Cadent
Your Gas Network

Appendix 09.09

LTS Pipelines (Piggable and Non-Piggable)

RIIO-2 Spend : XXXX

Investment Decision Pack Overview

This Asset Health Engineering Justification Framework outlines the scope, costs and benefits for our proposals. We have prepared this Engineering Justification Paper (EJP) and a Cost Benefit Analysis (CBA) for these assets.

We have 4,985 km of high-pressure (HP) pipelines which operate between 7 and 75 Bar. Failure of these pipelines can have significant consequences for safety and interruptions to supply. In addition to our general obligation to maintain the safety and reliability of the network, our approach to managing and investing in these assets must allow us to comply with specific obligations under the PSSR and Health and Safety and Work Act 1974. In short, success for these assets is measured by ensuring no compliance failures.

Piggable and non-piggable pipelines have been grouped within this document as the assets themselves are not materially different; it is the survey mechanisms which differ.

We will need to continue to invest in RIIO-2 to resolve issues associated with asset ageing, external interference, susceptibility to corrosion or ground movement. Without investment, these issues will impede our ability to secure ongoing compliance.

We considered a number of initial options for investment: replace on failure, repair on failure, pre-emptively replace, pre-emptively repair, and do nothing. We rejected most of these because they either do not allow us to meet our obligations or they are prohibitively expensive.

Only one option feasibly delivers the required outcomes: pre-emptive repair. This option involves the pre-emptive repair or remediation of any pipeline-integrity risks before they cause any external impacts (full failure).

To assess this option further, we undertook CBA on seven different investment options to evaluate the proposed engineering solution. These investment options each imply a different level of expenditure, risk, and customer benefit. Our analysis indicates that none of the investment options has a positive NPV using benefist (and deterioration rates) within the industery agreed NOMs model. This result is a reflection of weaknesses in the modelling approach rather than an absence of positive benefits in the real world.

The chosen option delivers the *minimum level of investment required to meet legal obligations* and has the highest NPV (though still negative). This scenario effectively continues the approach adopted for managing these assets in RIIO-1, which is to use an **engineering assessment approach** to adjust inspection rates and invest in timely interventions to avoid asset failures. Options which involve going beyond this, for example, either investing to maintain stable monetised risk or investing to maximise whole-life net benefit *and* maintain stable monetised risk, are more expensive and have even lower NPVs.

Our chosen option is therefore to continue the engineering assessment approach for RIIO-2. This requires XXXX of expenditure in RIIO-2 .

Summary of preferred option	XXXX
RIIO-2 Expenditure	XXXX
Project NPV (based on NOMS model)	XXXX

Material Changes Since October Submission

The document price base has been updated 2018/19.

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2. Introduction

This document provides the investment case methodology for interventions required on our Local Transmission System (LTS) pipelines to achieve our required outcomes and meet our legal obligations.

The scope of this document is high pressure (HP) pipelines. We have 4,985 km of HP pipelines which operate between 7 and 75 Bar.

This case excludes pig traps, sleeves and pipeline protection, major projects and diversions, marker post, and ground movement.

To understand the investment needs of these assets, we have used a robust assessment framework. This recognises that these assets have a very low probability of full failure but can have significant consequences should they fail. Our approach to assessing investment has involved a review of the inspections and interventions to manage these risks and aligns with strict regulatory requirements.

This document is set out in line with Ofgem's requirements.

The approach adopted reflects compliance with external codes and company management procedures and reflects best practice. Our costs are competitively tendered and are efficient, and our proposed investments provide value for money and align with regulatory and stakeholder requirements. We are therefore confident we have identified the right mix of interventions and investment for this asset type.

3. Equipment Summary

Data sources

The pipeline asset base data requirements have been sourced from our Pressure System Database (PSDB), which is the repository of our safety data, to demonstrate compliance with the Pressure System Safety Regulations 2000 (PSSR).

Asset types

Gas is delivered into the Local Transmission System (LTS) of each of our networks via offtakes from the National Transmission System (NTS). Gas under high pressure in the LTS is moved around to feed our distribution networks and reduced to lower pressures before being delivered to customers.

The LTS is also used to provide diurnal storage via 'linepack' (compression of gas within the pipeline) to support the management of variations in daily demand.

Our 4,985 km of HP pipelines can be differentiated into those that are internally inspected using specialist tools, and those that cannot be internally inspected (due to either mechanical features or unsupportive flow conditions) and which are subject to an overland survey regime. These are known as OLI1 (piggable) and OLI4 (non-piggable) pipelines respectively.

Investment history

We have a rolling programme of inspections which are driven by safety regulation requirements. During RIIO-1, we have invested to incrementally increase the proportion of piggable pipelines.

Asset profile

A summary of the HP pipeline lengths (km) by network is shown in the following plot and table.

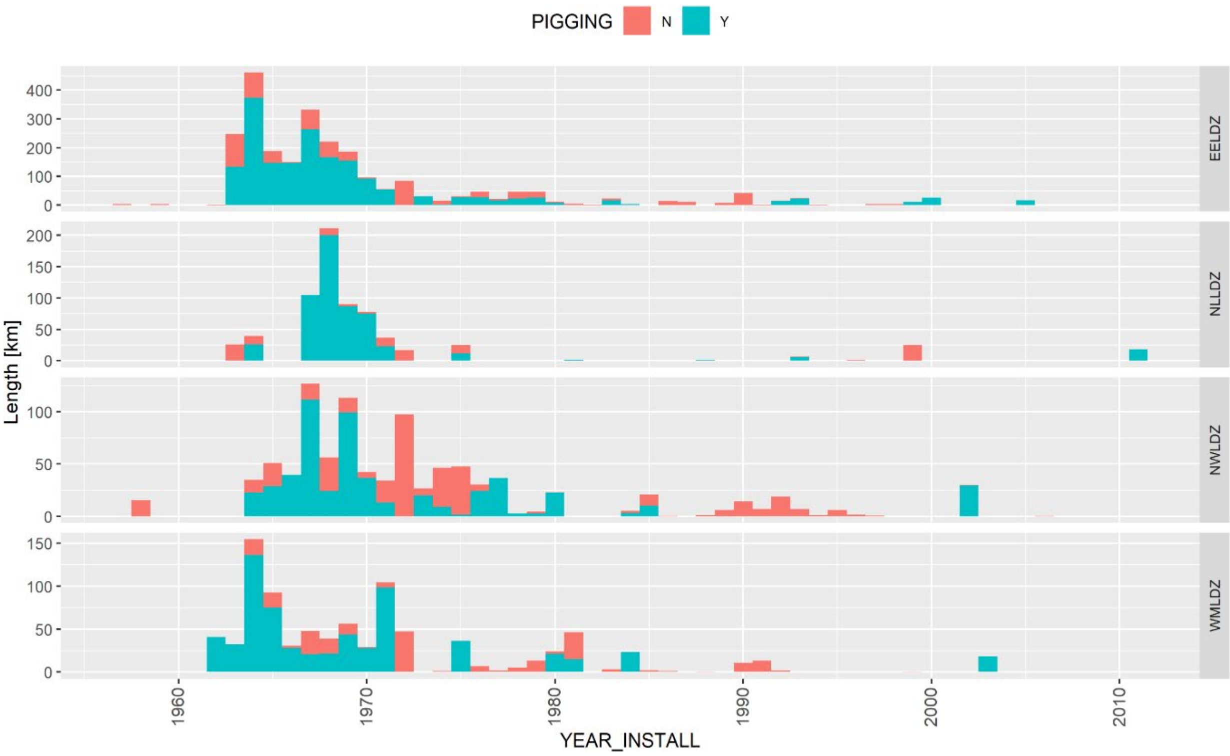

Figure 1: Length by install year (most of Cadent's pipes were installed in the early 1960s to mid-1970s)

The plot of install lengths shows that most of Cadent's pipes were installed in the early 1960s to mid-1970s with some minor additions scattered across networks up to the present. The majority of the LTS is piggable (blue).

	HP (km)	Lengths of pipeline that use OLI 1 inspection method (piggable)	Lengths of pipeline that use OLI4 (none piggable)
East of England	2,472	1,882	590
North London	694	592	102
North West	936	788	148
West Midlands	883	759	124
Cadent Total	**4,985**	**4,021**	**964**

Table 1: HP pipeline length by network, showing inspection method

We have a good understanding of our pipelines asset base through regular inspection.

4. Problem Statement

The assets require investment to resolve:

- Asset ageing factors
- External interference and susceptibility to corrosion or ground movement

Our base case supply-demand scenario for this investment case is our peak 1-in-20 year demand to comply with our licence obligations. The variability of demand in future forecasts is small; our demand would have to change significantly to allow us to consider decommissioning options for our deteriorating pipelines, rather than ongoing repair. We do not see the need to remediate our pipelines being materially impacted by the supply-demand scenario. We have therefore only considered one scenario within this investment case.

Asset ageing

As our assets age, they may become more susceptible to incremental deterioration, which in turn affects the ability of these assets to meet safety and reliability requirements.

