Northern Gas Networks

A23.C - NGN RIIO-2

Investment Decision Pack
Local Transmission System

we are the network

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2. Introduction

This Engineering Justification paper details our proposals for investment on our Local Transmission System (LTS) pipelines during RIIO-2. It includes narrative for upgrades on our LTS for asset health reasons and is to be used in conjunction with the accompanying Cost Benefit Analysis. This paper explicitly follows Ofgem's guidance and is set out in accordance with the headings therein.

Our LTS pipelines are a critical part of our gas transportation service and because they are expensive to replace we undertake regular inspections, maintenance and repair to manage increasing risks associated with asset health to ensure the longevity of the assets. During RIIO-1 we have undertaken a programme of works to intervene on the most vulnerable sections of our LTS, as well as undertaking mitigative interventions to ensure the pipelines are adequately protected from corrosion and are resilient to the environments in which they are situated. During RIIO-2 we plan to manage the assets in the same way and for this reason, we are not forecasting any large-scale pipeline replacement.

This engineering paper aims to outline the justification for our proposed RIIO-2 LTS investment, detailing our asset management decision making process during which we analyse risk and value and trade-off between different intervention options. It explains the drivers for investment, the inputs and assumptions used in our Cost Benefit Analysis and how our proposed investment benefits our customers and stakeholders.

3. Equipment Summary

The majority of the Local Transmission System (LTS) was constructed between 1960 and 1980, making pipelines our oldest assets still in operation. The LTS consists of 1,300km of high-pressure steel pipelines which are used to transport large volumes of gas over long distances around our network. The pipelines connect Nation Transmission System (NTS) Offtakes, Pressure Reduction Stations and Governors and feed the intermediate, medium and low-pressure networks through cascading pressure cuts across our network footprint. The Local Transmission System provides us with the capability to store large volumes of gas as 'linepack' which is used to meet peak demands throughout the day and cycling of pressures within the pipelines ensures we operate the network efficiently to limit supply constraints on the NTS during peak demand.

The Local Transmission System can be broken down into several sub asset classes:

OLI1 Pipelines – Steel pipelines of varied diameter and wall thickness operating above 7bar but not exceeding 100bar. The OLI1 classification determines that these pipelines can be internally inspected using Pipeline Inspection Gauges (PIGs).

OLI4 Pipelines – Identical in construction and pressure to OLI1 pipelines, however they cannot be inspected internally due to limiting features such as tight bends or smaller pipe diameters.

Pig traps – Above ground installations used to facilitate in-line inspections (OLI1 pipelines only). Equipment consists of launch and receiver pressure vessels, bridle/bypass pipework and isolation valves that can alter the flow of gas to propel the inspection tool through the pipeline.

Overcrossings – Above ground pipework typically installed to traverse man-made infrastructure (roads, railways) or natural obstacles (watercourses, ditches) where below ground installation is not feasible.

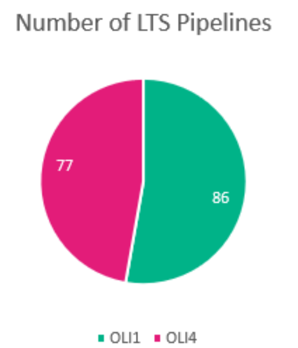
Sleeves – Larger diameter steel pipework installed outside the pipeline when additional protection is required, such as under roads or railways. Post installation each end is sealed to the carrier pipe, the sleeve annulus can be filled with a variation of materials such as grout, epoxy resin, nitrogen or left vacant.

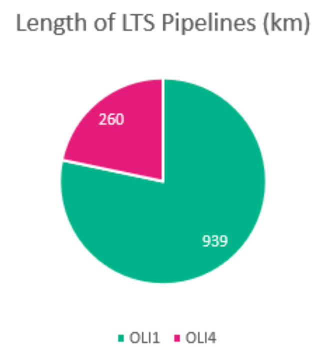
Block Valves – Full-bore line valves that allow safe shut down and isolation of pipeline sections for maintenance activities or in the event of an emergency.

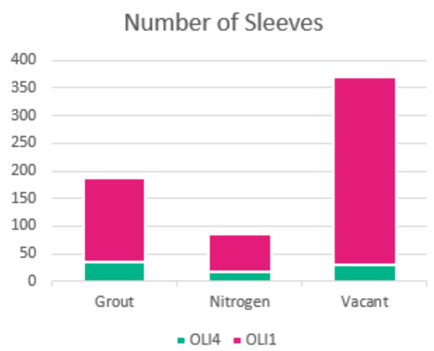
Cathodic Protection – A technique used to reduce the corrosion of metal pipelines. An impressed current system utilises a ground bed and transformer rectifier unit to ensure the pipeline acts as a cathode of an electrochemical reaction, with the ground bed corroding as the anode. Sacrificial anode systems consist of an anode 'bag' bonded to the pipeline, this system is used if impressed current systems pose a risk of electrical interference to other infrastructure e.g. railways.

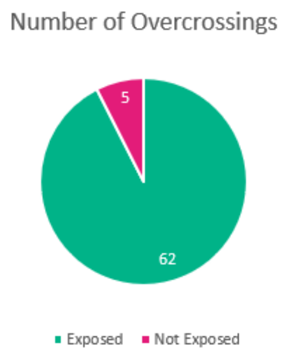
Overcrossings and Sleeves are part of the LTS asset portfolio, however do not form part of this Engineering Justification paper as the investments are covered within 'Other Capex' in accordance with Regulatory Reporting.

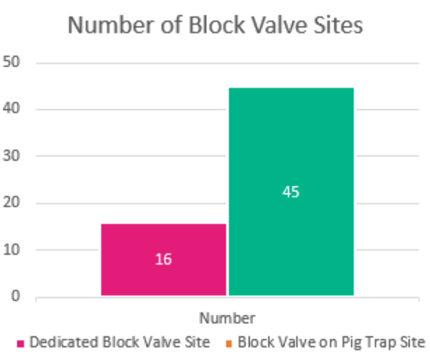
The graphs below provide asset information for the key components of the Local Transmission System:

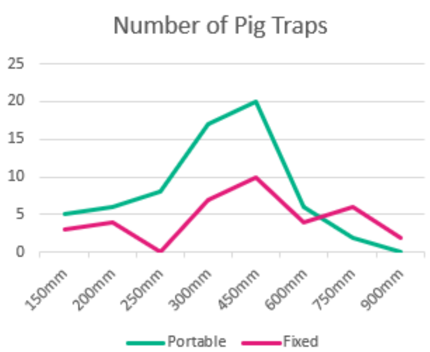








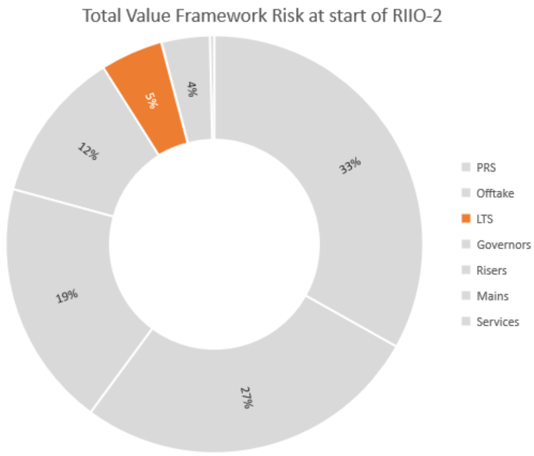




4. Problem Statement

Why are we doing this work and what happens if we do nothing?

