Cadent
Your Gas Network

Appendix 09.33 Pipeline Sleeves

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 an Engineering Justification Paper (EJP) and a Cost-Benefit Analysis (CBA) for these assets.

Overview

We have 2,041 pipeline sleeves in use across our 4 networks on our high pressure (HP) pipelines at road, rail and water crossings. These sleeves are designed to provide either protection from damage, pressure containment in the event of failure, or to facilitate construction. We carry out pipeline integrity surveys across our HP pipelines; these surveys enable us to ensure that our pipeline sleeves are not impacting on the integrity of the pipeline. 86% of these surveys are carried out internally within the pipe. Associated cathodic protection test points are also used to test pipeline sleeve health. We have a comprehensive survey programme that enables us to understand the condition of our sleeves.

Cadent has contributed to industry wide work on improving the integrity management of sleeves. This has been facilitated by the UK Onshore Pipeline Operators Association (UKOPA) and resulted in the development of an industry good practice guide (Managing Pipeline Sleeves – UKOPA/GP/005 dated January 2016). This approach forms the basis for managing sleeve integrity within Cadent.

Our survey data, combined with this UKOPA model has been used to inform this investment case, and gives us a reasonable understanding of the relative likelihood of sleeves failing and potential impacts.

We have considered a baseline/reactive option and two proactive options within this investment case. The only feasible option that allows us to comply with our specific obligations under the Pipeline Safety Regulations (PSR) and Health and Safety and Work Act 1974 is our preferred option (option 1).

Whilst we have considered an alternative option (option 2) of intervening on a lower volume of sleeves in RIIO-2, this would breach our obligations under the HSWA 1974 (in respect of an employer's duty to ensure as far as is reasonably practicable that their employees (Section 2) and other persons (Section 3) are not exposed to risks to their health or safety), and under PSR 1996 (Regulation 13 Maintenance)[1]. For these reasons, this option has been discounted.

We have used CBA for illustrative purposes only, to show that even without our regulatory mandate, a proactive approach is optimum.

Our preferred option is therefore to continue to proactively intervene on pipeline sleeves for RIIO-2; this option will achieve a lower-risk profile by the end of RIIO-2 for investment of XXXX . The proposed expenditure is based on unit rates achieved in RIIO-1 which were derived from competitively sourced labour and materials. Consequently, we consider that the proposed expenditure is efficient for the proposed work types and volumes outlined.

Summary of preferred option	XXXX
RIIO-2 Expenditure	XXXX
NPV (switching analysis)	XXXX

<u>Material changes since October submission</u>

The costs have been uplifted to the 2018/19 price base.

[1] We would be aware of pipeline sleeve risks, due to our survey programme, but would be choosing not to intervene straight away. The HSE would deem this as failing the "as soon as reasonably practicable" test.

Table of Contents

2. Introduction

This document covers the investment case methodology for pipeline sleeves. Pipeline sleeves are used on High Pressure (HP) pipelines at road, rail or water crossings and are designed to provide either protection from damage, pressure containment in the event of failure, or to facilitate construction.

The proposed sleeve monitoring and interventions support compliance with our obligations associated with the Pipeline Safety Regulations 1996 (PSR) and specifically Regulation 13 (Maintenance).

Our pipeline sleeves investment case comprises the following main elements set out in the table below. This Engineering Justification Paper only discusses the material investment in pipeline sleeve remediation, **under our Cadent line reference 98c**.

Cadent line reference	Line description	RIIO-2 investment Total
98a: Sleeve Remediation Surveying & Batteries	**Opex** spend on surveying and replacements of batteries for remote monitoring units	Redacted due to commercial sensitivity
98b: Sleeve Monitoring Unit Remediation	**Capex** spend remediating the N2 Remote monitoring units (replacement of monitoring units)	
TOTAL minor elements		
98c: Pipeline Sleeve Remediation	Any form of remediation to pipeline sleeves including fitting end-seals, filling the annulus of the sleeve to prevent corrosion, replacing nitrogen filling lines and re-charging the sleeves with nitrogen once the intervention is completed.	
TOTAL for this paper		

Table 1: Pipeline sleeves: key components of this investment case

Cadent has contributed to industry wide work on improving the integrity management of sleeves. This has been facilitated by the UK Onshore Pipeline Operators Association (UKOPA) and resulted in the development of an industry good practice guide (Managing Pipeline Sleeves – UKOPA/GP/005 dated January 2016). It forms the basis for managing sleeve integrity within Cadent. This review was the catalyst to compiling the initial data set for these assets which has supported and informed our sleeve remediation delivery plans for RIIO-1. It was recognised that it would be necessary to continue efforts to improve the data quality for these assets during RIIO-1 and it is anticipated that these efforts, supported by targeted surveys and remediation, will extend in to RIIO-2.

