nationalgrid

Methodology for Network Output Measures

Gas Transmission - May 2018

ABOUT THIS DOCUMENT

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 Special Condition 7D (Methodology for Network Output Measures).

The Methodology objectives are to:

- 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 pipeline system for the conveyance of gas;
- allow the assessment of network expenditure - the assessment of historical and forecast network expenditure on the pipeline system of NGGT;
- allow comparative analysis – comparative analysis of performance over time between:

  (i) geographic areas of, and Network Assets within, the pipeline system of NGGT;

  (ii) pipeline systems for the conveyance of gas within Great Britain; and

  (iii) pipeline systems for the conveyance of gas in Great Britain and in other countries
- communicate relevant information - the communication of relevant information regarding the pipeline between the Authority and other interested parties in a transparent manner.

FOREWORD

National Grid's gas transmission network already ensures the safe and reliable transportation of gas to 23.2 million industrial, commercial and domestic customers around Great Britain, and our customers are asking it to do more. We are ensuring the network can meet the flexible needs of our customers, so it can manage the changing flows, within day, and physically across the network.

Through our proposed NOMs Methodology we aim to be able to quantify the level of performance that our assets are delivering for customers. This will provide additional justification for the expenditure needed to maintain and/or improve our safety, reliability and environmental performance across our network.

We believe our new Methodology significantly improves our ability to articulate the risks we are managing and also assists in explaining how the investments we make ensure these risks are being managed effectively.

Anthony Green,
Head of Network Engineering
Gas Transmission

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1. OBJECTIVES OF THE METHODOLOGY

1.1. METHODOLOGY OBJECTIVES

The document details the methodology that has been developed as a modification to "Gas Transmission – The Development and Maintenance of a Methodology for Network Output Measures" dated May 2008 (Issue 4.0).

The methodology has been developed to better facilitate the NOMs Methodology Objectives as set out in Special Condition 7D of the Licence. This includes improvement to the specific Network Output Measures outlining the categories of data that are to be used and the methodology that is to be applied to derive each of the Network Output Measures. The objectives of the Methodology are to;

- 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 pipeline system for the conveyance of gas;
- allow the assessment of network expenditure - the assessment of historical and forecast network expenditure on the pipeline system of National Grid;
- allow comparative analysis – comparative analysis of performance over time between:
    - geographic areas of, and network assets within, the pipeline system of NGGT and associated Above Ground Installations (the 'NTS');
    - pipeline systems for the conveyance of gas within Great Britain; and
    - pipeline systems for the conveyance of gas in Great Britain and in other countries.
- Communicate relevant information - the communication of relevant information regarding the pipeline between the Authority and other interested parties in a transparent manner.

The new NOMs Methodology will support the evaluation of current Network Output Measures, either directly or indirectly:

- Directly, as an <u>input to or output from</u> the Methodology:
    - the **Network Replacement Outputs** – used to measure the asset management performance of NGGT; and
    - the **Network Risk Measure –** the overall level of risk to the reliability of the NTS based on the condition of the Network Assets and the interdependencies between Network Assets.
    - the **Network Asset Condition Measure** – current condition, expected reliability and predicted rate of deterioration in the condition of the Network Assets.
- Indirectly, as a consideration when monetising network risk, but will be continued to be reported elsewhere through the Regulatory Reporting Pack (RRP):

- the **Network Performance Measure –** the technical performance of assets that have a direct impact on the reliability and cost of services provided as part of the transportation activities; and
- the **Network Capability Measure** – the current level of capability and utilisation of assets required to deliver services to customers.

It should be noted that the Methodology covers the monetisation of both condition and non-condition related failure modes. For Network Risk and Network Replacement Measure reporting, only condition-related risk will be included. However, we propose to use the same monetised risk approach, as detailed by this Methodology, to value the risk reduction benefits delivered by Asset Health investments within RIIO-GT2 investment planning. These monetised risk benefit valuations will include both condition and non-condition related risk.

Risk valuation is an essential step towards justifying investment through Cost Benefit Analysis (CBA); the calculated monetised risk reduction delivered through specific investments delivers fully quantified monetised benefit values for direct use in CBA. NGGT have developed specific Risk Trading, or Asset Investment Optimisation tools, for the purposes of both risk monetisation and NOMs reporting and for risk trading between asset investments.

Further detail on how the NOMs Methodology Objectives are supported by the new Methodology can be found in Section 3.1.

2. OVERVIEW OF THE METHODOLOGY

The focus of the methodology is the calculation of the Network Risk Measure that enables NGGT to:

- report the level of Network Risk at a point in time or into the future in financial terms(i.e. Monetised Risk); and
- to assist the justification of the maintenance and replacement activities (also referred as Asset Health investments) to deliver our customer requirements.

Our Methodology for Network Output Measures is underpinned by our Asset Management approach. This methodology document describes how we take the information about our assets in the context of our supply and demand obligations to derive the level of risk that is being managed and the asset management activities that National Grid will be undertaking to deliver a safe and reliable network.

The diagram below shows the interaction of the main elements that are used in our asset management decision making.

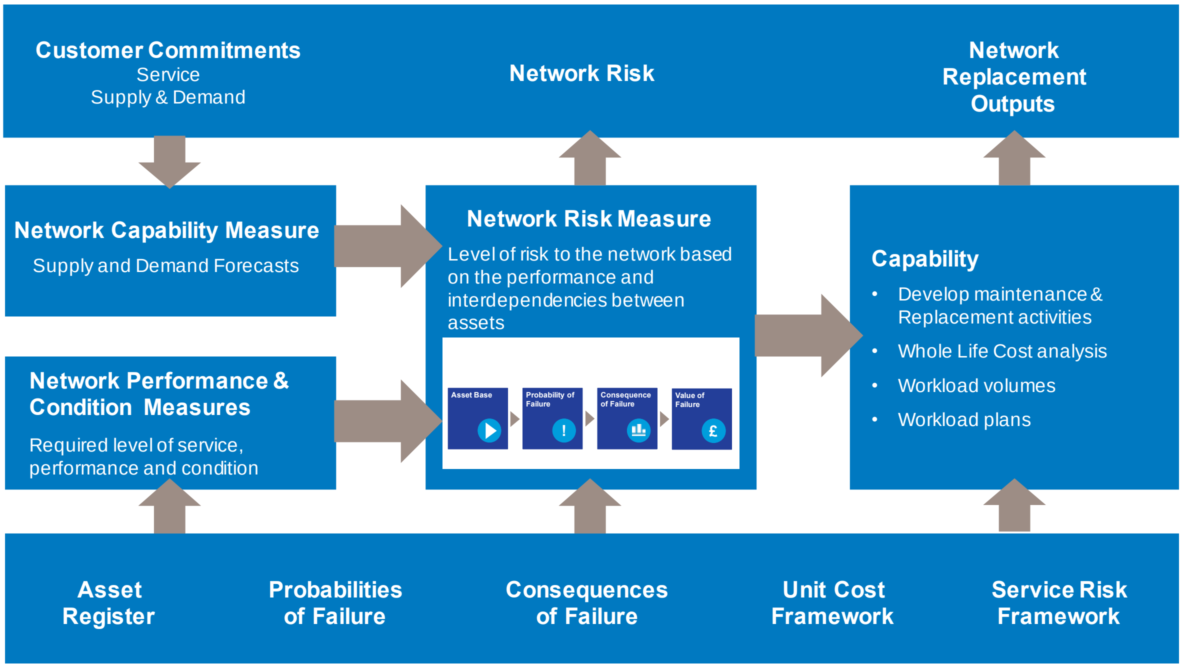

Figure 1 Asset management decision making elements and link to Network Output Measures

To inform the Network Risk Measure and calculate monetised risk, there are a number of inputs required to enable the monetised risk to be quantified. These include;

- NTS supply and demand data that reflects our customer current and future needs, both shippers and downstream gas users. This can be informed by our current Network Capability Measure that is currently part of our annual regulatory reporting requirements; and
- the current condition and performance of the assets, which assist in informing the overall level of Network Risk that is being managed.

The calculation of Network Risk in this methodology is based on specific operational assets contained within our Asset Register. This is underpinned by information about the assets in terms of potential failures, consequences and costs of these failures and the intervention unit costs to either inspect, maintain, repair, refurbish or replace the asset.

These specific elements will be explained as we describe the Methodology in detail throughout the remainder of this document. Supporting documents are provided that go into even greater detail as to how the following elements of the Methodology are derived:

- Probability of Failure
- Consequence of Failure
- Service Risk Framework

2.1. PRINCIPLES OF THE METHODOLOGY

The Methodology documents and assesses the asset related events that affect the ability of that asset base to perform its desired function and thus result in a material consequence on the performance desired by NGGT and its stakeholders. This performance of the asset base is valued in financial terms, i.e. Monetised Risk. Therefore, understanding and translating the probability of initiating asset events through to their consequences, according to the various factors involved allows the risk of the assets to be valued.

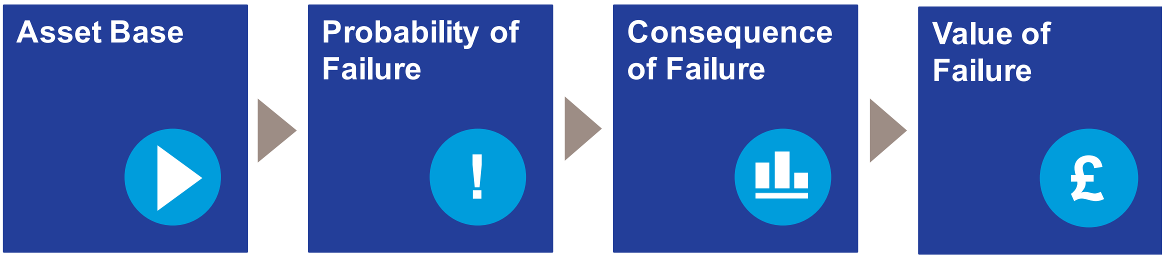

Figure 2 High level process for valuing the likelihood and consequences of asset failures

The methodology is based on a combination of Failure Modes Effects and Criticality Analysis (FMECA) and Event Tree Analysis (ETA) both of which are recognised risk assessment techniques, which facilitate the analysis and representation of the sequence of events and consequences following an initiating asset related event.

Service Risk Framework

The foundation of the methodology is the Service Risk Framework (SRF). This consists of a set of measures that in totality describes the service performance requirements of the asset base from the perspective of National Grid and its stakeholders. All assets either directly or indirectly contribute to the delivery of one or more of the measures within the SRF.

The impact of an asset on one or more of the measures within the SRF provides a consistent method of assessing and articulating the consequence of assets and ultimately its monetised risk value. The event trees, which are described later in this document, provide the linkages and factors for each asset event through to the consequence of that event in terms of the impact on one or more of the SRF measures.

Asset Base

The Methodology applies to all the NGGT operational gas transmission assets. Specific information about the NGGT asset base, contained within our Asset Register, drives the Methodology. Factors such as the age, performance, work history and duty of the assets are used to determine the probability of asset failure. Factors such as the configuration, location and capacity of the asset base are used to derive the performance consequences of asset failure. A list of assets covered by the Methodology is provided in the Probability of Failure supporting document.

