.
	Resilience to external shocks	Drought permit orders	**Source:** Water companies (various) **Construction:** The percentage chance in one year of having to apply for a drought permit to allow abstractions which take a water body beyond sustainable limits. This measure could be adapted to report on say the number of people living in areas likely to be impacted by drought permit orders in any given year, but this would take some manipulation of available data.	This describes the chance of normal supplies being interrupted by drought as planned for in the water company Drought Plans. The measure shows regional variations and is a forecast of the future likelihood of drought permit orders being required, based on an assessment of the historic frequency and severity of drought and how this might change in the future.

Domains	Sub-domains	Definition of measures	Data source and construction	Comment and justification
		Rate of service restoration after significant event	**Source:** to be determined **Construction:** to be determined	The time taken to restore normal service after an event is a significant component of resilience: common across sectors This is not an existing measure and would require some industry-led work to define 'service restoration' and 'significant event'. This is different from the downtime measure as it refers to the rate of restoring the service and so seeks to avoid being a measure of the magnitude of the external shock as opposed to the resilience to this. Water UK will be reviewing resilience measures in the near future.
Quality	Optimise capacity and performance	Number of water quality incidents	**Source:** Drinking Water Inspectorate, 2015 - http://www.discoverwater.co.uk/quality **Construction:** Number of serious, significant or major water quality incidents	Water quality incidents would impact both supply and quality.
		Leakage from water mains	**Source:** Water UK, 2016 - http://www.discoverwater.co.uk/leaking-pipes **Construction:** Cubic metres of water leaked per kilometre per day (average on an annual basis)	Provides an indication to the degree to which the industry is protecting resources and minimising wastage.
	Optimal user experience	Service Incentive Mechanism (SIM)	**Source:** Ofwat, 2016 - http://www.discoverwater.co.uk/customer-experience-rating **Construction:** Formed of a quantitative score of response to customer contacts and complaints and qualitative score using a customer survey	A composite measure designed to test water company ability to "get things right first time" and "resolve complaints quickly and efficiently".

Domains	Sub-domains	Definition of measures	Data source and construction	Comment and justification
Cost		Combined cost per l of water and sewerage services for a metered household excluding surface water charges	**Source:** Water UK, 2017 - http://www.discoverwater.co.uk/annual-bill **Construction:** Average household bills/amount of water used and sewerage treatment required Also – the cost for 2L can be found here: http://www.discoverwater.co.uk/price-comparison	Provides an assessment of unit cost: common across sectors. Note that this data is not readily available in this format. With the deregulation of the market it may be possible to compare wholesale costs – the supply of water i.e. pipes, maintenance, operations etc. but not retail costs (cost of customer services).
Sustainability	Decarbonisation	Carbon emissions	**Source:** Water UK, 2016 - http://www.discoverwater.co.uk/energy-emissions **Construction:** CO_2 emissions per mega litre of water treated	Provides an assessment of unit carbon emissions: common across sectors.
	Minimise environmental impacts	Rivers at good or better status under the Water Framework Directive	**Source:** Environment Agency, 2015 - http://www.discoverwater.co.uk/protecting-rivers **Construction**: percentage of rivers at good or better status under the Water Framework Directive	Provides evidence that wastewater is not detrimentally affecting river status.

Table 5-6: Proposed water and wastewater performance measures

Section summary

In moving from the long-list to a short-list of proposed measures, a robust and transparent process was used driven by three criteria - Content, Gateway and Weight.

For most sectors, there were a few key sources of data e.g. Ofcom[21] for digital communications, Water UK[22] for water and wastewater and DfT[23] for transport. Where new measures have been identified that are not currently reported on and for which data is not readily available, it is suggested that further development work is required to identify both the construction of the measures and the data that should populate these.

Performance measures with formal definitions have been proposed for each of the UK's key economic infrastructure sectors. Future work is required to construct and populate a number of new measures that are not currently used in existing performance measurement frameworks.

The pressures of regulation, customer service expectations and legislative drivers within and across infrastructure sectors are useful influencers for measure definition and data collection. However, these are not always linked to how infrastructure is performing and keeping a focus on this will be an important consideration for the NIC as it progresses this performance measurement agenda.

[21] Other than publicly available reports referenced elsewhere, a lot of the data held by Ofcom is not in the public domain
[22] http://www.water.org.uk/developer-services/metrics
[23] https://www.gov.uk/government/publications/input-and-impact-indicators

6 Cross-sectoral measures and interdependencies

Whilst a sector-specific approach was adopted in the development of the performance measures, it is acknowledged that these sectors work together within a wider infrastructure system, that some performance measures may be relevant to more than one sector and that there are inherent interdependencies (or feedback loops, both positive and negative) between different types of key infrastructure.

6.1 Cross-sectoral measures

Throughout the process, the two measures that were regularly cited as potentially being applicable to more than one infrastructure sector related to carbon emissions and investment cost-benefit ratios. Whilst most sectors reflect both elements in the final set of measures, these are couched in very different terms due to the different characteristics of performance in each infrastructure. In addition, during the final stage of discussions on the measures, it was felt that the rate of restoration of service after a significant event was an important measure to include for several sectors. The construction of this measure and the data required to populate this are yet to be defined and should be developed in future in collaboration with relevant external stakeholders. The definition of a 'significant event' and 'rate of restoration' will need to be explicit and consistently applied to ensure that this measure is robust.

The following table summarises the cross-sectoral measures that have been identified within the final set of proposed performance measures across the six infrastructure sectors.

Cross-sectoral measure	Digital communications	Energy	Flood risk management	Solid waste	Transport	Water and wastewater
Every day resilience – service downtime	Service downtime	Service downtime for electricity	N/A	N/A	N/A	Service downtime (loss of water supply)
Resilience to external shocks - rate of service restoration after significant event	Rate of service restoration after significant event	Rate of service restoration after significant event	N/A	N/A	N/A	Rate of service restoration after significant event
Cost – unit cost	Average cost (£) per GB of traffic	Cost per KWh	£ per property protected	£ per tonne of waste collected and disposed/ treated	£ per passenger/ tonne/km (derived for different transport modes)	Combined cost per l of water and sewerage services for a metered household excluding surface water charges
Decarbonisation - carbon emissions	CO_2 emissions (MtCO2) for the sector as a whole	Carbon emissions – CO_2 emissions per TWh	N/A	Carbon emissions from solid waste management for the sector as a whole	Carbon emissions (CO_2 per km travelled) derived for different transport modes	CO_2 emissions per mega litre of water treated

Table 6-1: Proposed cross-sectoral performance measures

6.2 Interdependencies

Looking across the final recommended measures for each of the key infrastructure sectors, interdependencies are evident; the performance of a particular sector is potentially reliant on another sector or potentially capable of compromising the performance of another type of infrastructure.

The 2016 consultation on the approach and methodology for the development of the NIA[24] identifies the following interdependencies:

- The increasing dependence on digital communications infrastructure across all other infrastructure sectors, and the resilience (and security) implications associated increasingly with this.
- The effects on the energy sector of the increasing electrification of transport. Added to this is the steady growth of personal device mobility, and the growing development of Internet of Things technologies, which will potentially require electrical devices to be 'on' for greater proportions of the time.
- Water, wastewater and flood risk management, and the role of whole catchment-based approaches.
- The use of resources from the waste and water sectors to generate energy.
- Water supply and energy because certain energy futures (such as those with increased Combined Cycle Gas Turbine (CCGT) power station capacity) could have implications for water demand, and conversely some water strategies (such as increased use of desalination plants) could have implications for energy demand.
- The importance of infrastructure corridors.

The following graphic suggests the main interdependencies between sectors. Infrastructure is recognised as being a system-of-systems and therefore in implementing the measures and assessing performance, it will be important that the NIC is aware of cascading effects and interfering feedbacks where reduced performance or failure in one sector can lead to multiple direct and indirect effects for other sectors.