Our approach to proposing investment needs is based on a current assessment of the overall risk profile of the sleeve population, the projected position at the end of RIIO-1, and our aim to have remediated the medium and higher risk sleeves by no later than the end of the RIIO-2 period. The forecast costs of the proposed interventions have been derived from work undertaken to date in RIIO-1. This is a measured approach which enables a progressive and reasonably practicable reduction in risk, whilst allowing improvements in our sleeve portfolio data to incrementally improve the targeting of resources.

In summary we have used the UKOPA asset risk framework to select the most optimum investment programme for RIIO-2. In reaching this position we have considered the two options set out below and discuss these further in section 7:

- **Option 1:** Reducing risk by end of RIIO-2, maintain risk-thereafter. Target a lower risk population by the end of RIIO-2 (derived from periodic assessment using the UKOPA framework)
- **Option 2:** Hold current risk flat (derived from periodic assessment using the UKOPA risk framework).

Our considered option is that to ensure legal compliance to remediate known risks “as soon as reasonably practicable”, option 1 must be followed.

We have also used CBA analysis to assess the costs and benefits of undertaking proactive sleeve remediation versus allowing our sleeves to deteriorate with the eventual consequence of suffering from a pipeline failure/ leak. We have used our LTS AIMs deterioration model to help us understand the consequence of pipeline failure. Due to the low levels of historic failures, we have limited data for us to understand the probability of failure of pipelines associated with sleeve deterioration. We have therefore used switching analysis to identify the probability of failure for the proposed proactive approach to be NPV positive. Within our CBA data tables, we have modelled a proactive repair option (Option 1) and included the benefits from avoiding reactive failures, and then added a further CBA case for sensitivity testing (CBA Option 2).

3. Equipment Summary

A summary of the number of pipeline sleeves in each network is shown below.

Table 2 provides the split by pipeline inspection type (i.e. either In-Line Inspection (ILI) or overland survey (known as an OLI4 survey).

Network		ILI	OLI4	Overall
EoE	EA	285	98	383
	EM	420	39	459
Lon		364	44	408
NW		353	46	399
WM		329	63	392
TOTAL		**1,751**	**290**	**2,041**

Table 2: Sleeve population by network and pipeline inspection type

An ILI is carried out by passing tools through a pipeline. These inspections identify metal loss or other features (e.g. caused by corrosion) and also pipe wall deformities. Where a pipeline passes through a sleeve an ILI will identify any such issues with the pipeline. OLI4 surveys are carried out above ground on pipes that cannot be inspected via an ILI. An OLI4 survey is unable to provide data on the condition of the carrier pipe within the sleeve and instead provides data on the sleeve where it is made of steel.

The following table summarises the sleeve population by sleeve-type and network.

Network		Sleeve Type			
		Steel	N_2	Other	Total
EoE	EA	237	39	107	**383**
	EM	70	22	367	**459**
Lon		318	61	29	**408**
NW		281	118	0	**399**
WM		229	51	112	**392**
TOTAL		**1,135**	**291**	**615**	**2,041**

Table 3: Sleeve population by network and sleeve type

An additional asset component of each nitrogen (N_2) sleeve is the associated remote monitoring unit. This unit continuously monitors the N_2 gas pressure. The N_2 displaces oxygen (0_2) and so prevents the establishment of environmental conditions that support corrosion. Should the monitor indicate that the N_2 pressure has dropped below a pre-set threshold then an alert will be raised which will prompt an operational response to re-charge the N_2 in the sleeve.

Cadent's sleeve records were consolidated in support of the UKOPA lead work to develop good practice in the management of sleeves. It is acknowledged that the data quality has some limitations, and actions have been taken during RIIO-1 to improve it. It is anticipated that these efforts will continue during RIIO-2 to enable our investment plans, and the targeting of resources to be improved iteratively.

4. Problem Statement

Overview

Sleeves started to be installed on pipelines constructed in the 1960s and so now represent an ageing asset. The sleeves were used at road, rail and water crossings and are designed to provide additional protection to the pipeline from the risk of 3rd party damage or to assist in the construction process.

The key risk associated with pipeline sleeves and the driver for our monitoring and remedial works is that of corrosion of the pipeline occurring within the sleeve which could lead to a gas escape with a consequential threat to the safety of the public, our employees and contractors, and to security of supply. This risk is heightened where the pipeline isn't subject to In-Line Inspection (ILI) as the condition of the sleeve, rather than the pipe, is examined during the alternative overland inspection regime (OLI4).

Investment Drivers

There are two drivers of investment that must be considered: Legislative (Safety) and Interruptions to supply. In addition, we recognise the importance of investment plans that are value for money. We aim to provide the most efficient and cost-effective long-term solution to minimise customer bills.

Safety (Legislative): We invest in these assets to comply with the Pressure Safety Regulations (PSR) 1996 Regulation 13 requirement to maintain our pipeline assets to secure its safe operation and to prevent loss of containment. Maintenance is essential to ensure that the pipeline remains in a safe condition and is fit for purpose. In addition, the HSWA 1974 (in respect of an employer's duty to ensure as far as is reasonably practicable that their employees (Section 2) and other persons (Section 3) are not exposed to risks to their health or safety).