We have developed a Value Framework which we use to calculate the risk we hold on our assets as well as to understand how the risk changes over time as our assets deteriorate. LTS Pipelines account for 5% of our total network risk and include four primary asset classes: OLI1 Pipelines (Piggable), OLI4 Pipelines (Non-piggable), Sleeves and Valves. Within our Value Framework we report on risk in five categories: Compliance, Customer, Environmental, Financial and Health & Safety (further explained in Section 6 of this document)



The table below shows the risk profile of our LTS assets at 2021 split by both the LTS asset classes and the risk categories:

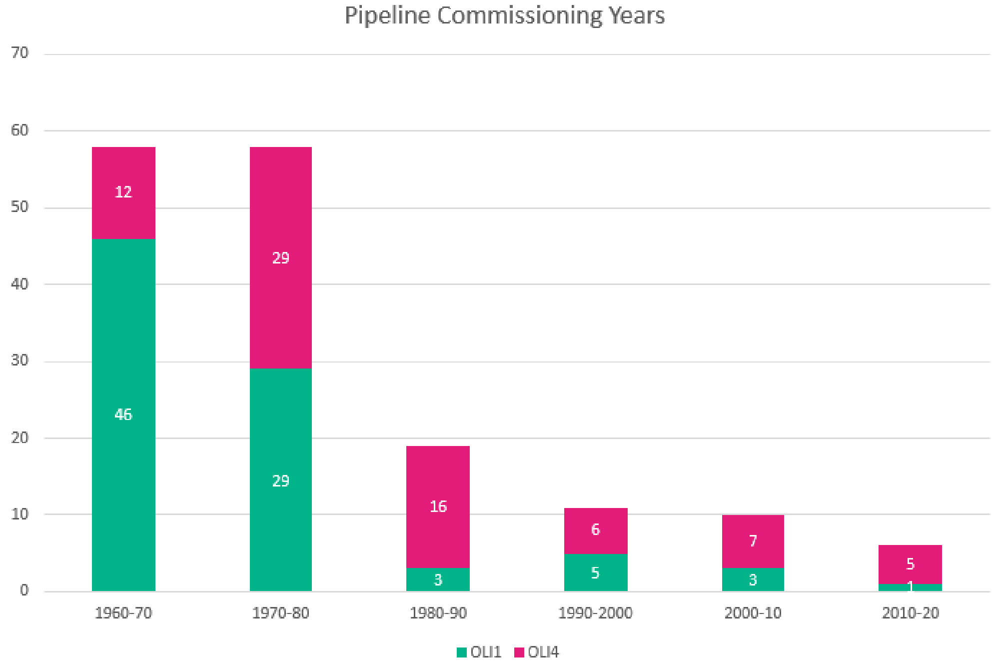
Risk Profile @ 2021 (£)	Compliance Risk	Customer Risk	Environmental Risk	Financial Risk	Health & Safety Risk	Total Risk	Percentage
OLI1 Pipelines	£0.77	£2.80	£0.06	£1.09	£5.48	**£10.20**	86%
OLI4 Pipelines	£0.27	£0.15	£0.02	£0.24	£0.88	**£1.56**	13%
Sleeves	£0.00	£0.01	£0.00	£0.03	£0.03	**£0.07**	1%
Valves	£0.00	£0.00	£0.00	£0.00	£0.00	**£0.00**	0%
LTS Total	**£1.05**	**£2.95**	**£0.08**	**£1.36**	**£6.39**	**£11.83**	**100%**
Percentage	9%	25%	1%	12%	54%	**100%**	-

Of the four asset classes within LTS Pipelines, OLI1 pipelines hold most of the risk at 86%, which is predominantly made up of Health and Safety risk. This is to be expected as OLI1 pipelines constitute a large percentage of LTS assets and through internal inspections have detailed condition assessments undertaken. OLI4 pipelines hold the second highest risk with 13% and as with OLI1 pipelines this is predominantly made up of Health and Safety risk. The discrepancy in risk values between OLI1 and OLI4 pipelines is due to the additional inspection data held for internally inspected pipelines. Through inspection of OLI1 pipelines, any additional defects, though not considered severe or requiring intervention, would increase risk attributed to that asset, this is not the case with OLI4 pipelines, leading to a significant variance in risk held. Sleeves and Valves hold the lowest risk with only 1% combined.

Health and Safety risk is by far the largest risk element within LTS, accounting for over half of the total risk attributed to this asset class. As pipelines are the primary asset within the LTS asset class, it is understandable that most of the risk (99%) be held across OLI1 and OLI4 pipelines. The discrepancy in risk distribution between OLI1 and OLI4 pipelines is due to the variance in asset data available between the asset types. In the instance of OLI1 pipelines, inline inspection provides accurate asset data including any defects, corrosion points or coating disbondment, this additional data provides an accurate assessment of actual asset condition and leads to an increase in modelled risk. Outside of the NARMs model we deem our OLI4 pipelines to be riskier than our OLI1 pipelines due to the fact we know less about them.

Customer risk accounts for the seconds highest total at 25% and is predominantly driven by OLI1 pipelines. Customer risk refers to the risk of a loss of supply incident and considers the number of properties affected, the costs associated with rectification, reconnection, GSOS payments and additional costs encountered during a loss of supply event.

The charts below summarise the age profile of all our pipeline assets. Although on its own age is not a reason to intervene, it can be viewed as a leading indicator to condition and faults. This analysis shows that of our pipeline population, 72% was installed prior to 1980. If age were the only consideration for intervention, a significant proportion of the asset class would require replacement. Targeted investment on protective assets (pipeline coating, cathodic protection etc.) allows us to extend the asset life of pipelines far beyond original design life, utilising existing assets in a means that provides superior value for the customers.



What is the outcome we want to achieve?

From our stakeholder research we know that health and safety, reliability and cost remain our customers number one priority and we are seeing increasing importance placed on the environment. From the risk analysis in Section 4 of this document, for this group of assets, Health and Safety and Customer risk are the two main risk drivers and so our objectives will focus around these rather than compliance, financial or environmental. We also know that our customers expect value for money and that we make the right investment decisions for both our existing and future customers. Therefore, we have devised four objectives covering risk, cost, service and uncertainty.

We want to manage total risk – We know that our customers value safety and reliability as their number one priority. Management of risk for the LTS is achieved through proactive intervention on protective assets such as cathodic protection, extending the asset life of the pipelines. In addition to what our customers want, we want to provide a safe working environment for our operatives and so must reduce these increasing risks. We will aim to maintain risk throughout RIIO-2 however we need to balance this ambition with service and cost constraints.