[24] https://www.gov.uk/government/consultations/national-infrastructure-assessment-consultation

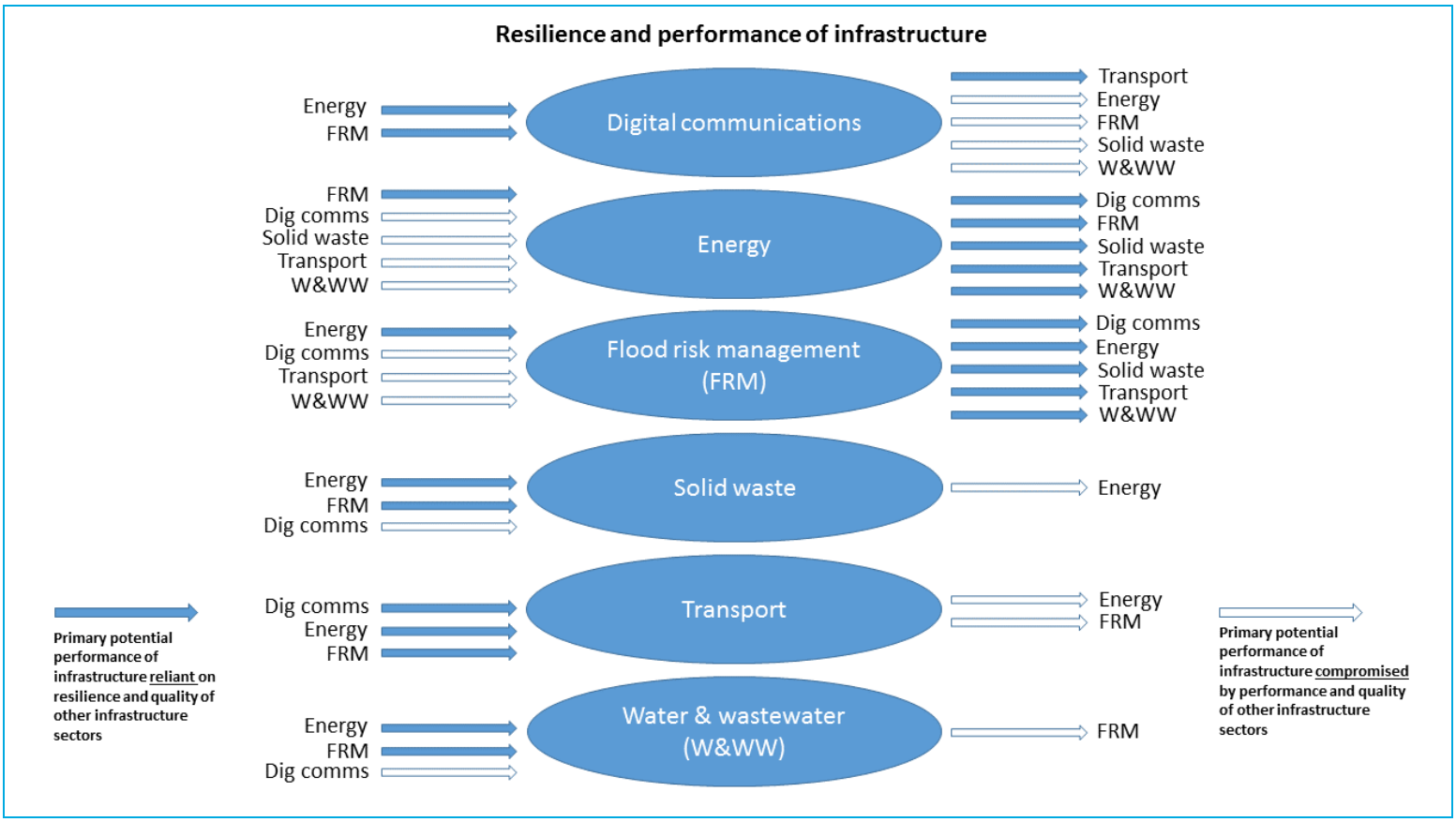

Figure 6-1: Interdependencies between key infrastructure sectors

Section summary

The initial conclusions to be drawn with respect to the interdependencies between infrastructure sectors are:

- All sectors are reliant upon a secure supply of power and increasingly effective flood risk management measures. Population growth and ongoing urbanisation at UK level will intensify this reliance.
- Digital communications, and the real time artificial intelligence this supports, is becoming increasingly important as more infrastructure systems adopt 'intelligent' operations, for example, smart motorways. Importantly, whilst smart operations aid performance, for example by helping to reduce congestion, their failure does not result automatically in the failure of other infrastructures because the highly sophisticated networking and routing technologies underpinning digital communications provide resilience.
- Only energy performance is dependent on solid waste performance in terms of providing material inputs for energy recovery.
- Transport has implications for energy with regards to energy use, but also has implications for flood risk management in terms of the management of highways/railways, drainage and access to facilities.
- The performance of the water and wastewater sector has implications for the energy sector, in terms of providing resources for energy generation (hydropower), but also cooling for power stations. It also can affect the performance of the flood risk management sector in terms of drainage and management of water storage facilities.

7 Conclusions and recommendations

7.1 Introduction

The study has proposed a set of performance measures for each of the NIC's key infrastructure sectors focusing on the domains of resilience, quality, cost and environmental sustainability and with the overall aim of helping to measure the performance of UK infrastructure against the three objectives set by Government:

- Support sustainable economic growth across all regions of the UK
- Improve competitiveness
- Improve quality of life.

The measures proposed in this report will be subject to further consultation and development within the NIC and with wider external stakeholders as part of the process leading up to the development of the NIA.

7.1.1 Technical Conclusions

From the outset, the Study Team and the NIC were keen to ensure that the measures were developed through an evidenced logical framework with the final measures linked to clear domains that then directly link to the overarching objectives. This organising framework was developed through a comprehensive review of existing national and international performance measurement frameworks and stakeholder consultation and was adhered to throughout the process. Inevitably the process of measure development involved several iterations and the involvement of NIC sector colleagues in the process has been helpful in ensuring that the measures are comprehensive, coherent and communicable.

Across the six infrastructure sectors, those which have been the focus of longer-term policy and action tend to be characterised more fully in terms of numbers of measures than more recent ones. The study also identifies that the availability of comparable infrastructure measures across national jurisdictions varies significantly for the six infrastructure sectors. Self-evidently, this reflects the extent to which infrastructures interface across different countries and the extent to which infrastructure communities are engaging with one another across national boundaries.

Developing a concise set of performance measures for each infrastructure sector has not been without its challenges. Initially the study team tended to focus on performance measures that already exist and can be populated with available data, but the NIC was keen to identify the 'best' measures regardless of whether these can or cannot be currently populated. Thus, several 'new' measures have been identified, but the actual construction and data required to populate them requires further work.

In addition, there was a clear steer from the NIC to keep the measures to a manageable number (up to 10 per sector) and capturing the complexity of infrastructure performance in a limited number of measures is not straightforward.

The pressures of regulation, customer service expectations and legislative drivers within and across infrastructure sectors are useful influencers for measure definition and data collection. However, these are not always linked to how infrastructure is performing and keeping a focus on this will be an important consideration for the NIC as it progresses this performance measurement agenda.

The issue of resilience has proven consistently hard to define or rather to agree a common definition. The study has come forward with varying perspectives on resilience, within and between infrastructure sectors, and the study concludes there is scope to do more work here.

Finally, the UK economy is currently exposed to significant uncertainty and ever changing technology and market developments, as well as the challenge of future climate change

and energy security. Whilst the intention has been to develop performance measures that have some longevity, it is inevitable that these will need to be reviewed on a regular basis to ensure that they are relevant to the current economic and policy environment.

7.1.2 Process Conclusions

The study has highlighted two valuable process conclusions:

- The underlying nature of the six infrastructure sectors varies considerably so care is needed with 'one size fits all' solutions. It is also important to remain alert to the drivers that infrastructures are facing; these are highly variable - for some infrastructures, the drivers are around fast moving technologies e.g. digital technologies, for others global challenges such as climate change (particularly for energy, flood risk management and water and wastewater) and societal changes in live/work models, this having a significant impact for transport infrastructure, have greater prominence. It is key to hold this variety in mind, and ensure measures reflect genuinely how each sector is performing given its context.
- Within the confines of the Study, it has not been possible to work the 'wisdom of the crowd' as much as would be desirable. The inputs provided from external infrastructure sector stakeholders were valuable, but should similar work be commissioned in future, greater engagement with academic and engineering experts would be a worthwhile consideration.

7.2 Recommendations

The following recommendations relate to the further development and implementation of the performance measures, and more generally:

- The measures should be reviewed and refined/updated where appropriate to ensure their relevance. This is particularly important for measures that are linked to current policy imperatives such as the take-up of smart meters. Regular review of the digital communications measures is also essential as the speed of change within the sector means that the recommended measures could become out of date very quickly.
- Defining resilience has proved challenging for the study, not least because it means variable things for the ways different infrastructure sectors work and are organised. It is recommended that further work is conducted to deepen and broaden thinking about the variety of ways in which resilience operates, especially for the day-to-day operation of infrastructures
- The cost domain has been a difficult one for the study, and in its final form does not contain any sub-domains. We consider there is a case for re-examining whether measures of economy, efficiency, and effectiveness can be built into the organising framework for future iterations.
- Wide consultation on the proposed measures will be an important task in ensuring that the wider 'conversation about infrastructure performance' between public and private sector partners develops and builds. In this context, it is suggested that:
    - Outside of the NIA, consideration should be given to producing a simple annual report on how progress against the identified measures is moving. This should not compromise the NIA, but start promoting a wider debate.
    - As new measures have been suggested for all sectors (requiring developmental work to inform their construction and identify/develop data sources), relevant external stakeholders should be engaged in this work to ensure current industry thinking informs measure development.
    - As the NIC further develops its understanding of infrastructure performance, it should assemble a repository of evaluation evidence (UK and wider) relating to infrastructure sectors. This would help build an understanding of

'what works', and help move the debate on from simple 'data' on to real 'intelligence' on how infrastructures are performing.

- It is beyond the scope of this study to define formal logic chains for mapping the different ways in which key infrastructures work. This has not impeded the development of the measures set out in this report, but in future exploring the case for developing formal theories of change by which the performance of key infrastructures can be monitored, and potentially evaluated, is recommended for the NIC's consideration.