Probability of Failure

Individual assets can fail in a number of ways; these are referred to as failure modes which are a specific deviation from the normal performance of the asset. Within the Methodology 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 these impact the probability of failure has allowed the increasing probability of failure, over time, for each of the assets to be assessed. The probability of failure has been determined from a number of sources, all of which are recognised asset management practices:

- NGGT historical maintenance / asset performance data;
- national and international published information; and
- expert opinion 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.

Consequence of Failure

The consequence of failure determines the impact that the asset will have should it fail according to one of the identified failure modes. The consequence of the asset failure is made up of the:

- probability that an asset failure causes that consequence;
- severity of the consequence; and
- quantity of the consequence.

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

- purpose of the asset and location of the asset within the network or site
- geographic location and 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;

The full list of factors and how they have been applied for each of the consequence measures are provided in Sections 4 and 5. The expected consequence of failure impact for each of the identified failure modes for all the individual assets on the NGGT asset base has been determined.

Value of Failure

The probability and consequence of failure for each asset is combined into a predicted number of events against each of the measures in the SRF. The value of failure is articulated through the valuation of each of the measures within the SRF.

All the measures have been valued from two perspectives; the private (or internal) value of service to NGGT and the societal (or external) value of service to society as a whole. Many of the measures carry both a private and societal value, others carry only one. The valuations have been derived from a combination of sources, namely:

- analysis of NGGT historical data;
- nationally published valuation information; and
- analysis of publically available reports to determine associated value.
- valuations undertaken by regulatory economists using relevant industry case studies

Reporting Risk Measure

The ability of the Methodology to develop an understanding of the deteriorating asset base; its increasing probability of failure and the consequences of that failure, together with the value of the consequence, allows the risk of the NGGT asset base to be understood and reported in monetary terms now and in the future.

Investment Planning

In addition to reporting level of risk and monetised risk, the Methodology also supports investment planning and decision making. Understanding the required investments, whether inspection, maintenance, repair, refurbishment or replacement that NGGT can make to the asset base and assessing the impact these interventions have on future asset performance and failure consequences, allows the monetary benefit of investments to be determined. This monetary benefit is assessed across the life of the asset and this assessment of whole life costs enables effective evaluation of potential investment plans.

When combined with the other decision making elements in use in National Grid, such as historical analysis, As Low As Reasonably Possible (ALARP) considerations and other mandatory legislative requirements, the methodology facilitates the production of future investment requirements for our asset base.

2.2. APPLICATION OF THE METHODOLOGY

Challenges

The NGGT 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:

- supply and demand scenarios, forecast and seasonal assumptions
- asset redundancy where multiple assets of the same type are in place to 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 other assets;
- asset degradation dependencies where assets are in place to prevent or slow the degradation of other assets; and
- assets operating within a meshed network where multiple supply sources are available to mitigate the failure of one or more assets within the network.

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

Systemisation

For such a large and varied asset base, any monetised risk Methodology needs to be able to be systematically applied. Systemisation is the only way that the consistency and repeatability 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.

The Methodology has been developed to be completely driven from the data that NGGT holds about its assets. Whilst this data driven approach provides the consistency and speed of application it is dependent upon the quality of data used. NGGT is continuing to roll-out a programme of work to improve the quality of the asset register and other data required to support this Methodology. The Methodology also considers the sensitivity and uncertainty analysis required to understand the impact of the data quality on monetised risk outputs.

Modelling the Asset Base

In order to best take account of the challenges specific to the asset base and to enable the methodology to be systematically applied to the whole asset base, the assets have been split into two groups:

- **Pipelines –** containing all the assets directly associated with the network of predominantly underground pipes and associated pipe protection (e.g. Cathodic Protection) ; and

- **Sites –** containing all the above ground assets (AGIs) that form the Entry points, Exit points, Multijunctions, Block Valves and Compressor sites.

The specific application of the Methodology to the asset groups and the mechanisms used to overcome the challenges of each is described in Section 4 for pipelines and Section 5 for sites. However, the Methodology is consistent and comparable across the two groups.

2.3. SERVICE RISK FRAMEWORK OVERVIEW

The purpose of the Service Risk Framework within the Methodology is to provide a consistent method of assessing and articulating the consequence of that asset failure and the service valuations. It provides a common language with which to consistently communicate risk associated with the physical and commercial performance of the asset base i.e. monetised risk.

The structure of the SRF has been designed in such a way so that it supports monetised risk reporting and strategic, tactical and operational expenditure decision making for both capital and operating investments. In doing so, there are several purposes that the framework fulfils. It articulates how the asset base will perform and how both capital and operating expenditure will impact upon:

- the monetised risk inherent in the asset base and thereby facilitating the mandatory reporting against the safety, environmental, reliability and financial commitments made by NGGT as part of the regulatory agreement;
- the service that customers and stakeholders expect and value, thereby providing the basis for undertaking Cost Benefit Analysis (CBA) and identifying future investment requirements and strategies;
- the performance of NGGT against relevant regulatory or other commercial incentives, thereby enabling the business to target the performance it is incentivised to deliver; and
- the other relevant performance metrics used to monitor performance both internally and externally thereby enabling the measurement of performance and the targeting of investment to deliver it.

2.4. SERVICE RISK FRAMEWORK MEASURES

The SRF consists of 13 measures grouped into five categories as shown in the table 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 Elements of the Service Risk Framework and associated Measures

Safety – includes the potential impact of the National Grid asset base 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.

Environment – includes our compliance with environmental legislation and the environmental permits we hold for some of our sites. The category also covers any environmental incidents or noise pollution caused by our assets as well as the volume of greenhouse and other gases emitted.

Availability and Reliability – covers our ability to receive and provide gas from and to our customers and any contractual or statutory compensation we may be required to pay if we fail to do so.

Financial – includes the other direct financial consequences of the failure of the asset base including gas shrinkage, repair costs, damage to associated plant and insurance excess costs.

Societal and Company - includes the potential wider impacts to society of our asset base such as the potential for transport disruption and damage to public property.

Each of the service risk measures is articulated in terms of a range of severities to appropriately and consistently capture the impacts experienced. For example, in relation to health and safety of the general public and employees the severities range from near misses and minor injuries through to multiple fatalities with associated enforcement notices.

Details of how each of these Categories and Measures are defined and measured are included in the Service Risk Framework document, accompanying this Methodology document.

2.5. MECHANISMS USED FOR VALUATION

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

- the direct costs to National Grid of the impact of the service provided – **Private (or Internal) value**; and
- The value to society as a whole of the service provided **– Societal (or External) value.**

These societal values for service failures recognise the benefits and disbenefits of service failures as experienced by customers, local communities and the environment. The social valuations have been developed using the existing, publically available, literature through a process of value transfer.

The private valuations recognise the direct costs to NGGT of the failure of service. The private valuations have generally been developed using an analysis of NGGT data, and where this is not available then other appropriate industry data has been used.

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.

Mapping of Measures to Private and Societal Valuations

The table below shows the mapping of each of the risk measures to either Social or Private valuations.

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 Application of private and social valuations for each Service Risk Measure

3. USE OF THE METHODOLOGY

3.1. REPORTING

The existing annual Regulatory Reporting Pack (RRP) as required under *Standard Special Condition A40: Regulatory Instructions and Guidance* (RIGs), already contains information covering a number of the Network Output Measures as follows:

- Network Performance Measure: Covered by worksheets 5 (or as amended post April 2017) of RIGs to enable Ofgem to monitor the performance of the network; and
- Network Capability Measure: Covered by worksheets 5.3 and 5.4 (or as amended post April 2017) of RIGs to collect information on the overall size and quality of the transmission service together with the overall levels of capacity booked and levels of actual demand.

The above measures will continue and be governed by RIGs. Further details are provided in Appendix B.

The table below shows how we believe the new Methodology supports, and aligns to, the reporting of Network Output Measures.

Reporting Asset Risk and Condition

Based on the improvements made in the calculation of risk, the methodology facilitates the ability to report the Network Asset Condition Measure and Network Risk Measure current status together with the predicted future risk with or without investment in monetary terms. This can facilitate the reporting of:

- Network Risk for Pipeline and Site assets, combined or separately;
- the total monetised risk across the assets at a point in time or forecast future risk without investment;

- the frequency of asset failure that can be expected driven from the data held about the assets; and
- The monetary consequence of the asset base driven by the probability, severity and quantity of consequence, which is valued using the Service Risk Framework.

Bringing these measures together allows reporting of risk through an established risk matrix approach across many industries. Typically, red zones would highlight ‘concern’ for the assets with amber / yellow being ‘cautious’ and green being ‘comfortable’.

The aim of an Asset Manager, such as NGGT, is to manage downward away from the concern zone. Utilising this type of metric allows NGGT stakeholders to see how the performance of assets is being managed over time. Stakeholders would receive annual updates as part of the RRP and this would enable the comparison of performance over time.

Parameters for Reporting

The Methodology brings together a number of data sources, which change over time, for example:

- Pipeline and Site assets may be commissioned, modified or decommissioned during any given year of a price control, which would be driven by our requirement to meet customer needs or driven by our replacement activities. The majority of changes would be driven by investment plans and therefore predominantly would be under NGGT’s control; and
- supply and demand to meet current and future requirements will change year on year with the capacity booking process and therefore could be considered an exogenous factor that would lead to either increase or decrease in risk at many sites or regions of the network outside NGGT’s control. Further discussions are required with Ofgem to understand how the impact of changes in failure consequence arising from supply/demand variations will be treated during the RIIO-GT2 reporting period.

For the purposes of reporting the Network Risk Measure during a price control period, and to avoid swings in risk driven by exogenous factors, we propose that the following elements would remain constant:

- supply and demand forecasts and their impact on failure consequences; and
- service valuations defined by the Service Risk Framework, at a constant price base.

This will allow NGGT to focus on elements that are within its control and, if reduced, would drive additional value for customers. Examples include:

- improving unit costs for maintenance and replacement activities;
- reducing the frequency of failure through maintenance and other potential innovative practices; or
- reducing the consequences of failure through additional protection or detection assets or measures.

Example of Monetised Risk Reporting

An example of how future monetised risk could be reported is shown below, which combines the frequency and monetary consequences of failure and how they change through investment. Actual reporting outputs will be agreed through consultation with Ofgem and other stakeholders and must support both annual regulatory reporting and the assessment of potential RIIO rewards and penalties.