Interruptions to supply: High Pressure (HP) pipelines enable the bulk transportation of gas from our offtakes from the National Transmission System (NTS) to the centres of population and also to large industrial and commercial customers. Consequently, the failure to manage pipeline assets increases the likelihood of interruptions to significant numbers of customers.

Required outcomes

We have an absolute duty to comply with our PSR regulations. The increase in safety risk stemming from no investment is unacceptable.

Additionally, customers and stakeholders have consistently told us that worsening levels of network safety, reliability and network security is not in line with their views.

In summary, the required outcomes for this investment is a safe and reliable system. Success is measured by ensuring a safe operation, legal compliance, and avoiding any failure which leads to downstream interruptions.

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

Understanding project success

Success will result in the delivery of a population of pipeline sleeves and associated carrier pipes that are effectively maintained.

Whilst the specific aim is that the sleeves will be broadly rated as low risk under the UKOPA sleeve ranking framework, it is anticipated that as a result of uncertain ageing factors across the population there may be a small proportion of sleeves that will be rated medium or high risk at the end of the RIIO-2 period. This dynamic growth in background risk will be manged through interventions in RIIO-3.

4.1. Narrative Real-life Example of Problem

The type and scale of intervention or remediation can vary significantly. Based on the most frequent issues and types of remediation identified during RIIO-1, we have provided two examples.

Cathodic Protection remediation:

This type of remediation can involve interventions to the cathodic protection (CP) test posts (TP) and associated CP system (i.e. including cables and connections and sacrificial anode), or to resolution of faults (e.g. where an electrical short circuit has occurred or the bonding between the sleeve and the pipeline has failed).

During RIIO-1 remediation, prompted by inadequate CP protection level readings identified during routine maintenance, was carried out at Smorrall Lane on the 8” dia. Exhall – Bedworth Junction pipeline (PSR nos. 1423) which has a MOP of 19 bar and is in our West Midlands (WM) network. The sleeve was installed to provide protection to the pipeline at this road crossing when the pipeline was commissioned in 1979.

The sleeve was excavated on and the material confirmed to be concrete located at a depth of 1.12 m in the verge next to a public footpath gate. A concrete sewer drain and also High Voltage cables were located in close proximity to the sleeve. The CP cable connection point to the steel pipeline was repaired and the CP TP replaced with a modern equivalent and relocated to a safer working location on the north side of the crossing.

Figure 3 & 4 below show the completed site with upgraded TP and marker post to identify the location of the pipe and sleeve at a hedge boundary.

Figure 3 & 4: Upgraded CP test point for pipeline adjacent to sleeve together with marker post

Without sleeve remediation and effective CP, the pipeline within the sleeve would have been at risk of failure due to corrosion leading to a loss of containment and a resultant HP gas escape. Such incidents pose both a safety threat to the public and our employees, and also potentially to the security of supply depending on the severity of the event, and its timing (i.e. if the incident occurs at a time of high or peak demand then the risk to supplies is greater).

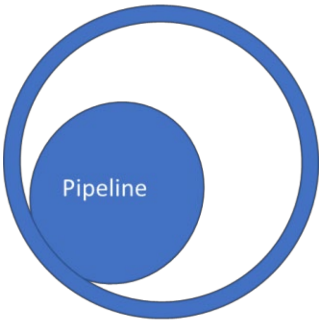
Pipeline sleeve general remediation

This is a broader scope of remedial work and could include the fitting of new end seals (these may be flexible or ridged), filling of the annulus of the sleeve with a grout to prevent corrosion or, in extremis the replacement of a section of pipeline. Two examples of sleeve remedial work undertaken during RIIO-1 are described below.

Firstly, a CP system problem was identified following an inspection on the sleeve at Flagshaw Lane on the 457mm dia. pipeline between Sutton on the Hill and Totley (PSR nos. 1163) which has an MOP of 37 bar and is in our East of England network (EM Local Distribution Zone). The sleeve was installed to protect the pipeline at the road crossing. The sleeve material is cast iron.

The pipeline ILI report had identified that the pipeline was in contact with the sleeve due to slight differential settlement between the pipe either side of the sleeve and the sleeve itself. Investigation on site confirmed this and attempts were made to cut back (shorten) the sleeve to provide clearance between it and the pipeline to enable the CP to be effectively remediated. However, this revealed that the pipeline was in contact with the sleeve over an extended length and so the sleeve was eventually removed, and alternative protection provided. The pipeline had been damaged through being in contact with the sleeve. Following formal damage assessment, it was repaired. This job incurred expenditure of XXXX.

Figures 5 & 6 below show schematically the pipeline position within the sleeve which caused the electrical 'shorting' of the CP system, and also excavation and initial pipe cutting operation to shorten the sleeve, before the decision was taken to fully expose and remove the sleeve.