A Literature review findings

A.1 Introduction

Background

This Literature Review forms part of a piece of work for the National Infrastructure Commission to develop performance measures that reflect the NIC's objectives:

- Support sustainable economic growth across all regions of the UK;
- Improve competitiveness; and
- Improving the quality of life.

The Review provides a summary of the main findings from a series of document reviews conducted by the Sector Leads who formed part of the team developing performance measures for the UK Infrastructure Commission. The document reviews sought out information and lessons learned in relation to the challenges associated with developing performance indicators for the following types of infrastructure:

- Digital Communications
- Energy
- Flood Risk Management
- Solid Waste
- Transport
- Water and Wastewater.

The overall work programme will draw on the findings from this Literature Review to devise indicators that take account of three 'domains' for each of the different types of infrastructure:

Resilience

Ability to anticipate, prepare for, and respond/adapt to everything - from minor everyday events to acute shocks and chronic or incremental changes, now and for future, including Climate Change Adaptation.

Quality

Optimise the capacity and performance of the current system, targeting both supply and demand, and providing balance access across the UK; and

Optimising users' experience – their experience meets/exceeds their expectations.

Cost

Capturing unit costs associated with each infrastructure sector.

Environmental sustainability

- De-carbonising energy and transport infrastructure; and
- Minimising other environment impacts e.g. air quality, biodiversity, conservation of culture and heritage (macro: large scale, micro: affecting individuals).

A.2 Approach

The team reviewed 32 documents across the six infrastructure types – some documents were relevant to more than one infrastructure type, so were reviewed multiple times, but through the lens of a specific infrastructure type.

Each document review used the following structure:

- Challenges identified
- Responses to the challenges
- Methods identified
- Other research identified.

Not all the documents that were reviewed identified challenges that were relevant to the issue of performance measurement and some of those which did identify relevant challenges did not always provide responses to those challenges.

Each section provides a summary of the relevant challenges identified by reviewers and, where provided in the literature, the solutions and methodologies, and concludes with a list of the documents which were reviewed.

The paper ends with a summary of Reflections and Conclusions that outlines common issues highlighted in the literature review.

A.3 Infrastructure Type: Digital Communications

Lessons from the Literature

One of the primary challenges in defining performance measures for Digital Communications infrastructure is how to sensibly measure performance in a rapidly evolving world. Another challenge is the limited data available which cover all, or a reasonable set of comparator, countries. Furthermore, the development of effective performance measures is heavily reliant on the data which are available.

Looking to the future, there is a commitment among stakeholders to focusing on outcome-based indicators rather than input indicators, for instance moving away from spending, which is the current focus of the National Infrastructure Plan (NIP).

New Zealand's National Infrastructure Unit (NIU) also alludes to previous performance measures being too complicated and a call for clearer, more simple measures that centre around the NIP and further the government's infrastructure agenda. The NIU also mentions the difficulties associated with performance indicators being driven by limited data, exacerbated by how the indicator framework needs to be able to be implemented quickly.

Documents Reviewed:

Ofcom (2016) Communications Market Review 2016.

Ofcom (2015) Connected Nations (Formerly the Telecoms Infrastructure Review).

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.

Schwab, K. (2016) The Global Competitiveness Report 2016–2017.

A.4 Infrastructure type: Energy

Lessons from the Literature

New Zealand's Infrastructure Performance Indicator Framework Development[25] has recognised that whilst existing activity and stock indicators measure the level of activity and the quantity of infrastructure, these are not reflective of performance, and they cannot be unambiguously interpreted, such that an increase is 'better' or 'worse' in terms of welfare or living standards. For example, it is possible to have "too much" infrastructure, given its cost and, thus, its opportunity cost - in other words the notional cost of goods and services foregone because of resources being used to finance infrastructure.

Therefore, the developed framework includes, and carefully distinguishes between, activity and performance indicators. Indicators must then be interpreted regarding trade-offs, for it is not always possible for an increase one indicator to occur without a reduction in at least one other.

The Framework was developed using the 'Pressure-State-Response' Model, which is based on the following principles:

- Start with pressure indicators (those that can affect the demand and the supply of infrastructure). These include long payback periods, the economies of scale and scope, network structure etc.
- Move to general objectives for infrastructure state indicators. The aim was to understand and make explicit what is meant by the better use of existing infrastructure and better allocation of new investments. In other words, the directions in which improvements can be made. This uses Welfare Economics to link back to the two 'betterment' objectives. A set of potential indicators was developed under the category of Capacity Utilisation, which impacted living standards through use and accumulation of other capital; a potential indicator to capture this type of issue is the ratio of used capacity to available capacity.
- Consider whether individual indicators can and should be aggregated.
- Consider specific pressure indicators for energy, such as relative energy retail prices and changes, for example, New Zealand gas prices relative to electricity prices.

The increased complexity of today's economy is making our current statistical tools outdated, both conceptually and methodologically. Also, when a lot of these measures were first introduced, such as the Global Competitiveness Index (GCI) in 2006, the effects of the 'Fourth Industrial Revolution' had not yet started to arise.

The GCI has therefore been modernised to capture concepts that matter for productivity and long-term prosperity better. The methodology, which is relevant across infrastructure types, is summarised below: [26]

Look at competitiveness (i.e. the set of institutions, policies and factors that determine the level of productivity of an economy, which in turn sets the level of prosperity that the country can achieve), by starting with a literature review of competitiveness drivers as well as a preliminary methodology for the new index.

Then look at five clear directions for measuring competitiveness during the rise of the Fourth Industrial Revolution:

- Productivity remains a key driver of prosperity;
- Future Orientation is central;
- The meaning of innovation is being updated;

25 Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.
26 Schwab, K. (2016) The Global Competitiveness Report 2016–2017.

- ICT infrastructure is imperative; and
- The world is levelled more than it used to be.

Develop a framework for indicators that consists of 12 pillars:

- Institutions;
- Infrastructure;
- Macroeconomic Environment;
- Health and Primary Education;
- Higher Education and Training;
- Goods Market Efficiency;
- Labour Market Efficiency;
- Financial Market Development;
- Technological Readiness;
- Market Size;
- Business Sophistication; and
- Innovation.

There have been very specific challenges related to data collection, and the difficulties associated with reflecting performance, rather than simply 'crunching' the data which are available.

Developing state-of-the-art indicators is not, therefore, a straightforward task; it requires financial and human resources to collect extensive detailed data and to analyse information. The more financially viable alternative is to use aggregate indicators. These are often readily available but their usefulness is limited and they can generate misleading results, if used inappropriately.

Recent efforts by several countries to collect more detailed end-use data have helped to develop energy efficiency indicators that provide important information for understanding past trends, assessing the potential for energy savings and enhancing energy efficiency policies. However, it is argued that the full spectrum of detailed indicators cannot be developed within a few years and it is increasingly important for countries to prioritise and continue these efforts.

Another ongoing challenge is the need for Energy infrastructure indicators to take account of, and complement, climate change adaptation activities. The Climate Change Risk Assessment for Scotland and the Scottish Climate Change Adaptation Programme (SCCAP) seek to enable complementarity with a focus on indicators of risks and opportunities, along with measures of on-the-ground adaptation, to understand trends in actions taken.

The sustainable growth pillar, which is included in the Eurostat and European Commission's report, highlighting the indicators to be used to support the Europe 2020 Strategy,[27] is monitored by three indicators on climate change and energy (greenhouse gas emissions, the share of renewable energy in gross final energy consumption and primary energy consumption).

As energy infrastructure ages, it needs to be replaced. This requires large-scale investment. Investors can be discouraged by the levels of return that monopoly network companies can make, given the requirements of OfGEM (Office of Gas and Electrical Markets), and the difficulties associated with forecasting overall energy demand, which is necessary for calculating expected capacity needs and return on investment. Thus, there is a need to design indicators that can measure the state of infrastructure which may then

27 Eurostat and European Commission (2013) Smarter, greener, more inclusive? Indicators to support the Europe 2020 Strategy.

be used to inform investment decisions. The methodology for these measures is summarised below:[28]

- The base year for most indices is 2005, with an index set at 100 for each infrastructure type. The values for other years within the same series represent a proportional change in the underlying measure relative to the base year;
- An increase or decrease reflects the change in an underlying measure, whether that movement is a positive or negative development;
- No averaging across indices; and
- Data is collected from a range of primarily public sources, such as government publications and regulatory reports by private sector infrastructure providers.

Documents Reviewed:

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.

Schwab, K. (2016) The Global Competitiveness Report 2016–2017.

Department of Energy and Climate Change (2015) UK Energy Sector Indicators 2015.

International Energy Agency (2016) Energy Efficiency Indicators: Essentials for Policy Making.

Infrastructure and Projects Authority (2016) Wholesale Energy Markets in 2016.

Moss, A. and Martin, S. (2016) Developing Indicators of Climate Change Adaptation for Scotland: A summary of the ClimateXChange adaptation indicator framework.

Eurostat and European Commission (2013) Smarter, greener, more inclusive? Indicators to support the Europe 2020 Strategy.

European Commission and DG Environment (2012) Assessment of resource efficiency indicators and targets.

