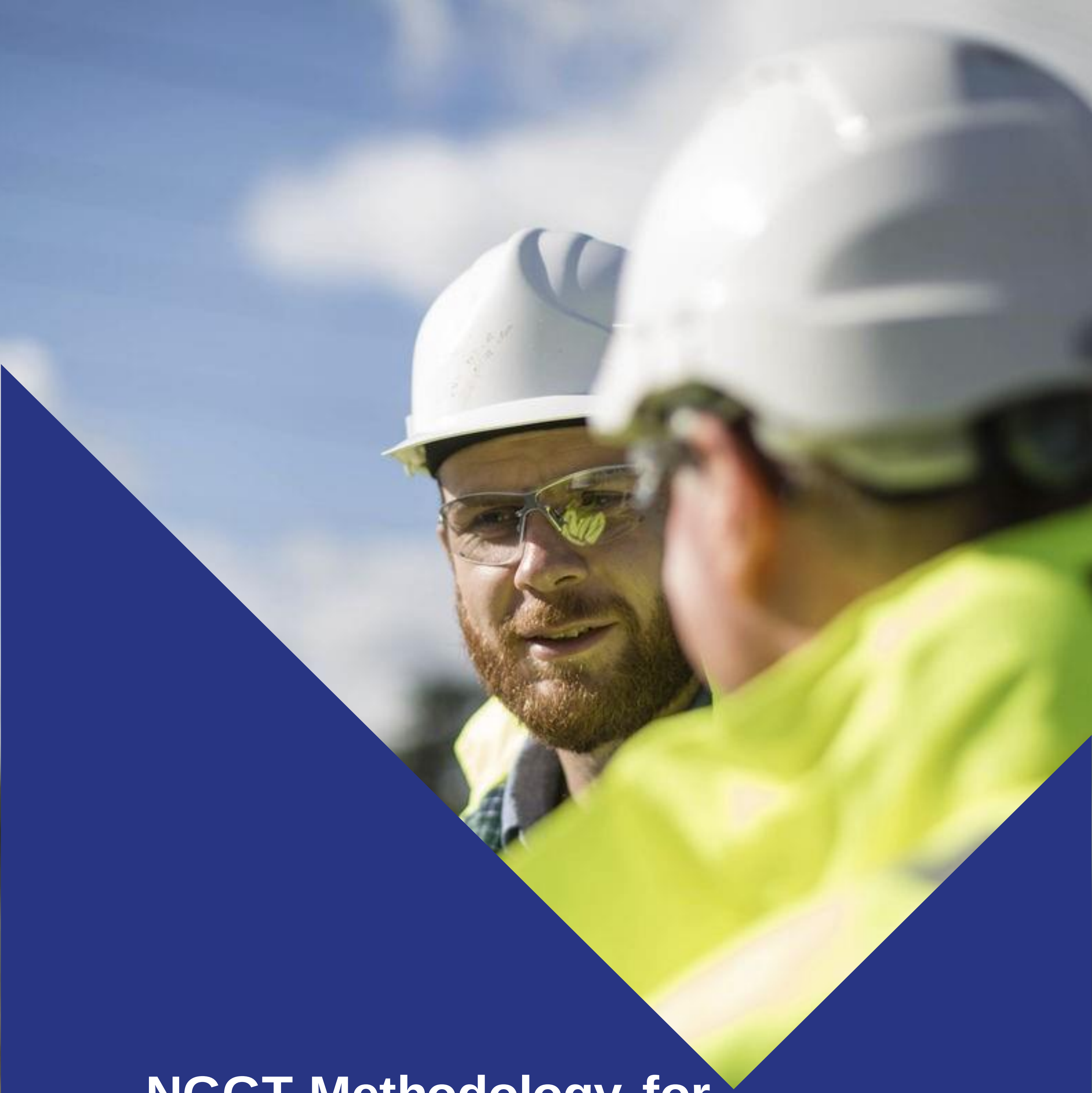

NGGT Methodology for Network Asset Risk Metrics (NARMs)

Main Overview Document

May 2021

nationalgrid

Contents

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Executive Summary

This document describes the methodology that National Grid Gas plc ("NGGT") in its role as holder of the Gas Transporter Licence in respect of the NTS (the "Licence") has been developed to meet the requirements of the Special Conditions 3.1 and 9.2 of the RIIO-2 licence.

The Network Asset Risk Metric (NARM) Methodology objectives are to:

- Provide transparent, logical links between:
  - The asset data that we collect through inspections, maintenance, and other asset management activities;
  - The data that we record in asset management systems;
  - Asset management decisions
  - Asset investment decisions
- Facilitate the monitoring of asset performance - the monitoring of the performance in relation to the development, maintenance, and operation of an efficient co-ordinated and economical transmission system and enable:
  - The robust estimation of current monetised risk, forecast/future monetised risk, single-year monetised risk, and the long-term monetised risk delivered by investments to prevent asset failures;
  - The robust estimation of the current monetised risk and long-term monetised risk benefits delivered, or expected to be delivered, through interventions on specific assets or groups of assets;
  - The identification and quantification of drivers leading to changes in monetised risk over time.
- Allow the assessment of network expenditure - the assessment of historical and forecast network expenditure on the NTS and enable to provide inputs to help explain and justify, through Cost Benefit Analysis (CBA):
  - Investment plans for managing and renewing our assets (where in scope for NARM assessment); and
  - Outturn delivery of investment options (costs, volume and risk benefits).
- Allow comparative analysis of performance over time between: different NARM asset categories and between individual NARM assets on the NTS; geographic areas of, and NARM assets within, the NTS; the NTS and other networks within the same sector; the NTS and networks outside Great Britain with similar assets should similar approaches as set out in the NARM Methodology be applied to estimate monetised risk for those networks; and the NTS and Distribution Networks within Great Britain.
- Communicate relevant information - the communication of relevant information regarding the NTS between Ofgem and other interested parties in a transparent manner and enable Ofgem to establish our Baseline Network Risk Outputs (BNRO) and to undertake an objective assessment of our BNRO delivery.

The NARM approach, underpinned by the new Long Term Risk Benefit (LTRB) and Unit Cost of Risk Benefit (UCR) measures, provides additional benefits:

- Demonstrates that the investments delivered deliver the maximum long-term benefits to consumers and deters companies from prioritising short-term measures where these are not in the consumers best interests.
- Ensures companies are appropriately incentivised to select, prioritise and target these investments as efficiently as possible.

The Gas Transmission (GT) NARM Methodology is presented through a suite of documents, summarising and detail the approach and assumptions adopted to quantity monetised risk and apply this to assessing the long-term monetised risk reductions delivered by asset investments:

The Main Methodology (this document), supplemented by the following supporting documents:

- Probability of Failure
- Consequence of Failure
- Service Risk Framework
- Long Term Risk and Network Risk Outputs

A detailed Validation Report is also available, demonstrating the capability and limitations of the adopted approach.

A Glossary of key terms used throughout the Methodology is included in Appendix D.

Foreword

Our gas transmission network ensures the safe and reliable transportation of gas to 23.2 million industrial, commercial and domestic customers around Great Britain. We are ensuring the network can meet the flexible current and future needs of our customers, so it can flexibly manage changing supply and demand patterns and adapt to the emerging challenges of migrating to a hydrogen-capable transmission system in support of our Net Zero commitments.

Through our new Network Asset Risk Metric (NARM) Methodology, we can now better quantify the level of performance that our assets are delivering for customers. This provides additional justification for the expenditure needed to maintain and improve our safety, reliability and environmental performance across our network.

The NARM approach provides additional confidence that we are delivering the investments that meet the long-term needs of customers and enable better evidence that these network risks are being managed effectively through the investments we are funded to deliver.

Mark Lissimore,
Head of Engineering and Asset Management
National Grid Gas Transmission

1. Introduction

1.1. Methodology Objectives

This document describes the methodology that National Grid Gas plc ("NGGT") in its role as holder of the Gas Transporter Licence in respect of the NTS (the "Licence") has been developed to meet the requirements of the Special Conditions 3.1 and 9.2 of the RIIO-2 License.

The Network Asset Risk Metric (NARM) Methodology ("the Methodology") objectives, as defined by Ofgem, are to:

- Provide transparent, logical links between:
  - The asset data that we collect through inspections, maintenance, and other asset management activities;
  - The data that we record in asset management systems;
  - Asset management decisions
  - Asset investment decisions
- Facilitate the monitoring of asset performance - the monitoring of the performance in relation to the development, maintenance, and operation of an efficient co-ordinated and economical transmission system and enable:
  - The robust estimation of current monetised risk, forecast/future monetised risk, single-year monetised risk, and the long-term monetised risk delivered by investments to prevent asset failures;
  - The robust estimation of the current monetised risk and long-term monetised risk benefits delivered, or expected to be delivered, through interventions on specific assets or groups of assets;
  - The identification and quantification of drivers leading to changes in monetised risk over time.
- Allow the assessment of network expenditure - the assessment of historical and forecast network expenditure on the NTS and enable to provide inputs to help explain and justify, through Cost Benefit Analysis (CBA):
  - Investment plans for managing and renewing our assets (where in scope for NARM assessment); and
  - Outturn delivery of investment options (costs, volume and risk benefits).
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- Communicate relevant information - the communication of relevant information regarding the NTS between Ofgem and other interested parties in a transparent manner and enable Ofgem to establish our Baseline Network Risk Outputs (BNRO) and to undertake an objective assessment of our BNRO delivery.

The NARM approach, underpinned by the new Long Term Risk Benefit (LTRB) and Unit Cost of Risk Benefit (UCR) measures, provides additional benefits:

- Demonstrates that the investments delivered deliver the maximum long-term benefits to consumers, and deters companies from prioritising short-term measures where these are not in the consumers best interests
- Ensures companies are appropriately incentivised to select, prioritise and target these investments as efficiently as possible

It should be noted that the Methodology covers the monetisation of both condition and non-condition related failure modes. For NRO reporting, only condition-related risk (leading to monetised risk deterioration) will be included.

Long term risk valuation is an essential step towards justifying investment through Cost Benefit Analysis (CBA); the calculated LTRB delivered by investment delivers fully quantified monetised benefit values for direct use in CBA. Through Methodology development, we have developed risk trading, or asset investment optimisation decision support models and tools, which fully systemise the calculation of LTRB. This investment optimisation capability allows the best combination of investment to be selected, delivering customer service requirements at the lowest cost. Investment optimisation and risk-based investment planning is beyond the scope of this document.

2. Overview of the Methodology

Network Asset Risk Metrics (NARM) are defined by Ofgem as: "*The Monetised Risk associated with a NARM asset or the Monetised Risk Benefit associated with a NARM asset intervention*".

Furthermore a Network Risk Output (NRO) is defined by Ofgem as: "*The risk benefit delivered or expected to be delivered by an asset intervention, and: is the difference between without intervention and with intervention Monetised Risk; can be measured over one year or over a longer period of time; and includes both direct (i.e. on the asset itself) and indirect (i.e. on adjacent assets or on the wider system) risk benefit.*"

For the purposes of this document we use the concept of Long Term Monetised Risk Benefit (LTRB) to cover both NARM and NRO benefits.

The focus of the Methodology is the calculation of the NRO measures that enables us to:

- Report the cumulative monetised risk benefits (LTRB) delivered by proposed and agreed (funded investments)
- Assist with the justification of the refurbishment and replacement activities to deliver our defined customer service expectations
- Measure the efficiency of delivering our NRO targets - the Baseline Network Risk Output (BNRO)

The Methodology underpins our overall strategy for embracing risk-based asset management. We are an ISO55001 certified organisation and are on a journey to fully embed risk-centred decision making, whilst maintaining our focus statutory compliance where applicable (ALARP; DSEAR; Pressure Systems (Safety) Regulations etc.).

Figure 1 shows the interaction of the main elements that are used in our asset management decision making, based on potential investments and underlying changes to the network and future supply and demand scenarios. The value framework[1] is our terminology for the engine/environment where the monetised risk and LTRB calculations are undertaken. This is a long-term view as we move towards the position where all asset investments, not just condition or heath driven, can be valued using long-term monetised risk.

[1] Copperleaf Asset | Asset Risk Management | Copperleaf

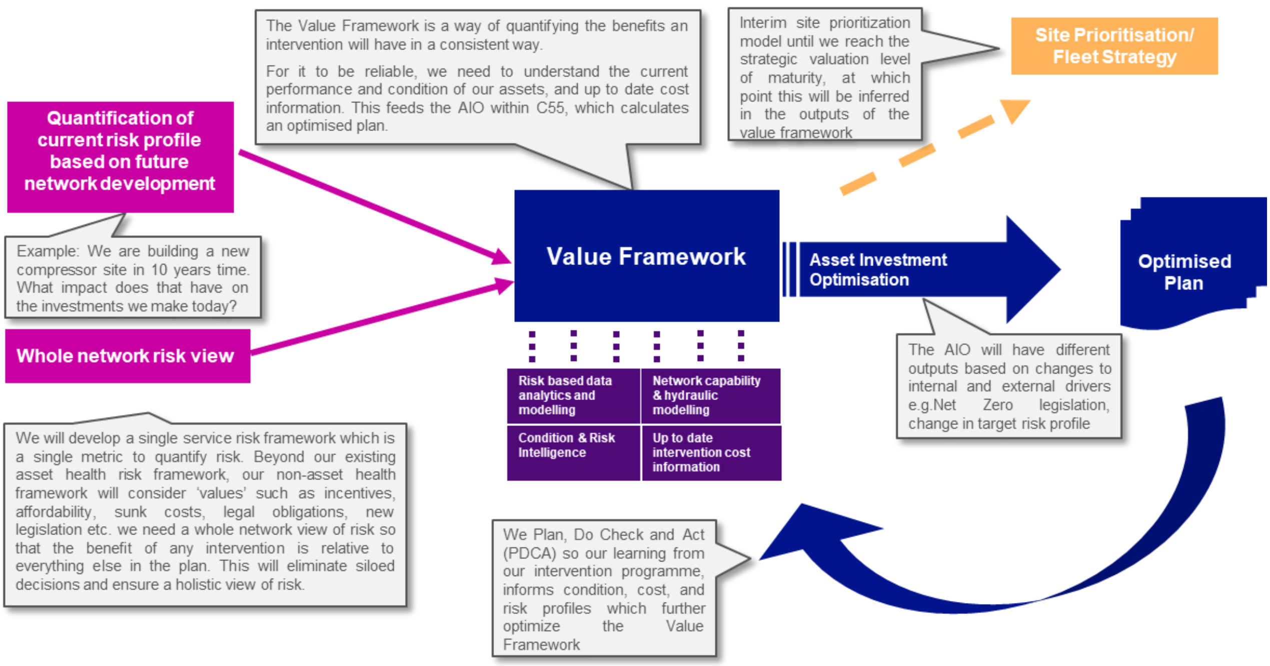

Figure 1 Risk-based asset management decision making and the value framework

Asset risk is calculated from data held in our maintained asset register (Ellipse). This physical asset data is supplemented by defect/failure records, measured or assumed failure consequences and the costs of defect remediation and maintenance. Proactive intervention costs are not directly part of the assessment of baseline monetised risk but are a key element of risk-based investment planning and the UCR measure implemented to measure the efficiency of delivering our BNRO targets.