External interference – third party or ground movement

Pipelines may be subject to damage by external parties or from ground movement. These can impact on the structural integrity of the pipeline (e.g. from dents, metal loss due to gouging, or damage to external protective coating systems or fittings).

Investment drivers

Two key drivers are discussed below: Safety (legislative) and interruptions to supply. In addition, we recognise the importance of investment plans that provide value for money. It is imperative we provide the most efficient and cost-effective long-term solution to minimise customer bills.

Safety (Legislative)

We invest to ensure continued compliance with the Pressure System Safety Regulations 2000 (PSSR), Pipeline Safety Regulations 1996 (PSR) and other legislative requirements. Our LTS transports large volumes of gas at very high pressure, failure would have significant safety implications.

Cadent Gas has an obligation to comply with PSSR. The aim of PSSR is to prevent serious injury from the hazard of stored energy as a result of the failure of a pressure system or one of its component parts.

Our proposed investment is in relation to compliance with Regulation 9 (Examination in accordance with the written scheme) together with interventions required in relation Regulation 12 (Maintenance).

Where an inspection identifies a fault, then these are further inspected, assessed and then repaired in accordance with the management procedure T/PM/P/11 where the pipeline diameter is greater than 150mm nominal diameter (i.e. most situations) or in accordance with the equivalent procedure T/PM/P/20 for smaller diameter pipelines.

We are also obliged to comply with the Pipeline Safety Regulations 1996 (PSR). PSR is specific legislation for those operating pipelines and requires us to demonstrate that all hazards that have the potential to cause a major accident have been identified, that the risks associated with the hazards have been evaluated, that the safety management system is adequate, and that it is audited to ensure that associated risks to members of the public and employees are as low as reasonably practicable.

Interruptions to supply

A second driver for investment in pipelines is to manage or mitigate the risk of capacity constraints and ultimately avoid supply interruptions. A pipeline with a fault may not be able to be run at its normal operating pressure, reducing the volume of gas it can transport. Pipeline failures can result in the loss of supply to downstream domestic, commercial or industrial customers. We must operate our pipes safely – this is the primary driver. Safety interventions deliver a reliable supply.

Impact of no investment

We need to invest in these assets to ensure a continuous and safe supply of gas to our customers.

In order to understand the investment requirements fully, the useful starting point for our analyses has been to consider the impact of no investment on these assets (i.e. what happens if we do not invest). This is the situation whereby we continue to meet our legal obligations to inspect these assets but interventions to deal with any defects or arising issues are not undertaken. We have developed failure rates and estimates of the consequence of failure to understand this position, as summarised in Sections 5 and 6.

Under the 'no investment' scenario (shown below), the failure and risk from these assets rise, albeit slowly given the typically long deterioration timescales for these assets associated with corrosion growth, which is inhibited by asset protection measures (external pipe coatings, and cathodic protection systems). In such a scenario, over RIIO-2 there may be limited deterioration due to corrosion growth in these assets with no investment. However, this deterioration can never be reversed without full replacement – an expensive option. Although the probability of failure will remain low, very significant consequences remain should they fail. Our investment is directed to manage the risk of these consequences and the related risks associated with HSE enforcement for non-compliance. It should also be noted that allowing deterioration across the asset base may lead to the need for replacement, a significantly more expensive option than the current refurbishment and repair approach.

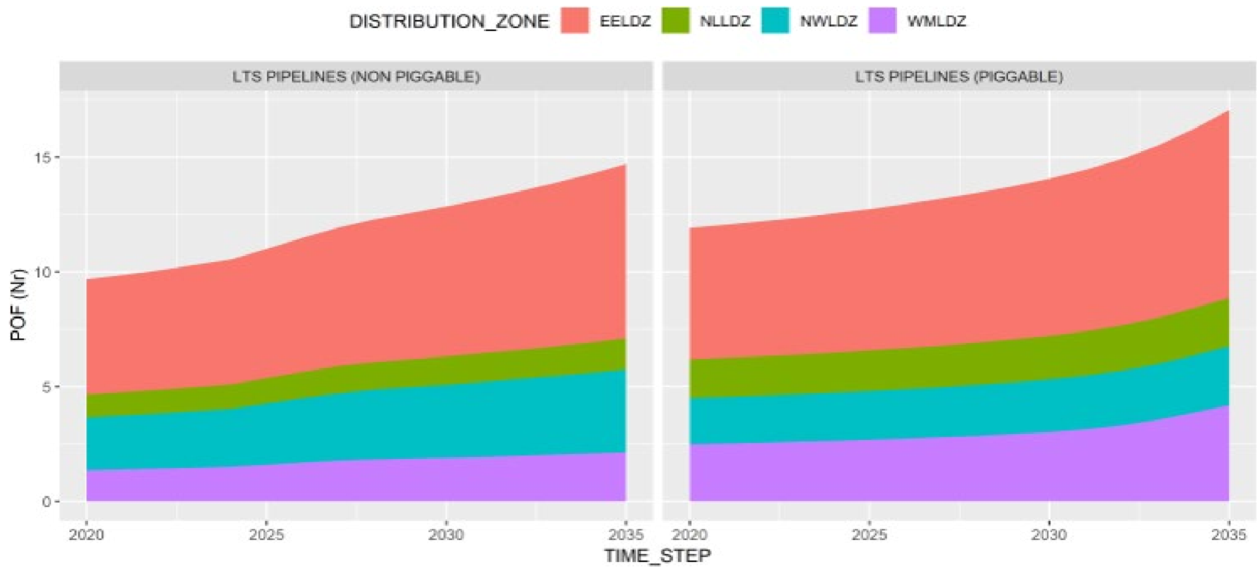

Figure 2: Probability of failure (POF) over time for reactive only (no investment) split by asset category coloured by distribution zone

The figure above shows an increasing, slow trend of failures across all networks, with 'piggable' showing a greater absolute value, due to having a longer total length.

Required outcomes

We consider the do-nothing position to be unacceptable. The do-nothing position does not ensure that we comply with PSSR or indeed with our fundamental safety obligations to the public, and our employees, associated with the Health and Safety at Work Act 1974.

Customers and stakeholders have consistently told us that worsening levels of reliability and network security are not in line with their preferences.

In summary, the required outcomes for this investment is a safe and reliable system. Success is measured by ensuring no compliance failures.

We will consider our investment plans to be acceptable and appropriate, if and only if these outcomes are met.

4.1. Narrative Real-Life Example of Problem

An example is shown below. This is a high-pressure pipeline in Kings Lynn.

The pipeline was damaged by a third party undertaking ground clearance works. While the failure is due to third-party interference, the impact of the damage was similar to that if corrosion of a small-bore fitting had caused leakage.

The location of the pipeline is shown by the ‘X’ and is parallel to a railway. Although there was no explosion, the zone around the pipeline affected by the damage affected the railway and businesses in the vicinity. It was necessary to install a 120m high-pressure steel bypass around the point of damage so as to ensure safe working zones. The excavations for the flow-stopping operation on either side of the location were about 6.5x3x2 m in size.

Figure 3: Kings Lynn example

The approximate cost of this incident was XXXX. It took one month to mobilise all resources and effect a full repair. During this time, in the run-up to Christmas, the supply to approximately 25k customers was at risk of very significant interruption and disruption.

Additional examples of failures at different sites are shown below:

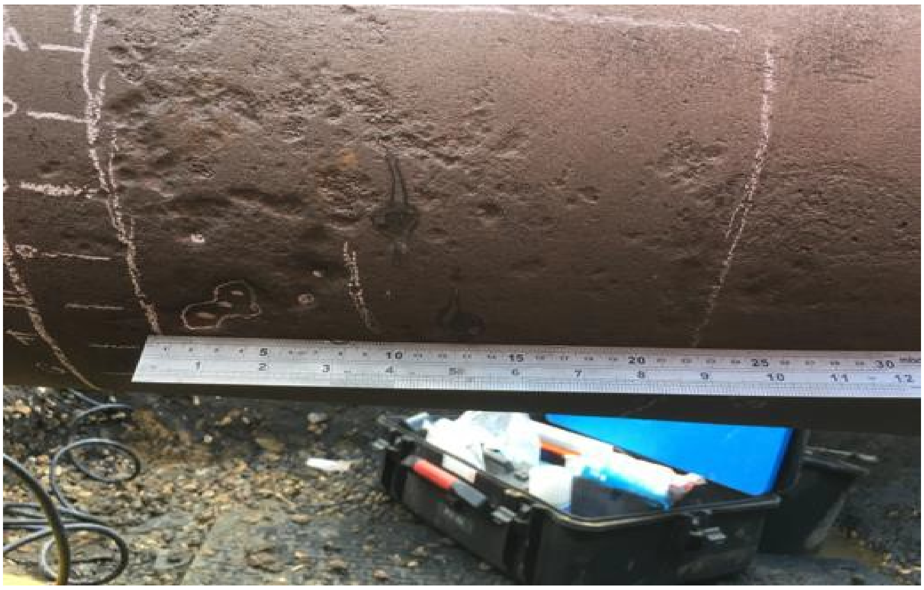

Figure 4: Corrosion example

Figure 5: Corrosion example with repair clamp

4.2. Spend Boundaries

This case excludes pig traps, sleeves and pipeline protection, major projects and diversions, marker post, cathodic protection and work occasioned by ground movement.