Figures 5 & 6: Pipe/sleeve interaction, and the initial sleeve shortening operation

Similarly, the document cover photograph shows an exposed steel sleeve at Counterdrain Drive, Spalding on the North Witham to Pinchbeck 273mm dia. pipeline that has a MOP of 37 bar. The sleeve was installed at the time the pipeline was constructed in 1969 to both facilitate construction and to provide protection where the pipeline crossed what is now a disused railway. It was identified during an ILI of the pipeline in 2016 that there was a slight metal loss feature (general corrosion) on the pipeline at one end of the sleeve and that the sleeve was positioned eccentrically in relation to the pipeline.

After initial investigation, during which time the pipeline was repaired, attempts were made to rectify the sleeve to pipeline 'shorting' error in the CP system. These proved unsuccessful and so eventually it was necessary to fully expose and cut back the sleeve to enable the CP system to operate effectively.

Without sleeve remediation, and the effective CP protection of the pipeline within the sleeve, then in both of the examples above the outcome may be more significant corrosion of the pipeline leading to either extensive and costly repair or a loss of containment and a HP escape. The latter presents both a safety risk to the public and our employees, and also a threat to the security of supply.

4.2. Spend Boundaries

The assets within the scope of this investment case are the population of HP pipeline sleeves together with their associated CP systems. Additionally, for N_2 filled sleeves, the assets include the monitoring and fill points.

Figure 7 below shows schematically the sleeve and carrier pipe, together with the CP monitoring and (for N_2 filled sleeves) the fill point. The schematic also shows a typical hand held device used to monitor and record CP readings, together with associated reference electrode.

Please note that our workload and expenditure proposals associated with CP systems more generally across our steel pipelines are covered in a separate investment case (09.35).

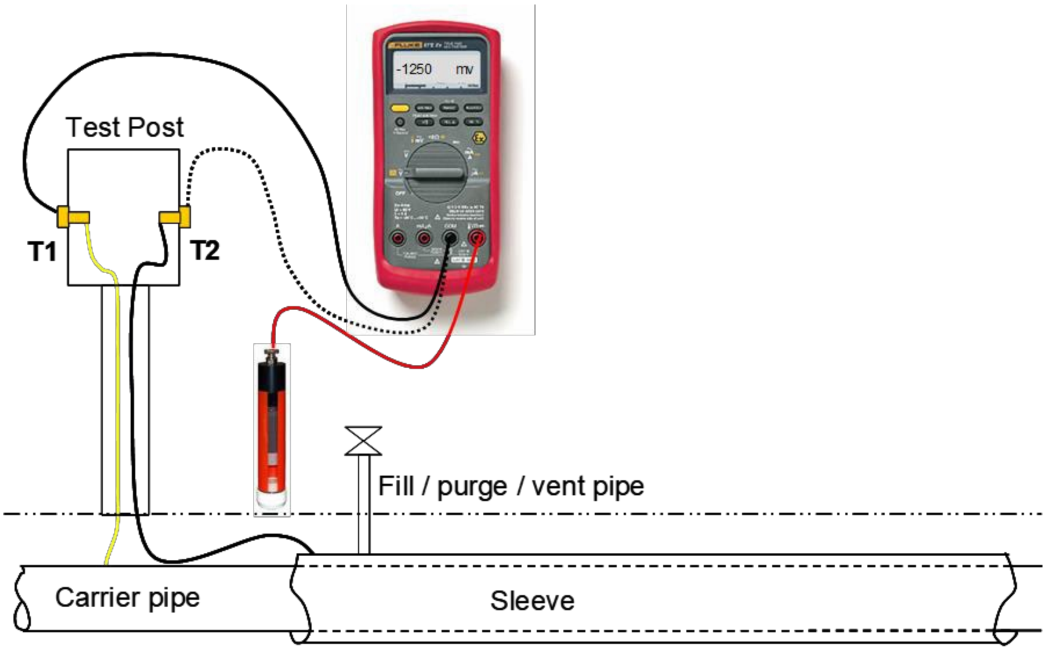


Figure 7: : Schematic of pipeline sleeve and monitoring/fill points

5. Probability of Failure

The probability of a pipeline failing is low because we put protective measures in place which prevent deterioration of the pipeline. These measures comprise pipeline coatings, cathodic protection or, for this investment case, a pipeline sleeve. We have had no pipeline failures in recent times as a result of sleeve deterioration because we have had an appropriate sleeve-management programme in place.

If the sleeve was to fail, then the probability of pipeline failure increases significantly.

We have an understanding of the probability of sleeve failure through our UKOPA study. As mentioned previously, the collaborative work with UKOPA resulted in the development of an industry good practice guide (Managing Pipeline Sleeves – UKOPA/GP/005 dated January 2016). [2]

One of the key outputs from the work led by UKOPA was a model that uses a range of pipe and sleeve asset factors, together with a range of consequence factors to derive an overall risk ranking factor (high/medium/low) for each sleeve.