This document outlines the key stages to undertake initial quantification of monetised risk and the extension of this approach to define the LTRB delivered by specific investments. Several supporting documents also underpin the Methodology, going into greater detail about the data used and assumptions applied:

- Probability of Failure supporting document
- Consequence of Failure supporting document
- Service Risk Framework supporting document
- Long Term Risk and Network Risk Outputs supporting document

A Validation Report is also available which explores the sensitivity of key data inputs and assumptions, tests the model outputs against real-world data (where available) and lists future Methodology improvements.

3. Principles of the Methodology

The Methodology documents and assesses the asset related events that affect the ability of that asset base to perform its necessary function and may potentially result in service consequences for employees and customers. To ensure comparability of investment benefits for different types of asset risk, a single metric must be developed. The use of a financial metric, or monetised risk is considered most suitable. To calculate asset-level monetised risk we need to understand and translate the likelihood of an asset being unable to perform its function, through to the consequences of this failure. By understanding the magnitude, or consequence quantity, of an asset failure it becomes possible to value this consequence using a variety of methods (Figure 2).

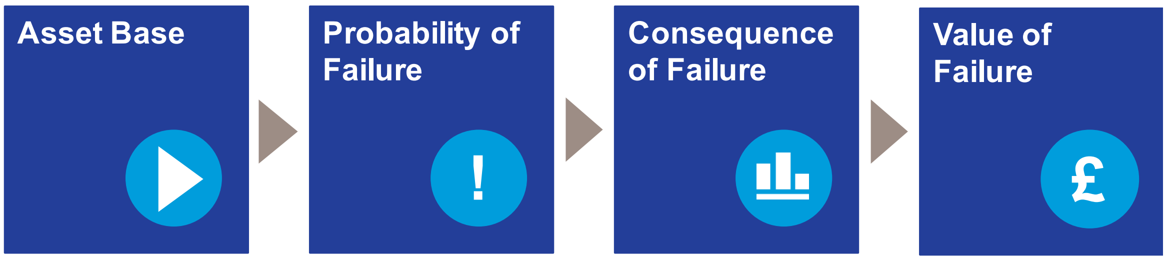

Figure 2 High level process for valuing the likelihood and consequences of asset failures

The principles of the risk monetisation elements of the Methodology are based on a Failure Modes Effects and Criticality Analysis (FMECA) and Event Tree Analysis (ETA), both of which are recognised risk assessment techniques. These facilitate the analysis and representation of the sequence of events and consequences following an asset failure event, to allow a consequence quantity and monetised risk value to be derived.

4. Service Risk Framework

The foundation of the methodology is the Service Risk Framework (SRF). This consists of a set of measures, arranged into categories, that describes the network performance needs of the company and customers. All assets, either directly or indirectly, contribute to the delivery of one or more of the measures within the SRF.

The impact of asset performance, on one or more of these service risk measures, provides a consistent method of assessing and articulating the consequence of asset failure and ultimately its monetised risk value. The risk maps or event trees, which are described later in this document, provide the relationships between an asset performance event through to the consequence of that event in terms of impact on one or more of the SRF measures.

4.1. Asset Base

The Methodology applies to all in-service NGGT gas transmission assets, although some are not included in RIIO-1 or RIIO-2 NROs. Specific information about the NGGT asset base, contained within our asset registers, drives the monetised risk calculations underpinning the Methodology. Factors such as the age, performance and utilisation of the assets are used to determine the likelihood, or probability, of asset failure. Factors such as the configuration, location and capacity of the asset base are used to derive the performance consequences of an asset failure should it arise.

4.2. Probability of Failure

Individual assets can generally fail in several ways giving rise to one or more consequences. These are referred to as failure modes, or failure consequences, which quantify the deviation from the normal performance of the asset. Only the failure modes that lead to a material performance consequence have been identified and used. Understanding the factors that drive the deterioration of the assets and how this impacts the probability of failure has allowed the increasing probability of failure, over time, to be assessed. This assessed probability of failure and rate of asset deterioration has been derived from several sources, all of which are recognised asset management practices:

- Historical maintenance / asset performance data;
- National and international published information; and
- Subject Matter Expert (SME) guidance and elicitation workshops.

The current and predicted probability of failure for each of the identified failure modes, for all the individual assets on the NGGT asset base, has been determined. Further detail can be found in the Probability of Failure supporting document.

4.3. Consequence of Failure

The consequence of failure determines the impact that the asset will have on a service risk measure should the asset be no longer able to perform its function. The consequence of the asset failure is made up of the:

- Probability that an asset failure causes a consequence (not all failures have direct consequences)
- The severity/magnitude of the consequence (i.e. a significant leak)
- The quantification of the consequence (e.g. a significant leak will result in 1000 cubic metres of lost gas)

For all assets, the factors that drive the consequence have been determined and quantified, including:

- The purpose of the asset and location of the asset within the network or site
- The geographic location of the asset and its proximity to buildings and transport links
- Whether the asset is Safety Integrity Level (SIL) rated and is covered by detect and protect systems
- Staff and public exposure to the assets and associated failure consequences

Further detail can be found in the Consequence of Failure supporting document.

4.4. Value of Failure

The probability and consequence of failure for each asset is combined into a predicted number of events aligned to each of the measures defined in the SRF. The monetary value (or monetised risk) of failure is expressed for each of the SRF measures, which can then be aggregated into higher level categories for investment optimisation and stakeholder consultation.

All service risk measures have been valued in terms of private or societal risk:

- The private (or internal) value relates to costs directly incurred (or avoided) by NGGT
- The societal (or external) value relates to an indirect impact on stakeholders (such as the gas distribution networks) and wider society (e.g. loss of a gas supply to indirect customers; disruption to transport links)

The private valuations recognise the direct costs arising from asset failure. The private valuations have been developed using an analysis of historical work and cost data, supplemented by relevant industry data and assumptions.

Societal valuations include the benefits and disbenefits of asset failures as experienced by customers, local communities and the environment. The societal valuations have been developed using available literature and best practice methods (such as value transfer and willingness to pay). We appointed specialist regulatory consultants to undertake this specialist analysis.

Many service measures carry both a private and societal value which can be used in combination or independently for investment optimisation and reporting.

The methods and data sources used for determining a valuation for each of the SRF measure, together with any considerations of overlap between societal and private valuations, is detailed in the Service Risk Framework supporting document.

4.4.1. Reporting Risk Measure

Since the original Methodology for Network Output Measures was published, Ofgem have provided greater clarity on how the NARM NRO will be used for assessing network risk and measuring the effectiveness of investments. The two key measures are:

- The Long Term Monetised Risk Benefit (LTRB)
- The Unit Cost of Risk Benefit (UCR)

These metrics will be reported through the annual Regulatory Reporting Pack (RRP) to Ofgem and used internally to validate and focus investment decisions. Further detail is provided in the Long Term Risk Benefit supporting Document.

4.4.2. Investment Planning

The Methodology also supports investment planning and decision making using our value framework and decision support optimisation tools. Understanding the best combination and timing of investments, whether inspection, maintenance, repair, refurbishment or replacement and assessing the impact these interventions have on future asset performance and network risk. The risk benefit delivered by alternative can be assessed across the life of the asset or intervention, and this assessment of whole life cost and benefit enables effective evaluation and justification of alternative investment options.

When combined with factors driving the need to invest, such as historical failure analysis, As Low As Reasonably Practicable (ALARP) considerations and mandatory legislative requirements for maintaining asset condition and performance, the monetisation of long term risk benefit is a powerful tool to help justify, focus and prioritise our investment decision-making.

5. Application of the Methodology

5.1. Challenges

The GT asset base is a large and interconnected system of physical assets that is geographically distributed across Great Britain. It is designed and operated to be safe and highly reliable. This presents a series of challenges for the application of the Methodology including:

- Consideration of current and future gas supply and demand scenarios, including uncertainty around the future demand for gas and future supplies (location, flows, capacity)
- The need to manage a flexible network to account for supply and demand fluctuations
- The need to manage operational outages (planned and unplanned) to maintain or repair failed assets
- Assessing risk in a resilient network where multiple configurations are possible to mitigate the failure, or unavailability, of other assets and prevent service issues
- Asset redundancy where multiple assets of the same type exist mitigate the failure of any individual asset
- Service failure dependencies where assets are in place to detect and protect against the impact of failure of dependent assets
- Asset degradation (deterioration) dependencies where assets are in place to prevent or slow the degradation of other assets (e.g. cathodic protection, cladding)

Our approach to these challenges is explained throughout this document and in the accompanying supporting documents.

5.2. Systemisation

Systemisation is the only way that the consistency and repeatability of risk calculations can be guaranteed. Systemisation also provides the efficiency and speed of application necessary to be practical for regular reporting to our stakeholders and to use as a basis for investment planning.

Our NARM Methodology has been built using the Asset Investment Manager (AIM) system, developed by Probit Consulting. We are presently migrating to a new solution, the Copperleaf Decision Support Analytics tools, which provides a wider investment portfolio management capability for NGGT. The Copperleaf solutions will apply the same monetised risk valuation approaches as defined in these documents but will include the ability to refresh the asset base more routinely and to manage sanctioned investments and resulting NROs more closely. This migration may have an impact on the monetised risk and LTRB values currently established. This will require discussions with Ofgem and possibly future revisions to the Methodology and to NRO targets.

The systemisation of the Methodology has allowed an almost fully data-driven approach to be adopted. Whilst this data driven approach provides the consistency and speed of application it is dependent upon the quality of data used. We continue to understand and improve the quality of the asset register and other data assumptions required to support this Methodology. We also consider the sensitivity and uncertainty of the data used and the impact of data quality issues on monetised risk valuation. The

Validation Report discusses this sensitivity analysis and holds a record of our proposed actions to improve the Methodology in future.

5.3. Modelling the Asset Base

To allow the widest possible application of the Methodology and to facilitate investment optimisation and risk trading, only two models were developed covering all NGGT assets:

- **Pipelines** – containing all the below-ground pipeline feeder assets and associated pipeline protection (e.g. cathodic protection; impact protection). These are generally linear assets covering a wide geographic area, with some pipelines running in proximity to population centres
- **Sites** – containing all the above ground assets (AGIs) that form the entry and exit points, multi-junctions (complex intersections of pipeline feeders), block valves (for network reconfiguration and isolation) and compressor sites. These are generally point assets and risk is generally localised to the site itself.

Having only two models means that investments on different asset types, or bundled investments containing multiple different asset types, can be optimised together avoiding the need for off-line consolidation of optimised investment scenarios. Within our AIM tool these risks were modelled independently. The under-development Copperleaf solution provides the capability to optimise investments across above- and below-ground assets within the same environment.

6. Service Risk Framework

The SRF provides a consistent method for assessing and articulating the level of monetised risk associated with service issues arising from an asset failing to perform its function. The SRF provides a common “currency” against which to consistently value and communicate risk associated with the performance of the network. As discussed previously, the SRF is expressed in our risk modelling tools as a value framework, which:

- Defines the relationship between an asset, its likelihood of failure and the monetised consequences of that failure
- Defines the calculations used to model risk characteristics of an asset and then value that risk in monetary terms

The structure of the SRF has been designed in such a way so that it can articulate, in fully quantified terms, how the asset base is performing and how this may change in the future based on differing levels of capital (CAPEX) and operational (OPEX) expenditure.

6.1. Service Risk Framework Categories and Measures

The SRF consists of 13 measures grouped into five categories as shown in the Figure 1 below.

Category	Service Risk Measure
Safety	Health and Safety of the General Public and Employees
	Compliance with Health and Safety Legislation
Environment	Environmental Incidents
	Compliance with Environmental Legislation and Permits
	Volume of Emissions
	Noise Pollution
Availability and Reliability	Impact on Network Constraints
	Compensation for Failure to Supply
Financial	Shrinkage
	Impact on Operating Costs
Societal and Company	Property Damage
	Transport Disruption
	Reputation

Figure 3 SRF categories and measures used for monetised risk valuation

6.1.1. Safety

Safety risk includes the potential impact of the asset failure on the health and safety of our employees and the general public. This also covers our compliance with the legislation relating to health and safety. The safety impacts of a widescale loss of gas supply (e.g. loss of a gas distribution zone, or LDZ) are not included. We have quantified this risk value, but in discussion with Ofgem it was agreed that the low likelihood (and potentially vast monetised risk impact) it was decided that to include it would distort LTRB and investment CBA analysis. This is currently under review and forms part of our Methodology improvement plan.

6.1.2. Environment

Environment (or environmental) risk includes our cost of compliance (or risk of non-compliance) associated with operating and maintaining our network, including environmental damage and noise pollution. It also includes the value of the loss of gas and associated carbon costs arising from the planned and unplanned emission of greenhouse gases. Costs of fuel gas for compressor assets are excluded as this is driven by operational need rather than asset condition.

6.1.3. Availability and Reliability

Availability and Reliability (AR) risk includes our ability to transmit gas from shippers to downstream consumers and any commercial or statutory compensation we may be required to pay if we fail to do so. AR risk is limited to unplanned outages (planned outages are assumed to be manageable through usual operational arrangements).

6.1.4. Financial

Financial risk includes the other direct financial costs incurred by NGGT when operating the asset base including gas shrinkage (unplanned only), repair costs, maintenance costs, damage to associated plant through asset failure and fines resulting from prosecution. Financial risk only includes the reactive costs of failure and managing failure. Intervention costs to proactively manage risk are not considered within the NARM Methodology, other than an input to the UCR metric[2].

Societal

Societal risk includes the potential wider impacts to society of our asset base such as the potential for transport disruption and damage to public property. Societal risk also includes the indirect costs of a widescale loss of gas, the costs of which are spread across the whole industry. Impact on this gas trading market are not currently quantified and this societal risk is quantified using customer compensation and reconnection costs (which are still significant).

Details of how each of these Service Risk Categories and Measures are defined and measured are included in the Service Risk Framework supporting document.

6.2. Mechanisms used for Valuation

All the measures and severities have been valued from two perspectives:

- The direct costs to NGGT of the impact of the service provided – **private** (or internal) valuations; and
- The value to society arising from the provision, or failure of, the gas transmission service– **societal** (or External) valuations

Figure 1 shows where either/or private or societal valuations apply for each of the service risk categories and measures.