Following assessment and prioritisation, where it is determined that an intervention is required, the works will typically involve the arrangement of access with the landowner, excavation around the pipeline to locate the feature and then an appropriate repair. This may range from the dressing-out of a feature, through to the installation of a full encirclement clamp (either a grouted – see Figure 5 above – or a fully welded fitting) which maintains the full integrity of the pipeline. In extreme cases, it may be necessary to carry out a 'cut-out and replacement' of a pipeline section under full bypass and flow-stopping conditions.

The approach adopted to assess, prioritise and then remediate a pipeline feature by Cadent is common to that adopted by other gas pipeline operators in the UK.

The pipeline inspection surveys that help identify the interventions required, as discussed in this paper, are mentioned for context only. The expenditure associated with the surveys is covered under opex and not included in this paper.

5. Probability of Failure

We have used the NOMS methodology, developed with Ofgem, to help us understand risks on our assets and the benefit that investment will have. The approach covers a number of asset categories including pipeline assets.

We have followed good practice set out in the NOMSs methodology[1] by developing failure rates and consequence of failure estimates.

We also have extensive pipeline inspection records, which provide us with the opportunity to understand our failure rates based on pipeline-inspection lengths.

In this section, we look at the probability of failure derived within our models (AIMs) and from a detailed review of our pipeline inspection data

Probability of failure from our models

Failure modes in the NOMs model

We have modelled failure modes of these assets, namely:

- Capacity failure – where the pipe network is under-sized to meet demand. This driver is not considered in this paper.
- Corrosion failure – either internal or external corrosion of the pipe.
- Mechanical failures – including material and weld defects created when the pipe was manufactured or constructed.
- Interference – external interference caused by third parties.
- Ground movement – either natural (e.g. landslide, or man-made such as excavation or mining).
- General failures – general and other causes (e.g. due to over-pressurisation, fatigue or operation outside design limits).

Our assessment of the probability of failure is part of developing our end-to-end analytical framework for these assets, which is shown in the risk map below. The yellow nodes show the failure effects. We do not consider the different detailed asset component failures that could occur to drive these failure effects.

[1] NOMS, March 2016

This risk map also shows the consequence of failure, which is explained in the next section.

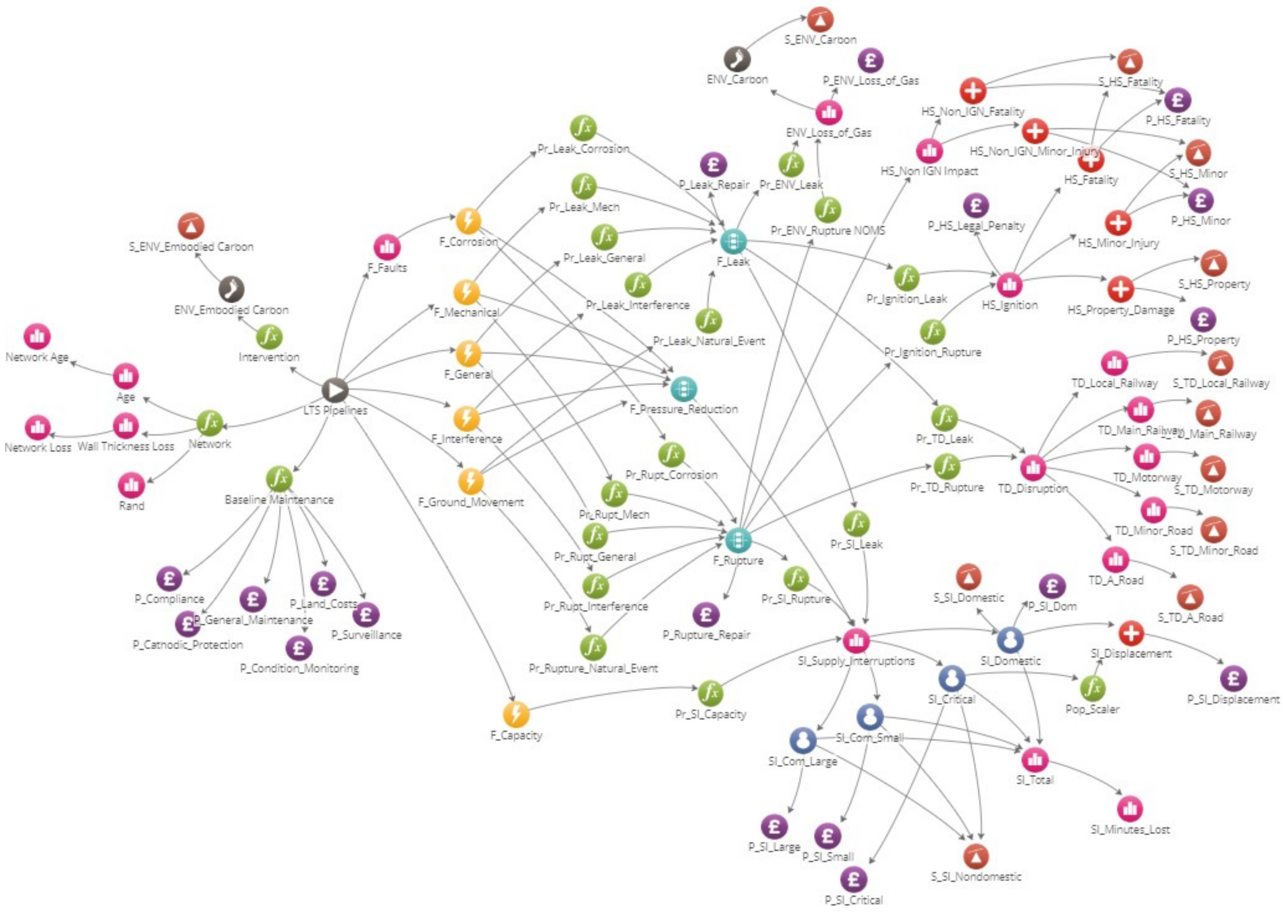

Figure 6: LTS risk map within our AIMs model

Applying the failure models to our asset base gives the following predictions of failure over time.

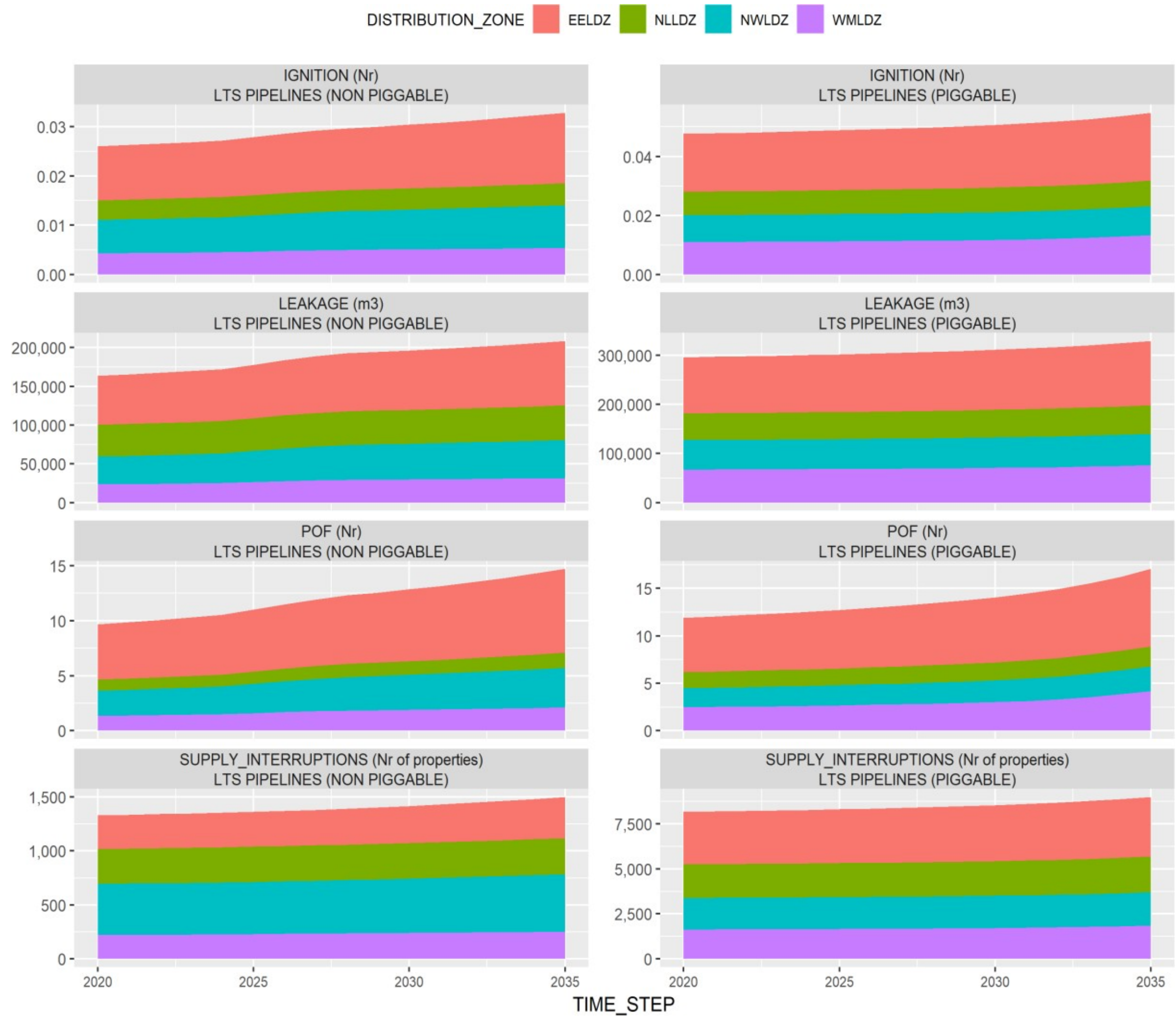

Figure 7: Key asset health and performance measures over time for 'reactive only' (no investment) split by asset category, coloured by distribution zone (note the Y-axis is independent for each plot).