[28] HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

A.5 Infrastructure Type: Flood Risk Management

Lessons from the Literature

To ensure that the Environment Agency (EA) and other risk management authorities achieve the aims of government flood and coastal erosion risk management (FCERM) policy, the Department for Environment, Food & Rural Affairs (DEFRA) sets outcome measures. On a specific issue, 'Households better protected as a percentage of the total number of households in England', has not been included in NIP 2014 due to lack of full time-series data. Furthermore, there have been some indicator alternations, 'Flood and Coastal Risk Management Grant-In-Aid (FCRM GiA) Expenditure per additional household protected' (which has been presented in previous years), has been reviewed and replaced with the Performance Indicator 'DEFRA's spending on FCERM'. This will better reflect DEFRA's spending within Flood Risk Management rather than the indicator being centralised solely around FCRM GiA.

The New Zealand Government has outlined three areas to measure the performance of services involved in the maintenance of flood protection and control works against:[29]

- Community Engagement;
- Performance of New Assets; and
- Managing Environmental Effects.

The performance measures identified around these areas must be applied to all the major flood protection and control works and set criteria must be used to define the works that fit into this category: 1) a set definition for 'Flood Protection and Control Works'; and 2) a set criterion for 'major' which is a set of four different criteria which relate to operating expenditure, capital expenditure, asset replacement value and the population benefited. Therefore, it seems that whilst scheme costs are considered, benefits appear to be simply defined as population benefitting.

Whilst the New Zealand Government has identified performance measures, the measures were out for consultation at the time that the report,[29] which was reviewed as part of this Literature Review, was produced, so this Literature Review does not include information on how the indicators were used.

Documents Reviewed:

Environment Agency (2015) Flood and coastal erosion risk management outcome measures.

Environment Agency (2014) Calculate grant in aid funding: Flood risk management authorities.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

New Zealand Government, Department of Internal Affairs (2013) Non-Financial Performance Measures Rules 2013 Supporting guidance for flood protection and control.

29 New Zealand Government, Department of Internal Affairs (2013) Non-Financial Performance Measures Rules 2013 Supporting guidance for flood protection and control.

A.6 Infrastructure Type: Solid Waste

Lessons from the Literature

There are no recognised means of estimating how effective a product, company or country is in making the transition from a linear to a circular mode of operation, nor are there any tools for supporting measurements of such activity.

A methodology using indicators which estimate the 'circularity' of products and businesses has been developed.[30] This methodology is useful to help understand how well a product or company is doing on its journey from linear to circular production. The Material Circularity Indicator measures how restorative the material flows of a product or company are.

Measuring policy effectiveness within Solid Waste is explored by DEFRA through monitoring data and the flow of materials in waste collection, recycling and disposal, as well as how these data compare to recycling targets set out in the Waste Framework Directive (2008/98/EC), the Packaging and Packaging Waste Directive (94/62 EC) and supply data for the Waste Statistics Regulation (2002/2150/EC). All sludges and dredging spoils are reported on dry weight.[31]

UK estimates for the generation and final treatment of total waste are built up from several estimation processes, including, WasteDataFlow, Environment Agency (EA) permitted site returns.

A challenge for indicators in Solid Waste is in devising comparisons, for whilst efforts are made to synchronise approaches across the UK, methodological differences exist for Construction, Demolition & Excavation (CD&E) and Commercial & Industrial (C&I) waste.

It is difficult to measure the value waste has on the economy and whether it is the best allocation of resources. One of the reports reviewed considers the recent and potential future contribution of the waste sector to wider economic growth. [32] There is a relationship between investment in infrastructure and extracting value from waste. Whilst investment goes into building 'the right kind' of infrastructure capacity and investing in the most productive technologies, there are significant opportunity costs and question marks over whether the investment displaces or substitutes for jobs and investment elsewhere.

The following three points could provide a lens through which to view performance measures related to the waste sector:

- Extracting greater value from waste, e.g. value extracted from waste (as a resource) has increased from £32 per tonne in 2004 to £43 per tonne in 2012[33].
- Increasing resource efficiency.
- Increasing the export of goods and services.

Documents Reviewed:

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

Department of Environment, Food & Rural Affairs (2016) Digest of Waste and Resource Statistics – 2016 Edition (Revised).

[30] The Ellen MacArthur Foundation; and Granta Design (2015) CIRCULARITY INDICATORS - An Approach to Measuring Circularity; Project Overview.
[31] Department of Environment, Food & Rural Affairs (2016) Digest of Waste and Resource Statistics – 2016 Edition (Revised).
[32] Department of Environment, Food & Rural Affairs (2015) Resource management: A catalyst for growth and productivity.
[33] Department of Environment, Food & Rural Affairs (2015) Resource management: A catalyst for growth and productivity, p.3.

Department of Environment, Food & Rural Affairs (2015) Resource management: A catalyst for growth and productivity.

The Ellen MacArthur Foundation; and Granta Design (2015) CIRCULARITY INDICATORS - An Approach to Measuring Circularity; Project Overview.

A.7 Infrastructure Type: Transport

Lessons from the Literature

There is a perceived need for improved outcome-based indicators rather than input indicators, such as measures of spending – progress can only be achieved through partnership working.

The National Infrastructure Delivery Plan 2016-2021 used existing performance measurement approaches prepared by the Infrastructure and Projects Authority to improve the use of outcome-based performance indicators, remove inconsistencies associated with current methods and establish a better framework of infrastructure performance measures, which are more clearly linked to common societal benefits.

Assessing infrastructure investments only on their observed performance may reward inefficiently low levels of risk taking; the most useful performance measures may be expressed as ratios and proportions, rather than absolutes, and this approach enables some account to be taken of demand pressures.

Turton and Dora[34] reviewed several international rail metrics and discovered that this was quite a small list which performed the same or similar functions to that of the GB Public Performance Measures. There are typically punctuality statistics, cancellation statistics and in some cases 'delay minutes' or 'passenger-weighted delay minutes'.

To develop a new set of metrics Turton and Dora proposed the following method:

- Data collation, desktop study and stakeholder workshops;
- Produce a compendium of metrics used in various railway organisations and by stakeholders, both in the UK and overseas, to manage the impacts of weather and climate change;
- For the metrics identified, summarise their characteristics, robustness and fitness for purpose within context; and
- Produce a guidance document for new or modified metrics that can improve the effectiveness of investment decision making and the quality of resilience, research and development activities.

Turton and Dora considered a total of 194 metrics with significant underlying data. The analysis noted that, for most metrics, there was no clear link between the 'condition' and the 'cause' of the condition, even where such data might have been thought to be available.

Stakeholders identified that key characteristics for any resilience or adaptation metrics must include being robust, reliable and consistent in the long term. Some stakeholders, particularly at the strategic or policy level, wished for consistent multi-modal metrics and emphasised the need for collaboration of groups working across modes. All sources appear to agree that such metrics are of vital importance across all sectors of the industry.

Existing subjective qualitative metrics, such as the National Rail Passenger Survey (NRPS), may be helpful in deciding which aspects of service are critical and what level of resilience is required.

34 Turton, P. and Dora, J. (2015) Tomorrow's Railway and Climate Change Adaptation Phase 1 Final Report (T1009).

Quantitative metrics such as PPM (Public Performance Measure), CaSL (Cancellations and Significant Lateness) and 'delay minutes' were found to be fit for their current purpose. However, they focus on issues which do not match adaptation requirements, or fail to capture vital information. Other sectors, both nationally and internationally, may provide ideas for development but do not appear to have found solutions for these issues and are largely using local versions of GB metrics.

Documents Reviewed:

Schwab, K. (2016) The Global Competitiveness Report 2016–2017.

Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.

INRIX (2015) INRIX 2015 Traffic Scorecard.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

ICIF and iBUILD (2015) A Critique of Current Infrastructure Performance Indicators: Towards Best Practice.

Turton, P. and Dora, J. (2015) Tomorrow's Railway and Climate Change Adaptation Phase 1 Final Report (T1009).

A.8 Infrastructure Type: Water and Wastewater

Lessons from the Literature

- Water infrastructure is considered in three categories:
- Urban Water (water supply, wastewater and stormwater);
- Rural Water (agricultural uses); and
- Water as a resource for hydropower (covered as part of Energy Infrastructure).

Data availability is a challenge; and while most data sets can be used to show historic trends, forecasts and 'nowcasts', which are increasingly required, are not always possible given current data constraints.

There is a risk new performance measures will follow data which are available; however, it should be noted that, in line with the European Environment Agency (EEA) guidance, indicators should not be driven by the availability of data. Furthermore, Beca and Covec[35] highlight an inconsistency in data gathered for different sectors and different geographies.

The search to provide aggregate indicators was said to entail two main challenges:

- The need to scale indicators so that they all have the same order of magnitude; and
- The need to weight indicators.

Beca and Covec[35] identified a way to try and maintain more consistent data gathering and performance reporting:

- Financial Reporting Regulations; and
- Mandatory non-financial performance measures.

The last guide to European Environment Agency (EEA) indicators, focused on the Core Set of Indicators (CSI) (EEA, 2005). Since then, many new indicators have been

35 Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.

developed and the evolving European Union (EU) policy context has created new opportunities for their use.