Category	Service Risk Measure	Private	Social
Safety	Health and Safety of the General Public and Employees	Y	Y
	Compliance with Health and Safety Legislation	Y	-
Environment	Environmental Incidents	Y	Y
	Compliance with Environmental Legislation and Permits	Y	-
	Volume of Emissions	-	Y
	Noise Pollution	Y	Y
Availability and Reliability	Impact on Network Constraints	Y	-
	Compensation for Failure to Supply	Y	Y
Financial	Shrinkage	Y	-
	Impact on Operating Costs	Y	-
Societal and Company	Property Damage	-	Y
	Transport Disruption	-	Y
	Reputation	Y	-

Figure 4 Private and social valuations for each service risk measure

2 Long Term Risk and Network Risk Outputs Supporting Document, Section 8.2

7. Use of the Methodology

7.1. Reporting

Ofgem have consulted on their proposed NARM Handbook and NARM Workbooks[3] (decision still outstanding as of April 2021), which details the process for BNRO reporting at closeout and define the targets for each network. These documents should be referenced to understand how the LTRB and UCR metrics calculated are to be used within the RIIO-2 NARM Funding Adjustment and Penalty Mechanism, which is designed to be equivalent for all energy networks. The data requirements for the annual RRP is not currently defined and will be consulted upon by Ofgem later in 2021. We anticipate that future reporting requirements will need us to report planned, forecast and actual values for:

- LTRB per intervention (investment) and asset
- UCR per intervention and asset
- Intervention costs (by project and asset type)
- Intervention volumes
- Unit costs (by asset type)

Our NARM Methodology and decision support tools are fully capable of meeting these requirements. Full details upon how these NARM metrics are calculated can be found in the Long Term Risk & Network Risk Outputs supporting document, which is a new addition to this new version of the Methodology.

7.1.1. Long Term Risk Benefit

LTRB is defined as the cumulative monetised risk benefit over the life of an intervention, where an intervention is an activity which replaces an existing asset or extends the life of an existing asset. Figure 5 illustrates the concept. Please note, all charts show deterioration as linear but in reality they are Weibull curves.

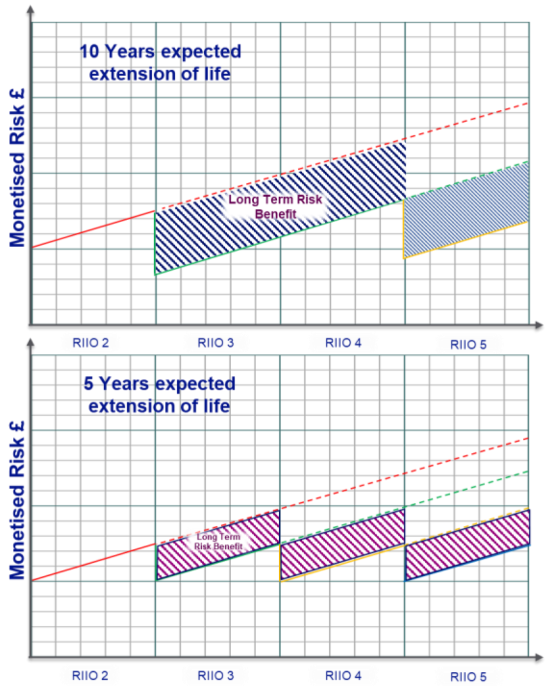

Figure 5 Long term monetised risk benefit visualisation for 10- and 5-year interventions

[3] https://www.ofgem.gov.uk/publications-and-updates/consultation-issuing-network-asset-risk-workbooks-and-network-asset-risk-metric-handbook

We discount all LTRB values using the same discount rate used for financial discounting in cost benefit analysis (3.5% in RIIO-2). This is to effectively de-weight the LTRB in future years, based on the assumption that the magnitude of benefits delivery in future years is less certain

7.1.2. Unit Cost of Risk Benefit

The UCR is calculated for each intervention by dividing the total intervention cost (not the unit cost) by the approved expenditure for that investment, adjusted for agreed efficiencies and RPE. The UCR is a dimensionless metric that equates to the spend to deliver a unit reduction in LTRB.

An example of a UCR calculation is presented below:

We plan to replace 10 "widgets" at a cost of **£1,000**

Replacing these 10 "widgets" delivers **R£2,000** of LTRB

The UCR for this intervention is R£2,000 / £1,000 = **2.0** (no units)

The normalised (per asset) UCR is 2.0 / 10 = **0.2** per "widget"

7.2. Investment Planning

The monetised risk valuations arising from application of the Methodology are already used in support of our asset health (condition) investment planning. As described in Figure 1 we are planning to extend this approach to all NGGT asset investments, including emissions, systems enhancement and decommissioning projects. We refer to this as the Single Value Framework (SVF).

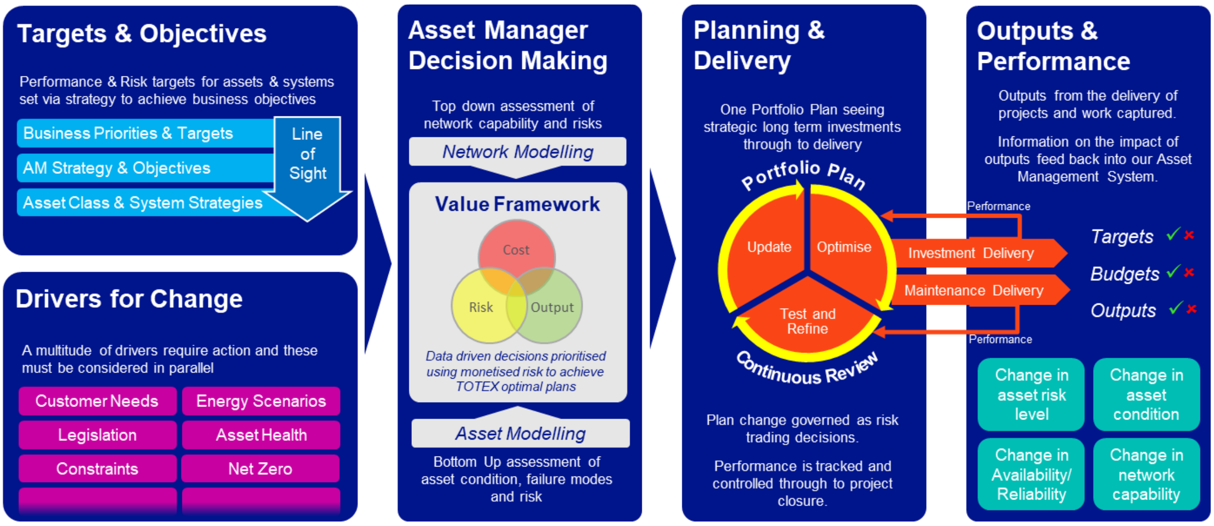

Figure 6 Investment planning conceptual model

The risk valuations determined by the Methodology will be used consistently across all planned investments, supplemented by a knowledge of our need for meeting customer objectives and achieving legislative compliance. This will allow asset health and other asset investments to be compared and prioritised on a consistent basis. It will also allow project to be bundled together more efficiently, enabling better works planning (deliverability and operational resource optimisation). More efficient project delivery, and improved management of change (to account for changes to project scope and timescale), will reduce the risk associated with project delivery and ensure we continue to drive value through our investment programme.

The Methodology provides a systemised and consistent approach to understanding the current and future risks associated with operating our network, but the risk valuations are generally strategic to enable a consistent approach to be adopted across all assets and site. For specific investment needs, the risk analysis will be site and location specific but will follow the same principles as defined in the Methodology (e.g. Best Available Technology (BAT) for emissions investments; site specific QRAs; etc.).

7.2.1. Interventions

Comparing the costs and benefits of all the intervention options is a key benefit arising from a consistent risk valuation approach when developing investment plans and optimising investment decisions. Interventions can be thought of as 'doing work' on assets, which can range from routine maintenance through to full asset replacement. Furthermore, any future need to increase or decrease the capacity and capability, or to implement new technologies or innovations, will increase or decrease the risk profile of the whole network. This in turn, will change the costs and benefits of any asset health/condition driven work that may be needed in the shorter term.

Interventions can affect the different failure modes of different assets, and typically they would be expected to reduce the likelihood of a failure occurring. Other interventions can affect the consequences of failure and mitigate the severity or quantity of service affected.

The Methodology allows for the modelling and prioritisation of both proactive and reactive interventions. . The costs will include both CAPEX and OPEX expenditure and therefore allow TOTEX investment planning to be undertaken. Benefits or disbenefits of investment or non-investment can be quantified in equivalent monetary terms.

Presently, asset optimisation is restricted to asset health investments, but our intention is to move to optimisation of the whole investment plan, following implementation of the SVF. This improvement to whole-plan optimisation will be documented in future versions of the Methodology.

7.2.2. Intervention Costs

There are two sets of cost data that are aligned to the NARMs Methodology:

- **Proactive costs** – the cost of delivering an asset life extension through a proactive intervention to manage risk
- **Reactive costs** – the costs of operating and maintaining the network in its current condition and in the future without proactive intervention

Reactive costs are associated with our Financial Risk service risk category. At present these are fixed in the model and deteriorate annually based on a modelled relationship with condition. At present, we do not model alternative reactive interventions (such as time- and risk-based maintenance), but we may do so in the future.

Proactive costs are applied at an asset or investment (project) level to quantify the cost of delivering work to improve existing asset condition (now and future). The costs and monetised risk benefit of alternative interventions can be compared through investment optimisation and/or CBA analysis.

The intervention cost to deliver the LTRB is used to define the UCR, which will be used through the proposed Ofgem NARMs incentive mechanism to quantify the value of reward or penalty for RIIO-2 asset health performance. This is applied at intervention (UID[4]) level and aggregated into risk sub-categories for regulatory output assessment.

7.2.3. Decision Support Tools

As discussed in the Systemisation section, we value network risk using a decision support tool which also enables us to model alternative investment options. By comparing the monetised risk value of an asset (or group of assets), both with and without proactive interventions, it is possible to forecast the plan that delivers the optimum benefit at the lowest cost to customers. The DST allows alternative investment scenarios to be explored, by constraining the model to achieve define service risk outputs, agreed in consultation with stakeholders. Examples of service risk outputs include:

- Financial targets and constraints (e.g. customer willingness to pay)

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[4] Unique IDentifier. This is used to ensure all investments are linked to their business plan funding source

- Compliance with legislation (standards and timing)
- Health and safety minimum standards (e.g. ALARP)
- Unplanned outage requirements (planned outages are not directly considered, but can be used as an investment constraint)
- Environmental compliance
- Emissions targets (e.g. carbon emissions)

Alternative future supply and demand requirements for the network (e.g. FES and Net Zero) generate a wide range of current and future network risk profiles and a different long-term investment plan to meet these requirements. The use of a monetised risk value metric within an investment planning optimisation and decision support tool is complex, and falls outside the scope of this document

7.2.4. Alternative gas supply and demand scenarios

Gas supply locations are market-driven, and we must ensure that asset health investments are best targeted to maintain the flexibility to meet customer needs for the future.

To value the contributions of individual pipelines and sites to overall network resilience (and the avoidance of supply loss) we recognise that the implications of this supply loss will depend on the prevailing demand and supply conditions. This is because depending on the prevailing gas sources different assets will contribute greater or less amounts towards overall system resilience, and hence monetised risk. Customers fed by single pipeline feeder (and its associated AGIs) will be equally vulnerable under all supply/demand scenarios, and this level of fixed risk contributes most of the modelled Availability and Reliability risk (e.g. loss of a feed to a gas network Local Distribution Zone (LDZ), with no ability to flow-swap)

Following feedback from stakeholders and the Validation Report expert review, extensive changes were made to how we estimate Availability/Reliability risk, allowing the sensitivity of risk to changes in supply and demand scenarios to be tested . The changes made are summarised as follows:

- A 1 in 20 supply and demand scenario was chosen after sensitivity testing against other high terminal flow scenarios. This uses gas flows extracted from hydraulic modelling, rather than the historic telemetry data used previously. This aligns to our License requirement to deliver a network that can meet1 year in 20 year gas demand
- A revised approach to value the loss of a gas terminal was implemented, using the expected entry flows under the applied 1 in 20 demand scenarios
- Previously it was assumed that the loss of an exit point could be “flow swapped” in agreement with a Gas Distribution Network (GDN). This assumption has been removed as the opportunity to use another offtake is unlikely under 1 in 20 demand conditions.

8. Pipelines Asset Monetised Risk Valuation

This section summarises how the Methodology has been applied for our below-ground pipelines assets. More detail can be found in the accompanying supporting documents and validation report. An example calculation for a pipeline asset is included in Appendix A.

8.1. Pipelines Modelling Approach

Assets included within the pipelines risk valuation mechanism include :

- Pipeline segments (defined as the average distance between girth welds)
- Cathodic protection (CP) systems and associated CP test posts
- Marker posts;
- Impact protection, including nitrogen sleeves and protective concrete/plastic slabs
- Pipe bridges and river crossings.

8.1.1. Specific Challenges

There are four specific challenges to be addressed when assessing the monetised risk of assets of pipelines:

- Pipelines are linear assets which by their nature have potential impact across a large spatial area. Specific sections of a single pipeline may present a wide variety of risk characteristics, often within short distances due to presence of defects, proximity of population centres, or different levels of protection (e.g. depth of cover). Using an average impact and risk across an entire pipeline section will not accurately reflect the risk associated with localised sections
- The length of pipelines and their replacement costs means that they are never replaced entirely, rather individual targeted interventions are targeted where a high risk of failure exists (e.g. defect resolution following an internal survey)
- The risk associated with pipelines is not only geographic or condition-based but will depend on the level of protection (or additional risk) provided by associated **secondary assets**. Secondary assets include protection from corrosion by CP, or the additional risk of interference where a pipe section is exposed at a river crossing
- The interconnectivity of the pipeline network determines how critical they are to the supply of gas. The degree of resilience associated with specific pipeline sections, should an unplanned outage occur must be considered. In addition, pipelines risk varies under different gas supply and demand scenarios, depending upon their contribution to overall network capacity (including line-pack).

8.1.2. Pipeline Segmentation

We have modelled our below ground pipelines network at pipe segment level. Pipeline feeders have been split into individual pipe segments represented by a girth weld section of approximately 12 metres in length. This allows the specific characteristics and impacts of each pipe segment to be understood and the monetised risk calculated. The risk for any pipeline section or feeder can then be aggregated from the individual segments, which is invaluable for intervention planning where the benefit delivered can apply to a single 12m section, or many adjacent sections. This ability to aggregate pipe sections is a key benefit of our approach, for both investment planning/optimisation and regulatory reporting.