Gas Transmission Assets

Current - Start of Period

Network Risk Measure

Total Monetised Risk : £ 1,283 m

Monetary Consequence	L1	L2	L3	L4	L5	L6	L7
C7	79	24	16	8	6	2	
C6	79	24	16	8	6	2	1
C5	106	52	45	27	18	5	4
C4	167	104	96	87	37	9	6
C3	304	299	143	112	79	19	16
C2	294	334	282	213	129	61	50
C1	263	289	321	289	247	198	120

Frequency of Asset Failure

Forecast End of Period - With No Investment

Network Risk Measure

Total Monetised Risk : £ 1,856 m

Monetary Consequence	L1	L2	L3	L4	L5	L6	L7
C7	76	123	142	108	78	60	25
C6	42	76	123	142	108	78	35
C5	65	132	176	211	136	97	50
C4	104	124	209	212	156	111	92
C3	96	161	191	207	139	79	81
C2	67	119	121	157	115	51	61
C1	51	78	67	41	23	47	53

Frequency of Asset Failure

Figure 5 Example presentation of outputs from the new NOMs Methodology

3.2. INVESTMENT PLANNING

The Methodology will be used to support a move towards monetised risk based investment planning for the NGGT asset base. The Methodology will be used alongside the existing investment planning approaches, such as historic analysis, Plant Status (significant defects) review, ALARP, quantitative risk assessment and detailed business cases to support in the planning and justification of Asset Health investments.

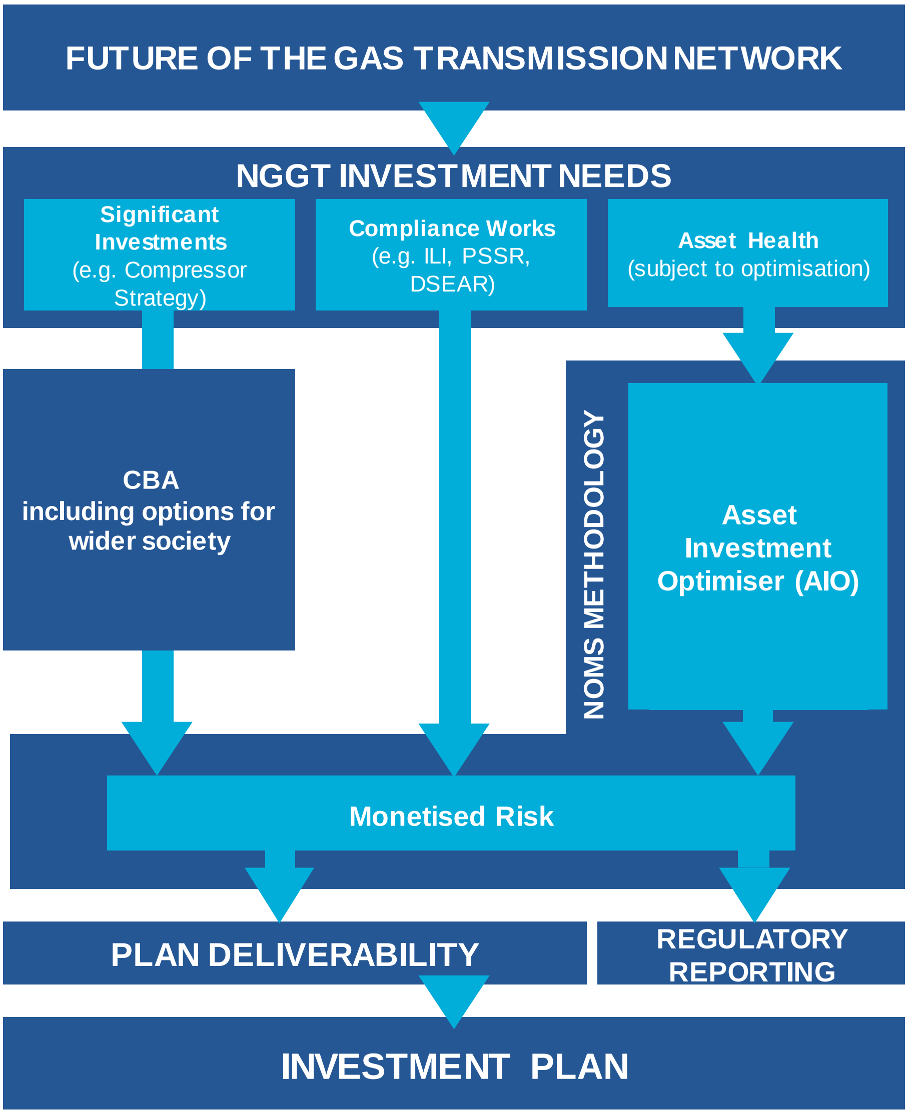

Figure 6 Relationship between the NOMs Methodology and asset investment planning

It is intended that the SRF used for the Methodology and associated valuations will be used consistently across all of investment approaches, where appropriate to do so.

The Methodology presented in this document provides a systemised and consistent mechanism for understanding the current and future risk of the entire NGGT asset base in monetary terms. For specific business cases, the analysis may be more detailed and site and location specific but will follow the same principles as this Methodology (e.g. BAT for emissions investments).

Interventions

Considering all the different types of intervention options for every asset is a key facet of using the Methodology for investment planning purposes. Interventions can be thought of as 'doing work' on assets, which can range from routine maintenance through to full asset replacement.

The purpose of these activities is to efficiently and effectively manage the risk and to avoid serious detrimental impact to the capability and performance of the asset base.

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 accounts for the consideration of proactive and reactive interventions. As such, costs have been assigned to both, where appropriate reactive interventions may carry a greater cost to NGGT principally driven by reactive mobilisation costs and disruption. The costs will include both capital and operational expenditure and therefore facilitate Totex investment planning to be undertaken.

The following intervention types are accounted for with associated cost distributions:

- inspections such as surveys;
- maintenance activities;
- reactive interventions where defects have been identified either during routine inspection or in an emergency and remedial activity undertaken; and
- proactive intervention - refurbishment or replacement of assets.

Unit Costs to Support Interventions

For each asset a set of unit costs will be established for the potential interventions and maintenance activities. All costs will be expressed at a common price base consistent with the SRF price base (currently 16/17 Price Base Date).

Investment Decision Support

The Methodology has been systematically applied to allow the risk and performance of the whole asset base to be forecasted. Asset interventions are currently being identified and costed, which allows the whole life costs and benefits of interventions to be understood at any point in the future. This is outside the scope of this Methodology, but it is important to describe the relationship between monetised risk reporting and investment planning.

Intervention options will be optimised to deliver a desired level of risk, cost and performance across the asset base or on a subset of the asset base. Simplistically, risk monetisation can be used to identify the most cost beneficial interventions. This may not always provide a portfolio of investments that deliver the required company level of cost, risk and service performance. In these cases, risk and performance of the assets may be targeted to ensure a company level of performance is achieved. Furthermore, to ensure that individual asset risks conform to any required ALARP levels, constraints in the decision making are applied to drive any required additional investments.

Bringing all these elements together allows plans to be developed that identify the total investment required to deliver a level of risk and performance required by our stakeholders over the regulatory period that take account of costs and benefits beyond a single regulatory period.

Within a regulatory period, specific asset information, such as performance maintenance and inspection results will allow targeting of individual assets to drive the intervention.

When considering the costs and benefits of interventions Cost Benefit Analysis (CBA) methods are used that comply with Best Practice guidance such as the HM Treasury Green Book.

Potential Supply and Demand Impacts

The current transmission network facilitates a significant flexibility in the supply of gas onto the network. Under short-term planning horizons, it is relatively straightforward to assess risk and consequence to justify an investment. Under longer-term scenarios, the ability of shippers to vary the level of supply at Entry points can contribute to changes in consequence of the asset failure.

To value the contributions of Above Ground Installations (AGIs, which includes Compressors) and Pipeline sections towards NGGT NTS resilience and the avoidance of supply loss, we recognise that the consequence of asset failure (and hence monetised risk associated with consequences of failure) will depend on the prevailing demand and supply conditions.

For purposes of testing this Methodology we have considered national demand for a winter day, in combination with credible, localised supply scenarios (within licence obligations). Since localised supplies could be as high at summer demand levels as in this winter scenario, this approach is appropriate for ensuring that the NTS remains resilient to cope with a range of supply and demand conditions. See the Consequence of Failure supporting document for further details.

Supply conditions 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.

When determining the scenarios and levels of resilience to be applied for future investment planning and for future monetised risk reporting (these scenarios may not be one and the same) work is ongoing. Any changes to the approach, if there is a material impact on overall monetised risk, may require a change to this Methodology document process.

For the purposes of rebasing current performance (to support the incentivisation process ongoing with Ofgem to close out RIIO-GT1), the size of the supply/demand monetised risk present on the NTS and the value of the supply/demand monetised risk delivered through investment are directly proportional. As such, the actual method used to value supply/demand monetised risk is unlikely to impact on rebased performance. This assumption will be tested through ongoing sensitivity analysis and model validation

For RIIO-GT2 Asset Health investment planning, a suitable supply and demand scenario will be agreed with Ofgem which can demonstrate that the costs of required investments to control NTS risk do not unfairly disadvantage customers. NGGT will demonstrate to customers that their required level of investment meets customer expectations for supply resilience should assets fail in the future.

4. METHODOLOGY FOR PIPELINES

The methodology of quantifying the monetised risk of buried pipelines is based on standard Quantitative Risk Assessment techniques (QRA)[1]. An example calculation for Pipelines is included in Appendix A (A1).

4.1. SCOPE OF ASSETS

The scope of the assets included within the Pipeline elements of the methodology includes the following assets:

- Pipeline segments;
- Cathodic Protection (CP) Systems and Test Posts;
- Marker Posts;
- Impact Protection and Nitrogen Sleeves; and
- Pipe Bridges and River Crossings.

[1] IGEM - TD/2 - Edition 2– Assessing the risks from high pressure Natural Gas pipelines (amended July 2015)

Specific Challenges

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

- pipelines are long linear assets which by their nature have potential impact across a large spatial area. Specific parts of a pipeline may have one type of impact whereas others may have completely different impacts. Using average impacts and risk across an entire pipeline does not accurately reflect the monetised risk of that asset;
- the length of pipelines and their replacement costs means that they are never replaced as a whole, rather individual targeted interventions are undertaken on economical sections of the pipeline that are at risk of failure;
- pipelines operate as part of a system of assets within which there are interactions where some of the assets are designed to protect the base pipeline asset; and
- the way in which pipelines are connected determines how critical they are to the supply of gas. As a result, network considerations as to the capacity of alternative routes when pipe segments become unavailable, along with the Supply and Demand scenario chosen, is fundamental when assessing the risk of individual pipe segments.

Pipeline Segmentation

In order to resolve the first two challenges the methodology has been applied at pipe segment level. Pipelines have been split into individual pipe segments represented by a pipe 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 the whole pipeline can then be aggregated from the individual segments.

Within the methodology, interventions are identified and applied to individual pipe segments, which closely relate to the physical delivery of the work.

From a total current length of 7,772 km of pipeline nearly 700,000 individual pipe segments have been created. Although this significantly increases the number of base assets, the key advantage is that each pipe segment can be assumed to be homogenous as all asset attributes can be considered the same. Asset attributes of a linear pipe include; material, install year, wall thickness, depth, pressure, surface type, location, and surrounding consequence quantities such as number of houses, transportation, and other utilities.