The key asset health and performance measures 'reactive only' plot shows an increasing, albeit slow, trend across all networks evenly split between non-piggable and piggable.

Probability of failure from engineering review

Failure Modes

Our understanding of the typical failure modes or pipeline integrity risks is derived from our OLI1 and OLI4 pipeline inspections. OLI1 (ILI) are internal surveys using 'pigs', and are therefore used on the piggable pipelines, the OLI4 surveys are overland surveys and are used on our non-piggable pipelines.

These OLI1 and OLI4 inspections may identify a range of pipeline features including, but not limited to, metal loss, dents, gouges, and weld anomalies. These features are categorised and prioritised in accordance with the Cadent procedure T/PM/P/11 (Work Procedure for Inspection and Repair of Damaged Steel Pipelines Designed to Operate at Pressures Greater Than 2 Bar) and T/PM/DAM/1 (Defect Assessment Management Procedure). They are failures against the PSSR standard, pre-cursors to a full failure of the pipeline.

Failure Rates

We have forecast our failure rates from the observed failures in RIIO-1 following OLI1 and OLI4 pipeline inspections.

We have calculated an average intervention cost per km of inspection: the overall costs associated with interventions in each network and the respective length of pipeline inspected for a 4-year period (2014/15 – 2017/18). We have applied the average network intervention cost per km to RIIO-2 proposed inspection volumes in each network. We have assumed that our current rate of failure will continue into RIIO-2.

Understanding the pipeline-fault or risk: The OLI1 inspection reports will provide a general statement of the instances of metal loss detected during the survey, together with the main characteristics of such metal loss. Individual metal-loss feature reports will be provided for any feature within the reporting specification. Each report will describe the severity, type, size and location of the feature detected. In addition, a gouge report, a dent report, a girth weld anomaly report, and pipeline repair listings are also provided.

The OLI1 inspection reports will also provide an assessment of the changes that have occurred since the last inspection. The assessment will consider the growth of defects and differences in the reported number of defects.

We get an improved understanding of failure modes and pipeline-integrity risks by carrying out further investigations that could involve:

- further overland surveys using a range of techniques
- an engineering assessment of the most cost-effective intervention method

The techniques used to support the assessment may include:

- Close Interval Potential Surveys (CIPS)
- Direct Current Voltage Gradient (DCVG)

These techniques help identify the type, extent and location of the fault.

These additional investigations, and any resulting repairs or remediation activity, are all recorded in our financial records against ‘intervention expenditure’ for our LTS piggable and non-piggable pipelines. We use this expenditure profile as an indicator of the volumes and severity of LTS pipeline ‘failure’; in this context ‘failure’ refers to an instance of unacceptable risk requiring intervention.

Failure rates in RIIO-1: The table below summarises the expenditure incurred on remediation activity during a 4-year period (2014/15 to 2017/18) of RIIO-1, together with the length of pipeline inspected. This has enabled us to calculate an average intervention cost per km of pipeline inspected, as set out.

These results are showing that our North London network is in poorest condition; the other networks have significantly lower intervention costs per km inspected.

Intervention Expenditure by Network X/km				
	Costs (X)	OLI1 km	OLI4 km	Ave X/km inspected
EA				
EM		[redacted]		
Lon		Redacted due to commercial sensitivity		
NW				
WM				
Total				

Table 2: Intervention expenditure by Network in RIIO-1

In our analysis, we identified a small number (3) of much higher cost intervention jobs in the Lon and EA networks. The drivers for the higher costs were a combination of factors, particularly for the Lon job, which involved large and very deep (over 5m) excavations in a major traffic route in central London along with other factors contributing to a complex repair. We consider it reasonable to assume that a similarly small number of complex, high-cost remediation jobs are also likely in RIIO-2 and, therefore, these jobs have been included in the analysis summarised above.

5.1. Probability of Failure Data Assurance

Our records are part of PSDB. This is a fully audited system which is also used by the HSE. All major faults are also uploaded to the UKOPA national database as shown in the plot below.

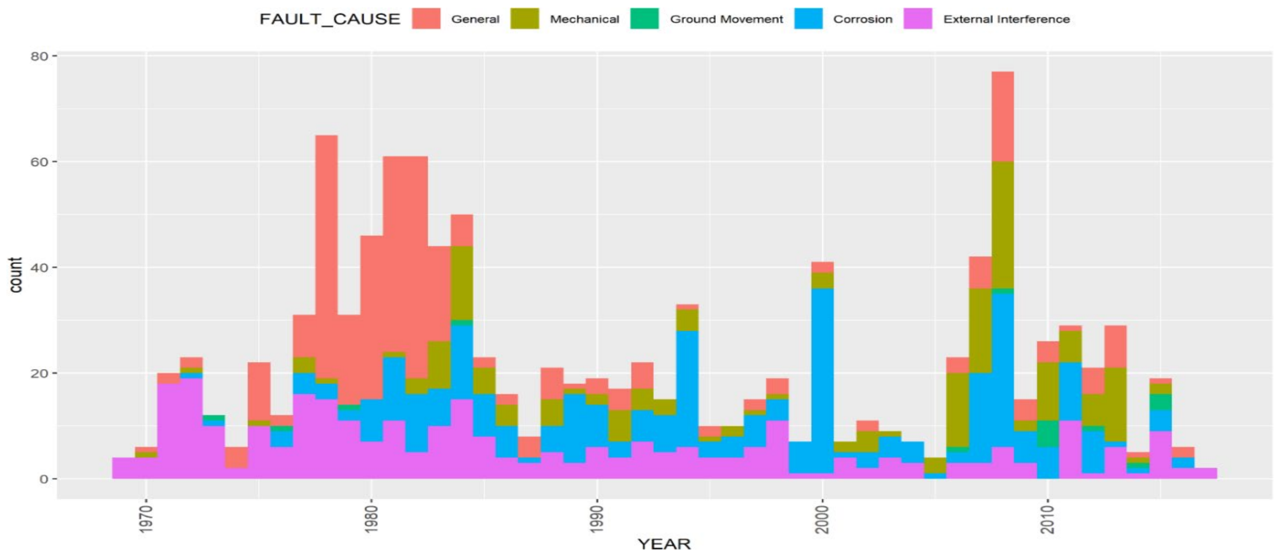

Figure 8: Annual count of fault cause for Cadent from UKOPA national pipelines database.

The plot above shows the fault data that is recorded on the UKOPA national pipelines database and used for risk assessment and investment decisions. The long-run average of total faults is approximately 20 per annum, which represents the overall PoF across non-piggable and piggable pipelines.

6. Consequence of Failure

Linking failures to consequences

Our surveys find defects which have not yet failed. By intervening to remedy defects, we avoid replacement and failure costs, ensure continuity of supply to our customers and comply with legislation.

In NOMS, failures are assessed in terms of their potential consequences. The consequences of failures are as follows:

- A **leak** is defined as a gas escape from a stable hole the size of which is less than the diameter of the LTS pipeline.
- A **rupture** is a gas escape through an unstable defect which extends during the failure to result in a full break or failure of an equivalent size to the pipeline.

The number of leaks or ruptures per year is calculated based on the probability of failure for each failure mode, combined with the probability that each of the failure modes will lead to a leak or rupture respectively.

These failures can then, in turn, result in a number of consequences. Our LTS AIM model includes the following consequences:

- Interruptions to supply (properties impacted)
- Transport disruption
- Property damage
- Fatality/injury (ignitions or explosions)
- Emissions (greenhouse gas)

Each potential consequence has been expressed as monetary values as per the agreed industry methodology, as shown below.

Customer Driver	Data source
Environment – GHG emissions	[redacted]
Safety – injuries and deaths	
Interruptions to supply – per property	
Other societal impacts	
Financial impact – cost of repairs (unit)	As defined in NOMS models.
Financial impact – cost of replacement (unit)	As defined in NOMS models.