From a total current length of 7,772 km of pipeline around 700,000 individual pipe segments have been created. The physical attributes applied to each pipe section include (but not limited to): material, install year, wall thickness, pipe depth, operating pressure, protection type (e.g. CP, nitrogen sleeve, slab) location. Each pipe section also is associated with the number of properties within defined hazard zones, proximity of transportation networks, and presence of other utilities (such as overline power cables). A visualisation of the NTS as represented in our models is shown in Figure 7

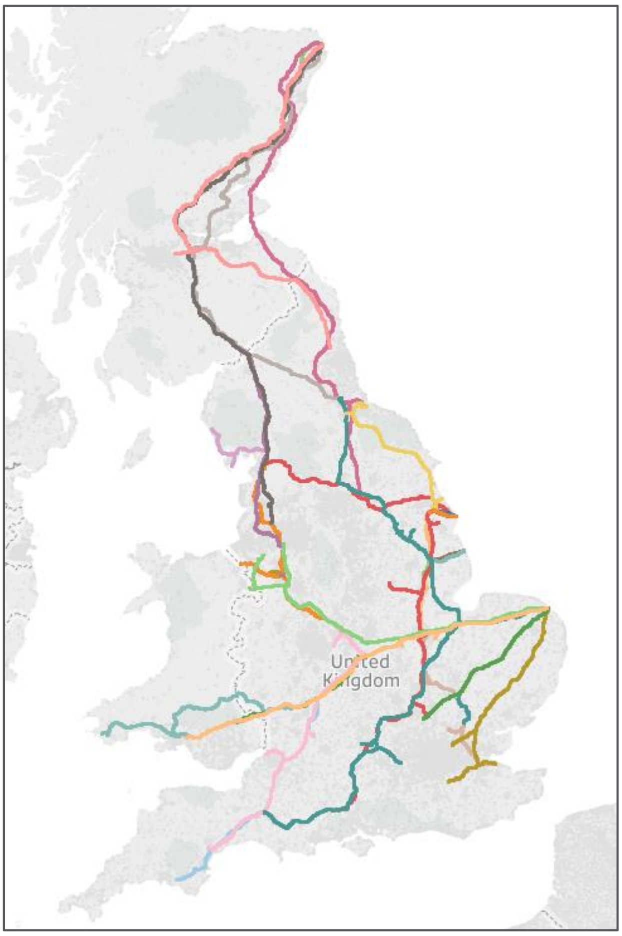

Figure 7 NTS pipeline network coloured by feeder name

The connectivity and interdependency between entry and exit points, pipelines and compressors/AGIs is modelled separately at a whole site level to calculate Availability and Reliability risk under different supply/demand scenarios. This is explained in the Consequence of Failure supporting document.

8.1.3. Asset Interactions

As discussed previously, the probability of failure and consequences of a pipeline failure are modified by the presence and/or condition of associated secondary pipelines assets (where the primary asset is the pipeline itself). These consist of:

- Cathodic Protection (CP) system (e.g. transformer/rectifier and ground-bed)
- Cathodic protection test posts (to monitor the performance of the CP system)
- Marker posts (to indicate the location of a buried pipeline and reduce likelihood of damage from 3rd parties)
- Slabs and sleeves (to minimise damage should external interference occur)
- Nitrogen sleeves (to protect the pipelines from both impact damage and localised corrosion)
- Pipe bridges (where the pipeline crosses roads, railways etc. and is generally exposed)
- River crossings (where the pipeline crosses a watercourse and is generally exposed to further specific hazards)

These assets are modelled such that their presence and/or assessed condition can have an impact on the probability or consequence of failure of the associated pipeline. Other than Financial risk, we do not consider other service risk categories for these secondary assets (the risk is allocated to the primary asset to which it is associated).

8.2. Probability of Failure

As discussed previously, the probability of failure in the pipelines model calculated against the primary pipelines asset using the secondary asset (such as the quality of the CP system) to inform this failure rate. Secondary asset interventions are then modelled using the benefit or disbenefit) they provide to the primary pipelines' asset. Further details can be found in the Probability of Failure supporting document. Failure modes for pipes are based on those defined in best practice[7]:

- **Corrosion** – external corrosion of the pipe resulting in reduced wall thickness and eventual leak or rupture
- **Mechanical failures** - including material and weld defects created when the pipe was manufactured or constructed
- **General failures** – general and other causes, e.g. due to over-pressurisation, fatigue or operation outside design limit
- **External interference** – caused by third parties
- **Natural events** - ground movement, either natural e.g. landslide, or man-made e.g. excavation or mining. This could also include flooding and other natural events

The base failure frequency of each 12 metre pipe section is determined from the underlying pipe attributes which are then calibrated to expected failure rates (based on industry data, which was then reviewed with industry experts[8]) . For example, for an external interference failure model the probability of damage is greater for pipes with lower wall thicknesses (and vice versa).

The risk models are then extended to include the interaction between primary and secondary assets where considered significant. For example, the condition of the cathodic protection system modifies the rate of corrosion of a defect and hence the probability of a leak. Most secondary assets (such as impact protection slabs/sleeves and marker posts) have an indirect relationship between their condition and the condition of the primary pipeline asset. For example, if a marker post, or protective slab is present it will service its purpose of showing the presence of a pipeline and reducing the likelihood of external interference.

Figure 8 shows the failure modes considered for pipelines primary and secondary assets and their modelled failure modes.

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[7] IGEM TD/2, Edition 2 – Assessing the risks from high pressure Natural Gas pipelines, amended July 2015. http://shop.igem.org.uk/products/180-igemtd2-edition-2-assessing-the-risks-from-high-pressure-natural-gas-pipelines.aspx

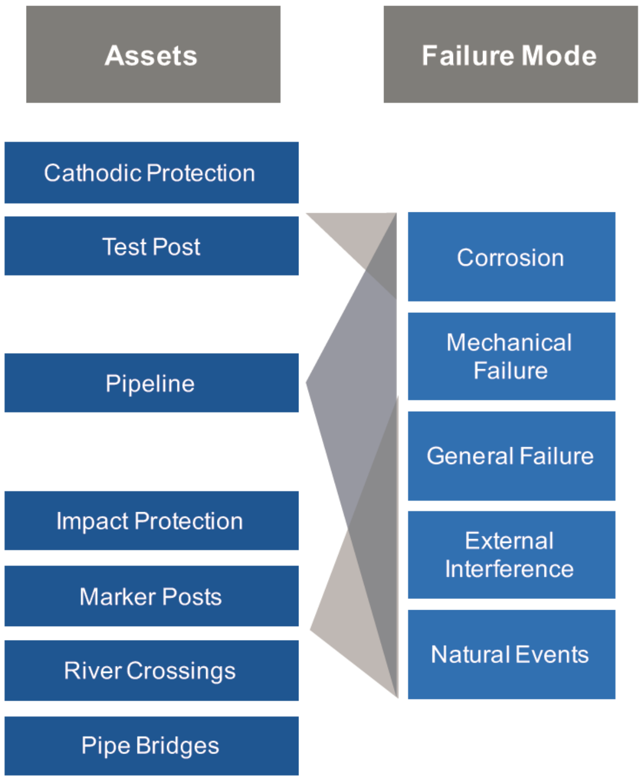

Figure 8 Relationship between pipelines primary and secondary assets and their failure modes

Inline Inspection (ILI) surveys are performed on a regular basis, informed by assessed risk (currently using the industry-standard Intervals2 methodology). These ILI surveys identify the numbers and severity of corrosion and mechanical defects and allow the remaining wall thickness of each 12m pipe section to be estimated. Cathodic protection surveys (CIPS) are also carried out on a routine basis and determine the current loss and indicate the effectiveness of CP along a pipeline. Other condition information is extracted from asset registers, based on inspections and planned maintenance.

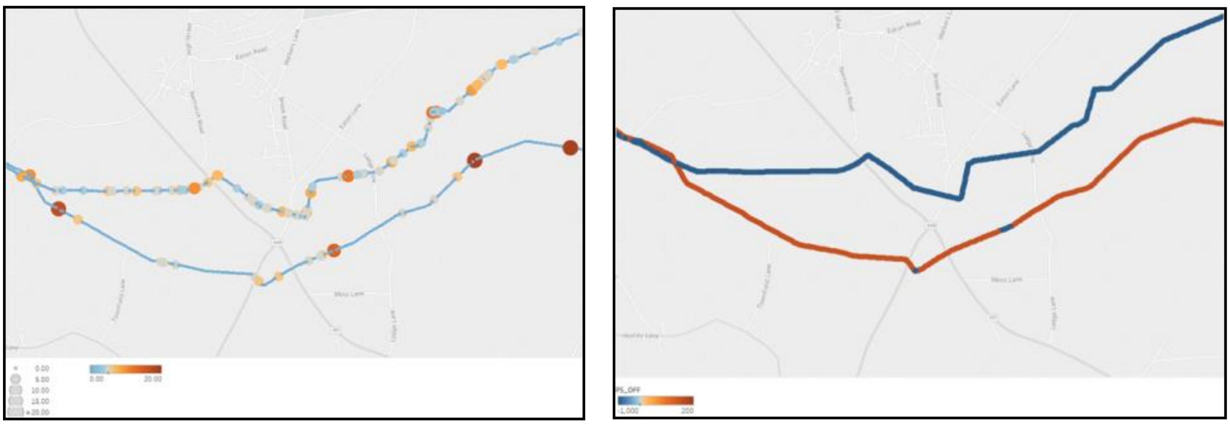

Figure 9 Examples of metal loss and CIPs survey results mapped onto pipe segments

Model calibration is carried out using data from EGIG[9] and UKOPA[10] reports. This approach was agreed to be suitable through the expert review documented in the Validation Report[11].

Secondary asset deterioration rates are derived through elicitation workshops involving NGGT SMEs and industry experts. The derived relationships between asset age and assessed condition are used to

[9] EGIG – Gas pipelines incidents, 9th Report of the European gas pipeline Incident Data Group (period 1970-2013)
[10] UKOPA Pipeline Product Loss Incidents and Faults Report (1962-2013)
[11] Validation Report, Section 6 and Appendices A and B

calculate an effective asset age based on the observed asset condition. This effective age is used in associated with the derived deterioration curves to calculate the current and future PoF[12].

8.3. Consequence of Failure

The following factors are used to quantify the consequences of asset failure arising from each of the modelled failure modes:

- **Probability of consequence –** the rate/likelihood that a specified consequence will occur, given a failure. Not all failures will result in direct consequences
- **Severity of consequence –** this reflects the potential different severities/types of the eventual consequence (e.g. the location of transport disruption or the magnitude of a health and safety event)
- **Quantity of consequence –** the scale of the consequence that arises, (e.g. the number of roads closed, or the number of individuals affected)

The consequences of failure are not in consistent units of measure at this stage; safety risk is measured as an annual expected number of deaths injuries; environmental risk is made up of volumes of carbon emissions and numbers of events per year (e.g. noise pollution).

By converting each failure to a quantified consequence value, it is now possible to value the failure in monetary terms (and in turn quantify the benefit of the failure not occurring as mitigated through a proactive intervention). The monetisation is always related to an increment of a "measurable" unit.

All consequence values (and associated monetised risk values) are **annualised** (e.g. the annual monetised risk value of a corrosion leak. This annualised value is an individual asset level. Which can then be aggregated to process, site or network

Pipeline assets have two main consequences of failure – leak and rupture. These may result in further consequences that flow through to the define pipelines SRF measures. The event tree, or risk map, for pipelines is summarised in Figure 10:

[12] Probability of Failure supporting document, Section 5.1.6

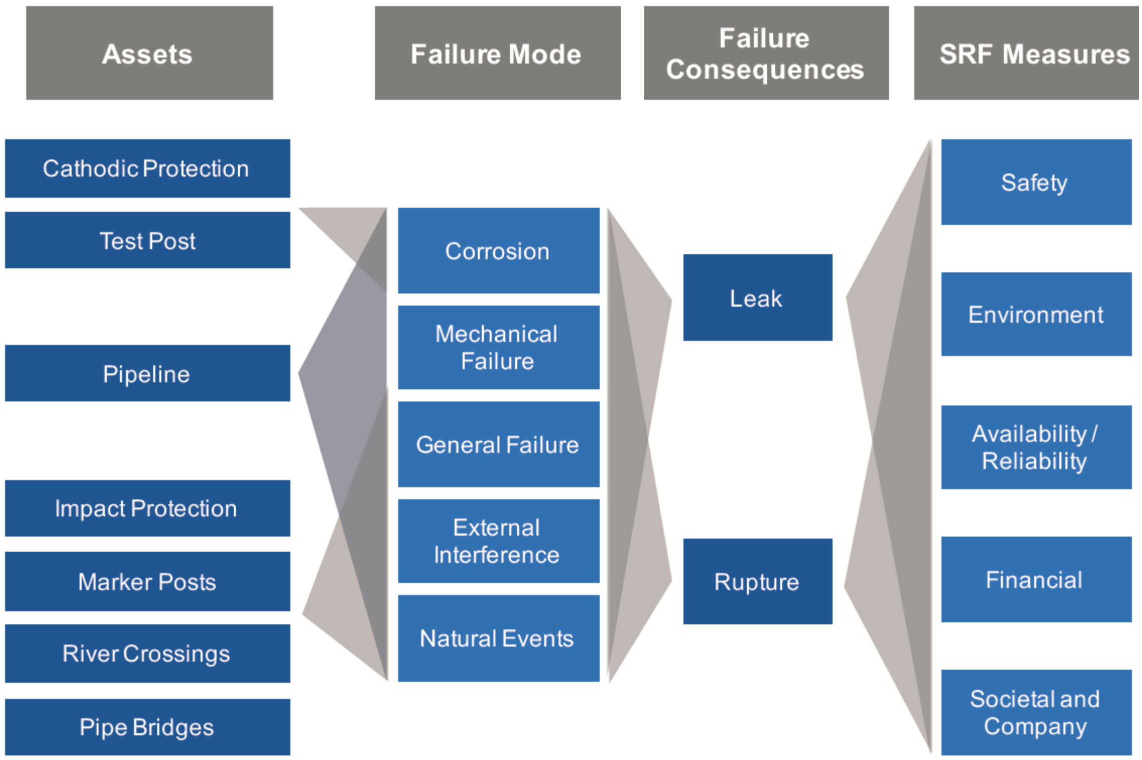

Figure 10 Relationship between pipeline failures, consequences and service risk measures

A **leak** is defined as a gas escape from a stable hole where the size is less than the diameter of pipe and a **rupture** is defined as a gas escape through an unstable defect which extends during failure to result in a full break or failure of an equivalent diameter to the pipeline. The number of leaks and ruptures per year are estimated for each pipe section as the failure mode frequency multiplied by the probability that the failure mode will lead to a leak or rupture. Each pipe section may have more than one failure mode and therefore the probability of failure is summed for all failure modes to give the expected annual rate of leaks or ruptures (which are then calibrated as previously explained). .