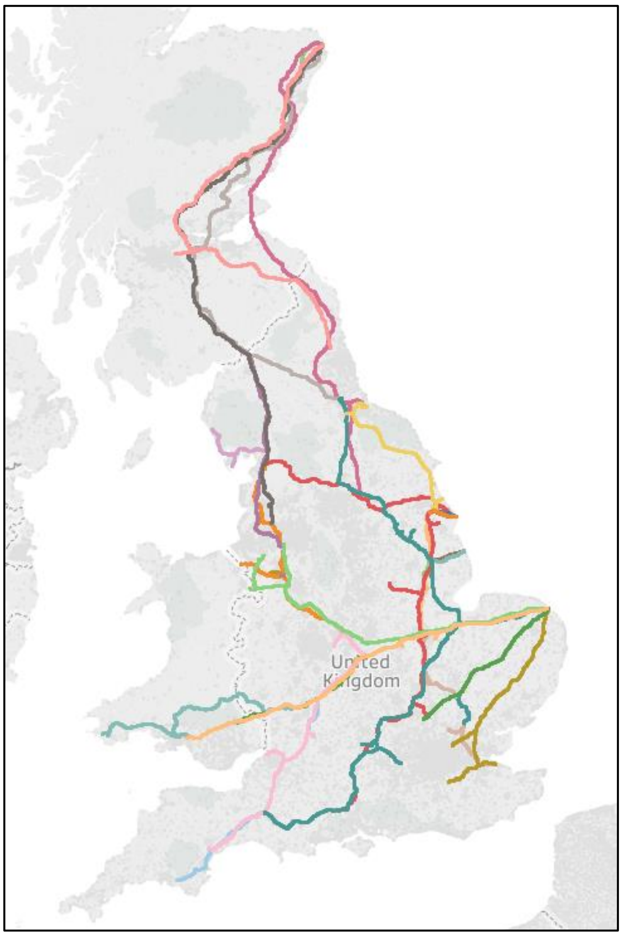

Figure 7 The NTS pipeline network displayed in our Monetised Risk calculation model

Network attributes are also attached to each pipe in a hierarchical manner by way of a connected network. Each pipe segment is aligned to other up and downstream pipe segments and sites. Network data, such as number of customers served from a particular part of the network, can therefore be attached to each pipe segment.

Asset Interactions

The third challenge is resolved by understanding the interactions between the assets within the pipeline system. Pipe segments are used as the base asset and assets that interact with pipelines treated as associated assets, namely:

- Base Asset
    - Pipe segments
- Associated Assets
    - Cathodic Protection (CP) System;
    - Cathodic Protection Test Posts;
    - Marker Posts;
    - Impact Protection;
    - Nitrogen Sleeves;
    - Pipe Bridges;
    - River Crossings.

Each of the associated assets is related directly to the base pipeline asset, although there may be a one-to-many relationship where appropriate. For example, a single CP System is attached to many pipeline segments, representing all the pipes in the pipeline in which the CP System provides corrosion resistance. A River Crossing is attached to all the pipes which cross a river, while Marker Posts are attached to the closest pipe.

Each associated asset has a set of its own asset attributes such as type, install year, and condition. In this manner, the associated asset can have an individual probability of failure as well as interacting with the base pipe asset(s) that it is linked to. The main consequence of failure, and hence resulting risk, is therefore calculated from the individual risks as well as this interaction.

4.2. PROBABILITY OF FAILURE

Probability of failure is split between pipes and associated assets and the interaction between them. Further details can be found in the Probability of Failure supporting document. Failure modes for pipes are based on those detailed in IGEM TD/2:

- 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 failure – general and other causes, e.g. due to over-pressurisation, fatigue or operation outside design limit;
- External interference – caused by third parties; and
- 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 pipe segment is determined from the underlying pipe attributes and a set of reduction factors are then applied to proportion this failure frequency up or down. For example, the probability of damage caused by external interference, increases for pipe segments with a decreased wall thickness.

The base equations are then extended to include the interaction between associated assets where considered significant. For example, the condition of Impact Protection affects the probability of external interference failure. Similarly, a CP System is used to protect pipes from corrosion, and if not working results in higher rates of wall thickness deterioration.

The diagram below shows the failure modes considered for the pipe together with the failure modes that are affected by the associated assets.

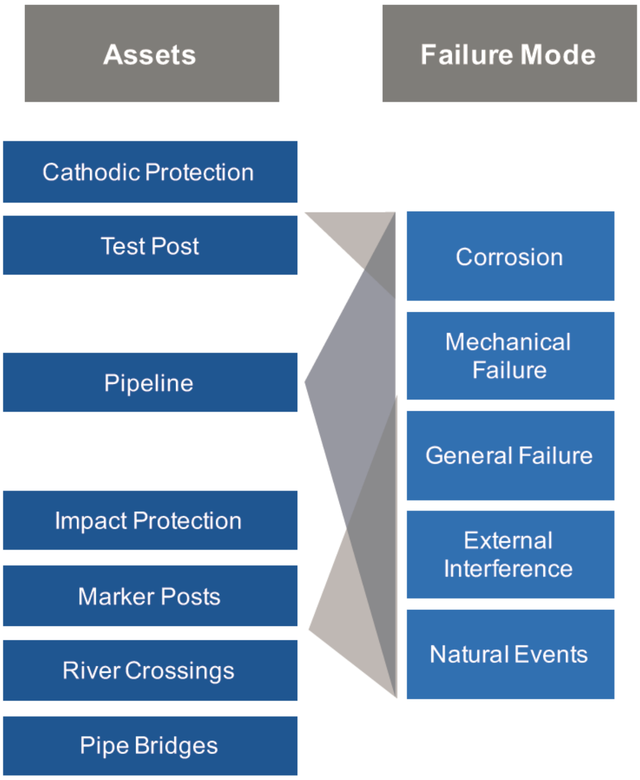

Figure 8 Relationship between Pipelines assets and their failure modes

The failure model, for each failure mode, is updated with data from NGGT data sources, such as survey and condition data. Inline Inspection (ILI) surveys are performed on a regular basis and provide the current remaining wall thickness (metal loss), material defects, and mechanical damage. Cathodic Protection Surveys (CIPS) are also carried out on a regular basis and determine the voltage loss and resultant effectiveness of corrosion protection along a pipe.

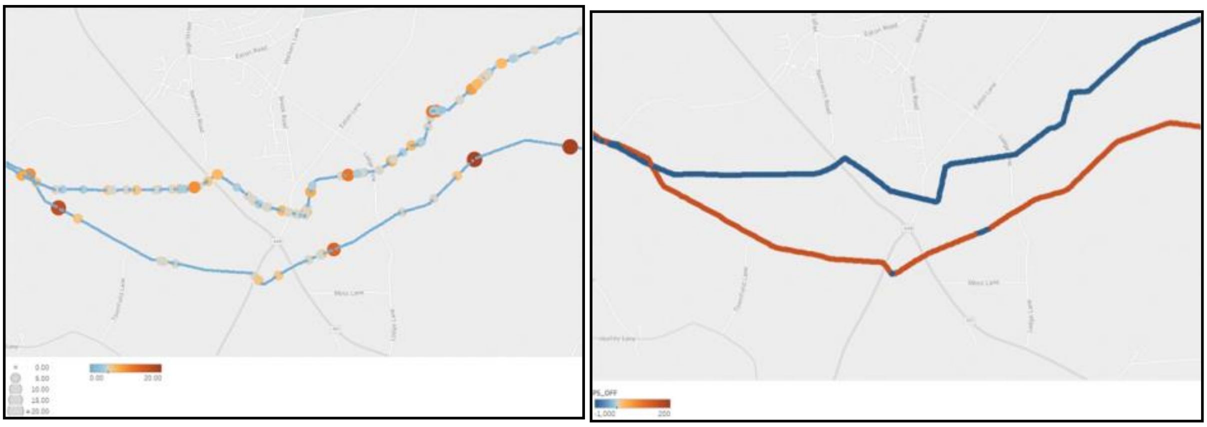

Figure 9 Examples of metal loss and CIPs survey results mapped onto pipe segments

After each failure model on all pipe segments has been calculated, the values from the following EGIG[2] and UKOPA[3] reports have been used to validate the failure frequencies.

Failure of the associated assets is based on asset management plans and expert elicitation of condition deterioration and failure rate curves. The condition curves are used

[2] EGIG – Gas pipelines incidents, 9th Report of the European gas pipeline Incident Data Group (period 1970-2013)

[3] UKOPA Pipeline Product Loss Incidents and Faults Report (1962-2013)

to generate an effective asset age based on the current measured condition of the asset. The effective age is then used as the starting age of the asset and a failure curve applied.

4.3. CONSEQUENCE OF FAILURE

Once the failure mode frequency has been calculated for each pipe segment, the consequences of failure are determined. Further details can be found in the Consequence of Failure supporting document. In calculating the consequence of asset failure we consider a number of elements before we are able to value the consequence, namely:

- Probability of consequence – this reflects the notion that not all failures of a given failure mode will always lead to the consequence for a number of reasons;
- Severity of consequence – this reflects the potential different severities/types of the eventual consequence e.g. the type of transport disruption or the severity of health and safety impact; and
- Quantity of consequence – this reflects the scale of the consequence, e.g. the number of roads affected or the number of people affected.

The assessment is developed in this way in order to ensure that the final risk assessment can be valued in monetary terms. The monetisation is always related to an increment of a "measurable" unit. For example the expected number of major roads that will be impacted or the number of employees that are expected to be injured. The expected value is a term used to refer to the expectation based on the probability of the event occurring.