Objective = to maintain total risk to the same level as the starting position of RIIO-2

We want to ensure cost efficiency – We know that our customers expect us to invest their money as wisely and as efficiently as possible. To do this we need to make sure we extract the maximum value from our existing assets before we install new ones however, we must understand the whole life cost of the decisions we make to ensure we are doing the right thing both now and in the future. To avoid escalating costs in the future we must consider the impact of investment on protective assets and interventions to ensure high value assets are fully utilised.

Objective = to invest no more each year than our average annual RIIO-1 spend (£3.6m)

We will protect our customers from future uncertainty – To ensure the investments we make in RIIO-2 are right for both our existing and future customers and to avoid the risk of asset stranding, we aim for our investments to payback within a 20-year period which is a timeframe in which we expect minimal changes in demand on our network. In addition, we will consider extending the life of existing assets wherever possible, opting to invest in protective interventions to mitigate deterioration of high cost assets.

Objective = to ensure our investments pay back within 20 years

How will we understand if the spend has been successful?

This asset class is covered within the NARMs methodology and we have set a relative risk target on which we will annually report performance against.

In addition to the NARMs target, we would expect to keep the numbers of pipeline defect interventions to remain consistent throughout the price control period.

4.1. Narrative Real-Life Example of Problem

Case Study 1 – Land Instability

Following evidence of land instability at Aislaby, North Yorkshire, we decided to undertake an assessment of the condition of our 19bar pipeline which was running through the affected area. This condition assessment included a review of the current ground conditions, likelihood of further slippage and installation of mechanical strain gauges to monitor the effect of the land instability over time. Following this assessment, it was determined due to the immediate risk to the pipeline that a localised diversion was the best solution to ensure integrity of the asset. A 400m diversion was necessary to move the 6" steel pipeline away from the affected area and thick wall pipe was installed to provide additional protection going forward.

Case Study 2 – River Bed Erosion

Through a routine maintenance inspection of one of our high-pressure pipelines crossing under the River Allen it was determined that erosion of the river bed had exposed a section of the pipeline. Cobbled mats were installed over the pipeline to prevent debris impact and undermining of the pipe. This solution only proved successful for a short period of time. Following multiple severe weather events, these cobble mats have been moved downstream and the pipeline is once again exposed. We are undertaking an expert assessment to determine a robust solution to ensure the long-term integrity of the pipeline.

Case Study 3 – Cathodic Protection Upgrade

Woodland Drive Transformer Rectifier (TR) site acts as one of four installations providing cathodic protection to a 38bar steel pipeline. Adverse readings indicated the TR unit was not effectively impressing current to the pipeline, reducing the level of protection and increasing the risk of corrosion. Remedial works included replacement of the TR unit and associated civils, excavation down to the pipeline and re-bonding. While the pipeline is excavated it is also standard practice to re-coat the exposed section as an additional layer of protection.

4.2. Spend Boundaries

The boundaries of spend proposed by this justification paper include capital investment on the assets listed in Section 3. It includes all necessary project costs such as design, procurement of materials, construction, commissioning and overheads. It does not include any costs associated with third parties such as NRSWA discounts or Network Rail lift and shift agreements and excludes any investment relating to other high-pressure equipment located on our Offtake or PRS sites. Also it does not include investments on Sleeves or Overcrossings as these costs are included within the 'Other Capex' Business Plan Data Tables in accordance with regulatory reporting.

5. Probability of Failure

The Probability of Failure (PoF) is the probability an asset will fail at a given point in time. When justifying our RIIO-2 Capital Investment, our Cost Benefit Analysis uses the NARMS methodology to calculate the PoF of our Local Transmission System assets. The algorithm we use to calculate the PoF for each Failure Mode is unchanged from the NARMS methodology:

PoF = Initial Failure Rate x (exp[(Effective Age – Default Age) x Deterioration Rate]) x Coastal Factor x Housing Factor x FS Factor x Flood Factor

This section discusses how we have used the NARMS methodology to understand the types of failure of Offtake assets as well as the rate of failure, or deterioration, which is a function of the assets attributes and age and condition.

Types of Failure

A failure in an asset is defined as the inability of an asset to fulfil one or more of its intended functions to a standard for performance that is acceptable and gives rise to a detrimental outcome. Failure in this asset class will lead to a gas escape which can be classed as either a leak or a full rupture of the pipeline. In the NARMS methodology these failures have been categorised into the following Failure Modes:

Defects – Faults or areas of weakness identified during inspections.

Corrosion – The gradual destruction of the pipeline by chemical reaction to the environment.

Mechanical Failures – Failings created during the manufacturing or construction process such as weld defects.

General Failures – Failings resulting from operation such as cyclic pressure fatigue or over pressurisation.

Interference – As a result of third-party actions.

Ground Movement – Can be either natural or man-made and may lead to stress on the pipeline.

Capacity – Where a pipeline becomes under sized to meet the demand.

The tables below show the Failure Rates of each primary asset at 2021/22 and 2025/26 without intervention and the rate of failure over the RIIO-2 period:

The table below show the Failure Rates of each primary asset at 2021/22, 2025/26 and 2069/70 to demonstrate the limited impact of deterioration within the GD2 comparative to the full asset life.

Rate of Failure

The Failure Rate for an asset is the frequency of failures at a given point in time, typically measured as the number of failures over a year. In the NARMs models' pipelines are split into subtypes (pipe, sleeve and block valve) at which risk analysis is performed due to the different failure characteristics and paths through the risk models and pipe attributes (above ground, below ground and Cathodic Protection) are captured to act as a risk modifier to the pipeline section they are located on.

We have used the NARMs models to calculate the Failure Rates for each Failure Mode and adjust it by pipe attributes such as condition, age, material, depth, wall thickness etc. The failure models are based on expert elicitation and industry recognised reports (UKOPA, IGEM, PIE and National Grid).

The tables below show the Failure Rates of each primary asset at 2021/22, 2026/27 and 2070/71 without intervention.

Asset Type	Total Expected no. of Failures				
	2021 / 22	2026 / 2027	RIIO-2 Failure Rate	2071 / 71	Long-Term Failure Rate
OLI1	108	108	0	509	509
OLI4	38	67	29	162	133
Sleeves	0	0	0	1	1
Valves	0	0	0	0	0

This demonstrates the limited variance in failure rates over the RIIO-2 period for OLI1 pipelines, sleeves and valves due to the deterioration profile of these asset classes, however it does show the worsening of our OLI4 pipelines over this period. When considering the effects of no intervention over a longer period, we see a significant increase in the expected numbers of failures. Failures do not always lead to a catastrophic event and many can be remedied however they are a leading indicator to asset health. Without intervention, over the long term there may be a need to replace large sections of pipelines earlier than otherwise would have been required had we continued to protect and re-life the assets during RIIO-2.

5.1. Probability of Failure Data Assurance

The data used in our probability of failure calculations comes directly from NARMS. The failure models are based on various industry standard guidelines (see GDN Asset Health Risk Reporting Methodology document) and the failure rates have been statistically derived using actual asset information such as age or material and historic failure data taking into consideration other influencing factors such as weather or temperature.