8.3.1. Safety Risk

Leaks and ruptures have the potential to ignite. The probability of a leak igniting is based on the size of hole and the operating pressure of the pipeline, as per IGEM TD/2. The probability of a rupture igniting is based on the diameter and operating pressure of the pipeline. This considers:

- Fireballs which occur in the event of an immediate ignition; and
- Crater fires which occur in the event of a delayed ignition of the gas released into the crater formed by the release or following the immediate ignition fireball

Health and safety incidents over different orders of magnitude can result from ignition impacts. These have been modelled and valued in terms of:

- Minor injury
- Lost time Injury
- Major injury
- Fatality

The damage to NGGT and public property arising from ignitions is also considered.

The number of properties (and by extrapolation the number of people) following an ignition is based around Building Proximity Distances (BPD) and Emergency Planning Distances (EPD)[13]. For NGGT employees the number of people at risk is estimated using annualised time working on an asset, representing the chance they would be in proximity to an ignition event. For the public, average property occupancy has been estimated using standard data sets and assumptions.

8.3.2. Environmental Risk

A release of gas occurs as a result of a leak or rupture. The amount of gas released is dependent on the size of hole, diameter of pipe, the operating pressure, and the duration of the leak or rupture. This is then converted to a Greenhouse Gas (GHG) equivalent value, expressed as tonnes of carbon dioxide equivalent (tCO_2e) to calculate the emission value. This is valued using BEIS-published carbon emissions valuations. The retail value of the gas lost is also considered as a societal cost.

8.3.3. Availability and Reliability (AR) Risk

Availability and reliability risk are the expected value of unplanned supply interruptions resulting from a leak or rupture. A connectivity model has been constructed that estimates the impact of any pipeline outage on downstream and upstream assets and connected customers. The value/capacity provided to the NTS by each pipeline asset under specified supply and demand conditions determines the value of AR risk for a specific pipeline. This approach considers the resilience of the wider NTS, resulting in single feed pipelines generally having higher values of AR risk.

The modelling approach taken for Sites and Pipelines modelling is largely identical. Each supply/demand scenario will give different values of AR risk for a specific site or pipeline.

8.3.4. Financial Risk

Financial risk for pipelines is limited to the annual costs of inspection and surveys (reactive maintenance), the costs of which are largely fixed. Many pipelines interventions are proactive and risk-based and are modelled and optimised as investments, not hard-coded into baseline financial risk. This allows investment decisions to be fully risk-based and not assumed a fixed (and increasing) level of annual expenditure to manage risk.

8.3.5. Societal Risk

Leaks and ruptures can result in disruption to transport services for safety reasons and further inspection. The severity of transport disruption is modelled and valued using the following factors, considering the different types and impact of disruption caused should a nearby asset fail:

- Motorway;
- Dual carriageway / A roads
- Minor roads;
- Mainline and underground rail services
- Local rail services

The potential for transport disruption is calculated using spatial proximity of road/rail assets within the EPD area.

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[13] IGEM -TD/1 - Edition 5 and the National Grid Incident Procedures

9. Sites Asset Monetised Risk Valuation

This section summarises how the Methodology has been applied for our above-ground site-based assets. More detail can be found in the accompanying supporting documents and validation report. An example calculation for a Sites asset is included in Appendix B.

9.1. Scope of Site Assets

The Sites model uses all equipment stored in our Ellipse asset register, which generally concern above ground assets (below-ground pipelines use our Geogrid geographical information system). For this version of the Methodology this consists of around 110,000 individual assets, covering civils, mechanical, electrical, safety/control and other miscellaneous asset types.

These are grouped in a variety of ways for the purposes of model building and model use, including regulatory reporting. Presently, reporting is carried out at Secondary Asset Class (SAC) asset level, in line with RIIO-1 reporting requirements. We are in the process of moving to a new, standardised asset definition based in ISO14224, which will be incorporated into future versions of the NARMs Methodology.

9.1.1. Specific Challenges

There are several challenges when assessing the monetised risk of site-based assets:

- Different asset types each have different failure characteristics and potential service impacts
- The highly connected nature of the individual assets on each site means that assessing asset risk in isolation does not accurately represent their risk to service performance
- Where there are multiple compressor units on a site the combined resilience provided by these needs to be assessed. This applies a valuation representing the level of redundancy should a unit become unavailable
- To accurately estimate the risk of asset failure, it is critical to consider any reduction in risk offered by Safety Instrumented System (SIS). SIS provides the ability to detect, logically process and activate any protection systems in the event such as a gas leak or other safety impacting event.

9.1.2. Determining the Service Impact of Asset Failure

Given the large variety of assets and system functions within an individual site, the Methodology links an asset to the potential service consequences through a key principle: the **asset purpose**. Once the purpose of the asset is known, the potential consequences of failure can be determined based on the type, or mode, of failure experienced.

A site is made up of a collection of assets, which are grouped into systems which work together to deliver a specific purpose, or function. The function (or inability to function) now and in the future define the risk associated with the asset.

For each asset system, we determine the different failure modes and associated consequences that could occur. These are then mapped to one or more service risk measures as defined in the SRF. These relationships between the asset system, asset, failure model and failure consequence are shown in Figure 11.

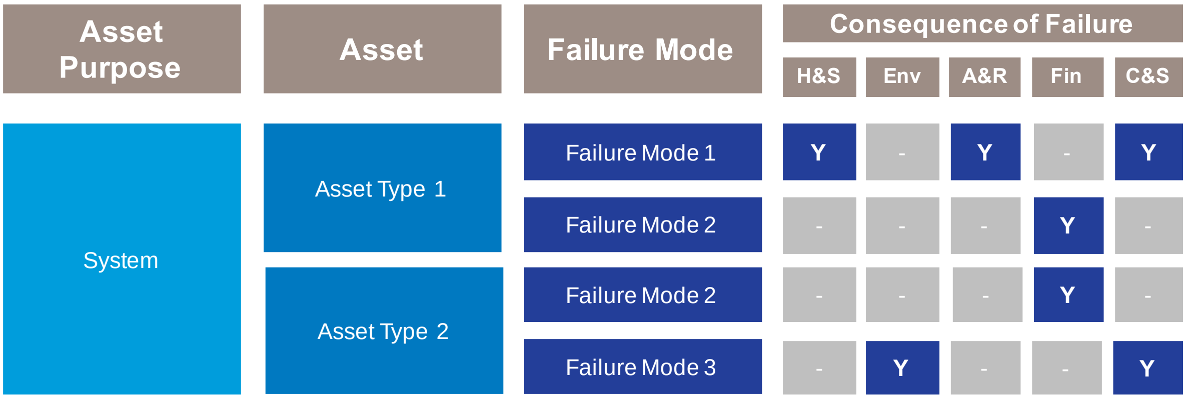

Figure 11 Relationship between Sites assets, failure modes and consequences of failure

The mapping of systems, asset types, failure modes and failure consequences is detailed within the Consequence of Failure supporting document.

9.2. Probability of Failure

This section summarises the approach for estimating the annualised failure rate, or probability of failure (PoF) for every Sites asset defined in the asset registry. Once the PoF is known the probability of a consequence (or failure mode frequency) can be defined. This reflects the fact that:

- Not all asset failures result in a direct consequence (e.g. where there is in-built asset/system resilience)
- An asset failure may result in multiple consequences (e.g. a gas leak results in environmental and potentially safety risk)

The annualised failure frequency is determined using a failure model that is specific to each asset type. The failure models have been developed from two sources of information, which are:

- Historical asset performance and defects data taken from our work management system. This is used to define the initial (baseline) rate of failure for an asset population
- Expert elicitation workshops using a formal and established method for eliciting failure characteristics of asset populations to inform a statistical model fitting process. This is used to predict the deterioration of an asset type under different levels of intervention and based on observed/measured condition

The work management defects data provides an asset-type specific rate of failure. Because of the relatively infrequent nature of defects occurring on a gas transmission system these failures are pooled into several of asset groupings (or equipment classes) based on assessment of common failure modes and consequences. The elicited models are developed to predict the deterioration in the rate of failure for each asset type over time. Combining the base failure frequency and condition-adjusted deterioration rate for every asset, we apply a modelled failure curve to predict the current and future annual rates of failure.

9.2.1. Elicitation of Asset Deterioration Rates

To determine frequency of asset failure and its change over time we have developed models using a structured data gathering, or expert elicitation, process. We have used elicited information to supplement defects data from our works management system as available time-based data in systems does not present evidence of the full life performance, and thereby risk, of assets. There are several reasons for this, which will be true for NGGT and other companies which undertaken extensive proactive inspection and maintenance:

- Assets are replaced before the end of their useful lives, because of legislative drivers or where the risk of an actual failure is unacceptable

- Available defects data may not cover a sufficiently long observation period, due to low frequency of occurrence and the age of the IT systems holding the data (legacy records may have been paper-based and not converted into a digital format)
- In some cases, an asset type has never failed through a specific failure mode over its operational life to date. This does not mean that there is zero risk of this failure mode occurring in the future

To get best value and accuracy when estimating asset deterioration curves through expert elicitation, we have adopted and applied the following principles:

1. A wide variety of experts are consulted to reflect a range of actual experiences
2. The information captured is not directly about the deterioration model form/shape, but rather information/data points used to derive the final deterioration curves
3. The information is captured as point estimates and with the uncertainty around the estimates
4. Involving a wide range of asset experts provides the opportunity to explore where variability is arising in results and the reasoning for this
5. The resultant deterioration curves are reviewed by the expert group and a consensus agreed and the ranges of sensitivity analysis to be carried out agreed
6. The deterioration model outputs are benchmarked against industry models and any significant differences are tested through further sensitivity analysis and validation

We have developed four different model types from using this formal elicitation process:

- Repairable failure model versus asset age. This is used to calculate the failure rates and the deterioration over time, assuming it can be returned to service through operational intervention (e.g. a repair)
- Non-repairable failure model versus asset age (i.e. end-of-life probability of failure). These are used when the asset fails and cannot be repaired and therefore requires reactive replacement (e.g. a battery)
- Asset Health versus age model. This is used to determine how the observed/measured asset condition can be used to change the position of an asset on its deterioration curve – calculating an **effective asset age** from an **actual asset age** (see below)

Elicited failure rate models are combined with the actual defect rates, taken from works management systems, ensuring that the base (Year 0) failure rates are consistent with real-world observations. Where failure rates cannot be derived from defects data (i.e. no historic failure record) then we use the elicited models only with greater uncertainty.

Figure 12 below summarises the steps undertaken to derive the elicited deterioration models for different asset types.

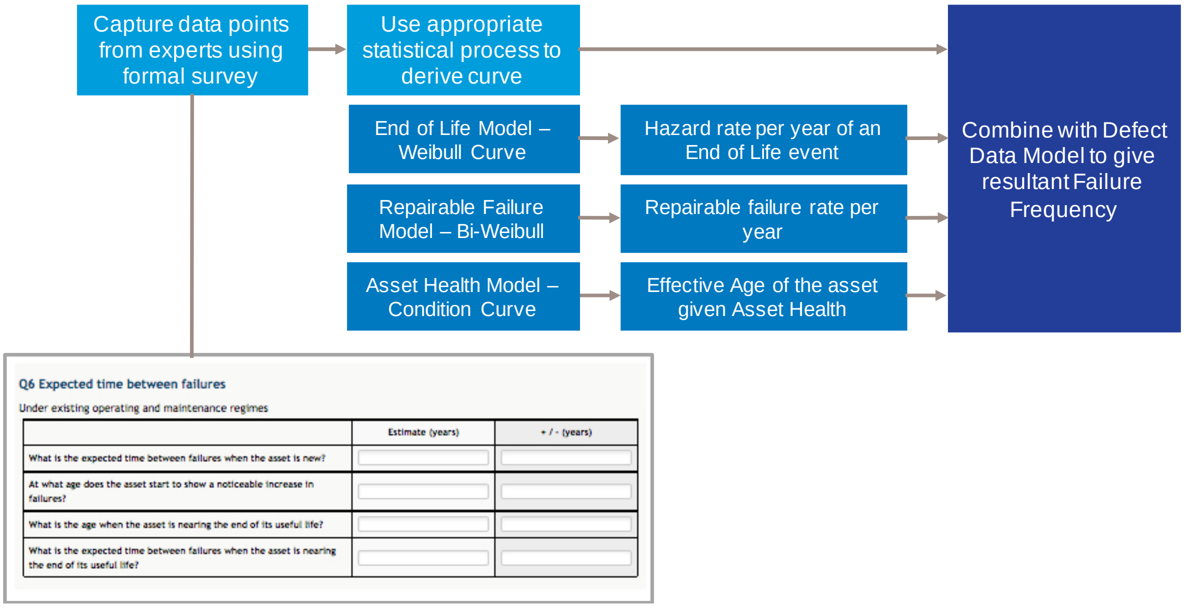

Figure 12 Asset expert elicitation approach taken to estimate future probabilities of failure

9.2.2. Annualised Failure Frequency

Defect information is captured against individual equipment assets within our asset register. Historically-captured asset defect data has been used to define the steady-state failure rate for each asset type. The steady-state is the base or start failure rate (Year 0) for future deterioration assessment. Figure 13 shows the way in which steady state failure rates have been calculated for each asset type.

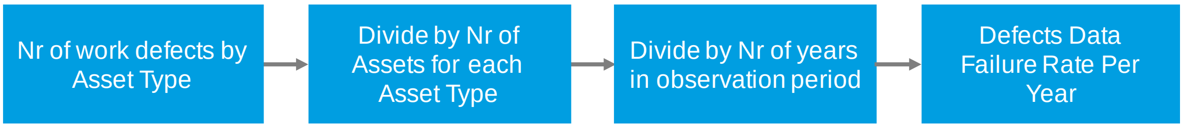

Figure 13 Estimation of base defects/failure rates for Sites assets

9.2.3. Combining Elicited and Defects Data to Determine the Frequency of Failure

The effective age of an asset assumed to be the actual age for Instrumentation, Control and Automation (ICA) and electrical assets. This is because assessed condition is not practical, or reliable for these asset types; their primary failure mode (other than random failure) is obsolescence and as such actual age is a more reliable indicator of risk.

For other asset types the effective age is determined using the Asset Health versus age model described above. The asset effective age within the elicited failure rate models (repairable and end-of-life as illustrated in Figure 14.