Probability of failure: The asset factors used include the age of the pipe/sleeve, coating type, whether subject to ILI, status of the CP system, sleeve material and thickness, and the annular fill type. These factors are combined in the model to determine a pipeline leakage factor and an associated ranking factor (high/medium/low).

Probability that failure will lead to an impact: Within the UKOPA model, a range of consequence factors are used to take account of the location, hazard size, and the probability of ignition. These are combined to determine a consequence factor and an associated ranking factor (high/medium/low). The 2 ranking factors are then combined to provide an overall ranking (high/medium/low).

This pipeline integrity risk is not impacted by the supply-demand scenario selected, because the risk is associated with the asset rather than volume of gas-transported.

As highlighted above the model derives a pipeline leakage factor which, whilst not a specific quantified probability of failure (PoF) for each sleeve, does provide a good proxy for a PoF. When combined with the consequence factor the model output provides a consistent framework for the assessment of the risk presented by each sleeve, and the aggregate risk in each network.

We have used the model risk output to target our response during RIIO-1 to the management of our sleeve population.

The initial assessment was undertaken in 2014 and represents the risk position in each network as at March 2014. This is shown schematically below in figure 8.

[2] http://www.ukopa.co.uk/documents/UKOPA-GPG005.pdf

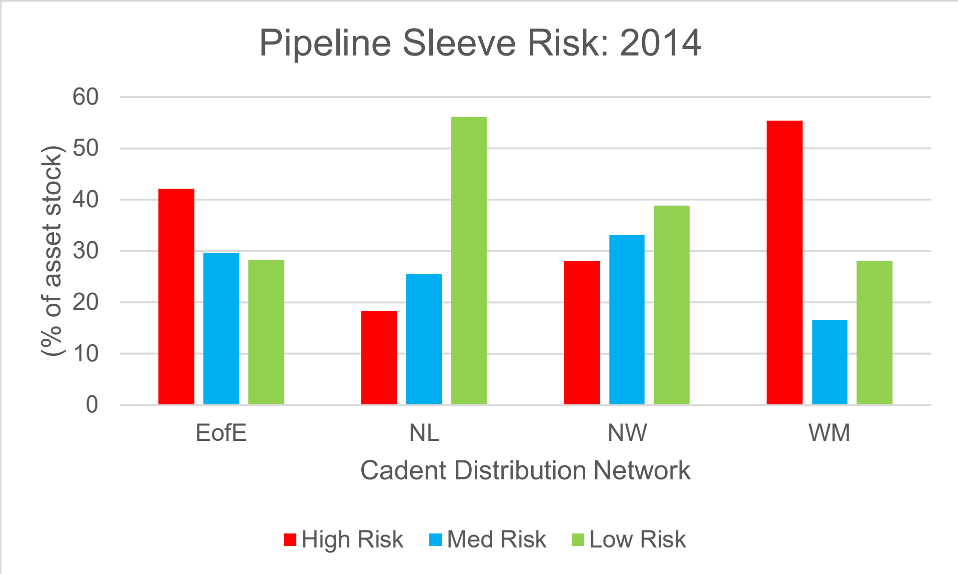


Figure 8: Likelihood that a sleeve failure will trigger a consequence at March 2014

Based on progress to date and our work plans we anticipate the projected pipeline sleeve risk profiles shown below in figure 9 at the start of RIIO-2.

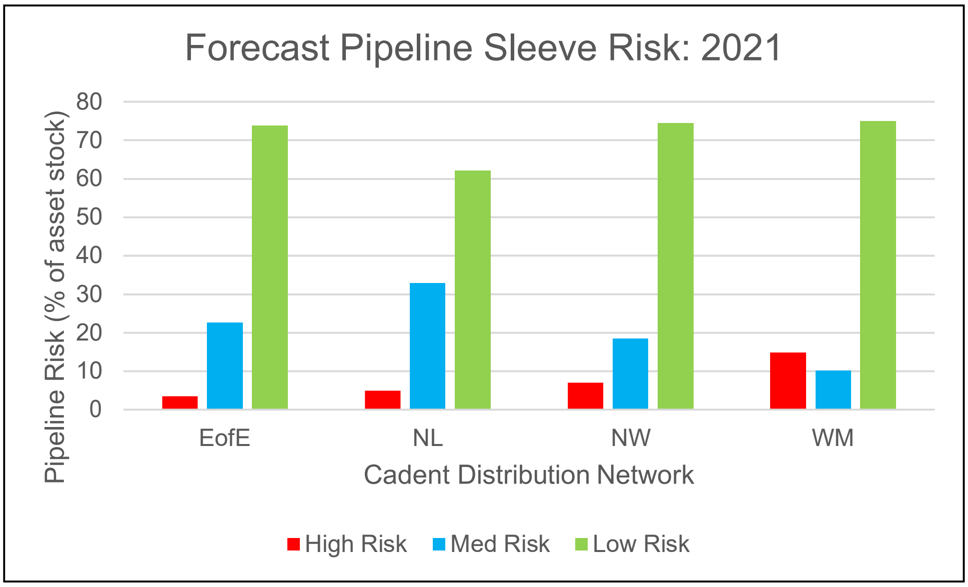


Figure 9: Likelihood that a sleeve failure will trigger a consequence (forecast for end RIIO-1)