Table 3: Sources of societal benefits

These have been estimated using a range of sources, including our own willingness-to-pay research with our consumers, as well as published government values for carbon and the risk of fatality and non-fatal injuries.

We have also included the financial consequences associated with fixing failures as they occur (e.g. repair costs) and remedying the consequences of failures (e.g. compensation and prosecution). Our financial impacts are based on a robust assessment of our costs.

Our AIMS/NOMs model contains the following consequence data (figures per annum) for a failure on the LTS network:

Region	Supply interruption: Properties impacted (pa)	Properties damaged (pa)	Value per property	Fatalities (pa)	Minor injuries (pa)	Level of emissions (Kg/m3)
EoE	732	0.03		0.005	0.005	821.36
Lon	1,198	0.26	[redacted]	0.024	0.024	1177.26
NW	918	0.13		0.013	0.013	762.69
WM	772	0.08		0.012	0.012	1539.58
Total	**838**	**0.09**		**0.010**	**0.010**	**986.61**

Table 4: Consequence of failure: properties, injury, emissions

Region	National railway (critical)	National Railway (other)	Motorway	A Road	Minor Road
EoE	0.0040	0.0000	0.0004	0.0029	0.0173
Lon	0.0065	0.0000	0.0018	0.0094	0.0184
NW	0.0080	0.0000	0.0033	0.0091	0.0184
WM	0.0058	0.0000	0.0023	0.0055	0.0212
Total	**0.0054**	**0.0000**	**0.0015**	**0.0055**	**0.0183**

Table 5: Consequence of Failure: Transport Disruption (per annum)

The average social cost of disrupting the transport networks is set out below.

Severity	
Transport disruption: Minor road	
Transport disruption: A road (modelled - average A roads)	[redacted]
Transport disruption: Motorway	
Transport disruption: National rail (critical routes)	
Transport disruption: National rail (other routes)	

Table 6: Social costs from transport disruption

Based on the above consequence data, the graphic below shows the distribution of consequences as recorded in the NOMs model:

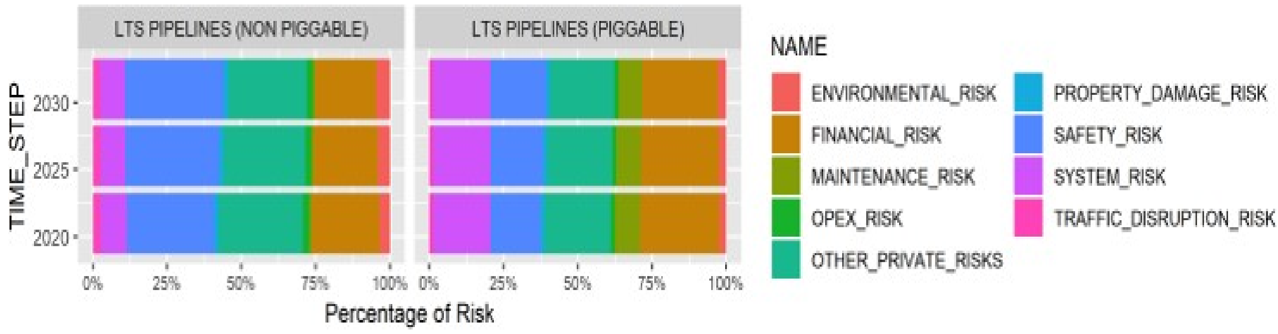

Figure 9: Proportion of risk components over time split by asset class

This plot shows the proportion of key risk components for each asset category over time. The proportions of risk are relatively constant, with safety, financial, and other private risks the top three.

7. Options Considered

Introduction and general approach

We have considered a range of solution options as part of this investment case:

- Replace/ Repair on failure
- Pre-emptively replace
- Pre-emptively repair - preferred

As discussed earlier, the implications of allowing a pipeline to leak or rupture is likely to have a serious impact on customers' gas supplies and the health and safety of employees and members of the public. As such, we have ruled out 'replace or repair on failure' and 'do nothing' options.

We have also ruled our pre-emptive replacement as the costs of such action would be significant.

Our preferred solution option for RIIO-2 investment therefore remains to pre-emptively repair or remediate any pipeline-integrity risks prior to them causing any external impacts (full failure).

We have therefore assessed a number of different investment options to determine the volume of intervention needed to manage risk effectively.

The investment options considered are shown below:

Option	
0	**Baseline** Repair/replace on failure
1	**Engineering Volumes Selection** Engineering assessment using failure rates from pipeline surveys in RIIO-1 to forecast RIIO-2 failure rates and costs, to meet legal obligations. The detailed information associated with this option has been described in Section 7.1 below.
2	**Minimum investment to maintain stable risk** Used our monetised risk model to assess interventions and capex spend needed to hold risk constant within the model for 20 years.
3	**Max Whole Life Benefits 20 years** Used our monetised risk model to assess interventions while maximising whole life net benefit and stabilising risk over 20 years.
4	**Minimum investment to maintain stable risk, 10 years** Used our monetised risk model to assess interventions and capex spend needed to hold risk constant within the model for 10 years.
5	**Engineering Volumes Selection min failures** We have taken the engineering volumes and asked the model to select the pipelines that minimise the pipeline failures
6	**Engineering Volumes Selection Excluding WTP** For comparison purposes, we have also considered our preferred option excluding customer willingness to pay for interruptions to see if the option is still value for money without this element considered.

Table 7: Options considered (Options 3 to 5 are variants for illustrative purposes)

Background to our monetised risk model: In RIIO-1 we have invested in the software tool AIM to allow us to build asset management capability using the NOMS approach. AIM includes an optimisation capability which allows us to model different investment options and produce optimised plans and test their cost-benefit. The CBA capability within AIM has the ability to find the solution to a problem with many restrictions and potentially millions of potential solutions (options).

AIM has been used to model Pipelines. This has involved forecasting how the pipelines asset base will perform into the future; in terms of asset failures, the impacts on consumers, the environment, and the financial impact. Our model has been applied in RIIO-2 at pipe level. This means that individual assets and their performance can be modelled producing precise results for the plan.

Cost Benefit Analysis approach: For each scenario, we have understood the year-on-year opex, capex and repex costs, together with monetised risk impacts in a CBA. The results of the analysis over RIIO-2 are shown in the Section 8 tables below for Cadent as a whole (network-specific CBAs have been submitted alongside this document).

Costs and benefits are discounted and shown in present value (PV) terms in line with Ofgem requirements and HM Treasury Green Book. The net present value (NPV) is the overall summation of all discounted costs and benefits.

7.1. Baseline: Repair or replace on failure

This option has been derived from the model and looks at the volumes and expenditure required if we just allow our pipelines to deteriorate and we do not repair any deficiencies following pipeline ILI and OLI inspections.

As this option is the do-minimum position, the proactive intervention volumes are zero, this is shown below:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	0	**0**
WM	0	0	0	0	0	**0**

Table 8: Intervention volumes: Baseline.

Accordingly the resulting capex spend for the proactive replacement of these assets is also zero:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	0	**0**
WM	0	0	0	0	0	**0**

Table 9: Capex costs: Baseline.

Note: Table 9 shows that there are no proactive costs with this option; however there would be reactive repair costs under this option.

7.2. Option 1: Engineering volumes selection

This option has been derived from an engineering assessment of failure rates in RIIO-1. We have carried out a forward-looking assessment of the likely intervention expenditure required in RIIO-2 based on the application of average network intervention costs per km of survey (RIIO-1) and the forward-looking inspection schedule for RIIO-2. This conservative approach assumes no material deterioration in condition between RIIO-1 and RIIO-2.

The average network intervention costs per km of pipeline inspection from RIIO – 1, are shown in Table 10 below:

Intervention Expenditure by Network X/km				
	Costs (X)	**OLI1 km**	**OLI4 km**	**Ave X/km inspected**
EA		121	530	
EM	[redacted]	349	167	[redacted]
Lon	[redacted]	106	111	[redacted]
NW	[redacted]	383	257	[redacted]
WM	[redacted]	74	96	[redacted]
Total		**1,034**	**1,161**	

Table 10: Intervention expenditure by network in RIIO-1: Option 1

We have applied the average intervention cost for each network, to the proposed length of pipeline to be inspected during RIIO-2. We have two different types of surveys; Overland surveys (OLI4) and internal surveys (ILI).

For the overland surveys, we recognise that these do not identify potential interventions at the same rates as internal surveys do. We have therefore applied 50% of the intervention costs/km survey for these overland surveys volumes for RIIO-2. Applying the average intervention costs in this way, for RIIO-2, results in the proposed intervention and expenditure shown in the tables 11 and 12 below (i.e. a total of X).