Our **Core Asset Data** for the LTS includes pipeline ID, diameter, length, material failures and property analysis. It is scored as amber within our Data Improvement Plan for NARMS which means there are some data gaps and assumptions have been applied. There are some inconsistencies between reference IDs and pipeline sectionalisation across data sources.

Our **Asset Health and Failure Data** includes design specification, age, condition, duty, capacity and location and environmental health factors. It is also scored as amber in our Data Improvement Plan. We currently use the industry benchmarked data from PIE as well as TD2 surveys and have undertaken validation of the new failure models with all GDN's to ensure consistent application. We intend to improve the failure models by the time we start RIIO-2.

Our **Financial Data** is scored as green which means our data is robust and complete.

We have submitted an update to our Data Improvement Plan in 2019 which outlines how we intend to improve our data so that the Monetised Risk is reflective of our network assets and current maintenance regimes.

We utilise the data we collect as part of our inspections and maintenance regimes to assess probability of failure and failure rates based on real time asset data. Inspection methodology varies between assets within the LTS asset class, such and inline inspection for OLI1 pipelines or CIPS surveys for OLI4 pipelines, but all provide accurate data on deterioration that can be used to forecast deterioration and failure rates. This has been incorporated into our investment strategies for RIIO-2, ensuring up to date asset data is factored the forecast expenditure for extending asset life or in the event of loss of supply.

6. Consequence of Failure

For each failure there may be a Consequence of Failure (CoF) which can be valued in monetary terms. In the NARMS methodology the CoF is calculated as the Probability of Consequence (PoC) multiplied by the quantity and Cost of Consequence (CoC) and are linked directly to Failure Modes which categorise the asset failure.

Types of Consequence

The NARMS methodology sets out the Consequence Measures for each Failure Mode categorised into four risk groups: Customer Risk, Health & Safety Risk, Carbon Risk and Other Financial Risk. These are detailed below for the Local Transmission System:

Customer Risk

Supply interruptions – Loss of gas supply to our domestic, commercial or industrial customers. Supply interruptions on the LTS may lead to hundreds of thousands of customers affected for a considerable duration.

Health & Safety Risk

Rupture / Leak Ignition – Where the gas escape ignites, creating severe thermal radiation at up to a 1-mile radius.

Non-ignition impacts – Where a release of confined kinetic energy leads to blast damage or a pressure wave.

Carbon Risk

Leak – Where gas escapes through a stable hole whose size is less than the diameter of the pipe.

Rupture – Where gas escapes through an unstable defect which extends during failure to result in a full break of failure an equivalent size to the pipeline.

Loss of gas – Where gas escapes through either a hole or full rupture of the pipeline.

Risk Categories in the NGN Value Framework

We have developed a Value Framework which we use to assess the value of intervention options consistently across asset classes. We use the NARMs methodology as the basis of our Value Framework and are consistent with the Consequence Measures. However, we have recategorised them into five risk groups, not four, so that there is clear distinction between NGN and societal costs and benefits and so that the present values being calculated are correct. The five risk groups within our Value Framework are: Customer Risk, Health & Safety Risk, Environmental Risk, Compliance Risk and Financial Risk.

To derive a monetary value for the Cost of Consequence each Consequence Measure is allocated a monetary value which is multiplied by the quantity of the consequence. The monetary values used within our Value Framework are based on the agreed NARMs assumptions and uses values common across GDN's such as the base price year, industry approved values such as the cost of carbon or the social cost of an injury and values specific to our business such as the cost of maintenance or the cost of loss of supply. The quantities we use are specific to our network such as the number of domestic properties at risk of a supply interruption and have been derived from system data, network analysis or assumptions based on demands, flow and redundancy.

When justifying our RIIO-2 capital programme the monetary value of each Consequence Measure is calculated to determine the benefit or avoided cost of an intervention. Examples include:

Health & Safety Risk – Societal benefits in avoided costs through reductions in the probability of fatality or non-fatality injury. These costs are in accordance with the NARMS methodology.

Customer Risk – Avoided GDN costs through a reduction in costs of supply incidents (loss of supply). These costs have been calculated from historic incidents and the probability and scale of the incidents are based on NARMs models.

Compliance Risk – Avoided GDN costs through a reduction in costs of fines and paying for explosion damage. These costs are in accordance with the NARMS methodology. They have been separated from direct Financial Risk as we consider them highly uncertain and likely significantly under estimated by the values in NARMs, which does not consider reputation, legal and handling costs.

Financial Risk – Avoided GDN costs through reductions in the costs to fix assets on failure and the direct financial cost of the gas leaked from and consumed by our assets. These costs are in accordance with the NARMS methodology.

Environmental Risk – Societal benefits in avoided costs through reductions in the volume of carbon emitted when gas is leaked or consumed. These costs are in accordance with the NARMS methodology and industry approved values.

7. Options Considered

Types of Intervention

There are various ways in which we can intervene on our assets within this asset group. Each intervention has its own merits and drawbacks and the key to effective asset management is to understand how the assets behave and use data and information to ensure the right decisions are made, balancing risk and value to deliver a safe and reliable service for our customers. The interventions available for this asset group are:

Maintenance and repair – Pre-planned inspections and reactive repair works to ensure that performance is optimised and the asset reaches its expected life. An example of this would be installation of a transmission shell around a defect following a planned Pipeline Safety Regulation (PSR) in-line inspection (ILI).

Refurbishment – A proactive planned intervention which includes inspection and replacement or servicing of major components and soft parts with the intention of extending the expected life of the asset. Examples of this include blasting and re-coating an overcrossing to ensure continued protection from the elements, or undertaking a localised diversion around a known issue along the pipeline such as drilling under a river where the pipeline has become exposed from river bed erosion and other remediation is not suitable.

Replacement – Installation of a new asset to replace an existing asset, often because of poor condition, the new asset will of the same capacity but likely be a newer model or design. When considering the LTS this intervention is typically a last resort due to the large expense involved. We are not proposing to replace any high-pressure pipelines in RIIO-2.

Addition – Installation of a new asset on our network to provide extra capacity or increased service levels, usually in response to increased growth, customer requests or a Cost Benefit Analysis assessment. Generally, our LTS pipelines have enough capacity that the only new pipelines we build are for new connections for example, a power station or biomethane connection. However, we have one pipeline with a capacity constraint and are mitigating the risk through contractual and commercial arrangements with large loads in the area, negating the requirement to reinforce a significant length of pipelines at significant cost.

Removal – Where we no longer require an asset, or we can manage our network in a more efficient manner we decommission and dispose of the asset from our network. We are not considering the removal of any high-pressure pipelines within RIIO-2.

Future Energy Pathways

We have gone with the default assumption of current assumed proportion of methane CO2 in natural gas projected forwards due to uncertainties in the potential energy pathways and because this is reflective of the current gas quality legislation. However, we acknowledge that significant changes to gas demand or the allowed methane content of gas, for example due to the blending with or conversion to hydrogen, would impact the benefits of our investments.