5.1 Probability of Failure Data Assurance

The UKOPA model was derived from consideration of the available data on all of our pipeline sleeves. Where data gaps existed, and/or the data indicated potential concerns (e.g. level of CP protection, ability to retain annular N_2 pressure) then the sleeve was rated as red or amber.

The data provided for the UKOPA modelling work is limited by some missing information, particularly in respect of the sleeve material, presence of an end seal, and annular fill type other than N_2. The data in respect of the pipeline and the principle inspection method/frequency for the pipeline (i.e. whether subject to ILI or OLI4 overland survey) is good (sourced from the Pressure Systems Database (PSDB)). Similarly, the CP system data for the pipeline is good (sourced from our corporate system Uptime).

Whilst we acknowledge that there will be some limitations and inaccuracies of the sleeve data we are confident that the UKOPA model, developed by the pipeline operator members of the Association with expert support, provides a reasonable basis to attribute an assessment of probability across our networks. However, as outlined in section 7 below, we believe that it is prudent and pragmatic to continue to undertake a programme of data validation and survey during RIIO-2 to support the progressive improvement of the sleeve data.

6. Consequence of Failure

The consequence of sleeve failure is, in itself, low, in the short term but failure leads to deterioration of the pipeline it protects. The consequence of pipeline failure is high.

If we are subsequently shown to demonstrate that we have not reasonably done what we could have to operate a safe network, we would be in breach of our statorty duties (Pressure Safety Regulations (PSR), and more generally under the Health and Safety at Work Act (HSWA) 1974 in failing to protect people from the risks associated with these major accident hazard pipelines (as defined by the PSR).

The UKOPA work has identified sleeves as being at medium or high risk of failure. These are known issues which mandate a response.

If the sleeve and carrier pipe within it are not effectively maintained, then there is a high risk of corrosion of the pipeline occurring within the sleeve annulus which could in turn lead to a high pressure (HP) gas escape. Such a scenario could put the safety of the public, our employees and contractors, and the security of supply to customers at risk.

This risk is heightened particularly on pipelines that are not subject to In-line Inspections (ILI) as the condition of the sleeve is examined, not the gas carrying pipe, during the alternative overland survey.

We have used the consequences of a pipeline failure as included in our LTS AIM model.

Our LTS AIM model includes the following consequences:

- Interruptions to supply (Properties impacted)
- Transport disruption
- Property damage
- Fatality / injury
- Emissions (Greenhouse gas)

In addition, we have also considered the avoided costs from removing the need to carry out a reactive repair. Delivering work reactively costs more as premium prices are incurred.

Our AIM model contains the following consequence data (figures per annum):

	Supply interruption: Properties impacted (pa)	Properties damaged (pa)	Value per property	Fatalities (pa)	Minor injuries (pa)	Level of emissions (Kg/m3)
EoE	[redacted]					
Lon						
NW						
WM						
ALL						

Redacted due to commercial sensitivity

Table 3: Consequence of Failure: properties, injury, emissions on LTS pipeline

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
All	**0.0054**	**0.0000**	**0.0015**	**0.0055**	**0.0183**

Table 4: Consequence of Failure: Transport Disruption (nr days disrupted per failure)

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

Severity	Value per day X
Transport disruption: Minor road	Redacted due to commercial sensitivity
Transport disruption: A road (modelled - average A roads)	
Transport disruption: Motorway	
Transport disruption: National rail (critical routes)	
Transport disruption: National rail (other routes)	

Table 5:Societal costs of transport disruption

In addition to the risks summarised above which would directly impact the public and our employees, another consequence of a pipeline failure would be significant unplanned expenditure associated with the initial emergency response, and the repair activity. The repair of HP pipelines usually involve flow stopping and bypass arrangements, significant preparatory civils works, and the establishment of an extensive safe working zone for a prolonged period with associated inconvenience (e.g. to road users and the wider public).

The cost of an unplanned HP pipeline repair can typically range from XXXX depending on pipe size and location (a case study is given in 09.09 LTS Pipelines). This illustrative cost range, which is derived from several HP pipeline repairs undertaken for various reasons during RIIO-1, does not take account of the actual or risk-adjusted potential direct costs associated with a wide scale supply loss (i.e. network isolation, recommissioning of the network and customers, support to vulnerable customers, compensation payments as appropriate) that could take an extended period running to weeks to rectify. These costs could substantially exceed the repair costs.