Pipeline assets have two main consequences – leak and rupture. These in turn result in a number of further consequences that link through to the SRF measures these are shown in the figure below:

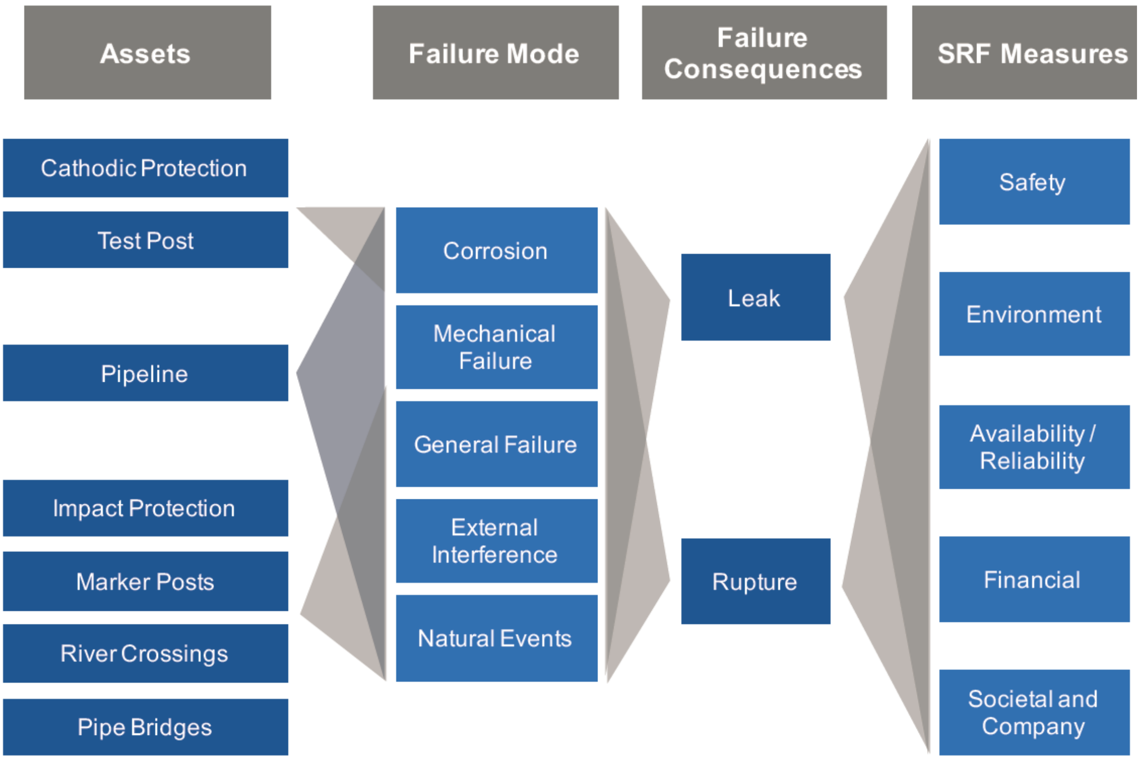

Figure 10 Relationship between pipeline failures, consequences and the Service Risk Framework

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 a gas escape through an unstable defect which extends during failure to result in a full break or failure of an equivalent size to the pipeline. The number of leaks and ruptures per year are calculated for each pipe segment as the failure mode frequency multiplied by the probability that the failure mode will lead to a leak or rupture. Each pipe segment may have more than one failure mode and therefore the probability of failure is summed for all failure modes to give the total number of leaks or ruptures. .

Environmental Impacts

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.

Health and Safety and Property Damage

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 can result from ignition impacts. These can differ in severity, and the following severities have been included:

- Minor injury;
- Lost Time Injury;
- Major injury; and
- Fatality.

Property damage has also been assessed resulting from ignition impacts.

The quantity of each severity following an ignition is based around Building Proximity Distances (BPD) and Emergency Planning Distances (EPD)[4].

Transport Disruption

Leaks and ruptures can result in disruption to transport services for safety reasons and further inspection. The severity of transport disruption is split into the following bands:

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

Transport disruption is calculated from the number of each road or railway within the EPD, by undertaking a spatial analysis of each pipe segment.

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

Availability and Reliability

Availability and reliability is calculated from the number of supply interruptions resulting from a leak or rupture.

To gain full coverage of the whole network in the short term a desktop study has been undertaken to build a logical model for all pipelines in the network. This takes into account, for any individual pipe segment failure, the loss of directly connected exit or entry points in addition to the loss of any dependent connected assets. Where an exit point site is part of the interconnected network then the loss of directly connected exit points are only due to a failure at that site. Where a site is situated on a spur its output consequence applies to all upstream sites until the point at which the site is supplied by two separate pipelines. See Consequence of Failure report for further details.

5. METHODOLOGY FOR SITES

5.1. SCOPE OF SITE ASSETS

The scope of the assets included within the Site elements of the methodology includes all operational assets on the following site types (primary asset level):

- Compressor
- Multi-Junction
- Entry Point
- Exit Point
- Pipeline Block Valve

A detailed list of the asset types and failure modes included is provided in the Probability of Failure supporting document. An example calculation for Sites is included in Appendix A (A2).

Specific Challenges

There are four specific challenges when assessing the monetised risk of assets on a site, namely:

- there are a large number of different types of assets each with different failure characteristics and potential service impacts;
- the highly connected nature of the individual assets on each site and the variety of functions similar asset types have means that assessing assets in isolation does not accurately represent their risk to service performance;
- at site level an additional level of complexity needs to be taken into account which relates to the reliability of the compressor units where there is more than one unit. This offers a level of redundancy should a unit become unavailable; and
- to accurately assess 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.

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 follow depending on how the asset has failed.

A site is made up of a collection of Asset Systems designed to undertake a particular task, i.e. its purpose. Individual assets operate within an Asset System and as such allow the asset's purpose to be inferred.

For each system, we determine the different types of failure modes that could occur which would lead to one or more of the consequences in the SRF. Separately, we identify for each asset type, when they fail, the failure modes they may exhibit and have captured this through an asset type to failure mode mapping.

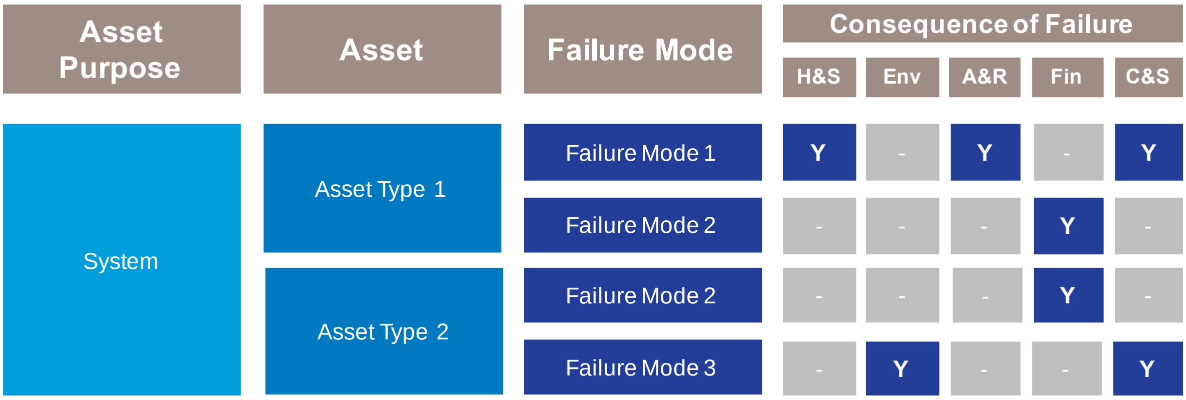

Figure 11 Relationship between Sites assets, failure modes and consequences of failure

This two-step approach allows the assets that have a shared purpose defined through the system to be determined, and then all relevant failure modes that relate to the asset type within the context of the system they operate to be applied.

This approach can be applied across all types of assets which are serving different purposes so that they can link to the appropriate service risk consequences and only the failure modes that are relevant to those consequences and the asset type under consideration.

The mapping of systems, asset types, failure modes and service consequences is provided in the Consequence of Failure supporting document.

5.2. PROBABILITY OF FAILURE

Further details can be found in the Probability of Failure supporting document. The first item to quantify is the failure mode frequency, which is made up of two elements: the frequency of failure for each asset and the proportion of the failures that would be expected to be of a given failure mode for that asset.

The frequency of failure 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 the work management system; and
- expert elicitation workshops using a formal and established method for eliciting failure characteristics of asset populations to inform a statistical model fitting process.

The work defects data provides an asset-type specific rate of failure that reflects the actual volumes of potential failures prevalent in the asset base. The elicited models are developed to predict the deterioration in rate of failure for each asset type. Combining the two sources of information, we are able to apply a failure model to a specific asset of a given asset type to predict the current and future annual rates of failure, i.e. number of failures per year.

Elicitation of the Frequency of Asset Failure

To determine frequency of asset failure and its change over time we have developed models derived from a formal expert elicitation process. We use elicited information to supplement the data in the system as typically time-based data in systems do not present evidence of the full life of assets and their behaviours. This is generally where assets are replaced before the end of their useful lives. Other reasons relate to the fact that defects data may not cover a sufficiently long observation period. In order to determine on the basis of cost benefit and risk performance when in the future to replace or refurbish equipment, deterioration models based on expert elicitation have been generated. A number of key elements are vital to ensuring that the models are fit for purpose. These are:

1. a wide variety of experience is consulted;
2. the information captured is not directly about the model form/shape, but rather information/data points used to derive the final models;
3. the information is captured as point estimates and also with the uncertainty around the estimates;
4. the information is provided by individuals rather than through a single consensus – this provides the opportunity to explore where variability is arising;
5. the resultant model curves are reviewed by the group and a consensus agreed together with the sensitivity ranges to be tested; and
6. the outputs from use of the models are benchmarked against industry models and any significant differences are tested through further sensitivity analysis and validated with NGGT and industry experts.

We have developed four model types from this elicitation process:

- Repairable failure model versus Age – used to calculate the failure rates and the deterioration over time that when it fails, can be restored;
- Non-repairable failure model versus Age (i.e. End of Life Probability) – used when the asset fails and cannot be restored and therefore requires replacement; and
- Asset Health versus Age model – which is used to determine the Effective Age of assets given Asset Health

Elicited failure rate models are combined with the defects data failure rates to ensure that the starting failure rates are reflective of the current asset base. Where failure rates are not available from defects data, then we use the elicited models only.

The diagram below summarises the steps undertaken to derive the Elicited models for different asset types.

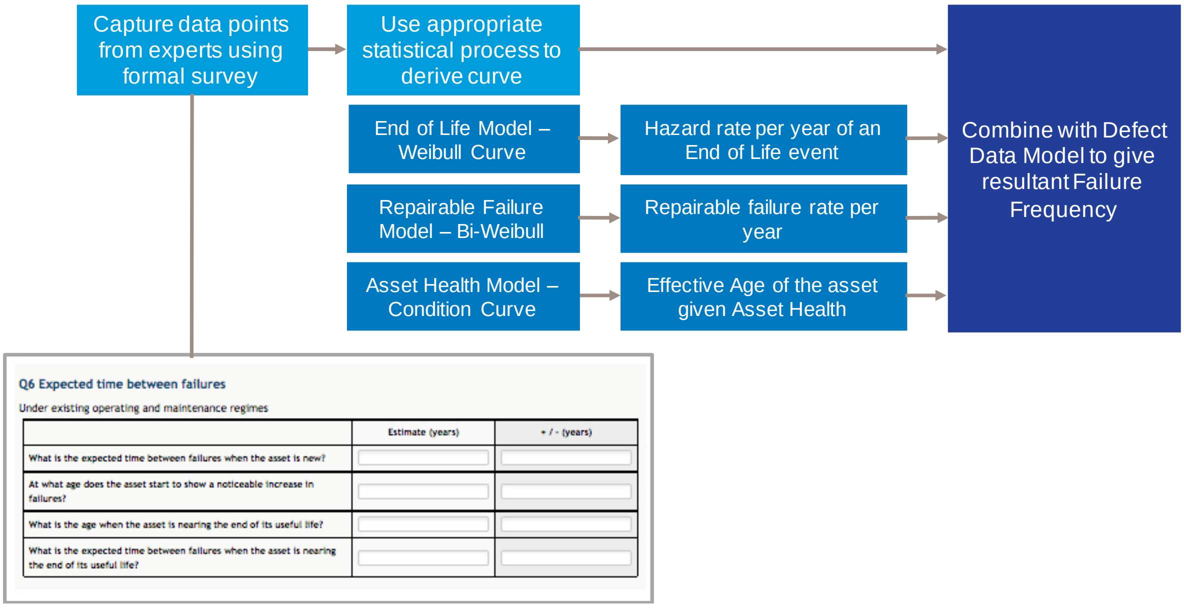

Figure 12 Asset expert elicitation approach taken to estimate future probabilities of failure

Defects Data and Derived Frequency of Potential Asset Failure

Defects data is captured against individual equipment assets. Historically captured asset defects data has been used to define the steady state failure rate for each asset type. The diagram below shows the way in which steady state failure rates have been calculated for each asset type.