	21/22	**22/23**	**23/24**	**24/25**	**25/26**	**Total**
EoE	0.024	0.024	0.024	0.024	0.024	**0.12**
Lon	0.012	0.012	0.012	0.012	0.012	**0.06**
NW	0.012	0.012	0.012	0.012	0.012	**0.06**
WM	0.012	0.012	0.012	0.012	0.012	**0.06**

Table 11: Intervention volumes Option 1 (km)

	21/22	**22/23**	**23/24**	**24/25**	**25/26**	**Total**
EoE						
Lon		[redacted]	[redacted]	[redacted]		
NW		[redacted]	[redacted]	[redacted]		
WM						
Total						

Table 12: Capex costs Option 1(X)

These intervention volumes have been derived from an inspection length of 2,187km.

7.3. Option 2: Minimum investment to maintain stable risk

This option has used our monetised risk model to assess interventions and capex spend needed to hold risk constant within the model for 20 years.

The intervention volumes are:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	1.78	1.34	0.17	3.48	11.96	**18.73**
Lon	1.74	1.45	1.34	1.09	2.63	**8.25**
NW	2.46	2.63	4.48	7.45	22.69	**39.71**
WM	0.11	0.12	0.38	2.71	5.77	**9.09**

Table 13: Intervention volumes Option 2 (km).

The resulting capex spend to proactively replace is:

	21/22	22/23	23/24	24/25	25/26	Total
EoE						
Lon						
NW						
WM						
Total						

Table 14: Capex costs Option 2 (X).

7.4. Option 3: Max whole life benefits (over 20 years)

This option has used our monetised risk model to assess cost beneficial interventions. We have considered those interventions that maximise whole-life net benefits. As shown in Section 8, investment in these assets is not cost beneficial, hence the proactive intervention volumes are zero, as shown below:

The intervention volumes are:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	0	**0**
WM	0	0	0	0	0	**0**

Table 15: Intervention volumes: Option 3 (km).

Accordingly, the resulting capex spend for the proactive replacement of these assets is also zero:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	0	0	0	0	0	**0**
Lon	0	0	0	0	0	**0**
NW	0	0	0	0	0	**0**
WM	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**0**	**0**

Table 16: Capex costs: Option 3 (X).

7.5. Option 4: Minimum investment to maintain stable risk, 10 years

This option has used our monetised risk model to assess **Minimum investment to maintain a stable risk over 10 years**.

We used our monetised risk model to assess interventions and capex spend needed to hold risk constant within the model for 10 years.

The intervention volumes are:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	1.78	1.34	0.17	3.49	11.97	**18.75**
Lon	1.82	1.45	1.34	1.09	2.63	**8.34**
NW	2.46	2.99	4.63	7.46	22.79	**40.33**
WM	0.11	0.12	0.38	2.71	5.77	**9.10**

Table 16: Intervention volumes: Option 4 (km).

The resulting capex spend to proactively replace is:

	21/22	22/23	23/24	24/25	25/26	Total
EoE						
Lon						
NW			Redacted due to commercial sensitivity			
WM						
Total						

Table 17: Capex costs: Option 4 (X).

7.5. Option 5: Engineering volumes selection min failures

In this option, we have taken the engineering volumes and asked the model to select the pipelines that minimise the pipeline failures.

The intervention volumes are:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	0.02	0.02	0.02	0.02	0.02	**0.12**
Lon	0.01	0.01	0.01	0.01	0.01	**0.06**
NW	0.01	0.01	0.01	0.01	0.01	**0.06**
WM	0.01	0.01	0.01	0.01	0.01	**0.06**

Table 18: Intervention volumes: Option 5 (km).

The resulting capex spend to proactively replace is:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 19: Capex costs: Option 5 (X).

7.6. Options Technical Summary Table

	Baseline	Option1	Option 2	Option 3	Option 4	Option 5	Option 6
Descriptio n	Reactively repair/replace upon pipeline failure	Engineeri ng volume selection	Minimum investment to maintain stable risk	Max whole life benefits	Minimum investment to maintain stable risk, 10 years	Engineering Volumes Selection min failures	Engineering Volumes Selection Excluding WTP
EoE repair volumes	0	0.12km	18.73km	0	18.73km	0.12km	0.12km
Lon repair volumes	0	0.06km	8.26km	0	8.34km	0.06km	0.06km
NW repair volumes	0	0.06km	39.72km	0	40.33km	0.06km	0.06km
WM repair volumes	0	0.06km	9.10km	0	9.10km	0.06km	0.06km
Design lives	10 – 20 yrs depending on repair method						
Total installed cost (X)		Redacted due to commercial sensitivity					

Table 20: Technical Summary Table for all options

7.7. Options Cost Summary Table

The following table provides a cost summary table for all modelled options. It explains the total RIIO-2 expenditure by intervention type. These costs form part of the CBA (as discussed in section 8); they demonstrate that we have considered a good range of options from spending small sums of money to significant sums of money, so we can understand the right level of investment for these assets.

	21/22	22/23	23/24	24/25	25/26	Total

Redacted due to commercial sensitivity

Table 21: Option Cost summary table (X)

For LTS Pipelines (Piggable and Non Piggable) all RIIO-2 costs have been derived from previous construction out-turn costs and we therefore deem that this investment case is within a cost confidence range of +/-5%.

Our RIIO-2 forecasts, as well as adjusting for workload and work mix factors, also include ongoing efficiencies flowing from our transformation activities and the updating and renewing of our contracting strategies. Our initiatives are outlined in Appendix 9.20 Resolving our benchmark performance gap. For Capex activities this seeks a 2.9% efficiency improvement by 2025/26 on the end of RIIO-1 cost efficiency level. No efficiency has been applied to this investment case.

8. Business Case Outline and Discussion

8.1. Key Business Case Drivers Description

Our objective is to build a plan which best reflects customer and stakeholder expectations and meets the required outcomes for this investment. In developing the RIIO-2 plan we have defined distinct programmes of work to ensure compliance with PSSR and to maintain a reliable supply through managing the risk to pipeline integrity, and pre-emptive interventions.

8.2. Business Case Summary

As discussed in Section 7, seven investment options were considered across each network.

Option No.	Option description	PV Expenditure & Costs X)	PV Environment X	PV Safety X	PV Reliability X	PV Other X	Total PV X	NPVX
0	Reactive Only							
1	Engineering Volumes Option (Chosen)							
2	Min investment to maintain stable risk (RIIO-2 only)							
3	Max Whole Life Benefits (RIIO-2 only)		Redacted due to commercial sensitivity					
4	Min investment to maintain stable risk (RIIO-2 and GD3)							
5	Engineering Volumes Option with Min Failures							
6	Engineering Volumes Option exc. WTP							

Table 22: Present value of costs and benefits for the modelled options

Table 23 above shows the discounted present value (PV) of financial and societal costs across five risk categories. All costs are considered to 2071 unless stated otherwise.

- PV expenditure and costs shows discounted sum of proactive investment (replacement or refurbishment costs), maintenance, repairs and other ongoing opex costs. Proactive investment has been considered over RIIO-2, although we have included some scenarios that consider 10 years of investment: RIIO-2 and RIIO-3. All other financial costs are considered over the full period to 2050/71. All financial costs are discounted using the Spackman approach.
- PV environment shows the discounted sum of leakage and shrinkage, using the base case cost of carbon.
- PV safety shows the discounted sum of the risk of fatalities and injuries, as valued using the Ofgem stated costs per Fatality and cost per non-fatal injury.
- PV reliability shows the discounted sum of interruption risk, as valued using our own valuation research (e.g. the willingness to pay study into the cost of interruptions to homes and businesses).
- PV other shows the discounted sum of any other impacts, as valued using our research into the cost of property damage and transport disruption.

Costs are presented as negative value. The total PV is the summation of the five categories of costs.

The baseline has been specified as the minimum investment position. The NPV for each option is computed as the difference between the total PV for each option and the total PV for the baseline. A positive NPV means an option has less costs associated with it relative to the baseline, and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial of the options considered.

In each option, the key differences are financial only, due to the costs of the capital investment rather than repairs or maintenance or other opex costs. There are only small changes in the PV of safety, environment and other societal costs and benefits across the options. The PV financial expenditures and costs differ significantly across the options.

The table below summarises the cost-benefit results for each option. This provides the NPV for the option, computed as the difference in total NPV relative to the baseline, to show which options are cost-beneficial or not. We also include the payback period, the RIIO-2 investment, replacement and refurbishment only, and the ratio of NPV to RIIO-2 investment to understand how much NPV per X spent in RIIO-2 the options generate.

Option No.	Option description	NPV - Relative to baseline X	Cost beneficial	Payback Year	RIIO-2 spend (Replace, Refurb) X	Ratio NPV to RIIO-2 replace/ refurb spend	RIIO-3 spend (Replace, Refurb) X	Ratio NPV to RIIO-2 and RIIO-3 (Replace, Refurb) X
0	Reactive Only							
1	Engineering Volumes Option (Chosen)							
2	Min investment to maintain stable risk (RIIO-2 only)							
3	Max Whole Life Benefit (RIIO-2 only)				Redacted due to commercial sensitivity			
4	Min investment to maintain stable risk (RIIO-2 and RIIO-3)							
5	Engineering Volumes Option with Min Failures							
6	Engineering Volumes Option exc. WTP							

Table 23: CBA summary for the modelled options

Table 24 shows CBA results:

- The NPV for each option is computed as the difference between the total PV for each option and the total PV for the baseline. A positive NPV means an option has less costs associated with it relative to the baseline and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial of the options considered.
- Payback shows the year when the sum of costs associated with an option is lower than that of the baseline i.e. this is the point at which the option can be considered to be cost beneficial. This is driven by the profile of the costs and the capitalisation rate.
- The table shows the RIIO-2 proactive expenditure. If applicable the RIIO-3 proactive expenditure is also shown.
- The ratio of NPV to RIIO-2 spend shows how much NPV per X spent in RIIO-2 the options generate. A positive figure means the investment is cost beneficial. The higher the figure the most cost beneficial the option is.