7. Options considered

Our objective is to develop and deliver a work programme which meets our regulatory obligations to maintain a safe pipeline system and which consequently best reflects customer and stakeholder needs and expectations. In RIIO-1 we have supported and invested in the development of the UKOPA sleeve risk assessment model to enable us to assess our portfolio of sleeves and subsequently make decisions within that industry recognised framework.

In developing our proposals for RIIO-2 we have considered the three options. These are explained more fully below in the relevant options summaries:

- **Baseline**: Reactively replace after pipe failures
- **Option 1: Reducing UKOPA risk by end of RIIO-2, maintain risk-thereafter.** Target a broadly lower risk population by the end of RIIO-2 (derived from periodic assessment using the UKOPA framework)
- **Option 2: Hold current (2021) UKOPA risk flat** (derived from periodic assessment using the UKOPA framework)

We recognise that we have an obligation under our Pipeline Safety Regulations to maintain our pipes and allowing them to fail prior to intervention would leave us open to prosecution from the HSE. We have however included this CBA for completeness, to demonstrate that a proactive approach to pipeline-sleeve maintenance is optimum. We have included a summary of our approach, the basis of calculation and the detailed results in Appendix 1.

7.1 Baseline: Reactively fix on failure.

This option assumes that we do not proactively invest on any of our pipeline sleeve protective measures and carry out no further monitoring of CP, and merely remediate the HP pipe when it fails.

Under this scenario, Cadent would be in breach of its obligations under the Pressure Safety Regulations (PSR), and more generally under the Health and Safety at Work Act (HSWA) 1974 in failing to protect people from the risks associated with these major accident hazard pipelines (as defined by the PSR).

We are also aware that a failure to maintain the compliance of our CP systems resulted in a Health & Safety Executive improvement notice (Notice Ref No: 306763291[3], served against National Grid Gas PLC on 11/11/2015 in respect of deficiencies in the approach to inspections and interventions on Cathodic Protection (MP/LP pressure) systems.

This option is our baseline case. However, this baseline option cannot be forecast in absolute terms due to the high levels of uncertainty. In this scenario, we have set the baseline as zero and, in the options, the *changes* in costs are considered. A specific example of this is where we have included the costs of reacting to a failure as avoided costs in each option rather than as absolute levels of anticipated costs in the baseline. This approach has also enabled us to test the sensitivity of the levels of avoided reactive costs more easily.

Our CBA has therefore used a switching analysis to look at what the cost and the impact of failure would need to be for the proactive approach to be more cost-beneficial than a reactive one.

The costs from avoiding such impacts of HP/IP pipeline failure have been added into Option 1 (below) as avoided costs.

[3] Notice 306763291: http://www.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=306763291

7.2 Option 1 – Target a low risk population by the end of RIIO-2

This option sustains our current approach to proactively target the higher and medium risk sleeves (as defined by the UKOPA framework) and so manage the condition of our pipelines. This option enables us to progressively reduce the risk profile of our pipeline sleeve population in a reasonably practicable way which we consider to be in accordance with our obligations under HSWA 1974 and PSR 1996[4]. This is our chosen option.

Specifically, we aim to remediate the population of high and medium risk sleeves (as forecast at the end of the RIIO-1 period) in RIIO-2. We have also assumed that we will be able to re-classify 5% of these higher risk sleeves as a result of the survey work we propose (i.e. by completing or amending data sets). Our proposals anticipate a reduced workload during RIIO-2 in comparison with RIIO-1 (i.e. remediating c 545 sleeves -v- c780 sleeves remediated in RIIO-1) with this reducing trend continuing in to RIIO-3 when we estimate we would remediate c10% of the overall population over the period due to ageing factors (i.e. c200 sleeves, or 40pa, remediated).

These assumptions to derive the remediation volumes for RIIO-2 & 3 are summarised below.

	Assumptions on proposed workload	Volume of remediation (pa)
RIIO-2	575 sleeves in high/ medium risk category at the beginning of RIIO-2. Approx. 95% of these will require remediation in RIIO-2, i.e. 545 sleeves. We have assumed that the survey work programme will enable the balance to be re-classified to a lower risk without investment.	C109 sleeves remediated pa during RIIO-2 c18 Nitrogen sleeve remediated pa c91 Construction sleeves pa remediated
RIIO-3	2% per annum deterioration rate	40 pa

Table 6: Key assumptions for Option 1

Based on the above assumptions, we forecast the following sleeve remediations during RIIO-2.

		2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	**Nitrogen**	4	4	4	4	4	**20**
	Const.n	38	38	38	38	38	**190**
Lon	**Nitrogen**	5	5	5	5	5	**25**
	Const.n	24	24	24	24	24	**120**
NW	**Nitrogen**	6	6	6	6	6	**30**
	Const.n	13	13	13	13	13	**65**
WM	**Nitrogen**	3	3	3	3	3	**15**
	Const.n	16	16	16	16	16	**80**
Total (c95% of 575)							**545**

Table 7: Volumes of remediations in RIIO-2: Option 1

[4] The HSE have been part of the working group for UKOPA, and as such are deemed to endorse the approach used.