For issues, such as the green economy and management of natural capital and ecosystem services, indicators are needed that not only provide information on the decoupling of resource use from economic growth and environmental impacts within Europe but also integrate a global perspective.

One study[36] investigated how indicators and targets of resource use might be used as part of the European Commission's Flagship Initiative for a Resource Efficient Europe. The study analysed several existing indicators that track the different types of resource flows in the economy, such as materials (abiotic and biotic), energy, water and land use. The selected indicators were then evaluated for their appropriateness for target setting at the EU policy level. The team carrying out the work analysed each of the resource related indicators against the RACER framework (Relevant, Acceptable, Credible, Easy, Robust) and a set of specific criteria related to key EU resource policy requirements, and proposed a "basket of indicators" to monitor resource efficiency performance in the EU in four areas: materials, energy, water and land.

Documents Reviewed:

Department for Environment, Food & Rural Affairs (2016) UK Government response to consultation on reforming the Water Abstraction Management System.

Environment Agency and Department for Environment, Food & Rural Affairs (2015) How to write a water company drought plan.

HM Treasury and Infrastructure UK (2011) National Infrastructure Plan 2011.

HM Treasury, Infrastructure and Projects Authority, Lord O'Neill of Gatley and The Rt Hon George Osborne MP (2016) National Infrastructure Delivery Plan 2016 to 2021.

HM Treasury, Infrastructure UK, The Rt Hon Danny Alexander and Lord Deighton (2014) National Infrastructure Plan 2014.

Environment Agency (2016) Draft Water Resource Planning Guidelines: Consultation Response.

Environment Agency, Department for Environment, Food & Rural Affairs, Ofwat and Welsh Government (2012) Water Resources Planning Guideline – the guiding principles for developing a water resources management plan (and the associated Technical Guidance).

Beca and Covec (2013) National Infrastructure Unit and NZ Treasury (2013) Infrastructure Performance Indicator Framework Development.

Ofwat – Improving regulation Available at: http://www.ofwat.gov.uk/regulated-companies/improving-regulation/ (Accessed: 5 December 2016).

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Reflections and Conclusions

32 documents were reviewed as part of this Literature Review, some of these addressed the issue of how to measure the performance of infrastructure in general, others discussed the issue in relation to a specific infrastructure, and some dealt with performance measurement only tangentially. Thus, it is difficult to draw firm conclusions from the literature review alone. The Literature Review highlighted several common issues, including:

- How best to capture Capacity, Capability and Performance;
- How best to measure performance in a rapidly evolving world;
- There is only a limited amount of data available for all countries, limiting international comparisons;
- Some indicators are open to a wide range of interpretations, which limits their communicative capacity;
- Existing activity or stock indicators measure the level of activity and the quantity of infrastructure, but are not reflective of performance, and cannot be unambiguously interpreted in terms of welfare or living standards;
- It is difficult to capture and interpret the full range of user experiences effectively;
- How best to estimate a product/company/country's progress in making the transition from a linear to a circular mode of operation;
- Methodological differences between different parts of the UK in relation to some infrastructure types, e.g. Solid Waste;
- Capturing variation between different geographies; and
- Taking account of risk, so as not to restrict the scope for innovation.
- It also pointed to several strategies and tools for addressing issues raised, including:
- Find the right balance between measures of inputs, processes and outcomes, which are clearly linked to measures of Capacity, Capability and Performance;
- Develop a comprehensive framework which covers key areas, e.g., Security of Supply, Access, Competition, Investment and Sustainability;
- Produce a relatively simple indicator framework that focuses on critical drivers of performance, rather than on a detailed analysis of performance;
- Measures need to capture the gap between what exists and what is desired;
- Develop sophisticated measures, e.g. ratios of inputs to outputs, identifying ranges of performance rather than mean averages, to capture complex relationships; and
- Avoid measures which fail to incentivise innovation.

The Literature Review also highlighted several criteria to be applied when devising and/or selecting measures, including ensuring measures are:

- Relevant;
- Acceptable;
- Credible;
- Easy;
- Robust;
- Reliable;
- Consistent over time;
- Use scales which are of the same order of magnitude; and
- Apply weights to reflect importance.

B Scoping consultation findings

B.1 Introduction

15 consultations were undertaken by the project team with representatives from the following organisations:

- All sectors – Adaptation Sub-Committee (ASC) of the Committee on Climate Change (CCC), IPA, University of Oxford (ITRC)
- Digital communications – Ofcom
- Energy – BEIS, Ofgem
- Flood risk management – Environment Agency
- Solid waste – Chartered Institution of Wastes Management (CIWM), Defra, Environmental Services Association (ESA), Resources and Waste UK (R&WUK)
- Transport – Civil Aviation Authority (CAA), DfT, Office of Rail and Road (ORR)
- Water and wastewater – Ofwat.

Interviews were conducted by phone using a pre-agreed aide memoire. Responses were recorded against the aide memoire headings and analysed against these for each infrastructure type as set out below. The analysis was undertaken by JBA.

B.2 Findings

B.2.1 General

This section sets out the findings from the stakeholders representing all sectors and brings out common issues identified by each of the individual infrastructure sector representatives.

Overall challenges in developing performance measures

The following common issues were identified:

- All measures will need continuous updating as policy/information availability/priorities change over time.
- Lack of consistent definitions and available data - legacy systems from different organisations/sectors and getting the data quality right at source have key impacts. Performance measures need to be relevant to those responsible for collecting the data to ensure the provision of timely, quality data is prioritised.
- Lack of consistent standards for infrastructure performance especially regarding stress-testing against extreme conditions.
- Developing a consistent set of measures to measure progress over the long term is difficult due to medium-long term uncertainties because of technological changes, economy performance, Brexit etc.
- Some variations may exist between regions of England (e.g. infrastructure investment in Midlands vs. London) – in public transport, digital connectivity, etc.
- Connecting data with outcomes; importance of defining what performance is being sought (i.e. what good looks like) otherwise performance measures track things but it is difficult to interpret what is good and what to compare the performance against.
- Management of interdependencies between sectors.
- Consistency in measuring performance across sectors to enable comparison: benchmarking can be difficult even if all are using the same measures as can be interpreted and addressed differently between sectors. In addition, there is a need

to be cognisant of the fact that different infrastructure types aim to achieve different outcomes.

- Difference between public and private sectors i.e. public sector delivery focus and private sector commercial focus
- Need to consider whether performance measures are addressing current or future requirements i.e. whether there is an element of forecasting in relation to future demand and supply.
- Avoid league tables or anything that could be interpreted as such
- Quality is difficult to define especially in relation to customer needs.
- Developing performance measures for resilience:
    - Crucially important is understanding what represents a failure; this can be very easy to misinterpret. For example, for digital communications, counting one or two second gaps in service may give a big output number suggesting failure, but the actual outcome in the real world is negligible because things just roll on uninterrupted. Ultimately, resilience could look quite different in different sectors and have different implications.
    - Risk of defining causes of failure, rather than the effect of the failure itself. And even if this risk is avoided, you are then saddled with the challenge of how the same failure affects different parts of the system. E.g. the recent flooding of Exeter and its bridge from a rail perspective was addressed within the two-hour resilience window set by Network Rail, but drying out affected people's houses, arising from the same resilience failure, took six months. Different perspectives of the same issue can be very difficult to square
    - Resilience should be a network thing, rather than a 'specific' thing. On this basis, the UK's road and digital infrastructures are phenomenally resilient because they contain substantial redundancy in their networks.

Issues for developing performance measures in relation to the individual infrastructure sectors

Generally, there is limited reporting by infrastructure organisations regarding the degree to which the state of UK infrastructure is improving or declining. However, robustness and efficiency of reporting varies across sectors and organisations. For example, Network Rail and Highways England undertake robust reporting at the national level, but water reporting is less consistent and focused on high level measures – difficult to understand what these should be attributed to. For example, are customer disruptions regarding water supply a result of leaks or severe weather events? From this noted the importance of moving away from outcomes to activities to measure resilience.

Experience of developing performance measures for infrastructure

Defra NI188 (climate change adaptation measure for local authorities) - focused very much on measuring capacity – this could be an important measure to include.

Adaptation indicators – see infrastructure score-card for ASC 2015 Progress Report.

Characteristics of successful performance measures

Importance of logical frameworks and following through three tiers from the overall goal to measurable outcomes and then performance measures (including process based measures) showing how the outcomes are/will be reached.

The ASC used the Magenta Book to own Adaptation Indicators that are used to measure progress against the National Adaptation Programme.

Good measures should be:

- Measurable – it must be possible to measure the indicator
- Relevant – to the experience of the consumer
- Cost-effective – it mustn't cost a fortune to measure
- Manageable – it must be possible to act to affect the value of the indicator, otherwise there is no point in measuring it.

Simple! Should be able to look at a performance measure and immediately understand if the message is positive or negative and by what scale to enable appropriate action to be identified and undertaken.

Examples of similar current work underway or recently completed

2014 National Infrastructure Plan (NIP) indicators – it was suggested that these should not be relied on too heavily in the development of measures for the NIC as these serve a different purpose and were compromised by trying to meet both 'economist' and 'engineer' mindsets (the former seeing efficiency in infrastructure as being driven by optimising constrained systems, the latter coming at efficiency from building in spare capacity).