- We have also provided the ratio of NPV to the combined RIIO-2 and RIIO-3 spend for those options where 10 years of proactive expenditure has been considered.

In assessing these CBA results, we recognise we need to balance NPV, payback, and the ratio of NPV to proactive spend, alongside other considerations such as affordability and compliance with legal standards and obligations.

Option 3, which maximises value to customers, shows that currently there is no investment in RIIO-2 that is cost beneficial. This therefore has the same proactive intervention costs and volumes as the baseline position. However, defering investment will not meet our obligations to manage safety and to maintain legal compliance. This scenario would mean that we would not investiagte defecvts identified from survey, but would ratehr allow them to continue to deteriorate.

Option 2, to hold monetised risk stable, requires a significant RIIO-2 capex spend which is highly non-cost-beneficial (as demonstrated by negative NPV; and the lack of payback within the modelled period). Option 4 shows that to hold monetised risk stable to the end of RIIO-3 will require even larger amounts. We have dismissed the option to maintain stable monetised risk due to the high cost and low benefits that this provides for our customers. In the short term, we do not consider maintaining stable monetised risk value for money or acceptable for our customers.

Our preferred option is Option 1. This option reflects the absolute duty we have to meet our obligations. By selecting this option, we recognise that monetised risk will increase, although safety risk will be managed.

Option 5 shows that, even if we can deliver the Option 1 volumes in a way that minimises failures / maximises value for our customers, the investment is still not cost-beneficial.

Option 6 shows that the impact of removing WTP for interrruptions from the results has little impact on the findings.

Table 24 shows that we have considered a number of options within the period. We have run a significant number of options – which reflect a range of cost levels and volume constraints. In all options investment is not cost beneficial.

However, our preferred option is the least cost option to manage the safety and compliance risks we face; we therefore consider this to be the best value for money option for our customers. Moreover, in the medium to long term we consider the preferred option to prevent increasing more expensive remediation (including replacement) to maintain safety risk, maintain compliance and manage interruption to supply performance – and therefore our preferred option is consistent with managing the whole life cycle costs of these low probability, high consequence assets.

These results are similar across all four regions. The table below shows the results for the regions for the preferred Option 1:

	NPV X	Cost benefit	Payback	RIIO-2 spend X	Ratio NPV to RIIO-2 and RIIO-3 (Replace, Refurb) X
Piggable					
EoE					
LON					
NW					
WM	Redacted due to commercial sensitivity				
Total					

	NPV X	Cost benefit	Payback	RIIO-2 spend X	Ratio NPV to RIIO-2 and RIIO-3 (Replace, Refurb) X
Non Piggable					
EoE					
LON					
NW					
WM		Redacted du to commercial sensitivity			
Total					
EoE					
LON					
NW					
WM					
Total					

Table 24: Regional profile of NPV

The performance against the key measures for each of the options, summarised across our four regions, is shown in the graphs below:

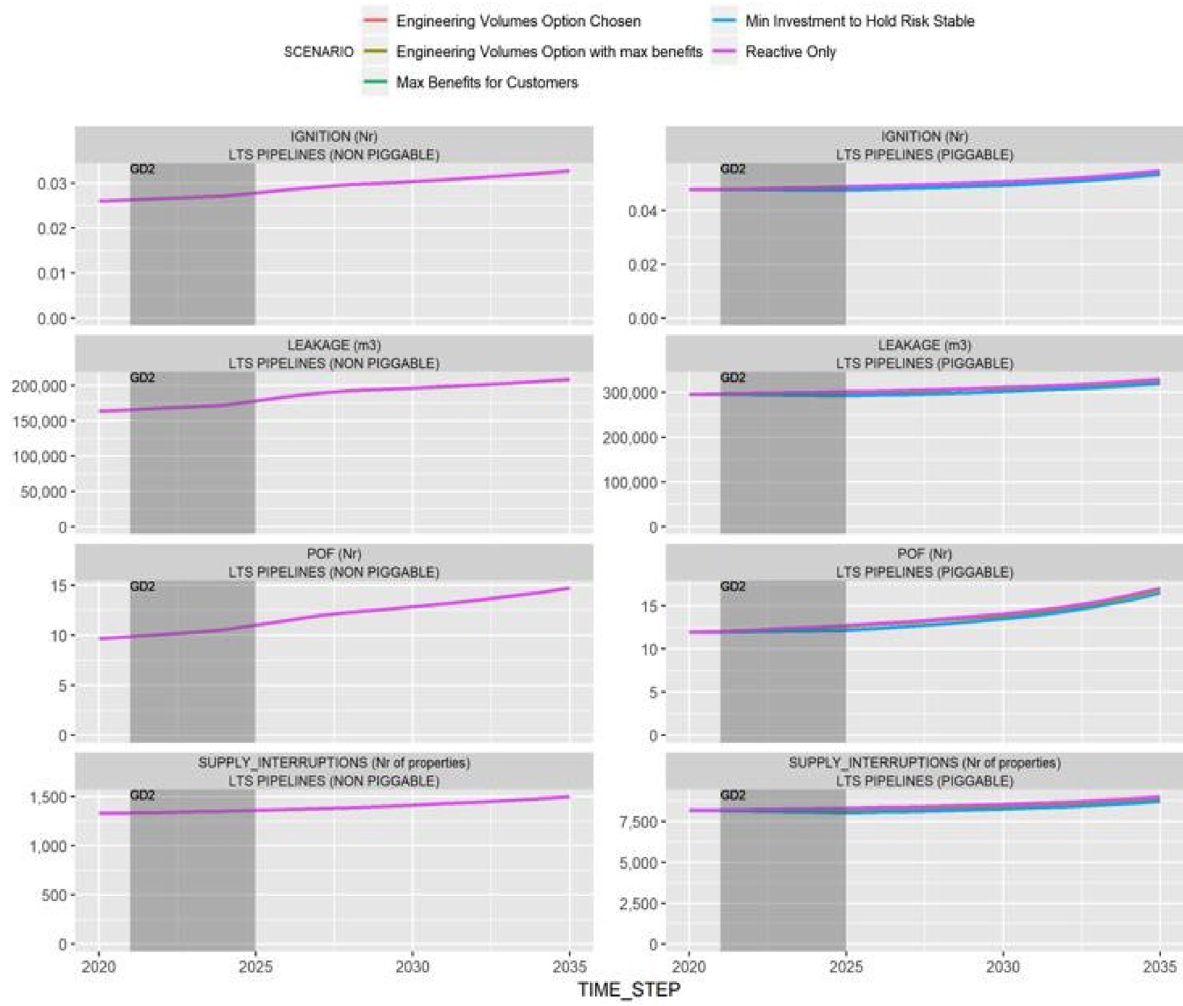

Figure 10: Key asset health and performance measures over time per asset category coloured by scenario (NB the Y-axis is independent for each plot)

This shows several varying options of investment and risk that were investigated and compared to the ‘reactive only’ option (pink line) for each asset category (non-piggable and piggable). All options can be seen to be near identical to the reactive-only option, all showing a very flat performance over RIIO-2 (shaded box). All options were assessed and compared against the final chosen option - based on an engineering assessment of all options (Engineering Volumes Option Chosen).

The options, as represented in the model, are not cost-beneficial using the values in our LTS model. The option to hold risk stable is high cost and highly non-cost-beneficial.

Based on the above-modelled results, we have compared Options 0,1, and 2 in more detail in the following table. This table excludes Options 4, 5 and 6 which are for comparison purposes only, as part of our sensitivity testing process.

Option	Pros and Cons
0	Cadent would be in breach of its obligations under the PSSR, and more generally under the Health and Safety at Work Act 1974 in failing to protect people from the risks associated with these major accident hazard pipelines (as defined by the PSSR). We would also be in breach of the conditions of our Safety Case and our License conditions.
1	Engineering assessment – we continue to proactively manage the condition of our pipelines by adjusting inspection rates to meet the results of past inspections, to ensure timely interventions take place to avoid the dangers of catastrophic asset failures.
2	The costs associated with this scenario are extremely high, and not viable for our business plan. This shows the limitation of the LTS model to be used for investment planning rather than as a reporting tool.

Table 25: Discussion of the Pros and Cons for the modelled scenario and baseline

Option 1 is the option Cadent have chosen to take forward into RIIO-2. While not cost-beneficial as modelled using the NOMs approach, this option ensures we meet our legal obligations and manages the risks effectively for these low probability/high consequence assets.