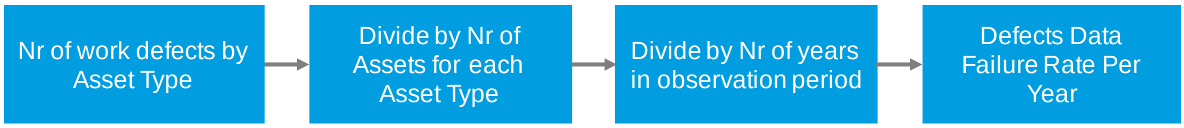

Figure 13 Estimation of base defects/failure rates for Sites assets

Combining the Elicited and Defects Data Models to Determine Frequency of Failure

The Effective Age is the True Age of the asset for ICA (Instrumentation and Control Assets) and Electrical assets. For all other assets the Effective Age is determined using the Asset Health Model which is based on expert elicited information. The Effective Age is in turn used to drive the elicited failure rate models (Repairable and End of Life). This is represented in the diagram below.

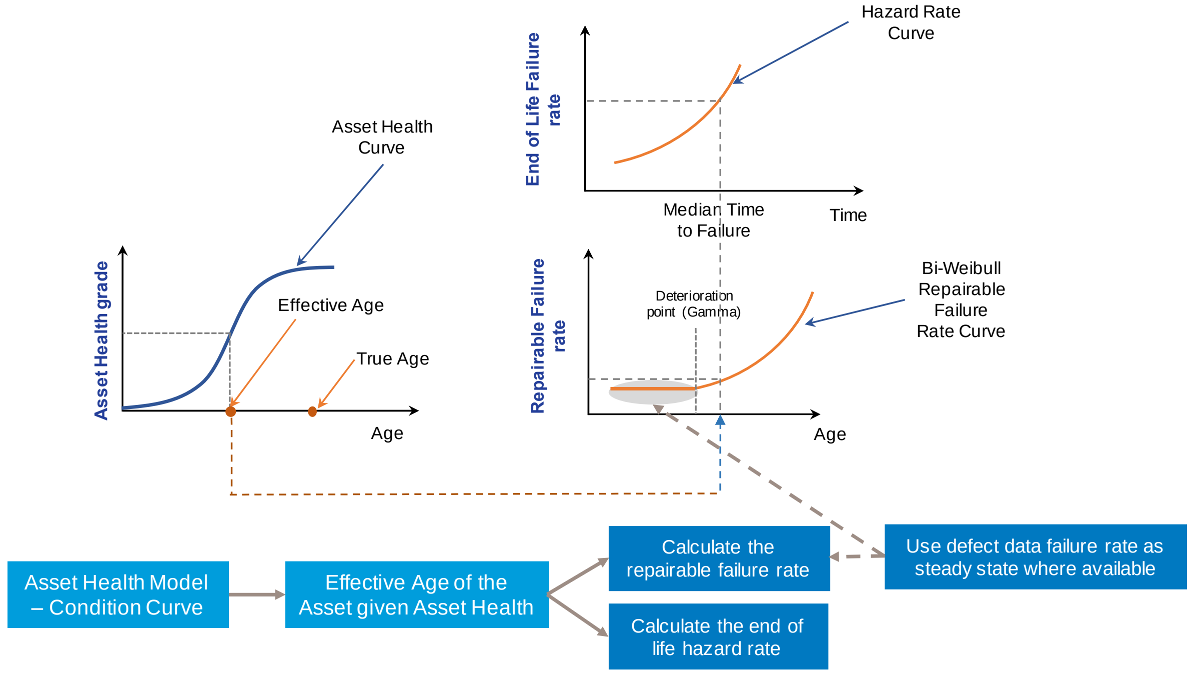

Figure 14 Using assessed asset condition to model asset deterioration rates and end of life

Where models driven by actual defects data are available, these are used to replace the elicited steady state part of the Repairable failure model which is indicated by the grey shaded area of diagram above. The defects data failure rates are used to ensure that the starting failure rates are reflective of the current asset base. Where failure rates are not available from defects data, then we use the elicited models only.

Determining the Failure Mode Frequency

Once the frequency of asset (equipment) defects are calculated using the frequency of failure models, we calculate the proportion that is expected to materialise as one or more of the failure modes that is relevant to the consequences in our SRF.

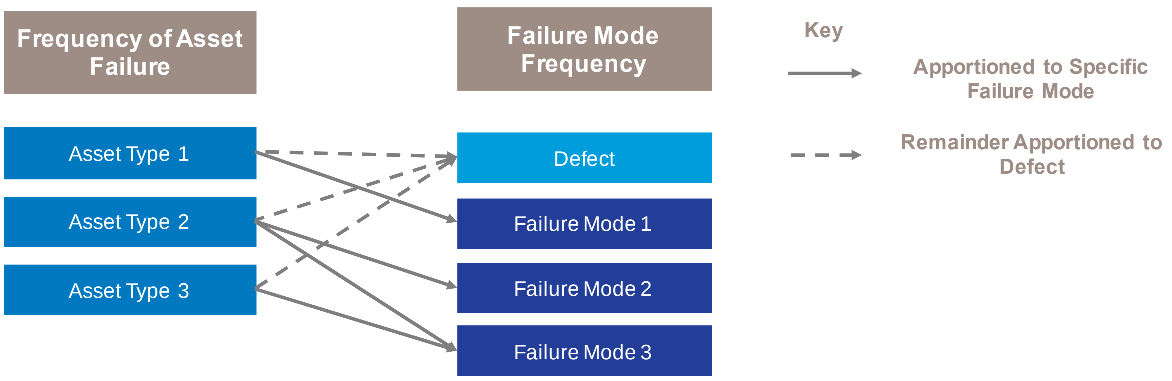

Figure 15 Assigning the proportions of Site asset failures which result in specific consequences

A number of different failure modes can occur in the system. However, we only include in the risk assessment the failure modes that lead to the consequences relating to the SRF. We have developed the failure modes mapping and identified relevant industry data to determine the proportion that represents failures (defects) that relate to each mode of failure.

The key references used to determine the failure modes and proportions are:

- OREDA Offshore Reliability Data[5]
- User Guide for the AGI Safe Package[6]

Application the Frequency of Asset Failure

Application of the frequency of failure model to each individual asset is achieved using the Effective Age of the asset. This is essentially an age value that reflects the prevailing condition or Asset Health.

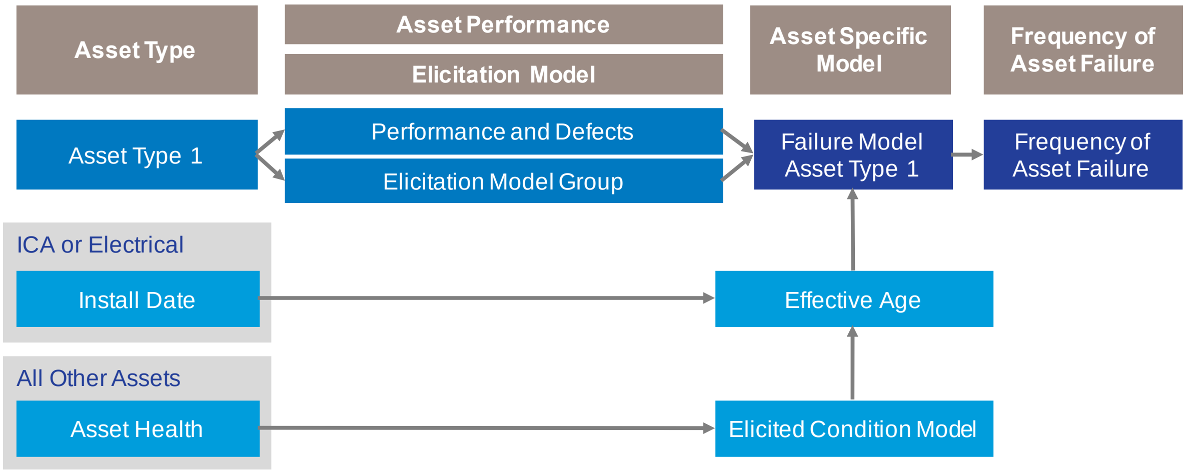

Figure 16 Use of assessed asset condition (or install date) to inform the frequency of asset failure

The Effective Age is important where assets are highly maintained or maintained to different degrees across the asset base. In these circumstances, a better indicator of the potential to fail is the effective age not the true age.

As an exception to using Asset Health as an indicator of Effective Age, we have considered that ICA and Electrical equipment do not show obvious outward signs of asset health degradation. As such, we assume the true age as the Effective Age of ICA and Electrical equipment.

Once the Effective Age is available, we are then able to apply the full failure model to predict the failure rate of an individual equipment asset for each year over the next 25 to 40 years. There are around 250 asset type based failure rates that are combined with 50 different Elicitation Group models.

5.3. CONSEQUENCE OF FAILURE

Further details can be found in the Consequence of Failure supporting document. Once the failure mode frequency has been calculated for each individual item of equipment in the asset hierarchy, the consequences of failure need to be determined. In calculating the consequence of asset failure we consider a number of elements before we are able to value the consequence. These are:

- Probability of consequence
- Severity of consequence
- Quantity of consequence

The assessment is developed in this way to ensure that the final risk assessment can be valued in monetary terms.

[5] 5th Edition 2009 Volume 1 Topside Equipment. Prepared by SINTEF, Distributed by Det Norske Veritas (DNV)
[6] V5.1. DNV GL Report 13492 December 2014

The consequences that result from asset failure are lined link to a relevant measure on the SRF. For example, an asset failure that presents as a gas leak could potentially lead to a fire. The fire in turn could lead to an injury or impact on transport.

The figure below shows how the consequential effects link to the Service Risk Framework. The following sections describe how each of the consequential effects, their probabilities, severities and quantities of impact are determined and applied.