The NIP also displays mixed use of activity, output, and outcome indicators. Measures should not be about measuring infrastructure per se (which activities and outputs encourages), but about measuring the impacts of infrastructure (which outcomes forces). Measures need to show the extent to which objectives for infrastructures are being realised/achieved.

Developing aggregate measures to span infrastructures needs to be built in to the study, potentially bringing in academic thinking in this area (ITRC). The NIP focused on the performance of individual infrastructures, rather than understanding how particular infrastructures 'work across' and how the system as a whole is performing which these measures should assess.

More attention needs to be given to those measures that academia and industry themselves are using, and whether these can be re-purposed for public policy purposes.

ITRC work on interdependencies is of key importance and must be considered.

All individual organisations have their own performance measures e.g. DfT – performance stats regarding road conditions amongst others. Network Rail – delay minutes by route and cause. Electricity stats – Engineering Technical Report (ETR) 138 – Resilience to Flooding of Grid and Primary sub-stations[37].

Tomorrow's Railways and Climate Change Adaptation (TRaCCA38) – performance measures re: climate change.

BECA - Infrastructure Performance Indicator Framework Development39

IBuild - Infrastructure BUsiness models, valuation and Innovation for Local Delivery40

World Economic Forum – Global Competitiveness Reports

ITRC – The Future of National Infrastructure[41]

37 http://www.naturalsols.co.uk/Ducts/Energy%20Networks%20Association%20%28ENA%29%20Substation%20Resilience%20to%20Flooding%20report.pdf
38 https://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/t1009
39 http://www.infrastructure.govt.nz/plan/2011implementation/ipifd-mar13.pdf
40 https://research.ncl.ac.uk/ibuild/
41 http://www.itrc.org.uk/the-future-of-national-infrastructure-a-system-of-systems-approach/#.WRgkIPnyuUk

Suggestions for performance measures and their strengths and weaknesses

Typology of People, Freight, and Data was suggested.

Resilience across all sectors – see the Adaptation Indicators Infrastructure Scorecards (ASC). Potential to align this performance measures project with the work the ASC is doing to review 70 of its indicators that require additional analysis/data processing etc. The ASC will not have any findings until January and the performance measures project

Index related indicators are generally very difficult to explain although assist with consistency across indicators and sectors.

All sectors - cost, capacity margin, service delivery and emissions were suggested.

Cross-sectoral measures

Best to refer to ITRC work for interdependencies as they are leading authority on the subject.

Further sources of information

Natural Hazards Partnership, UK Regulators Network, Civil Contingencies Secretariat in the Cabinet Office. NB: Recommendation to the Government no.10 in Committee on Climate Change 2015 Progress Report relates to working with the Cabinet Office. Also, need to refer to UK National Risk Assessment and Sector Resilience Plans.

Annex A to the NIP Report (2014) and the work by IRTC.

B.3 Digital communications

Overall challenges in developing performance measures

None identified in addition to the common challenges that apply to all.

Issues for developing performance measures in relation to the individual infrastructure sectors

Key issue is to ensure that the indicators collected are relevant to the ultimate consumer experience of the service. It is easy to put a very strong emphasis on easily measured items such as headline download speed, but sometimes these only have a tenuous link to the customer experience. As an example, if a consumer clicks on a page in an on-line newspaper, what is downloaded is an assembly of information from up to 150 different sources, each sitting on servers of differing business and capacity. These can also download scripts which may run or crash. These things have a much greater impact on how the user perceives the service than the raw download speed.

In mobile, the coverage maps issued by the operators are tuned towards a receiver which is a high-quality radio receiver (usually a Nokia). Most smartphones are much poorer radio devices so coverage at the margins of availability is often overstated by the operators compared to the consumer experience.

Highly technical measures such as packet loss, jitter and latency can have very little impact on the consumer experience although they are beloved of engineers.

Experience of developing performance measures for infrastructure

Currently defining a whole new set of Quality of Service (QoS) measures that will be published by Ofcom in 2017. This is ongoing work and is proving challenging to define QoS indicators that are measurable and meaningful.

Their research is leading them along the line that consumers are most interested in a consistent service rather than one which is very good sometimes but very poor at other times. This is particularly relevant in broadband where contention ratios determine how many consumers must share a common pipe back to the Internet. Where contention

ratios are high, very good service at quiet times can become very poor when lots of users are on concurrently.

Characteristics of successful performance measures

None identified in addition to the characteristics that apply to all.

Examples of similar current work underway or recently completed

The EC has commissioned TUV Rheinland to collect and map broadband availability and performance. However, the results are poor because of the varying capabilities and resources available to the different regulators who should gather the data. The results are based on some good data, some erroneous data and downright lies.

The International Telecommunication Union (ITU) gathers some very basic data but it is very 'old school' and focuses on 'lowest common denominator' data.

Suggestions for performance measures and their strengths and weaknesses

Ofcom reviewed the long list of measures prepared by GreySky and suggested adding mean time to provide and mean time to repair telephone lines as something that is increasingly important to people. As we become more dependent on online services for living, working and entertainment, being without access is increasingly painful for consumers. Ofcom was in broad agreement with the rest of the measures but suggested that Jitter is something that could be omitted.

Potential data sources to populate measures

Because of its statutory powers and obligations, Ofcom is the best source of data. It is aspiring to improve and become more open. It has vast quantities of data that are not currently published but is moving in the direction of wider publication. In fact, much of the data is held at the level of OS UPRN (Ordinance Survey Unique Property Reference Number). When made available at that level, it will be possible to calculate performance indicators for whatever level of geographic disaggregation is desired (cities, regions, towns, counties, etc.).

Cross-sectoral measures

No specific measures identified.

Further sources of information

BDUK, thinkbroadband, Point Topic, SamKnows, P3, Route Metrics, GWS because they have good data on particular aspects of the industry. However, most of it is also harvested by Ofcom.

B.4 Energy

Overall challenges in developing performance measures

In addition to the general issues highlighted, a specific issue for energy is that BEIS indicators are not yet embedded due to the recent merger of DECC and BIS.

Issues for developing performance measures in relation to the individual infrastructure sectors

Energy sector statistics are well established as a government responsibility with long time series for some. Few are ever dropped apart from very obscure ones. User experience measures (e.g. attitudes tracking surveys) are some with the widest uncertainty/confidence levels. Measures become more specific when they are dealing with specific issues such as the roll out of a technology.

Ofgem works to the three objectives of affordability, decarbonisation and security of supply but these are not always compatible. Data availability now and in the future, is

also an issue for example if policy and regulation changes data may not be collected for that purpose any more.

Experience of developing performance measures for infrastructure

Development of "energy sector indicators" product (2012 to 2015), BEIS.

Characteristics of successful performance measures

Coverage and not introducing bias due to missing coverage (e.g. National Grid only has larger scale supply information); enough time series to draw conclusions; measuring multiple outcomes (e.g. carbon as well as power output); availability due to privacy, policy/political issues; always identifying the level of uncertainty; data collection burden e.g. for planning applications on local small scale sites.

Examples of similar current work underway or recently completed

UK Government "Energy in brief" 2016

UK Government "Energy Sector Indicators" (2012-2105)

Measures have been developed by:

- OECD
- International Energy Authority
- EEA
- Eurostat

Prime Minister's delivery unit completed work on indicators under the previous Government and there may be guidance about performance measures/indicators

Not aware of specific energy sector indicators published by Devolved Administrations.

Suggestions for performance measures and their strengths and weaknesses

See other publications listed, particularly Government ones. Statistics already include imports/exports and some international comparisons that will be important and new import/export connections will also need to be monitored when in place (Norway, Iceland).

Switching is a key issue currently for consumers that is requiring new infrastructure to enable faster (one day) switching. Embedded benefits and performance/costs of the networks being used by new renewable supplies is also a current issue; Onshore and offshore competition (wind farms) also an issue.

Potential data sources to populate measures

Comprehensive energy and climate change stats published by Government.

Ofgem website has a data portal with a wide range of indicators; Ofgem wholesale energy market report (2016) may have indicators; Ofgem Evaluation of the Low Carbon Network Fund may have indicators. (Ofgem).

Devolved administration level published. There may also be some regional renewable datasets. Energy production data is collected and held by BEIS at a local site level so can be reported at any scale however there are not any ongoing indicator reports/aggregated data at city level at present. NB postcode (LSOA) level data covers small scale renewable generation but there are some privacy issues if the data is disclosed. A general issue about the energy system is that there is no simple relationship nor therefore the indicators to report supply and demand together at sub-national scales.

Cross-sectoral measures

Important as, for example, resilience of fuel supply has a direct relationship with the transportation networks (e.g. tanker routes). Could identify common measures for critical infrastructure and resilience.

Setting out the overall objectives of the infrastructure system(s) is crucial to identify cross-sectoral measures.

Further sources of information

BEIS statistics department and Ofgem.

B.5 Flood Risk Management

Overall challenges in developing performance measures

None identified in addition to the common challenges that apply to all.