Arup conducted analysis on the potential benefits of our H21 Programme (see A13 - NGN RIIO-2 Consumer Value Proposition) that showed 45% of the gas in our network is expected to be Natural, 15% biomethane and the remaining 40% hydrogen by 2040; due to a combination of blending and sub-areas of our networks being fully converted. This is consistent with Net-zero by 2050 aligned with the ENA Navigant report.

We have not explicitly modelled changes in the methane content of gas in our CBAs, as overall gas demand and the change in C02 content of the gas is not expected to be different enough to materially impact the NPV, Payback & Option Ranking of our preferred investment programme. This is because carbon risk benefit accounts for only 1% of the overall risk benefit and this will be reduced by up to 40% by 2040 across all scenarios if the ambitious but realistic ENA Navigant report pathway is chosen. Our chosen programme represents value for money over a 20-year period regardless and is mainly driven by health and safety and customer benefits such as avoiding explosions or loss of supply. The investments also ensure that we are compliant with relevant legislation. Our strategy therefore represents a no regrets investment programme that is consistent with net zero and will deliver value to customers whether a hydrogen or electrification pathway is chosen.

How we make Asset Decisions

We aspire to make conscious decisions that are balanced across our asset portfolio to ensure we can leverage the most value out of our assets. In making conscious decisions we can evaluate the risk we hold as a business and the impact it has on our strategic objectives. Asset management relies on accurate data, during RIIO-1 we have been working to improve our data and the way we capture and store this information, so it can be used to benefit our decision-making process. We use a wide range of asset data, global value such as the cost of carbon and specific values such as the loss of supply, costs from our Unit Cost Database and the NARMs methodology to calculate risk and value. Technical experts analyse options and set constraints within our Decision Support Software which maximises the value of our investments for the given constraints. We use the value measures from our Decision Support Software in Ofgem's Cost Benefit Analysis template to compare the Net Present Value (NPV) of each option against the baseline scenario to determine the most suitable capital programme in RIIO-2. The diagram above is a simplified representation of this process.

Options Analysis

Over time our network assets deteriorate and to ensure we continue to deliver a safe and reliable service, something that our customers have told us they want, we need to invest in our network to reduce the risk of a supply interruptions or health and safety incidents.

We have considered three options which have undergone a review of risk and value to determine the optimal solution for our customers. This analysis uses the NARMs methodology to assess risk and uses global values (e.g. carbon) and NGN specific values (e.g. loss of supply) to assess the benefit of intervention, as detailed earlier in this paper. We have used our Asset Investment Planning system to maximise the value for each option and used the value measure outputs in our Cost Benefit Analysis to compare the net present value of each option against the baseline scenario to determine the most suitable capital programme in RIIO-2.

Additional Loss of Supply avoided costs have been included in our Cost Benefit Analysis that have been derived outside of the NARMs methodology. This is to account for specific, known river bed erosion risks on several pipelines which NARMs does not model. We have used elicited expert engineering judgement for the input values and our Value Framework to forecast avoided cost of intervention.

To demonstrate the impact of assumed impact of loss of supply, sensitivity analysis has been included for the preferred options across all variables contributing to the additional loss of supply risk. Due to NARMs not accurately accounting for loss of supply risk due to pipeline resilience, a network mythology has been applied to provides a more accurate representation of failure. This incorporates several factors to provide monetised risk value, derived from likelihood of failure, likelihood of loos of supply due to failure, customer numbers fed from the crossing, cost per day and duration to provide a total risk value:

$$P_f \times P_c \times N_c \times C \times N_s \times D = T_r$$

In the instance of LTS pipelines these values have been determined through network analysis, known project lead times and loss of supply metrics:

P_f **Probability of Failure:** Variable probability of the asset failing

P_c **Probability of Consequence:** Probability of loss of supply event following asset failure, fixed at 100%.

N_c**Number of Customers:** Value of customers impacted through loss of supply event, fixed at 54,940 customers based on network analysis.

N_s**Number of sites:** Number of sites targeted within the investment strategy, set at 2.

C **Cost per Day:** Cost of per day per customer of loss of supply, set at £300 based on network loss of supply metrics

D **Duration of Loss of Supply**: duration between loss and reconnection of supply, base value of 60 days, 15 included for sensitivity analysis.

Sensitivity analysis has been undertaken within the cost benefit analysis to demonstrate the impact each loss of supply factor has on total risk and payback to capex investment in RIIO-2.

Option	Scenario	Sensitivity	Probability of Failure (PoF) (Pre-investment)	Probability of Failure (PoF) (Post-investment)	Duration of Loss of Supply (days)
Baseline (a)	Baseline	None	0.10%	-	60
Option 1 (a)	Maintain Total Risk (+/- 1%)	None	0.10%	0.001%	60
Option 2 (a)	Maintain Total Risk (+/- 1%)	Post investment PoF	0.10%	0.005%	60
Option 3 (a)	Reduce Total Risk	None	0.10%	0.001%	60
Option 4 (a)	Deferred Investment	None	0.10%	0.001%	60
Baseline (b)	Baseline	Pre-investment PoF	0.05%	-	60
Option 1 (b)	Maintain Total Risk (+/- 1%)	Pre-investment PoF	0.05%	0.001%	60
Baseline (c)	Baseline	Duration of Incident	0.10%	-	30
Option 1 (c)	Maintain Total Risk (+/- 1%)	Duration of Incident	0.10%	0.001%	30
Baseline (d)	Baseline	Pre-investment PoF & duration of incident	0.05%	-	30
Option 1 (d)	Maintain Total Risk (+/- 1%)	Pre-investment PoF & duration of incident	0.05%	0.050%	30

7.1. Option Summaries

The investment options considered for this asset group are listed below:

7.1.1. Baseline – Do nothing / increase risk

This option is used as the baseline for which all other options are measured against. It does not include any capital investment but instead considers the cost of ongoing maintenance activities and repairs on failure. There are no direct benefits accrued under this option however it does include societal impacts associated with leakage, fatality and injury.

7.1.2. Option 1 (a) – Maintain Total Risk (+ / - 1%)

This option aims to maintain from the risk position at the start of RIIO-2. It uses our Decision Support software to optimise the portfolio of assets to deliver the maximum value whilst constraining the system to deliver a risk outcome of between -1% and +1%.

Sensitivity analysis has been undertaken on this option to demonstrate the impact of additional loss of supply factors. The options that make up the analysis are:

- **Option 2 (a) Post investment Probability of Failure** – here we increase the post investment PoF from 0.001% (1 in 100,000 years) to 0.005% (1 in 50,000 years). This increases the probability of asset failure post investment which in effect decreases the impact of intervention

- **Option 1 (b) Pre-investment Probability of Failure** – here we decrease the pre investment PoF from 0.1% (1 in 1,000 years) to 0.05% (1 in 2,000 years). This must have a new Baseline to be able to do this which we call Baseline (b). This decreases the probability of asset failure pre investment which in effect decreases the impact of intervention.

- **Option 1 (c) Duration of Incident** – here we decrease the duration of a Loss of Supply incident from 60 days to 30 days. This must have a new Baseline to be able to do this which we call Baseline (c). This decreases the consequence of asset failure which in effect decreases the impact of intervention.