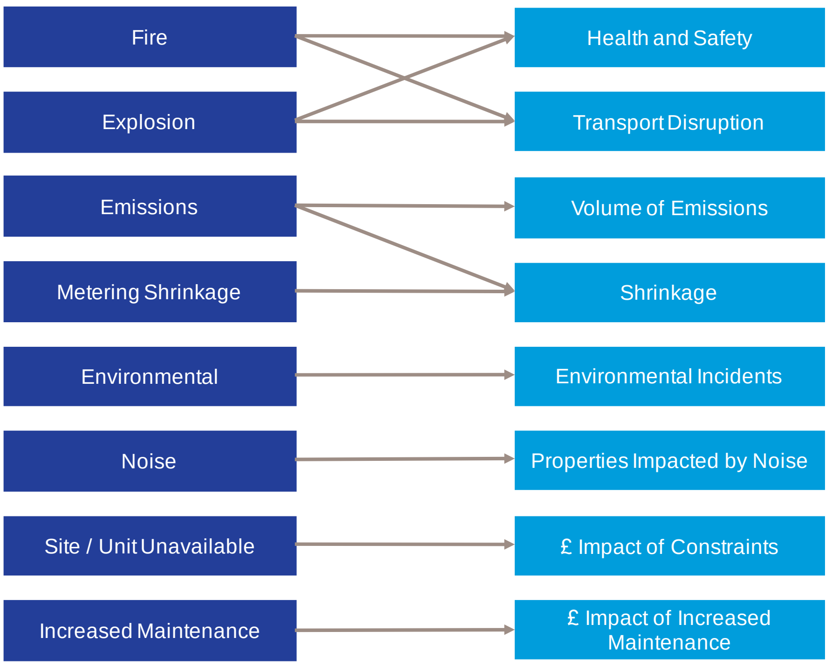

Figure 17 Mapping of failure modes to Service Risk Measures

Fire and Explosion (Safety)

The logic diagram below above summarises the conditions that lead to fire, and those that lead to explosion for Sites assets.

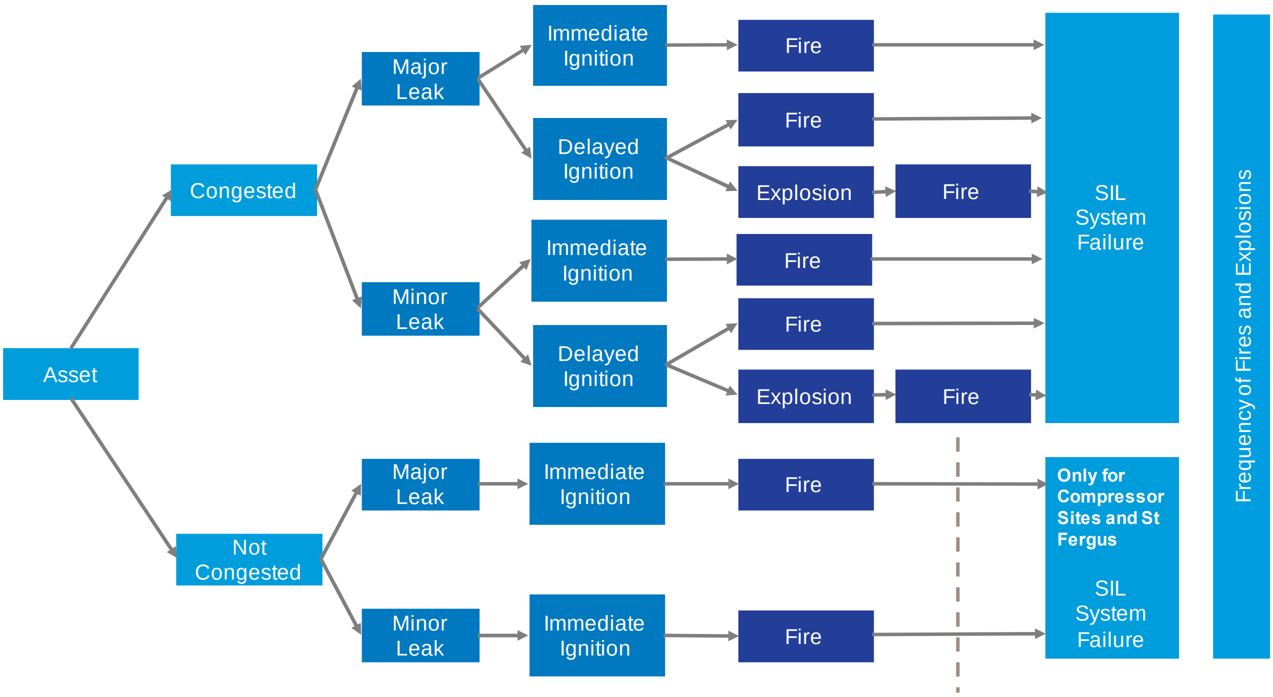

Figure 18 Logic diagram to describe how leaks may potentially arise in fire/explosion consequences, including the protection provided by SIL systems

Death or Injury (Safety)

Following a fire or explosion, the methodology considers that there is the potential for impact on health and safety of employees and members of the public. The methodology determines this in two steps: severity of the incident, and the quantity of people potentially affected. Fires are assumed to be constrained to within site boundaries and therefore will not result in fatalities or major injury to members of the public.

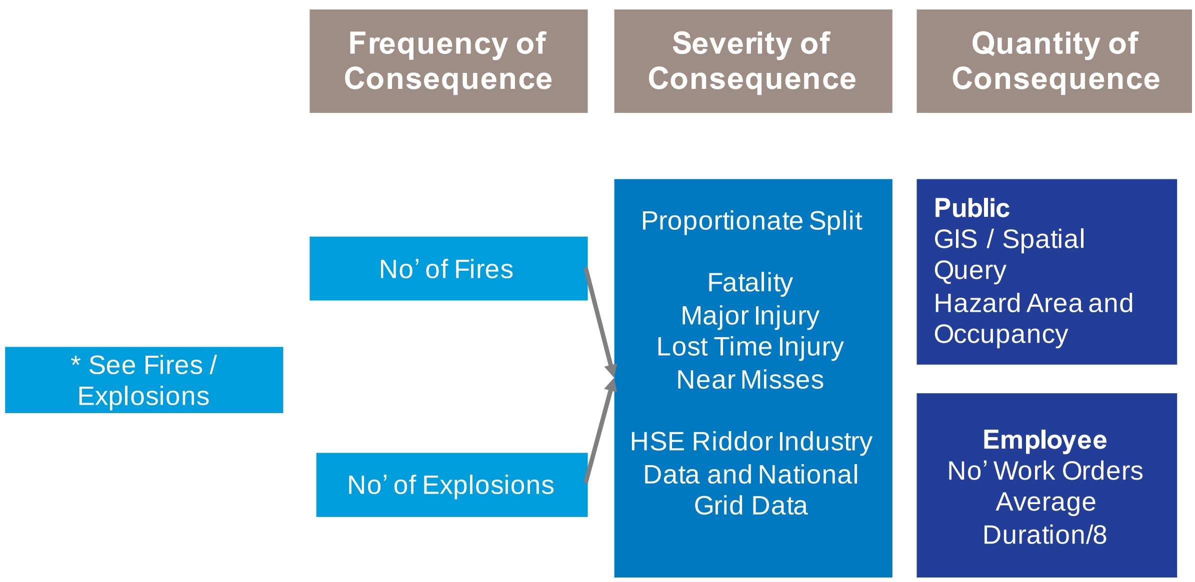

Figure 19 Relationship between fire/explosion and Safety risk to public and employees

Transport Disruption (Societal)

In order to calculate the disruption caused to traffic from a leak, fire or explosion incident the cordon distances within the NGGT Incident Procedures have been used. These cordon distances have been applied to each site and the affected transport routes identified. A time to release the cordon has been used to determine the duration of the incident.

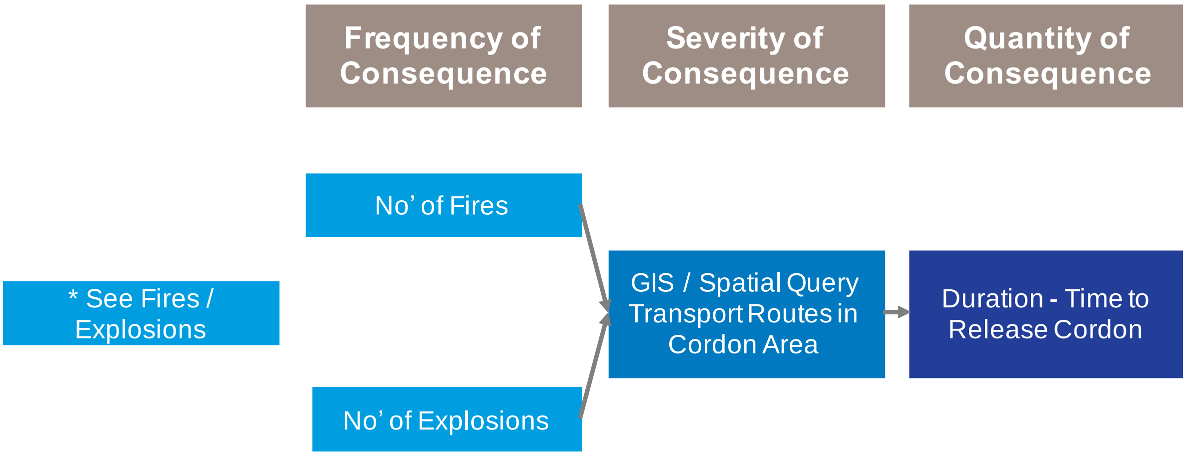

Figure 20 Relationship between fire/explosion and transport disruption risk to public and employees

Availability and Reliability

For purposes of testing the Methodology we have considered the national demand for a winter day, in combination with credible, localised supply scenarios (within licence obligations). Since localised supplies could be as high at summer demand levels as in this winter scenario, this approach is appropriate for ensuring that the NTS remains resilient to cope with a range of supply and demand conditions. Supply conditions 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. The approach is summarised below:

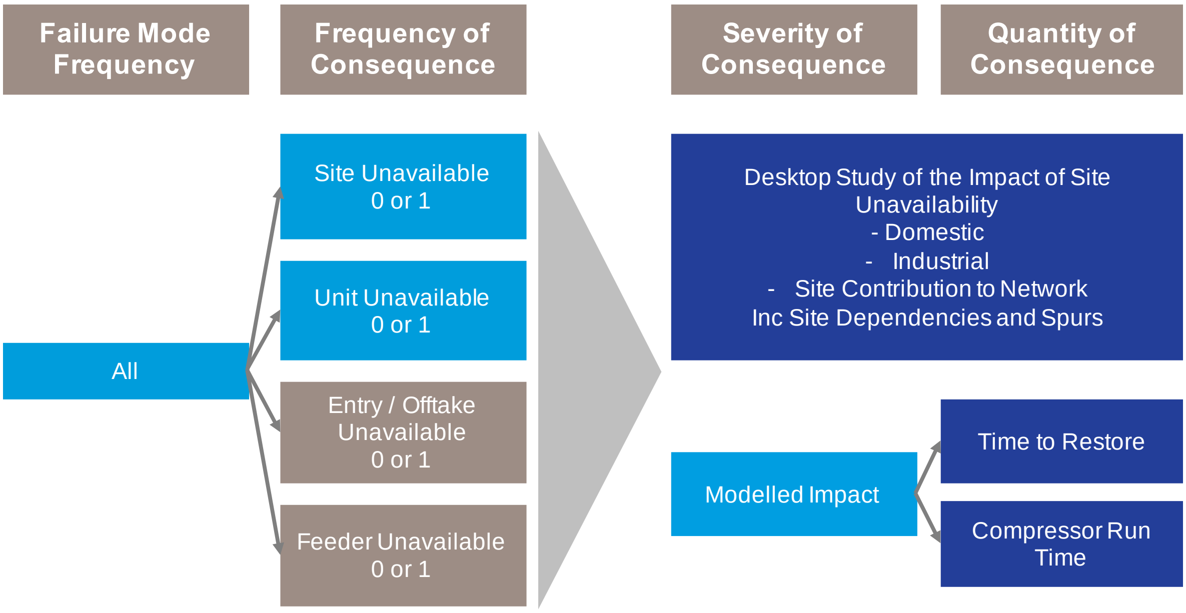

Figure 21 Relationship between unit/site availability and loss of supply (or capacity to deliver/supply gas)

Noise Pollution (Environmental)

The failure modes that lead to noise pollution are based on the asset type and purpose as shown in the mapping provided in the Consequence of Failure supporting document.