Issues for developing performance measures in relation to the individual infrastructure sectors

Main outcome measures for flood risk management (FRM) concern achieving better flood and coastal erosion protection for people and property. New assets and maintenance can increase the Standard of Protection. Environment Agency's Corporate Scorecard has performance measures concerned with increasing the resilience of people, property and businesses to the risks of flooding and coastal erosion, protecting and improving water, land and biodiversity, improving the way we work as a regulator to protect people and the environment and support sustainable growth, working together and with others to create better places and ensuring that we are fit for the future.

Outcome Measures are also identified in relation to the Medium Term Plan used to select projects for investment in FCRM schemes. The outcome measures cover cost-benefit, number of households moved to a lower flood probability category, households with a reduced risk of coastal erosion.

The Outcome Measures above are focused on the Environment Agency's capital programme; the Corporate Scorecard also includes revenue measures. The outcome measures for asset condition and the basis of the data is not yet known by JBA and should be investigated further.

Homes better protected in terms of moving properties between risk bands and assessing economic benefits are relatively straightforward to collect; asset condition is more of a subjective assessment.

Experience of developing performance measures for infrastructure

Defra Outcome Measures (OMs) for FCRM Partnership Funding. When conducting this work, some OMs were inherited in terms of moving households from one risk level to another. This relates very much to understanding the level of residual risk that exists – not well demonstrated by activity hence current ASC research considering the degree to which flood risk schemes alleviate long term risk on a more qualitative basis.

Characteristics of successful performance measures

None identified in addition to the characteristics that apply to all.

Examples of similar current work underway or recently completed

None identified in addition to examples cited in the general section

Suggestions for performance measures and their strengths and weaknesses

Key importance to have a measure around wider benefits covering CBA and wider measures. Considered it could be difficult to collect and quantify this if it is not a

requirement of the current Grant in Aid approval process. Also, suggested it may be useful to have a measure concerning contributions linked to Partnership Funding. Data is collected on partnership funding in the MTP and is available to be used if required.

The performance of FCERM schemes against climate change resilience is fully factored into the economic appraisal and optimisation of investment options. Outcome Measures are used to determine the availability of national funding and support final decisions on option affordability and choice.

The Environment Agency's project reporting tool (PPMT) may be a better source of information than the MTP as the MTP is only updated annually.

Potential data sources to populate measures

Medium Term Plan – there is a varying degree of completeness across the information collected.

Information is available at scheme level (via Project Appraisal Reports and the MTP) and aggregated to programme level and different geographies (including EA Areas, LA areas, ONS regions, counties, parliamentary constituencies). Can record scheme detail measures at most geographies.

Cross-sectoral measures

No specific measures identified.

Further sources of information

Environmental Agency economists.

B.6 Solid waste

Overall challenges in developing performance measures

Some measures should be relatively easy to identify, but those related to waste (or waste/resources management) can be problematic as waste arises from every premise in the country and goes through collection, transfer stations, processing/recycling plants and transport before final rest/use/disposal sites. The challenges will be in linking the other five infrastructures (digital, energy, flood defence, transport and water) to waste generation and / or resource consumption. Industrial strategy needs to be closely linked to resource and waste management to reflect the importance of secondary materials as industrial feedstocks.

Issues for developing performance measures in relation to the individual infrastructure sectors

Waste is a devolved issue to Devolved Administrations so there will be some regional variations in data and possibly the performance measures due to a varying emphasis on collection and recycling strategies (e.g. for food and organic waste). Waste management is heavily influenced by policy (e.g. on organic waste collection, recycling and reduction to landfill). Performance measures can first focus on the existing datasets related to household or municipal solid waste, which are extensive. Data on commercial and industrial wastes are patchy.

There are uncertainties in waste generation and waste management data, partly due to exemptions of small scale plants (considered to have low environmental impact but which can manage significant quantities of waste individually and in aggregate). Data on re-use is sparse.

The extent of, or spend on, waste infrastructure is not always the answer. The type of waste infrastructure is also important; for instance, local dedicated recycling facility, for a

specific waste stream, would help to circularise production. Efforts and benefits of waste prevention are difficult to see in metrics.

In fact, waste and overall resource use could form an indicator of the efficiency and effectiveness of all activities and products used in the country – and hence relate to the other five infrastructures. This would be a complex task and the stuff of future developments. At this stage, we should focus on the existing datasets that best describe the objectives and outcome.

Experience of developing performance measures for infrastructure

Engagement in high level discussions about waste indicators, focus has been on recycling, processing and landfilling capacities.

Involved in development of LATS – local authority biodegradable waste landfill tradable allowances – I&C waste arising survey and chaired the Electronic Duty of Care (EDoC) Technical Advisory Group. EDoC is not a measure but could be the most important tool available to generate data to support design and use of measures.

Characteristics of successful performance measures

Currently a lot of waste data are available; successful metrics can be populated by existing data of waste arising, recycling and disposal.

Performance measures should first focus on the existing data sets related to household or municipal solid waste, which are weight based and extensive. Data on commercial and industrial wastes are patchy. Weight based data are probably not the best as it would mask efforts higher up the waste hierarchy and carbon intensity of products. It is also possible that some recycling targets and facilities could cause unintended consequences, for instance, to packaging waste PRNs.

Data collection must be simple without imposing new burdens on businesses. UK Governments will need to take a view on the use of the Duty of Care and Electronic Duty of Care (EDoC) to gather data important at a strategic level across the UK. Data based on Landfill Tax Returns are a good source for measuring disposal, supported by other data already available at a national level by regulators /government e.g. recyclate exports. These metrics can be of two types:

- National economic characteristics linked to waste generation, recycling and disposal, and
- Extracting value from waste by the waste management sector (to include Gross Value Added).

Defra report 'Resource management: a catalyst for growth and productivity (February 2015[42])' is a good example that shows how national waste data could be linked to industrial activity (e.g. Raw Material Consumption per unit of GDP; Domestic Material Consumption per unit of GDP).

Examples of similar current work underway or recently completed

EU has a range of targets in place related to waste recycling and disposal and the circular economy, but these are not performance measures. Some are related to circular economy.

EU Parliament ENVI Committee commissioned a report on measures/indicators[43] in 2015.

42 https://www.gov.uk/government/publications/resource-management-a-catalyst-for-growth-and-productivity
43 http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542206/IPOL_STU(2015)542206_EN.pdf

The EC plans to propose a monitoring framework for the circular economy by building on existing indicators. See para 23 on June 2016 report on the action plan[44].

Clearly there is advantage in common standards and reporting for Circular economy including its infrastructure needs/delivery at the EU level rather than having different governments adopting different systems making comparison and aggregated reporting difficult or dangerous.

Ellen McArthur Foundation has done work on measures/indicators[45] but for individual businesses rather than operating at a regional/national level.

Suggestions for performance measures and their strengths and weaknesses

Recycling targets are often fraught with difficulties as they could potentially have unintended consequences. Greater recycling could reduce energy recovery from waste. Waste links to the effectiveness of other infrastructures; e.g. digital working could lead to reduced travel and resource consumption – thereby reducing waste generation.

Measures/metrics should include:

- Household waste collected, treated and recycled, by type and per household – comprehensive data exists.
- Industrial and commercial waste arisings and fates [NB NIA needs to be very clear on its scope under the title "solid wastes" – we assume this excludes M&A and agricultural wastes for example] I&C waste data is dis-aggregated between the four UK countries and used to be based on infrequent sample surveys – NIA could highlight the importance of data collection and reporting including through widespread adoption of the Electronic Duty of Care tool (EDoC). This investigation should contact Welsh Government / NRW and Scottish Gov / SEPA to explore plans and surveys / measures already underway.
- Measure of industrial investment in circular economy infrastructure – this has a relationship to delivering sustainable growth and jobs (e.g. providing metal recycling facilities could reduce import and increase industrial activity). Could include an assessment of infrastructure permitted (by permitted through-put) and already under development. Infrastructure capacity with planning permission could be another readily collectable data set but is likely to lead to over-estimates of future capacity as some sites receive planning permission but never proceed – as may projects commissioned but not completed

Potential measures must include metrics related to circularising economy as it decouples growth from waste generation and resource constraints. Two possibilities here:

- Ways of introducing resource deployment (utilisation, waste minimisation and recycling) that is circular by design allows growth without the need for more resources. It creates greater value from each unit of resource by recovering and regenerating products and materials after their use.
- Another related area is in designing more durable goods (e.g. cars, washing machines and mobile telephones) which offers huge waste minimisation opportunities.

Potential data sources to populate measures

Waste Dataflow – good data related to household (HH) and municipal solid waste (MSW).

Environment Agency permitted site returns which need to be compared with actual throughput capacities. Some plants are exempted and mask the overall waste flows through waste processing plants.

44 http://www.consilium.europa.eu/en/press/press-releases/2016/06/20-envi-conclusions-circular-economy/
45 https://www.ellenmacarthurfoundation.org/programmes/insight/circularity-indicators

Estimates for tonnages received by landfill – generally reliable.