- **Option 1 (d) Pre-investment Probability of Failure & duration of incident** - here we decrease the pre investment PoF from 0.1% (1 in 1,000 years) to 0.05% (1 in 2,000 years) and we decrease the duration of a Loss of Supply incident from 60 days to 30 days. This must have a new Baseline to be able to do this which we call Baseline (d). This decreases the probability of asset failure pre investment and decreases the consequence of asset failure which in effect decreases the impact of intervention.

7.1.3. Option 3(a) – Reduce Total Risk

This option aims to reduce risk from the risk position at the start of RIIO-2. It uses our Decision Support software to optimise the portfolio of assets to deliver the maximum value whilst constraining the system to deliver a risk outcome of between -5% and 0%.

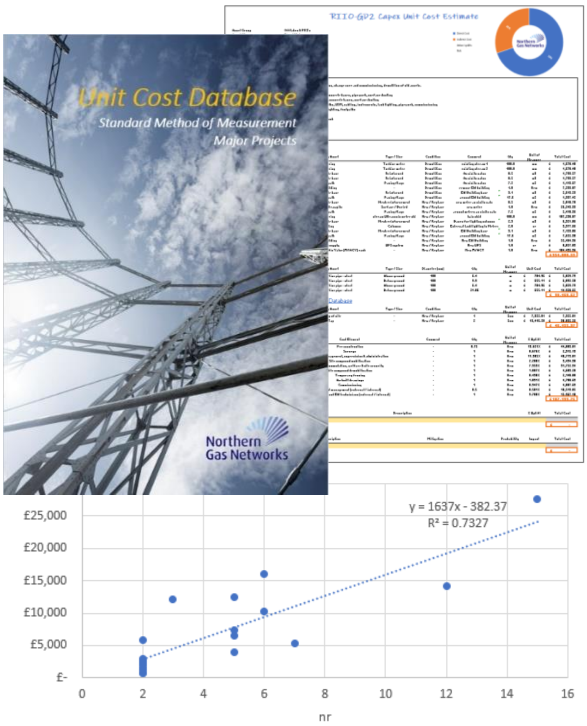
7.1.4. Option 4 (a) – Deferred investment

This option considers the effects of deferring investment until RIIO-3. This option delivers the baseline ‘do nothing / minimum’ solution during RIIO-2 and then undertakes the preferred option between Options 1 and 2 during RIIO-3.

7.2. Options Technical Summary Table

Option	Scenario	Sensitivity	First Year of Spend	Final Year of Spend	Volume of Interventions (RIIO-2)	Design Life (Refurb / Replace)	Total RIIO-2 Capex Cost (£m)
Baseline (a)	Baseline	None	-	-	-	-	-
Option 1 (a)	Maintain Total Risk (+/- 1%)	None	2021/22	2025/26	66	20 / 40 years	£12.1
Option 2 (a)	Maintain Total Risk (+/- 1%)	Post investment PoF	2021/22	2025/26	66	20 / 40 years	£12.1
Option 3 (a)	Reduce Total Risk	None	2021/22	2025/26	161	20 / 40 years	£18.3
Option 4 (a)	Deferred Investment	None	2026/27	2030/31	0	20 / 40 years	£0.0
Baseline (b)	Baseline	Pre-investment PoF	-	-	-	-	-
Option 1 (b)	Maintain Total Risk (+/- 1%)	Pre-investment PoF	2021/22	2025/26	66	20 / 40 years	£12.1
Baseline (c)	Baseline	Duration of Incident	-	-	-	-	-
Option 1 (c)	Maintain Total Risk (+/- 1%)	Duration of Incident	2021/22	2025/26	66	20 / 40 years	£12.1
Baseline (d)	Baseline	Pre-investment PoF & duration of incident	-	-	-	-	-
Option 1 (d)	Maintain Total Risk (+/- 1%)	Pre-investment PoF & duration of incident	2021/22	2025/26	66	20 / 40 years	£12.1

7.3. Options Cost Summary Table



The unit costs used in both our Cost Benefit Analysis and capital expenditure forecasts have been derived using our Unit Cost Database (UCD) to provide confidence in their accuracy, consistency and credibility. We have developed our UCD during RIIO-1 and is a set of processes and systems used to allocate the costs of our capital projects to assets. We have developed a standard method of measurement which is a measurement rule book which details what costs should be included and excluded in a assets costs as well as detailing how the asset should be measured. These rules ensure that costs are allocated accurately and consistently to assets and the measures (e.g. m^2) capture the asset quantity delivered. All our capital project costs in RIIO-1 have been input into this database which has allowed for a significant number of data points for each asset providing greater cost confidence. The UCD uses these data points to derive cost curve models which provide a cost trend for a given yardstick and allows for an accurate cost estimate for a given asset based on actual historic costs. A cost estimating template is used to build up the individual elements of an asset intervention such as the indirect costs associated with construction projects such as mobilisation, site set up and welfare, and direct costs such as civil, mechanical and E&I costs associated with the intervention.

The table below shows our unit costs in 2018/19 prices which have been used in our CBA options analysis and the final proposed RIIO-2 capital expenditure forecasts.

Asset Class	Unit Cost (£m)	Inclusions / Exclusions
OLI 4 to OLI 1 Conversion	£0.33	**Unit costs include:** design, procurement, construction, commissioning and NGN overheads. Works include installation of new Pig Trap, including plug valves and all associated fittings, pipe stands, lifting eyes etc, concrete base, small bore equalisation bypass (rider) pipework, lift and position and bolt down, modifications to existing pipework. **Unit costs exclude:** In-line inspection and remedial works.
River Erosion Remediation	£0.48	**Unit costs include:** design, procurement, construction, commissioning and NGN overheads. Works include various methods of remediation including installation of concrete cobbled mats, sand bags, river bank stabilisation, river bed cut and fill etc. **Unit costs exclude:** Works required to any Above Ground Installations (AGIs).
Resilience Diversions	£3.05	**Unit costs include:** design, procurement, construction, commissioning and NGN overheads. Includes all works necessary for an HDD, pipe jacking or open cut diversion including; excavation, laying of pipe and fittings, bed and surround, pressure test, welding, phased array, and reinstatement back to original surface. **Unit costs exclude:** Works required to any Above Ground Installations (AGIs).
Block Valves	£0.06	**Unit costs include:** design, procurement, construction, commissioning and NGN overheads. Works include any modifications to the valve pit, handrailing, or covers. Includes alterations to footpaths and access tracks. **Unit costs exclude:** Mechanical works to the valve or pipeline
Cathodic Protection (non-excavation)	£0.03	**Unit costs include:** design, procurement, construction, commissioning and NGN overheads. Works include replacement of a transformer rectifier unit and associated civils, excavation to pipework and rebonding and connection to electrical supply. Recoating of exposed pipework where necessary. Includes post CP survey. **Unit costs exclude:** Alterations to power supplies
Cathodic Protection (excavation)	£0.05	

8. Business Case Outline and Discussion

8.1. Key Business Case Drivers Description

The table below shows the results of each option compared to the objectives discussed in Section 4 of this document. The following narrative then discusses the strengths and weaknesses of each option.