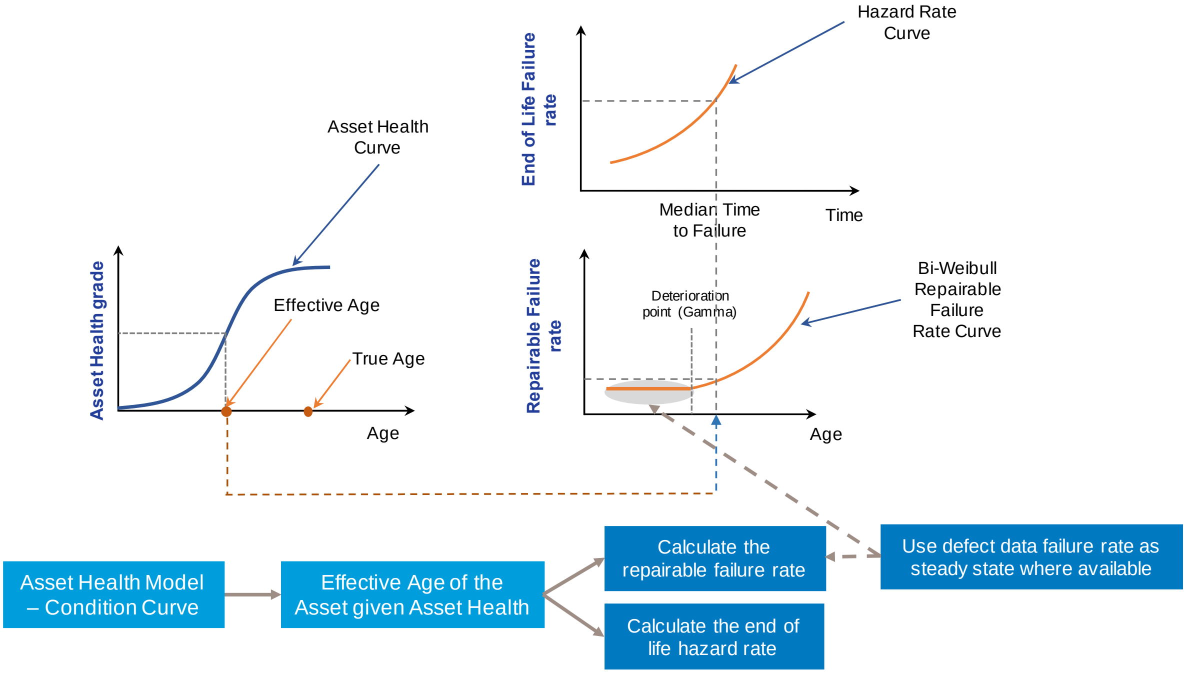

Figure 14 Using assessed asset condition to model asset deterioration rates and end of life

All initial (Year 0) failure rates are now based on actual defects data based on populations of similar asset types. This is necessary as many of our assets have never failed and aggregation (into equipment classes) is needed to create a sensible population size for statistical analysis.

9.2.4. Determining the Failure Frequency by Failure Mode/Type

Once the frequency of asset defects is calculated we calculate the proportion of each defect that is expected to materialise as one, or more, of the failure modes that is relevant to the consequences of failure defined in the SRF. This mapping process is shown in Figure 15.

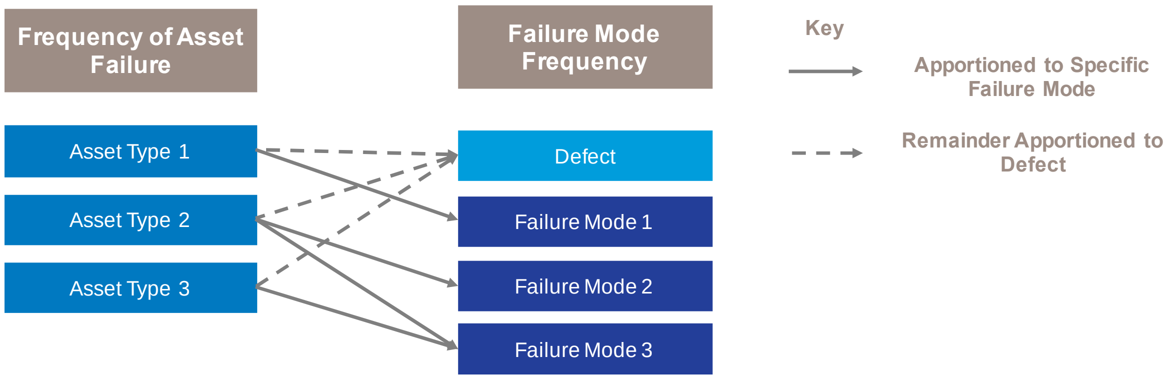

Figure 15 Assigning the proportions of Site asset failures which result in specific consequences

A single asset type can have zero, one or many different failure modes. We only include failure modes that lead to consequences that can be valued within the SRF. We have developed the failure mode mapping for each asset type and have used available industry data to determine the proportion of defects that relate to each failure mode and subsequent consequences of failure.

The key sources used to determine these failure modes and proportions are listed below. These have been discussed and verified by industry experts:

- OREDA Offshore Reliability Data[14]

[14] 5th Edition 2009 Volume 1 Topside Equipment. Prepared by SINTEF, Distributed by Det Norske Veritas (DNV)

- User Guide for the AGI Safe Package[15]

9.2.5. Application of the Frequency of Asset Failure

Application of the frequency of failure model to each individual asset is carried out using the derived effective, or condition-adjusted, age of the asset. This is essentially an age value that reflects the prevailing condition or health of the asset.

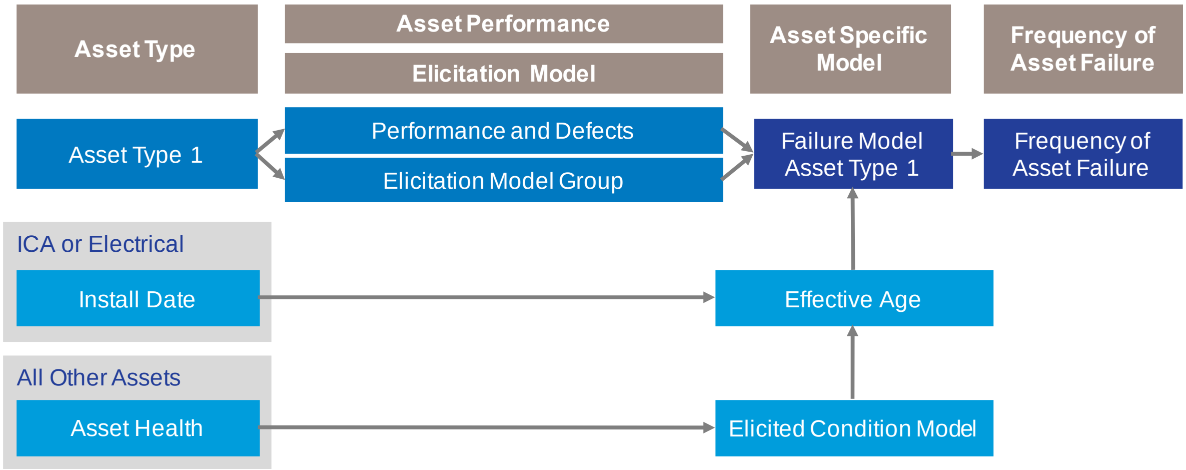

Figure 16 Use of assessed asset condition (or install date) to inform the frequency of asset failure

The use of the effective age is important where assets are regularly maintained or are subject to different frequency and types of maintenance (e.g. inspection versus full overhaul). In these circumstances, a better indicator of the potential to fail is the effective age rather than the true age.

As stated previously, ICA and electrical equipment do not generally show outward signs of condition degradation as they age as obsolescence, rogue component or random failures are more prevalent failure modes. For ICA and electrical assets, we assume the true age rather than the effective age of ICA and Electrical equipment to inform deterioration rates. Likewise, if reliable condition data does not exist for other asset types, we will substitute actual for effective age in deterioration calculations.

Once the effective age has been derived, we apply the process as described in Figure 14 to predict the base and future annualised rate of failure for every modelled asset.

9.3. Consequence of Failure

Once the probability of failure and future deterioration rare has been calculated for each asset, the consequences of failure (CoF) can be determined. The CoF estimation process is carried out in three phases, one leading to the next:

1. The probability / likelihood of defined consequence occurring
2. The severity / magnitude of consequence if it does occur (e.g. major or minor)
3. The quantity of this consequence for each severity (e.g. volume of gas emitted; number of deaths/injuries)

This is necessary to provide a quantified consequence for each service risk measure that can be valued using the SRF.

The consequences that result from an asset failure are linked to zero, one or many service risk measures. For example, an asset failure that presents as a gas leak (emissions) could also potentially lead to a fire. The fire in turn could lead to a death/injury and/or impact on transport disruption. This interaction between failure modes and consequences of failure is illustrated in Figure 16.

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[15] Version 5.1. DNV GL Report 13492 December 2014

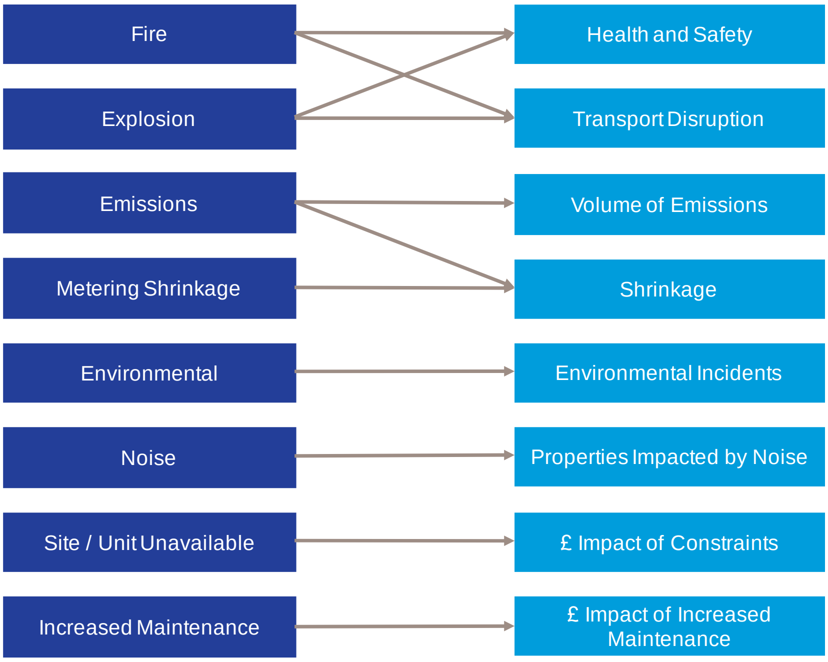

Figure 16 Mapping of failure modes to service risk measures

9.3.1. Fire and Explosion (Safety)

Figure 17 summarises the conditions that lead to fire, and those that lead to explosion for Sites assets.

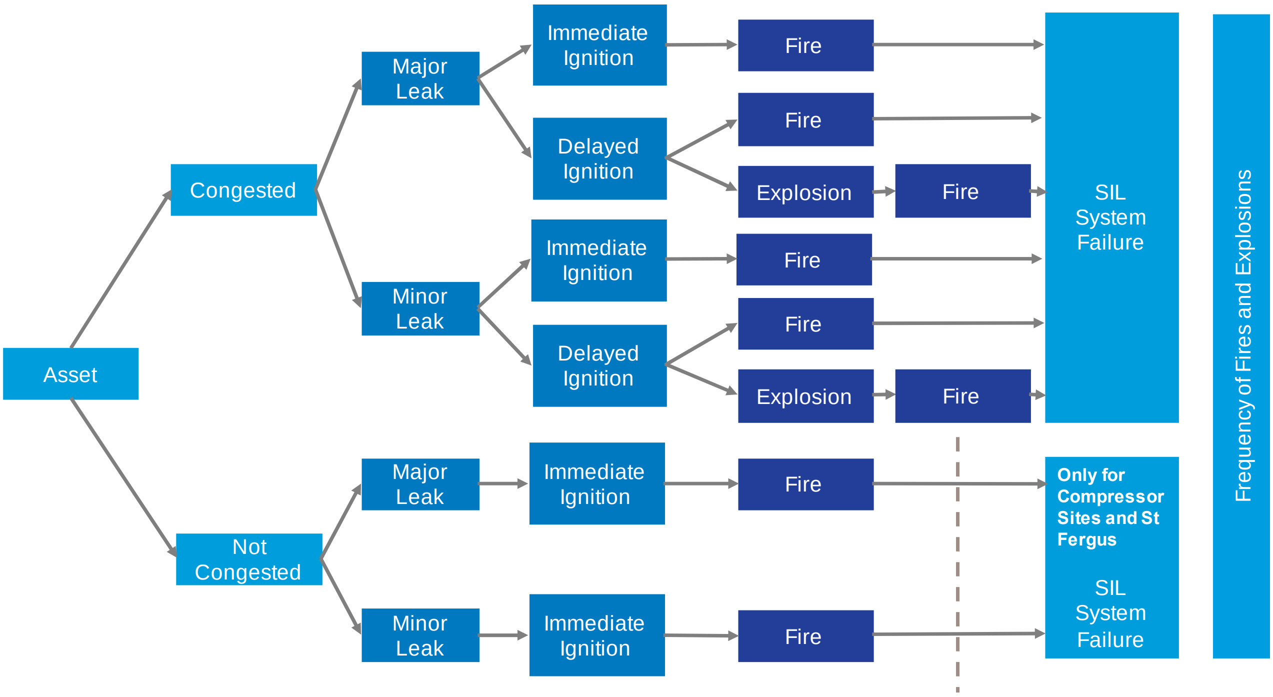

Figure 17 Logic diagram to describe how leaks may potentially arise in fire/explosion consequences, including the protection provided by SIL systems

9.3.2. Death or Injury (Safety)

Following a fire or explosion there is the potential for health and safety impacts upon employees and the public. The Methodology determines this impact in two steps: predicting the severity of the incident and based upon this the number of individuals potentially affected. Fires are assumed to be constrained to within site boundaries and therefore will not result in fatalities or injuries upon members of the public (employees only). This is illustrated in Figure 18.