This preferred option uses a common approach that is used by other gas pipeline operators in the UK, to assess, prioritise and remediate pipeline-integrity risks and features.

Applying this approach for RIIO-2 results in the proposed intervention expenditure (following inspections) is shown in the table below, i.e. a total of X (2018/19 price base).

Pipeline Intervention Overall X)						
	2021/22	2022/23	2023/24	2024/25	2025/26	Total
Total		Redacted due to commercial sensitivity				

Table 26: Proposed Total ILI/OLI4/HI4 Intervention Expenditure in RIIO-2

	21/22	22/23	23/24	24/25	25/26	Total
		Redacted due to commercial sensitivity				

Table 27: Proposed ILI/OLI4/HI4 Intervention Expenditure by Network in RIIO-2

In our analysis, the length of pipeline inspected over the period is effectively a driver for the intervention workload. We are confident in respect of our inspection workload proposals given they are direct outputs from both the intervals tool and the PSDB, as previously highlighted, and experience has shown that the inspection schedules do not vary significantly year to year.

The intervals tool uses a range of engineering integrity and operational information to identify the appropriate inspection frequency. The factors considered include the following: likelihood of external interference, susceptibility to corrosion or ground movement, and the age of the pipeline and the applicable construction standard. Additionally, the operating stress level and a measure of the security of supply provided by the pipeline are inputs to the tool. The inspection frequency cannot exceed 15 years.

Benefits: In addition to ensuring compliance with safety legislation, the proposed RIIO-2 investment, will deliver the following benefits as modelled in NOMs, summarised below.

Name	Scenario	2020	2025	2030	2035
POF (Nr)	Baseline				
	Preferred Option				
IGNITION (Nr)	Baseline				
	Preferred Option				
LEAKAGE (m^3)	Baseline	Redacted due to commercial sensitivity			
	Preferred Option				
SUPPLY_ INTERRUPTIONS (Props)	Baseline				
	Preferred Option				

Table 28: Performance summary

This table shows the selected investment option holds risk broadly constant at a level lower than the reactive-only baseline. This is shown in Figure 11:

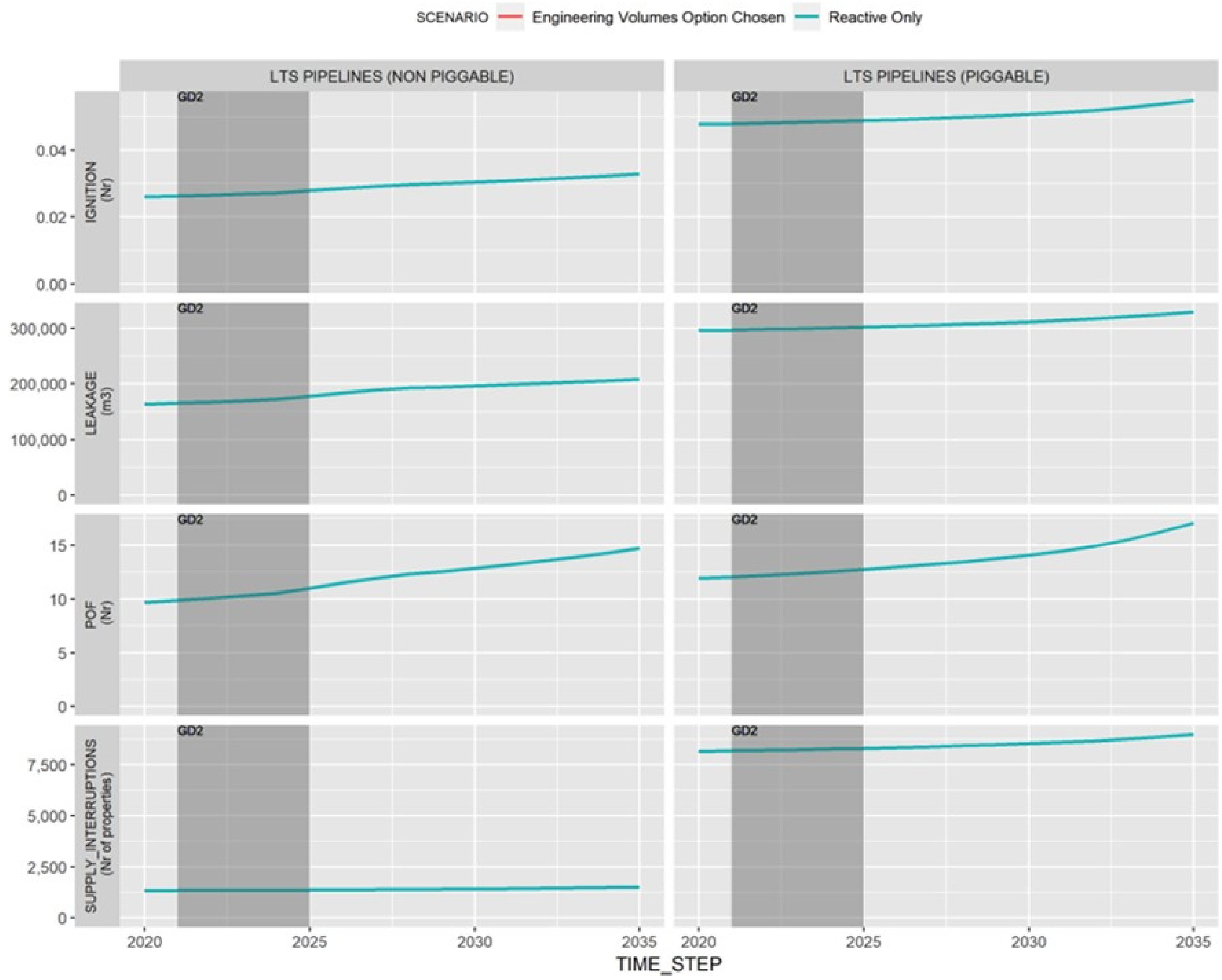

Figure 11: Key asset health and performance measures over time per asset category for reactive only and the final chosen scenario.

This plot shows a comparison of reactive only (no investment) compared directly to the chosen scenario for four key asset health and performance measures. The chosen scenario shows an **indistinguishable difference**, a near-identical and stable position compared to the 'reactive only' forecast, due to regular maintenance and the underlying deterioration being very slow.

While maintaining stable monetised risk and performance in the short to medium term, the chosen option also ensures that, through effective remediation of corrosion and other defects identified through the OLI1 and OLI4 inspections, the whole-life cost of the LTS pipeline is minimised. Lack of investment in lower-cost remediation activities would result in ever-increasing corrosion and subsequent defects. In the medium to long term, this would result in a pipeline asset that would require ever-increasing levels of more expensive remediation (including replacement) to maintain safety risk, maintain compliance and manage interruption to supply performance.

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

The preferred option is to maintain our current inspection programme, as established with the HSE, and respond to faults identified (Option 1), and repair the pipelines before failure. This meets our legal requirements.

9.2. Asset Spend Profile

The expenditure profile is summarised below:

	21/22	22/23	23/24	24/25	25/26	Total
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 29: Proposed total ILI/OLI4/HI4 intervention expenditure in RIIO-2 X

We have considered our ability to deliver the proposed workload. Given that our proposals are broadly similar on an annualised basis to RIIO-1, and that the majority of any inspection and intervention works would be procured from mature markets, there are no constraints on delivery.

9.3. Investment Risk Discussion

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.09.01	Supply & Demand deliverability risk of Resource availability within the Gas industry	Potential cost increases in labour / commodity markets as demand is greater than supply	Low	Intelligent procurement and market testing. Apprenticeship and Training programmes to fill skills gaps
09.09.02	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing overall programme costs.	Low	Established market place - ability to manage the known commodity market
09.09.03	Unforeseen outages and failures restrict access for planned work	Programme and delivery slippage due to delay of planned outages and or site access	Low	Proactive asset management with ongoing condition surveys and response plans to prevent failures

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.09.04	Unseasonal weather in 'shoulder months', Autumn and Spring reduce site access/outage windows	Increased demands affecting access to sites and planned outages delay and cost increases	Low	Controlled forecasting and maintenance of flexibility to react to unforeseen events. Detailed design solutions to minimise outages and reduce exposure.
09.09.05	Unexpected / uncommunicated obsolescence during RIIO-2 period of equipment components	Inability to maintain equipment at full capacity with risk of impact upon supply	Low	Maintain a close relationship with equipment supply chain and manage a proactive early warning system where spares / replacements become at risk.
09.09.06	Legislative change - There is a risk that legislative change will impact the delivery of our work.	Potential increase in the amount of consultation and information exchange required and require us to align our plans with the safety management processes operated by 3rd Party landowner / asset owners. The potential impact is more engagement and slower delivery	Med	We have established management teams to address these issues. We have also identified UMs for key areas.

Table 30: Risk Register

9.4. Regulatory Treatment

This investment will be tracked through the NARMs methodology, the benefits are recorded in our submitted NARMs tables.

This investment is accounted for in the Business Plan Data Tables 2.04 (Non-Routine Maintenance).