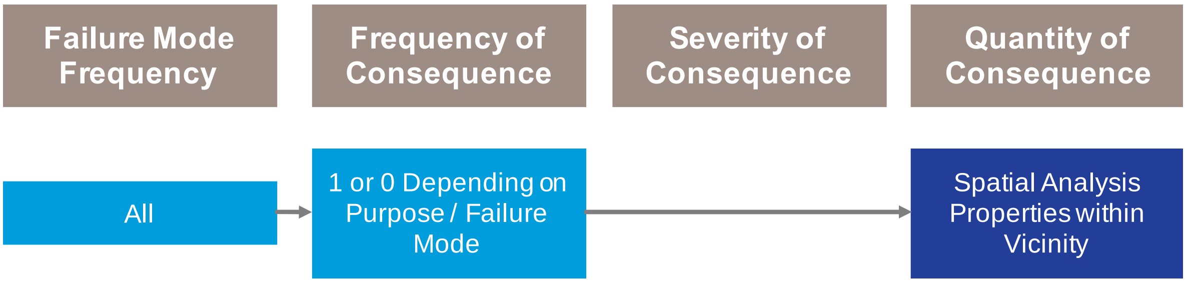

Figure 22 Estimating the noise nuisance resulting from asset failure

Emissions and Shrinkage (Environmental)

The failure modes identified to impact emissions relate to:

- Emergency Shut Down (ESD) venting which have been identified to occur with unit or system trips
- Major and minor leaks

Fuel gas burned to power compressor stations has been explicitly excluded from the Methodology although it contributes significantly towards NGGT emissions targets. This is because:

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 needed to maintain overall monetised risk, to the detriment of customers.

We therefore assume the contribution of fuel gas to overall monetised risk is fixed in time. Investments to control emissions volumes and quality are made outside of this Methodology. However, any Asset Health investments made as a result of emissions-driven investment will be reflected in future NTS monetised risk. The approach is summarised below:

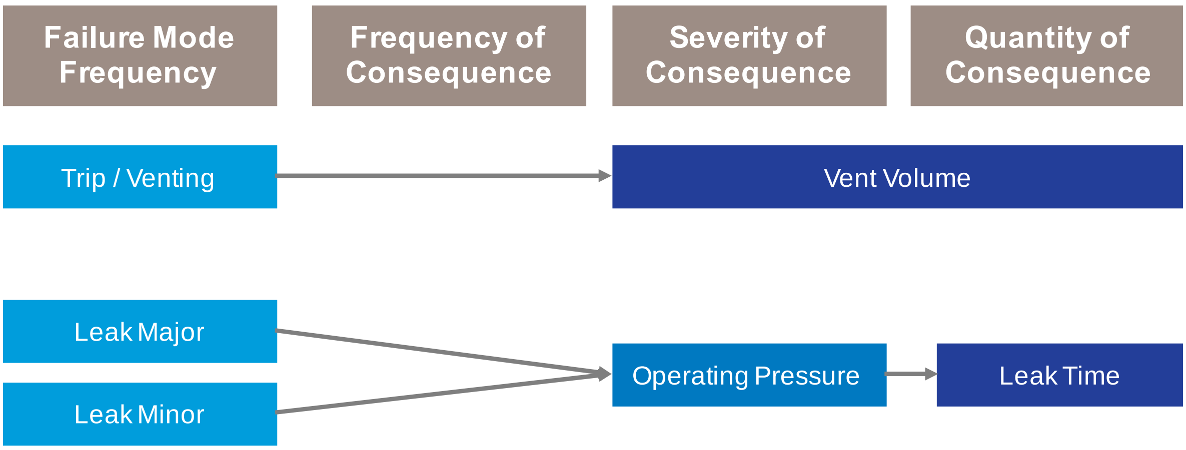

Figure 23 Estimation of emissions arising from asset failure

6. GOVERNANCE OF THE METHODOLOGY

6.1. ANNUAL REVIEW

The methodology, in addition to being a Licence requirement, also forms part of National Grids ISO55001 accredited Asset Management System. The Asset Management System includes processes for:

- Performance Evaluation: including Asset Performance & Health Monitoring, and Asset Management System monitoring; and
- improvement: including Management review, audit and assurance.

The Asset Management System annual monitoring outlined in Section 3 will be used as a basis to review the Methodology in addition to the annual review requirement specified in the 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 the Asset Management System.

Updates to parameters will be carried out driven by specific information obtained from NGGT's Network Assets, such as:

- improved asset health information regarding the Failure rates of Network Assets; or
- through external third party events that would improve the quantification of risks against the Network Output Measures.

Modifications to the data within the Methodology will be made should NGGT believe this would drive an improvement in the quantification of the asset risks and improve its decision making processes. For example, an innovation may be implemented that significantly reduces the intervention costs and the methodology data would be updated to reflect the material change.

6.2. MODIFICATIONS TO METHODOLOGY

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 be submitted for acceptance together with implementation timescales and the process for changing the Network Replacement Outputs.

6.3. DATA ASSURANCE

Standard Special Condition A55 Data Assurance requirements (DAG) requires NGGT 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 the Authority. As part of the Network Data Assurance Report (NetDAR) submission, we measure and manage the overall risk profile of each regulatory submission / License obligations via our annual DAG risk assessment process.

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 v1.3.

We will take a proactive approach in forward planning our control activities for our reporting Network Risk Measure and Network Condition Measure under this methodology via our DAG assessments. For example, activities on controls, procedures, method statements and audits will be set in place to ensure probability risk on our controls are managed and improved year on year.

7. DOCUMENT CONTROL

Version	Date of Issue	Notes
1.0	3rd April 2018	Version for public consultation
2.0	22nd May 2016	Final version submitted to Ofgem

APPENDIX A – A1. - PIPELINES EXAMPLE

The table below shows an example pipe segment together with results for an indicative 12 metre pipeline section.

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 $CO^{2}e$.
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.

Indicative aggregated risk of a 10km pipeline

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 A – A2. - SITE EXAMPLE

The table below shows an example for a single asset on a compressor site.

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 B – NETWORK OUTPUT MEASURES REPORTING ALIGNMENT

NOM	Licence	Comments
Network Asset Condition Measure Current condition, expected reliability and predicted rate of deterioration in condition of the Network Assets;	*(a) the current condition of the assets which collectively form the pipe-line system to which this licence relates (including the condition of the principal components of those assets) (collectively, "network assets"), the reliability of network assets, and the predicted rate of deterioration in the condition of network assets which is relevant to making assessment of the present and future ability of network assets to perform their function ("network asset condition");*	**Current condition** is an input to the monetised risk methodology, informing the probability of failure. Over time it will replace dependence on the age of the asset as an indicator for the likelihood of the assets failing. This is reported as part of RRP Table 6.6 as the Asset Health rating of assets. Going forward this may include reporting actual asset failure rates (to be agreed with Ofgem). **Reliability of the assets** is also an input to the monetised risk calculation, particularly with reference to future prediction of the probability of failure. Reliability is not clearly reported as part of our RRP submission. It is partly covered by Tables 6.4 and 6.5 of the RRP submissions at an asset system level. Going forward, reliability is a fundamental input to calculate asset monetised risk. **Predicted rate of deterioration** is an input to the monetised risk calculation informing how the probability of failure will change in the future. This will inform the future NTS risk, for example end of period risk. Overall the calculated risk is an indicator of the **ability of network assets to perform their function**. The present ability to perform their functions is reported through RRP tables 5.3 Utilisation and performance and 5.4 Under the new NOMs methodology Network Asset Conditions can be reported as volume of assets within a risk band, spread of asset failure rate
Network Risk Measure The overall level of risk to the reliability of the pipe-line system based on the condition of the Network Assets and the interdependencies between Network Assets;	*(b) the overall level of risk to the reliability of the pipe-line system to which this licence relates as a result of network asset condition and the interdependence between network assets ("network risk");*	**Network Risk**, covering all elements in the Service Risk Framework including the reliability of the NTS as described in the licence condition, is a defined output of the NOMs methodology. Under the NOMs methodology risk will be presented as a monetary value for the entire system or agreed component parts

NOM	Licence	Comments
Network Performance Measure The technical performance of assets that have a direct impact on the reliability and cost of services provided as part of the transportation activities;	*(c) those aspects of the technical performance of the pipe-line system to which this licence relates which have a direct impact on the reliability and cost of services provided by the licensee as part of its transportation business ("network performance");*	**Network Performance** relates to the current performance of the NTS. The performance of the network will continue to be reported through the metrics in the Tables 5.1 – 5.7 of the annual RRP submission. Current network performance is an indicator of effectiveness of historic asset intervention decisions. The technical aspects that relate to risk of loss of service are covered against the Network Asset Condition NOM.
Network Capability Measure The current level of capability and utilisation of assets to deliver services to customers	*(d) the level of capability and utilisation of the pipe-line system to which this licence relates at entry and exit points and other network capability and utilisation factors ("network capability");*	**Network Capability** is similarly part of the RRP reporting regime. Changes to Network capability expressed as capacity at Entry and Exit points are principally driven by the connected customer as we invest to maintain the obligated capacity. Elements of capability and utilisation inform the consequence of failure in the new NOMs methodology. We are proposing that the elements of the capability and utilisation that have an effect on the system monetised risk are fixed for a regulatory period.
Network Replacement Outputs Are used to measure the asset management performance of National Grid Gas Transmission (NGGT).		**Network Replacement Output** as a measure of asset management will be based on demonstrating the risk reduction that is forecast to be delivered by intervention compared with the future risk without investment. Annual reporting of current network risk will give an indication that the interventions are being made sustainably to achieve the agreed risk performance.

GLOSSARY

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.

ALARP - As Low as Reasonably Practicable

Authority - OFGEM – Office of Gas and Electricity Markets

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.

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 way in which a specific asset might fail.

FMECA - Failure Mode Effects and Criticality Analysis

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).

Multi-junctions - join pipelines with branched connections and are used to split flow of gas through transmission system and provide multiple routes for gas delivery.

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

Quantity of Consequence - the scale or volume of the consequence

QRA - Quantitative Risk Assessment

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

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.

SIS - Safety Instrument System

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

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 - 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, taking into account all of the value of potential consequences of the failure of the asset.