Option	Description	Sensitivity	RIIO-2 Primary Interventions		Total NPV Compared to Baseline (£m)	Objectives			
			Replace	Refurb		Total Risk change at 2026	Total Risk change at 2070	RIIO-2 Annual Capex Cost (£m)	Payback (years)
Baseline (a)	Baseline	None	0	0	£0.0	2%	137%	£0.0	0
Option 1 (a)	Maintain Total Risk (+/- 1%)	None	0	66	£128.4	1%	21%	£2.4	8
Option 2 (a)	Maintain Total Risk (+/- 1%)	Post investment PoF	0	66	£126.0	1%	21%	£2.4	8
Option 3 (a)	Reduce Total Risk	None	0	161	£83.8	0%	82%	£3.7	10
Option 4 (a)	Deferred Investment	None	0	0	£34.2	2%	69%	£0.0	34
Baseline (b)	Baseline	Pre-investment PoF	0	0	£0.0	2%	137%	£0.0	0
Option 1 (b)	Maintain Total Risk (+/- 1%)	Pre-investment PoF	0	66	£96.0	1%	21%	£2.4	12
Baseline (c)	Baseline	Duration of Incident	0	0	£0.0	2%	137%	£0.0	0
Option 1 (c)	Maintain Total Risk (+/- 1%)	Duration of Incident	0	66	£96.4	1%	21%	£2.4	12
Baseline (d)	Baseline	Pre-investment PoF & duration of incident	0	0	£0.0	2%	137%	£0.0	0
Option 1 (d)	Maintain Total Risk (+/- 1%)	Pre-investment PoF & duration of incident	0	66	£80.2	1%	21%	£2.4	21

Baseline (Do Nothing)

This option increases LTS risk by 2% and proposes no capital investment in RIIO-2. By not investing in LTS assets deterioration of pipelines will increase beyond the possibility of repair or remediation, leading to large scale replacement of our transmission pipelines. Effective asset management of high value assets, such as pipelines, is to extend asset life through interventions designed to extend the deterioration curve, maximising the value realised through the assets. The baseline option is not viable as it severely limits the utilisation of high value assets and would lead to the necessity of large-scale pipelines replacement at significant cost. This is evident in the Total Risk change at 2070 which shows risk increasing by 137% over the 50-year period.

Option 1 (a) - Maintain Total Risk (+/- 1%)

Risk increases by 1% against the 2021 baseline value, the increase is primarily due to increase of 2% in health and safety risk. The marginal increase is due to the impact of intervention on risk held within the LTS asset class. Interventions are typically associated with protective assets and therefore do not provide a significant initial risk reduction, rather extend the deterioration curve and provide benefit later in the asset's life. If we consider the risk change over a 50 year period, we can see risk increase by 21%. This is the lowest risk increase of all options which shows that over the longer term this option delivers better on risk than all others.

This option has a forecast expenditure in RIIO-2 of £12.1m and when added to the Third-Party Diversions of £2.1m the total annual average investment equates to £2.8m. This is a 22% reduction when compared to RIIO-1 and therefore meets our second objective on cost. When compared to Option 3 (a), this option has a smaller capital investment however when compared to Option 4 (a) which defers investment to RIIO-3, this option obviously has a higher capital investment.

This investment delivers the most benefit of all options and represents the best value for our customers with a Total NPV compared to the baseline of £128m. It also offers the fastest payback of all options of 8 years, which meets our third objective.

Option 3 (a) - Reduce Total Risk

Risk is held stationary to the 2021 position which has been determined through our decision support software as the maximum feasible risk reduction that can be achieved through intervention scenarios. If we consider the risk change over a 50 year period, we can see risk increase by 82%. This is considerably more than Option 1 (a) which invests less than this option. This shows that significant investments on these assets is not the best way of managing them and rather a targeted approach to maintenance, refurbishment and re-life is a more effective asset management strategy.

This option has a forecast expenditure in RIIO-2 of £18.3m, the highest capital investment of all the options. When added to the Third-Party Diversions of £2.1m the total equates to an annual average investment of £4.1m. This equates to a 14% uplift on investment compared to RIIO-1 and so fails to meet our second objective.

The option has a lower total Net Present Value when compared to the baseline than Option 1 (a) and therefore does not deliver better value for our customers.

Option 4 (a) - Deferred Investment

Deferring investment to RIIO-3 proves the same risk profile as the baseline scenario, an increase of 2% over RIIO-2.

This option considers zero investment in RIIO-2 and is therefore is the lowest capital cost option considered. However, when looking at the total expenditure over 50 years it is Option 1 (a) which has a slightly lower total proving that delaying investment only increases maintenance costs and financial risks in the future.

Deferment to RIIO-3 has a lower total Net Present Value when compared to the baseline than all options and therefore does not deliver better value for our customers. This scenario demonstrates that to delay investment will reduce costs in the short term, but the benefits investment could have gained are lost. The pay back for this option is the slowest of all options at 38 years, due to no benefits being delivered until the first year of RIIO-3.

Conclusion

Due to the slow initial deterioration of the primary LTS assets the forecast risk increase without investment through the RIIO-2 period is negligible. To only consider risk change over this period however is not reflective of the reality in managing these assets. Failure to invest in protective measures and secondary LTS assets may not result in a large risk variance within the RIIO-2 price review period but will lead to the deterioration of the pipeline infrastructure beyond the possibility of repair, necessitating replacement to ensure safe operation. As the LTS is considered a long life, high value asset, the most effective asset management strategy is maximising the asset utilisation for as long as the pipeline integrity can be maintained, investing in protective measures such as cathodic protection and pipeline remediation allows this.

Our preferred option is Option 1 (a) as it allows us to maintain risk to within 1% for a 22% reduction in spend when compared to RIIO-1. This option has the highest NPV of all options proving that this option best delivers for our customers. It also provides the lowest risk increase over 50 years which proves that this option provides the best long-term strategy for this asset class.

Sensitivity Analysis on our Preferred Option

In calculating the Additional Loss of Supply avoided costs that have been derived outside of the NARMs methodology due to known pipeline resilience projects that are required in RIIO-2, we have applied several assumptions. Sensitivity analysis has been completed on these assumptions, for the preferred option only, to demonstrate the impact of each variable if a lower tolerance is used. The outcome of each scenario sensitivity is detailed below.

Option 2 (a) – Sensitivity on the Post investment PoF

Total NPV reduces by only 2% and payback is not affected. We can conclude that the post investment Probability of Failure is not sensitive to the results of our Cost Benefit Analysis.

Option 1 (b) – Sensitivity on the Pre investment PoF

Total NPV is reduced from £126m to £96m however remains higher than either the Option 3 (a) to reduce total risk or Option 4 (a) to defer investment. Payback takes two years longer than before as it moves from 10 years to 12. We can conclude from this that the pre investment Probability of Failure has more of an impact than the pre investment Probability of Failure however it does not change the outcome of the Cost Benefit Analysis enough for another option to be preferred.