But there are serious data gaps related to commercial and industrial (C&I) waste streams for the whole economy. This is because there are no binding targets for C&I waste (in contrast to HH/MSW streams). There has not been a pressing need to collate the C&I data, compounded by the general difficulty in understanding the overall picture with C&I waste management.

UK estimates for generation and final treatment of total waste can be drawn from WasteDataFlow and Environment Agency permitted site returns. Estimates for tonnages received by landfill, based on Environment Agency permitted site returns (they do differ from estimates published in HMRC Landfill Tax Bulletins which are sourced from landfill tax receipts). Some of the recovery operations are covered by exemptions or simple registrations and they are not included in the total.

Environment Agency records on Transfrontier shipments

Environment Agency holds the National Packaging Waste Database (NPWD) and reports on other Extended Produced Responsibility (EPR) scheme performance e.g. batteries and WEEE. These are UK estimates for recovery/recycling from packaging based on Packaging Recovery Notes (PRNs) and Packaging Export Recovery Notes (PERNs).

Data can be collected at devolved administration levels (except for packaging waste) and Waste Data Flow can report down to LA level too. However, due to lack of reliable C&I waste data, it is not possible to use them for projecting into future.

Local authorities are also tied into long term contracts, so may have limited ways to benefit from choice of infrastructure in the locality.

EDoC could be used to deliver strategically important data and information at a regional level as well as national / UK.

Cross-sectoral measures

At first waste appears to have a direct relationship with energy (e.g. 1.5% of current electricity generation is from waste combustion). However, waste generation can be linked to all activities (industrial, commercial and domestic). It follows that waste indicators will provide a national drive towards resource efficiency and sustainability in the UK. It will point to desired outcomes (such as good water and air quality, reduced GHG emission, value for money etc.).

Major infrastructure projects could report on overall resource use and / or waste produced, incorporated into final build or wastes used as raw material in construction as was done for the London Olympics

In fact, the following measures will be valuable:

- Waste generated per GDP / head of population
- Waste disposed per GDP / head of population (a residual waste measure which could be derived from existing datasets and could be more revealing tan existing reports for recycling for example as consumption and waste production habits change.

Further sources of information

Waste group at Southampton Uni, which is also linked to other universities on transport and other matters.

Scottish and Welsh Governments have done some good work on both data and reporting. The Scottish Government produced its circular economy strategy in Feb 2016 which included a section on measures and reporting, Welsh Government has embarked on its policy review and will have been thinking about this issue. Natural Resources Wales

(NRW) and the Scottish Environment Protection Agency (SEPA) may also have information.

Standardisation across the UK in terms of data collection and reporting / measures across the circular economy including infrastructure is important to avoid miss-matches and false comparisons. Ideally these standards should be developed and adopted at an EU level

B.7 Transport

Overall challenges in developing performance measures

None identified in addition to the common challenges that apply to all.

Issues for developing performance measures in relation to the individual infrastructure sectors

Difficulty finding standard measures for resilience - recovery depending very much on scale of incident and has multiple potential causes. Specific to airlines is interplay between different airports - connectivity (where can fly to) rather than accessibility (closest airport). Capacity in the air can be an issue and - like performance - can be constrained by factors beyond UK, e.g. Scandinavia to Spain flights routing through UK airspace during French Strike. Potential measures range from objective (e.g. environmental impact) to subjective (passenger quality).

Route based analysis can be used for rail. Challenge of whether assessing a steady state or a growing market (compare with digital sector which has big technological shifts that one market size supports). Longitudinal analysis can be more helpful (rather than comparisons between routes).

For roads, there is the challenge of maintenance versus customer experience i.e. investment leads to short term pain (applies to rail too). Financial incentive of PFI makes comparisons difficult with non PFI.

Experience of developing performance measures for infrastructure

Some involvement in developing measures for Single Departmental Plan, Network Rail performance monitoring. NB: Network Rail just starting a network wide resilience study. ORR has had research done: general issue is how high to set the bar? Trade-off between price and quality. Cost of capital an indicator? Residual value challenge.

Characteristics of successful performance measures

Performance measures need to be developed for which data are readily available and dependable. There also needs to be confidence that these can be collected on a consistent basis between different modes enabling comparison., for example the asset management model is commonly applied across sectors.

Measures must be targeted/with a clear purpose and tied into user needs (particularly passengers/consumers. They should also be realistic/meaningful. Interplay is important– e.g. for trade-offs, especially to avoid perverse incentives.

Examples of similar current work underway or recently completed

DfT Single Departmental Plan.

European Maritime Safety Agency (EMSA) safety stats - noting that these show difference in approach - UK captures all vessels (including fishing) elsewhere only those over 15m.

Not much information on bringing together sectors. Some European or global comparisons may do this.

Mainly international comparisons focusing on benchmarks, rather than learning how performance regimes are designed (implication was that UK is thought leader).

Suggestions for performance measures and their strengths and weaknesses

As set out in Single Departmental Plans.

Value for money should come back to a similar basis for all sectors. Could be some standardisation of quality surveying methods? Sustainability and Carbon type impacts.

Importance of safety - HSE safety measures cut across sectors e.g. workforce lost time. Where does safety fall in relation to the identified domains? The nature of safety risk could vary considerably across sectors - e.g. railway vs gas supply. Interest in whether systems are fail safe. Is user perceptions as well as actuality (can vary - example was four lane running, statistically much safer than users seem to think).

Potential data sources to populate measures

Port freight, seafarers, domestic waterborne freight, safety stats (including search and rescue), RoRo, domestic passengers and some key river crossings. New 'window' system capturing arrival forms electronically (7/8 per vessel) of limited value presently as mostly images of forms but should improve. HMRC data.

Aviation Act gives access to airport data. Eurocontrol shares delay data. Harder to get carrier data. Airport Council International has some global pax quality stats

ORR Data Portal. Network Rail.

Data is available at sub-national levels, but not always meaningful. Port location is geographically influenced/incidental, does not have any correlation to population or economy.

Role of geography is complex – e.g. as airports, wherever they happen to be, offer different services/fulfil different roles. Some sense in separating south east airports from others (and they sometimes do). Challenges from the fact that causes of delay/poor overall quality not exclusive to airports and may well even be from well outside UK... Put forward suggestion of competition (number of airlines present) as part of a measure?

Rail - different route characteristics make performance comparisons difficult (age of assets relevant, nature of asset mix critical). Limited by systems and data. ROAD - Road – congestion levels vary significantly across the country that leads to problems with averaging.

Cross-sectoral measures

Some environmental measures mentioned (e.g. benefit of reducing vehicle km) that might cross some sectors. Some ports have calculated their contribution to the economy/community (e.g. through jobs) that go beyond sector. Not clear - not consistent in application or probably approach.

Need to understand purpose – e.g. could they be to show that doing well in one sector not enough to attract FDI e.g. if other sectors are lagging? May be useful to identify where more investment is needed on a sub-national basis.

Domestic customers quite different from commercial/government. Issue of commonality between modes within transport as well as across sectors e.g. passenger expectations differ for different modes (rail; air). Freight user expectations may vary significantly by payload. Sometime may need to accept that interim proxy needed if 'ideal' can't yet be provided.

Depends on purpose? And whether/who being held to account for them. Used for funding (mostly negative views on these). If not accountable would this reduce the necessity to

demonstrate causality? Is presumption that infrastructure is deficient (not enough/wrong type/wrong place) - possibly mismatch across sectors?

Further sources of information

Suggested UK Regulators Network (secondees from separate regulators) - Airports commission report for indicators.

User Groups, Rail Freight Operators, User groups, Campaign for Better Transport (CBT). RAC foundation, ORR.

B.8 Water and wastewater

Overall challenges in developing performance measures

None identified in addition to the common challenges that apply to all.

Issues for developing performance measures in relation to the individual infrastructure sectors

High level indicators difficult to drill down into more useful form, baseline not currently set so it is difficult to see the impact of building or doing something differently in the future.

The sector is heterogeneous and therefore generic measures are hard to identify.

Key areas for Ofwat that would need to be covered are: asset health, water resources, flooding, wastewater and social/economic aspects.

Experience of developing performance measures for infrastructure

Ofwat project on indicators due to report March 2017 at the earliest – will send copy of terms of reference when available

Characteristics of successful performance measures

For NIC needs to be high level and pragmatic - opportunity to learn between sectors and add value by considering interdependencies (e.g. water and energy).

Examples of similar current work underway or recently completed

Other sources of national performance measures are: US Homeland department, Asian Development Bank, International Water Association conference in October 2016, World Bank.

Suggestions for performance measures and their strengths and weaknesses

Ofwat developing high level indicators (due March). Serviceability important but as technology develops may be potential to link to condition.

Potential data sources to populate measures

Data is available but not easy to put together. PR14 information not consistent - water company indicators negotiated with their customers. Ofwat water dashboard published November. Ofwat 8 performance commitments.

Information is available at water resource zone and/ or asset scale. Issues around integrating local and regional data into a coherent comparison. Ofwat Dashboard compares companies with their targets (but not necessarily consistent targets).

Cross-sectoral measures

High level indicators add value (e.g. security of supply and asset health). Is the NIC role to co-ordinate sectors?

Further sources of information

Additional colleagues in the Environment Agency.

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