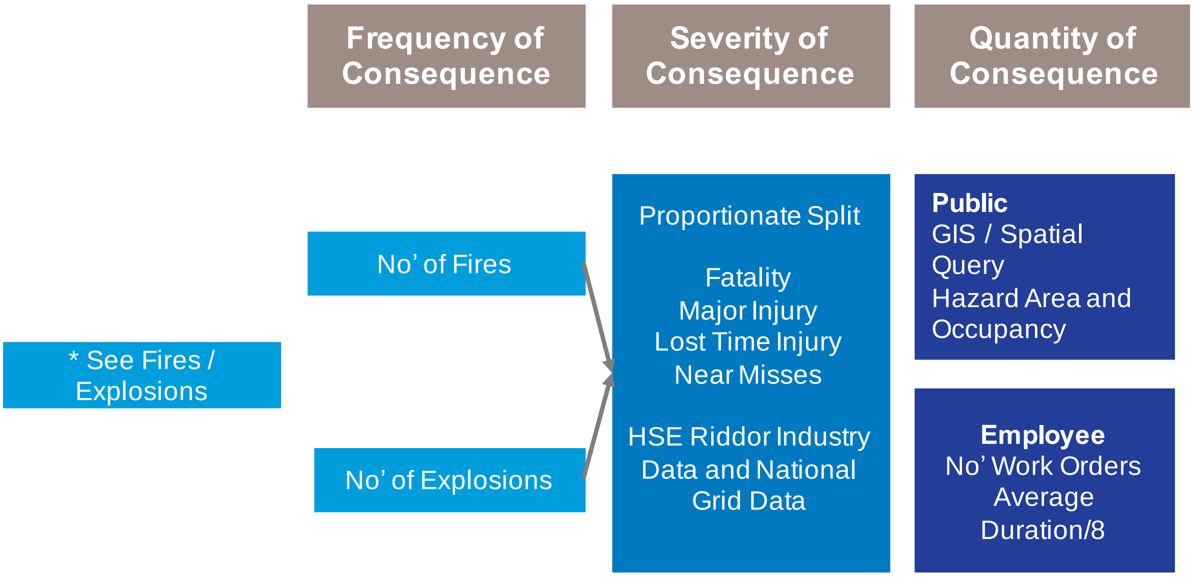

Figure 18 Relationship between fire/explosion and Safety risk to public and employees

9.3.3. Transport Disruption (Societal)

To estimate disruption caused to transport infrastructure following a leak, fire or explosion the cordon distances based upon NGGT Incident Procedures have been utilised. These cordon distances have been applied to each site and pipeline section and the impacted transport routes identified through spatial analysis. An assumed timescale to release the cordon has been used to determine the duration of the incident. This is illustrated in Figure 19.

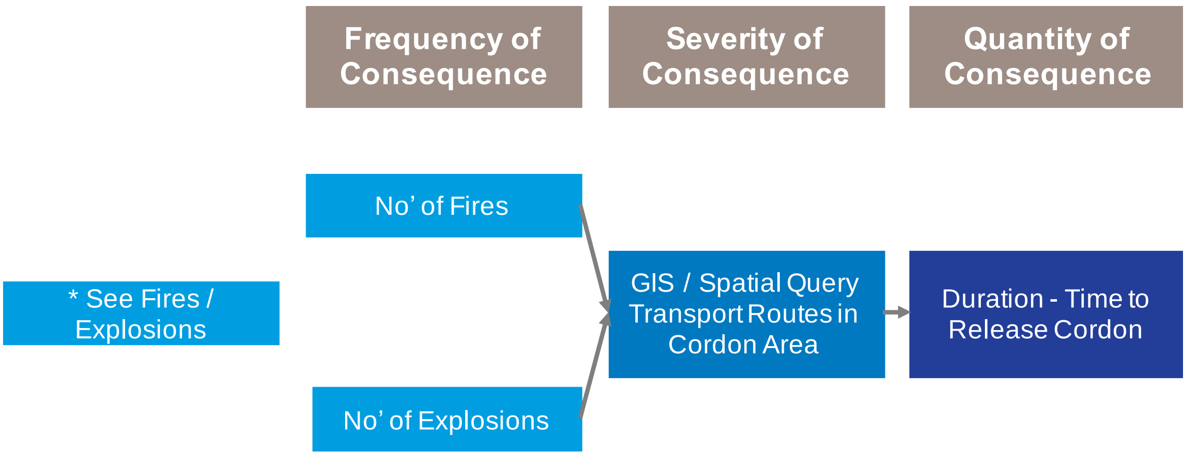

Figure 19 Relationship between fire/explosion and transport disruption risk to public and employees

9.3.4. Availability and Reliability

To value the contributions of both sites and pipeline sections towards NTS resilience and the avoidance of supply loss, we recognise that the consequence of asset failure (and hence consequence value) will depend on the prevailing demand and supply conditions.

Following the Validation Report expert review some extensive changes were made to how we estimate Availability/Reliability risk, allowing the sensitivity of risk to changes in supply and demand scenarios to be tested[16]. The changes made are summarised as follows:

[16] Validation Report, Section 9

- A 1 year in 20 year supply and demand scenario was chosen after sensitivity testing against other high terminal flow scenarios. This uses gas flows extracted from hydraulic modelling, rather than the historic telemetry data used previously
- A revised approach to value the loss of a gas terminal was implemented, using the expected entry flows under the applied 1 in 20 demand scenarios
- Previously it was assumed that the loss of an exit point could be "flow swapped" in agreement with a Gas Distribution Network (GDN). This assumption has been removed as the opportunity to use another offtake is unlikely under 1 in 20 demand conditions

The approach adopted is summarised in Figure 20. Further details can be found in the Consequence of Failure supporting document and the Validation Report. As above an identical approach is adopted for Sites and Pipelines assets, for pipelines each feeder section is treated as an individual site.

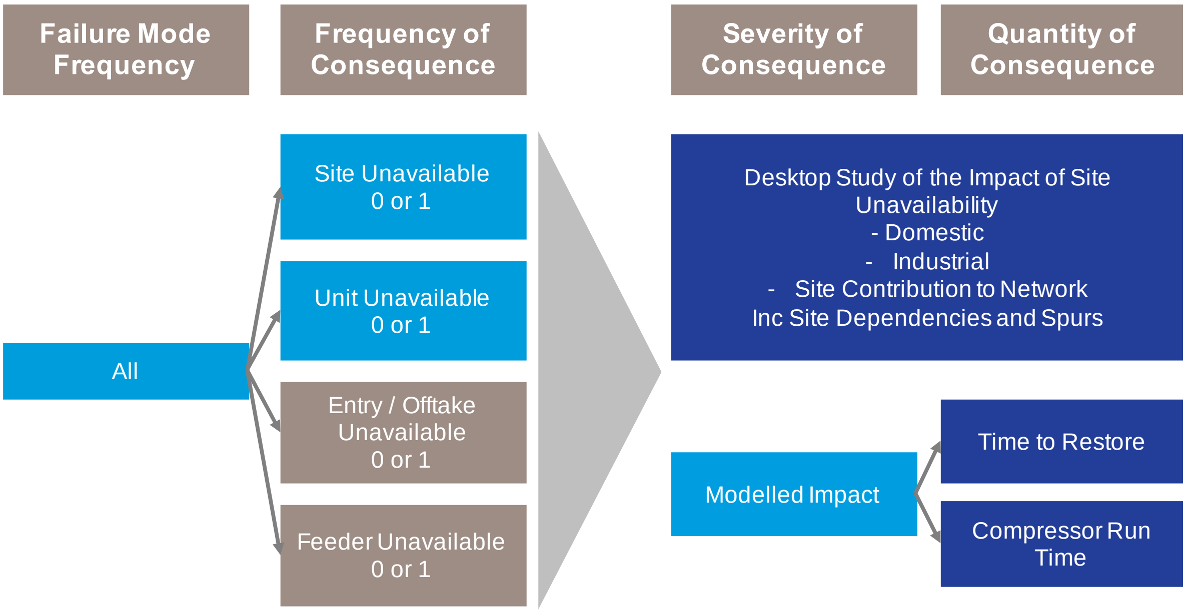

Figure 20 Relationship between unit/site availability and loss of supply (or capacity to deliver/supply gas)

9.3.5. Noise Pollution (Environmental)

The failure modes that lead to noise pollution are based on the asset type and purpose. The distance between the asset and properties potentially experiencing a noise nuisance through asset operation are estimated using spatial analysis. This is shown in Figure 21.

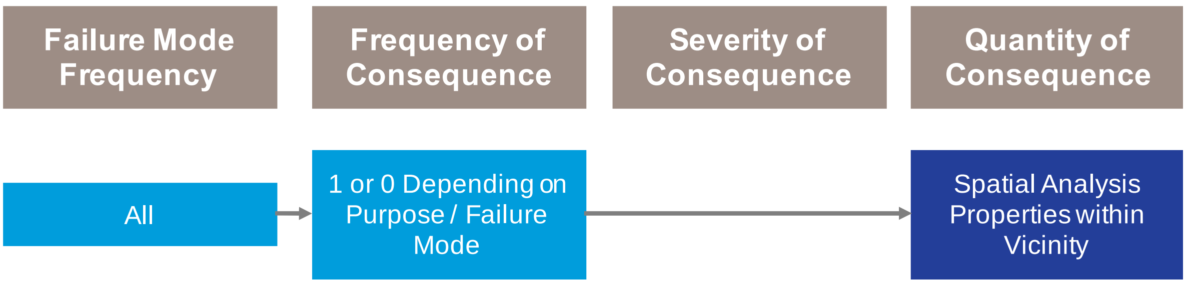

Figure 21 Estimating the noise nuisance resulting from asset operation

9.3.6. Emissions and Shrinkage (Environmental)

The failure modes potentially resulting in emissions due to loss of unburned gas are as follows:

- Emergency Shut Down (ESD) venting due to unplanned compressor unit trips
- Major and minor leaks from pipework, valves etc.

- Emissions incurred through operation and maintenance of assets

Fuel gas burned to power gas generators in compressor units has been explicitly excluded from our Methodology although it contributes significantly towards overall NGGT emissions. The burning of fuel gas is dependent on operational need, to maintain pressures in the NTS, and therefore inclusion of fuel gas in our models could adversely skew the required level of asset health investment. We therefore assume the contribution of fuel gas to overall monetised risk is fixed in time.

Maintenance emissions based on planned operations to isolate and make safe assets ready for routine inspection and inspection. These are estimated on a per asset basis and will increase over time as additional maintenance may be required over time as assets deteriorate (and will reduce if the asset is proactively replaced for refurbished).

This approach is summarised in Figure 22.

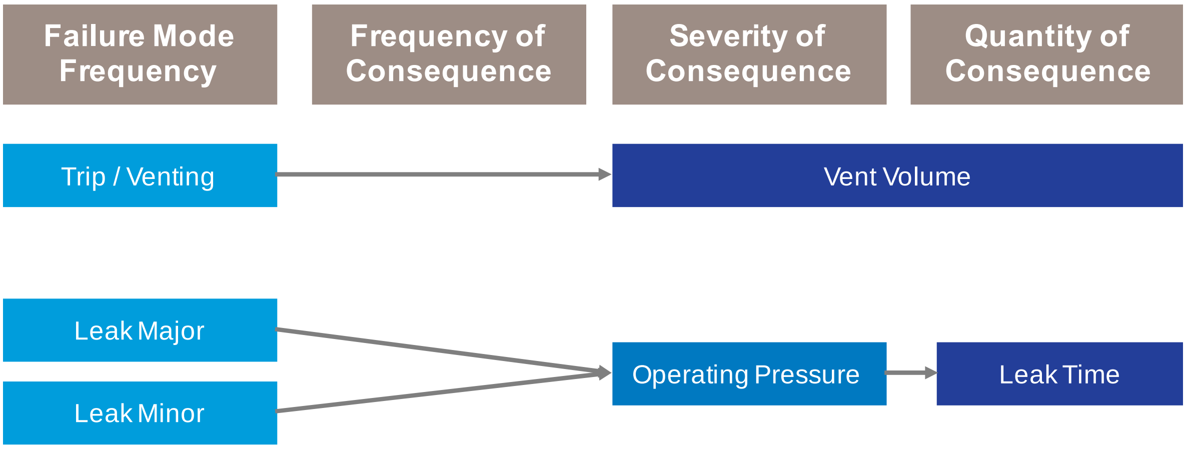

Figure 22 Estimation of emissions arising from asset failure

10. Governance of the Methodology

10.1. Annual Review

The Methodology, in addition to being a Licence obligation, also forms part of National Grid's ISO55001 accredited Asset Management System and Objectives (AMSO). The AMSO includes processes for:

- Performance evaluation: including asset performance & health monitoring
- Improvement: including management review, audit and assurance

AMSO annual monitoring will be used as a basis to review the Methodology in addition to the annual review requirement specified in the RIIO-2 Licence. The key parameters used in the Methodology, such as predicted rates of deterioration, costs of interventions and maintenance will be maintained and reviewed through these mechanisms.

As per License requirements, we will continue to review the Methodology, at least on an annual basis. Actual modifications to the data and assumptions contained within the Methodology will be made should we believe this would drive an improvement in the quantification of the asset risks and improve its decision making capabilities.

An action plan to update the Methodology is included within the Validation Report. We propose that changes are incorporated in line with RIIO business planning periods, unless they cause a material change in network risk. Should material changes in monetised risk be identified these changes will be incorporated subject to discussions with Ofgem, based on agreed materiality thresholds.

Asset updates will be carried out in line with RIIO business planning periods to avoid the need to constantly restate and agree targets. As above, should changes to our asset base result in material changes to network risk these will be incorporated subject to Ofgem agreement based upon agreed materiality thresholds (not confirmed at time of writing).

10.2. Modifications

Modifications to the Methodology, other than key parameters as specified within this Methodology and supporting documents, will be consulted on with interested parties allowing at least 28 days, making written representations to the proposed modifications.

Proposed modifications will then be submitted to Ofgem for direction. This submission will include implementation timescales and if required any resulting rebasing requirements of BNRO.

11. Data Assurance

Standard Special Condition A55 Data Assurance requirements (DAG) requires us to undertake processes and activities for the purpose of reducing risk, thereby managing the subsequent impact and consequences of any inaccurate or incomplete reporting, or any misreporting, of information to Ofgem. As part of the Network Data Assurance Report (NetDAR) submission, we measure and manage the overall risk profile of each regulatory submission and license obligations via our annual DAG risk assessment process and RRP submissions

The likelihood of the data submission being inaccurate, incomplete or submitted late is measured via the DAG probability metric, namely:

- **Data inherit probability**: In terms of the data from core systems and / or other sources, any data source used for the regulatory submission will be risk assessed in terms of complexity, completeness, extent of manual intervention, and the application of the reporting rules based on the complexity and maturity.
- **Control framework probability**: We manage the controls of the systems used, processes and governance framework via the Control Framework risk measures, as specified in DAG guidance document Version 1.3

Document Control

Version	Date of Issue	Notes
1.0	3rd April 2018	Version for public consultation
2.0	22nd May 2018	Final version submitted to Ofgem
3.0	17th May 2021	Draft version for public consultation

Appendix A

Pipelines Example

The table below shows an example pipe segment together with results for an indicative 12 metre pipeline section. The numbers presented are for this example only, are subject to change as the Methodology is updated.