Option 1 (c) – Sensitivity on the Duration of Incident

Much like Option 1 (b) the Total NPV is reduced from £126m to £96m however remains higher than either the Option 3 (a) to reduce total risk or Option 4 (a) to defer investment. Payback takes two years longer than before as it moves from 10 years to 12. We can conclude from this that the pre investment Probability of Failure has more of an impact than the pre investment Probability of Failure however it does not change the outcome of the Cost Benefit Analysis enough for another option to be preferred.

Option 1 (d) – Sensitivity on the Pre-Investment PoF and the Duration of Incident

This option considers applying Option 1 (b) and 1 (c) sensitivities however does not consider Option 2 (a) as we determined the results were not sensitive to this input. This option is an extreme worse case and as a result Total NPV is reduced from £126m to £80m. Even in this situation where every variable input is lowered the investment still delivers a good total NPV and our customers would still get a return on their investment well within the life of the intervention.

8.2. Business Case Summary

The table below details the headline business case metrics to allow a high-level comparison of the options:

Option	Scenario	Sensitivity	Total RIIO-2 Expenditure (£m)	Total RIIO-2 Capital Expenditure (£m)	NPVs based on Payback periods (relative to baseline, £m)						Preferred Option
					2030	2035	2040	2050	2060	2070	
Baseline (a)	Baseline	None	£15.4	£0.0	-	-	-	-	-	-	✗
Option 1 (a)	Maintain Total Risk (+/- 1%)	None	£27.5	£12.1	£3.2	£11.4	£19.4	£36.5	£65.4	£128.4	✓
Option 2 (a)	Maintain Total Risk (+/- 1%)	Post investment PoF	£27.5	£12.1	£2.8	£10.6	£18.4	£34.9	£63.4	£126.0	✗
Option 3 (a)	Reduce Total Risk	None	£33.7	£18.3	£0.0	£8.1	£16.0	£31.2	£50.1	£83.8	✗
Option 4 (a)	Deferred Investment	None	£15.5	£0.0	-£13.2	-£14.3	-£13.5	-£9.2	£2.9	£34.2	✗
Baseline (b)	Baseline	Pre-investment PoF	£15.4	£0.0	-	-	-	-	-	-	✗
Option 1 (b)	Maintain Total Risk (+/- 1%)	Pre-investment PoF	£27.5	£12.1	-£2.3	£1.7	£5.8	£15.8	£38.6	£96.0	✗
Baseline (c)	Baseline	Duration of Incident	£15.4	£0.0	-	-	-	-	-	-	✗
Option 1 (c)	Maintain Total Risk (+/- 1%)	Duration of Incident	£27.5	£12.1	-£2.2	£1.8	£6.0	£16.0	£38.9	£96.4	✗
Baseline (d)	Baseline	Pre-investment PoF & duration of incident	£15.4	£0.0	-	-	-	-	-	-	✗
Option 1 (d)	Maintain Total Risk (+/- 1%)	Pre-investment PoF & duration of incident	£27.5	£12.1	-£5.0	-£3.1	-£0.8	£5.7	£25.5	£80.2	✗

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

The preferred option is Option 1 (a) – Maintain Total Risk

9.2. Asset Health Spend Profile

The table below details the preferred option's workload and expenditure during RIIO-2:

Asset Class	Intervention	Workload	Unit	Capital Expenditure (£m) 2018/19 prices						
				21/22	22/23	23/24	24/25	25/26	Total	Average
OLI4 to OLI1 Conversion	Refurb	5	assets	£0.3	£0.3	£0.5	£0.3	£0.3	**£1.8**	**£0.4**
Pipeline Resilience	Refurb	6	assets	£0.0	£1.5	£1.5	£1.5	£3.4	**£8.0**	**£1.6**
Block Valves	Refurb	14	assets	£0.2	£0.2	£0.2	£0.2	£0.1	**£0.8**	**£0.2**
Cathodic Protection	Refurb	40	assets	£0.3	£0.3	£0.3	£0.3	£0.3	**£1.5**	**£0.3**
CBA Subtotal	-	-	-	**£0.8**	**£2.3**	**£2.5**	**£2.3**	**£4.2**	**£12.1**	**£2.4**
Third Party Diversions	Refurb	1	sum	£0.0	£0.4	£0.4	£0.4	£0.8	**£2.1**	**£0.4**
Price Control Deliverable	Refurb	1	sum	£2.4	£5.5	£6.9	£3.8	£0.9	**£19.5**	**£3.9**
Third Party Subtotal	-	-	-	**£2.4**	**£5.9**	**£7.3**	**£4.2**	**£1.7**	**£21.5**	**£4.3**
Total	-	-	-	**£3.2**	**£8.2**	**£9.8**	**£6.5**	**£5.9**	**£33.6**	**£6.7**

The total forecast capital expenditure for the Local Transmission System has been included within this Cost Benefit Analysis and can be referenced back to the following documents:

- RIIO-2 Business Plan – Table 6.3
- RIIO-2 Business Plan Data Tables – Table 3.01
- A23.C - NGN RIIO-2 Investment Decision Pack – Local Transmission System - CBA

The LTS asset class is comparatively small when considered against other asset classes, and the preferred scenario within the RIIO-2 investment strategy targets protective interventions only, limiting the risk of variability of failure rate and unit cost. Controls and processes have been put in place throughout the development of our RIIO-2 Capital Expenditure programme to ensure we mitigate both our customer's and our own exposure to risk, both in terms of the options considered and our approach to management of our high value assets. In undertaking a minimal cost approach, protective asset intervention as opposed to pipeline replacement, the scenario is a low risk approach due to the strategy of investment proposed. Any variability in unit cost or rate of failure within the types on intervention would not have a significant impact on total investment.

Workload and unit cost risks are inherent when forecasting failure rates and intervention solutions for large populations of assets. The bullet points below outline the steps we have undertaken to ensure we limit these risks to provide an accurate capital programme.

Workload Risk Mitigations

- We have used the NARMs methodology to calculate individual asset's Probability of Failure which uses asset attributes to determine specific failure rates.
- We have undertaken recent surveys during 2019 on our pipelines to determine the sections at risk. This latest information has been used within our modelling.
- We have considered various options including workload volumes and chosen the solution which provides our customers with the most appropriate balance between cost, risk and service.
- We have sense checked our preferred option against other asset data such as age, condition surveys, fault trends.
- We have shared our preferred strategy with our businesses industry experts to sense check volumes and costs
- Our RIIO-2 strategy is comparable with our RIIO-1 strategy and so we have a proven record we can manage our assets in this way.

Unit Cost Risk Mitigations

- We have used our Unit Cost Database to determine our unit costs. This database holds c.17,000 datapoints which have been collated in a consistent way to ensure our historic costs accurately inform our RIIO-2 unit costs.
- We are not planning to undertake new work activities. We have undertaken all interventions previously and have historic costs allocated within our Unit Cost Database.
- We have benchmarked our unit costs against other GDN's to ensure our unit costs are efficient.
- We have experienced Project Managers who have a proven track record of delivering this type of work in the past and we have a commercial team of quantity surveyors who are focussed on delivering value for money.