Asset Attribute	Value	Units	Description
Asset Length	12	m	Length of the pipe segment.
Installation Year	1984	Year	Year of installation.
Diameter	1,050	mm	Pipe diameter.
External Pipe Coating	EPOXY RESIN	-	Coating type.
Original wall Thickness	14.3	mm	Wall thickness.
CIPS Potential Loss	-1,147	Voltage	Measured data - Potential loss of corrosion protection system.
Percentage Metal Loss	12	Percent	Measured data - Maximum metal loss as percentage of wall thickness.
Inner Properties	7	No'	Properties within 1 Building Proximity Distance (BPD).
Middle Properties	144	No'	Properties within 4 times Building Proximity Distance (BPD).
Outer Properties	1,481	No'	Properties within Emergency Planning Distance (EPD).
Outer Minor Roads	7,657	m	Length of minor roads within Emergency Planning Distance (EPD).

The pipe segment is situated on the edge of a village and contains a number of properties and a minor roads within the hazard planning zones. The pipe segment was installed in 1984 of length 12 m and has the attributes given in the table below. Attributes include length, diameter, install date, coating, wall thickness, observed/measured data (CIPS and ILI Metal Loss), and additional consequence data (properties and roads).

Failure Mode Frequency			Description
Corrosion	1.31×10^{-12}	No' / Year	External corrosion of the pipe resulting in reduced wall thickness and eventual leak or rupture.
Mechanical Failure	-	No' / Year	Material and weld defects created when the pipe was manufactured or constructed.
General Failure	5.13×10^{-6}	No' / Year	General and other causes, e.g. due to over-pressurisation, fatigue or operation outside design limit.
External Interference	1.40×10^{-6}	No' / Year	External interference caused by third parties.
Natural Events	1.64×10^{-7}	No' / Year	Natural events including ground movement, landslide, flooding and other natural events.

These attributes are used to calculate the primary failure modes. For example, wall thickness corrosion is calculated by using the measured metal loss as the starting point and then deteriorating this by a 'low' deterioration, due to the Cathodic Protection system measurement providing high corrosion resistance. The probability of failure is also adjusted based on the coating type.

Frequency of Consequence			Description
Rupture	1.01×10^{-7}	No' / Year	A gas escape through an unstable defect which extends to a full break of an equivalent size to the pipeline.
Leak	1.02×10^{-6}	No' / Year	A gas escape from a stable hole whose size is less than the diameter of pipe
Ignitions	1.39×10^{-7}	No' / Year	Probability of ignition dependant on the hole size and pressure.
Transport Disruption	2.03×10^{-7}	No' / Year	Disruption to transport services for safety reasons and further inspection.

A probability of a leak or a rupture arising from a failure is then calculated based on industry standards (UKOPA and EGIG) and validated to determine the expected annual frequency of leaks and ruptures.

Expected Quantity of Service Consequence			Description
H&S - Minor Injury	4.50×10^{-5}	No' / Year	Number of minor injuries.
H&S - Lost Time Injury	4.50×10^{-5}	No' / Year	Number of lost time injuries.
H&S - Major Injury	1.08×10^{-4}	No' / Year	Number of major injuries.
H&S - Fatalilty	3.25×10^{-5}	No' / Year	Number of fatalities.
Environmental - Emissions	38.67	kg / Year	Mass of gas emission in CO^2e.
S&C - Transport - Minor Road	1.56×10^{-3}	m / Year	Length of minor roads within the EPD.
S&C - Property	2.06×10^{-4}	No' / Year	Number of properties within the EPD.

Given a leak or rupture, service valuations (as defined in the service risk framework) are then calculated based on multiplying the expected failure frequencies with the probability and quantities of consequence. Probability of consequence is based on industry accepted equations as defined in IGEM/TD2.

For example, the volume of gas for a leak or rupture is calculated based on an assumed hole and a duration to derive an expected volume of gas lost, which is then converted into various severity bands as well as a carbon equivalent as part of the environmental measue.

Expected Risk Value of Consequence			Description
Health and Safety	979	£ / Year	The expected Health and Safety risk value.
Environment	2	£ / Year	The expected Environmental risk value.
Availabilty and Reliabililty	2	£ / Year	The expected Availability and Reliability risk value.
Financial	1	£ / Year	The expected Other Financials risk value.
Societal and Company	31	£ / Year	The expected Societal and Company value.

The expected consequence values are multiplied by the private and social financial costs to derive annual monetised risk values.

The indicative aggregated risk of a 10km pipeline is shown below.

Expected Risk Value of Consequence			Description
Health and Safety	54,000	£ / Year	The expected Health and Safety risk value.
Environment	3,000	£ / Year	The expected Environmental risk value.
Availabilty and Reliabililty	2,000	£ / Year	The expected Availability and Reliability risk value.
Financial	750	£ / Year	The expected Other Financials risk value.
Societal and Company	5,000	£ / Year	The expected Societal and Company value.

The individual segment results and monetised risk valuations will be aggreated to a population level for risk reporting and investment planning purposes. This is an example of a typical pipeline that includes the pipe segment.

Appendix B

Sites Example

The table below shows an example for a single asset on a Compressor site. The numbers presented are for this example only, are subject to change as the Methodology is updated.

Asset Information			Description
Asset Type	Pressure Control Valve		The asset.
Installation Year	2007	Year	Year of installation of the asset.
Asset Health	2	-	The health grade of the asset.
Process	Compressor		The process on a site in which the asset resides.
Process Stream	Compressor Unit		A process may have a number of individual streams.
System	Compressor Seal System		The asset system in which the asset resides.

The asset location is based on where it is located on the asset hierarchy in our asset register. The purpose of the asset is implied by the system in which it resides which is to provide the compressor seal function. This asset works alongside other asset within this system ranging from the compressor seal itself to transmitters and alarms. The asset register holds attributes, such as installation date and asset health.

Asset Frequency of Failure			Description
Effective Age	9	Years	The effective age of the asset.
Frequency of Failure (Repairable)	0.008	No' / Year	The number of repairable failures expected for the asset every year.
Hazard Rate (End of Life)	0.043	No' / Year	The number of non-repairable failures expected for the asset every year.
Total Frequency of Failure	0.051	No' / Year	The total frequency of failure calculated from the above failure rates.

The effective age is calculated using an asset type specific model. This in turn is used to calculate the expected Frequency of Failure and end of life failures. Failure is taken to be a defect in the asset requiring corrective action. All our models have been developed based on a combination of defects data from our systems and from expert elicitation. The models have been validated by gas transmission experts and also validated against industry data.

Failure Mode Proportion			Description
Loss of Compressor Unit - Trip	0.925	-	The proportion of failures that result in this failure mode.

The proportion of asset failures that lead to a Loss of Compressor Unit - Trip. These failure modes and proportions are derived from *OREDA Offshore Reliability Data 5th Edition 2009 Volume 1 Topside Equipment . Prepared by SINTEF, Distributed by Det Norske Veritas (DNV). Volume 1 of the 2009 edition contains the most extensive range of data for topside equipment relevant to onshore assets.*

Failure Mode Frequency			Description
Loss of Compressor Unit - Trip	0.047	No' / Year	The expected frequency of the failure mode.

This is calculated from the Total Frequency of Failure and the Failure Mode Proportion.

Probability of Failure Mode Leading to Consequence			Description
Loss of Compressor Unit	1.00	-	The probability that the identified failure mode will lead to loss of the compressor.
Environment - Emissions	1.00	-	The probability that the identified failure mode will require venting of the compressor.

The identified failure mode leads to a loss of the unit and to venting of the gas within the unit.

Expected Quantity of Service Consequence			Description
Network Constraints	32,000	£ / Year	The value of the network constraints from the loss of the unit.
Environment - Emissions	47,232	kg / Year	The mass of gas vented in kg of Carbon Dioxide equivalent.
Financial - Repair Cost	2,000	£ / Year	The repair costs of the asset.

The impact of the loss of the unit on Network Constraints. The environmental emissions are based on the average amount of gas vented from an Emergency Shut Down. The repair costs are those for the Pressure Control Valve.

Expected Risk Value of Consequence			Description
Health and Safety	-	£ / Year	The expected Health and Safety risk value.
Environment	145	£ / Year	The expected Environmental risk value.
Availability and Reliability	1,510	£ / Year	The expected Availability and Reliability risk value.
Financial	102	£ / Year	The expected Other Financials risk value.
Company and Societal	-	£ / Year	The expected Societal and Company value.

Finally, the quantity of consequence values are multiplied by failure mode frequency and the probability of failure mode leading to consequence and the private and social financial valuations to derive annual monetised risk values.

Appendix C

Glossary

ALARP	As Low as Reasonably Practicable
Asset Attributes	Set of details about the asset such as; type, install year, condition, etc.
Asset Base	Assets that are currently included within the monetised risk calculations as outlined in the Probability of Failure supporting document.
Asset Management	Coordinated activity of National Grid to realise value from its assets by balancing cost, risk and performance benefits.
Asset Purpose	The functional purpose of the asset
Asset Register	National Grid core system holding the individual Asset Base and Asset Attributes.
Asset Risk	Means the estimated average expected impact of a Network Asset with given characteristics (such as those referred to in the definition of Asset Data) failing over a given time period, so that when scaled up to a sufficiently large population of identical Network Assets, the sum of the individual Asset Risks will equate to the total expected impact of asset failure for the population over the same time period.
Authority	OFGEM – Office of Gas and Electricity Markets
Baseline Network Risk Output	Means the cumulative total, for a given risk sub-category, of Network Risk Outputs for all items allocated to "NARM Funding Category A1" in the licensee's Network Asset Risk Workbook.
Block Valves	To allow for maintenance and emergency isolation of pipeline sections to meet requirements of IGEM TD/1
CBA	Cost Benefit Analysis
CIPS	Close Interval Potential Survey (CIPS); A secondary validation for buried systems; it provides an indication of the performance of the cathodic protection system to identify defects on the pipeline assets.
Compressor Sites	Raises gas pressure in the pipeline system such that required flows and system pressures can be achieved.
Current Monetised Risk	Means the monetised risk of an existing asset or group of assets, based on the most recently gathered or derived asset data.

DAG	Data Assurance Guidance as specified in Standard Special Condition A55 of the Licence.
EGIG	European Gas Pipeline Incident Data Group
Entry Points	Allows gas to enter the network such that gas volumes and gas quality can be measured and controlled as dictated by operational requirements.
Event Tree Analysis	Logical modelling technique that explores responses through a single initiating event and plots a path for assessing probabilities of the outcomes and overall system analysis.
Exit Points	Connection of the Distribution Networks or Industrial/ Power Station customers to the Gas Transmission networks monitors the pressure and measures the gas flowing from the National Transmission System.
Failure Mode	A mechanism in which a specific asset might fail
FMECA	Failure Mode Effects and Criticality Analysis
Forecast Monetised Risk	Means the monetised risk of an asset or group of assets expected to be in operation on a network in a given future scenario, based on the forecast view of Asset Data for the given scenario.
Frequency of Failure	Frequency with which an engineered system or component fails, expressed in failures per unit of time
GHG	Greenhouse Gas
HSE	Health and Safety Executive
ICA	Instrumentation and Control Assets
IGEM	Institution of Gas Engineers and Managers
ILI	In Line Inspection Survey; provides the principal validation for pipeline systems; it provides indications of metal loss including orientation, depth and position within the pipe wall.
Key Parameters	Elements or data items that can vary either based on improved data quality, increase in historical or performance data, improved intervention & units cost data and changes to external valuation of consequences. The elements and data items of the methodology are Probability of Failure, Consequence of Failure, Intervention and Unit Costs, Service Valuations, Asset Base and Asset Attributes (All elements that are likely to change over time).

Long-term Monetised Risk	Means the monetised risk measured over a defined period greater than one year from a given start date and equal to the cumulative Single-year monetised risk values over the defined period.
Monetised Risk	Means an estimation of Asset Risk as derived in accordance with the NARM Methodology as well as the similarly derived estimated risks associated with aggregated asset groupings, and disaggregated sub-components, as relevant.
Monetised Risk Benefit	Means the risk benefit delivered or expected to be delivered by an asset intervention, which: (a) is the difference between without intervention and with intervention Monetised Risk; (b) can be measured over one year or over a longer period; can be measured over one year or over a longer period; and (c) includes both direct (i.e. on the asset itself) and indirect (i.e. on adjacent assets or on the wider system) Monetised Risk Benefits.
Multijunctions	Join pipelines with branched connections and are used to split flow of gas through transmission system and provide multiple routes for gas delivery.
Network Asset Risk Metric	Means the Monetised Risk associated with a NARM Asset or the Monetised Risk Benefit associated with a NARM Asset Intervention.
Network Risk Output	Means the risk benefit delivered or expected to be delivered by an Asset Intervention and is calculated as the difference between Monetised Risk values associated with the "without intervention scenario" and the "with intervention scenario", measured over a period equal to the assumed intervention lifetime from the end of the Price Control Period, which can vary for asset category or specific assets and intervention types.
Pipelines -	Transport gas from one facility to another, in a safe and reliable manner, from the entry points to the exit points at the end of the transmission system.
Proactive Investment	An investment justified based on monetised risk reduction over the life of an asset. Generally, these are investments that we can choose to do (see Reactive Investment)
Probability of Consequence	The likelihood (probability) of occurrence of each consequence
Probability of Failure	Is the likelihood that a piece of equipment will fail at a given time

QRA	Quantitative Risk Assessment
Quantity of Consequence	The scale or volume of the consequence
Reactive Investment	An investment undertaken based on 1) actual failure e.g. a repair 2) policy e.g. maintenance, obsolescence 3) legislation e.g. PSS. In general, we cannot choose to do these investments as they are either mandatory, to maintain an acceptable level of asset performance or meet legislative requirements to avoid prosecution.
RIG	Regulatory Instructions and Guidance as specified in Standard Special Condition A40 of the Licence
RRP	Regulatory Reporting Pack
Service Risk Framework	A consistent method of assessing and articulating the consequence of that asset failure and the service valuations
Service Risk Measure	Elements of the Service Risk Framework with specified service valuations
SIL	Safety Integrity Level – referenced in IEC 61508 'International Standard for electronic and programmable electronic safety related systems' which requires SIL to be set and maintained for protective systems.
Single-year Monetised Risk	Means the Monetised Risk measured over a given one year time period.
SIS	Safety Instrumented System
Treasury Green Book	HM Treasury guidance for public sector bodies on how to appraise proposals before committing funds to a policy, programme or project.
UKOPA	United Kingdom Onshore Pipeline Operators' Association
Uniform Network Code (UNC)	The legal and contractual framework to supply and transport gas within the United Kingdom. It has a common set of rules which ensure that competition can be facilitated on level terms.
Whole Life Benefit	The total direct financial and monetised risk benefit delivered by an intervention over the life of the intervention. This is total Whole Life Cost and Whole Life Risk with and without intervention.

Whole Life Cost	The total cost of an asset over its whole life, taking account of the initial capital cost, as well as operational, maintenance, repair, upgrade and eventual disposal costs.
Whole Life Risk	The total monetised risks of an asset over its whole life, considering all the value of potential consequences of the failure of the asset.

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