As a result of the above volumes of remediation the resulting investment required for Option 1 is set out below.

	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW			[redacted]			
WM						
Total						

Table 8: Forecast investment in RIIO-2: Option 1 XXXX)

The supporting assumptions to derive the CBA for this investment case is contained in Appendix 1.

7.3 Option 2 - Hold current (2021) asset risk flat

This option looks to keep the total number of sleeves in each risk category at 2021 levels, throughout RIIO-2 & 3.

As set out in the graphic above, at the end of RIIO-1 we anticipate there being c 575 sleeves assessed as high/medium risk under the UKOPA framework. We estimate that c150 of these will be high risk, and c425 would be medium risk. There would be c 1,460 sleeves assessed as low risk.

We have estimated, based on engineering judgement, that over the 5 year RIIO-2 period as a result of ageing factors c10% of the population (i.e. 10% of c1,260 sleeves – we have excluded the c780 sleeves remediated during RIIO-1) would deteriorate to such an extent that it's risk rating would increase. Consequently, we would estimate that to broadly hold risk flat we would undertake c 125 remediation jobs during RIIO-2. In the longer term post RIIO-2, assuming that our estimate of a 2% pa population deterioration rate is broadly accurate, then we would anticipate that c 200 sleeves (i.e. 2% of the entire population of c2041) would require remediation over a 5 year period (or c40 sleeves pa) to hold the population risk level flat.

	Assumptions on deterioration rate	Volume of remediation (pa)
RIIO-2	c575 sleeves in high/ medium risk category at the beginning of RIIO-2. Whilst c1,450 sleeves assessed as low risk at start of RIIO-2 we have assumed that the c780 sleeves remediated during RIIO-1 wouldn't deteriorate during RIIO-2. Hence the population at risk of deterioration is c 2041-780= c1260, and by end of RIIO-2 10% of these will have deteriorated and will require intervention to hold risk flat.	25 sleeves pa (of which ~4 N_2 sleeves and ~21 construction sleeves
RIIO-3	2% per annum deterioration rate	40pa

Table 9: Key assumptions for Option 2

Based on the above assumptions, we therefore forecast the following sleeve remediations during RIIO-2. The key assumption in deriving both the forecast workload volumes and associated expenditure for this option is that both are prorata to the respective volumes and investment of our preferred approach (see option 1) by the workload of each option, i.e. a factor of 125/545 is used to derive the option 2 values. There are rounding variations in the summing of option 2.

		2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	Nitrogen	1	1	1	1	1	**5**
	Const.n	9	9	9	9	9	**45**
Lon	Nitrogen	1	1	1	1	1	**5**
	Const.n	7	7	7	6	6	**33**
NW	Nitrogen	2	2	1	1	1	**7**
	Const.n	3	3	3	2	2	**13**
WM	Nitrogen	1	1	1	1	1	**5**
	Const.n	3	3	2	2	2	**12**

Table 10: Volumes of remediations in RIIO-2: Option 2

As a result of the above volumes of remediation the resulting investment required for Option 2 is set out below.

	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon		Redacted due to commercial sensitivity				
NW						
WM						
Total						

Table 11: Forecast investment in RIIO-2 (XXXX): Option 2

We have not assessed this option using CBA; we judge it to be none compliant with safety legislation.

This option would result in our high & medium risk sleeves remaining without remediation for longer, within our networks, with the increased risk of pipeline deterioration as a result. With reference to the HSE's interpretations of "as soon as reasonably practicable", we would have knowledge of a risk through our pipeline survey programme but would essentially be choosing not to remediate the risk within a reasonable timescale. In the event that we suffered a pipeline integrity failure as a result of a sleeve, we would not comply with the HSE's test of "as soon as reasonably practicable" which could also be interpreted as a breach under the HSWA 1974 (in respect of an employer's duty to ensure as far as is reasonably practicable that their employees (Section 2) and other persons (Section 3) are not exposed to risks to their health or safety), and under PSR 1996 (Regulation 13 Maintenance).

Consequently, we are not proposing that this option be adopted.

7.4 Options Technical Summary Table

The following table sets out the technical details of each option considered. Note this table summarises the pipeline sleeve remediation included in our investment line 98c only.

	Baseline	Option 1	Option 2
Description	Reactively fix pipelines upon failure	Target a broadly low risk population by the end of RIIO-2	Hold current (2021) asset risk flat
First year of spend	N/A	Year 1	Year 1

	Baseline	Option 1	Option 2
Last year of spend	N/A	Year 5	Year 5
Volume of interventions	0	90 Nitrogen sleeves remediated 455 Constructions sleeves remediated	22 Nitrogen sleeves remediated 103 Constructions sleeves remediated
Design life	N/A	Various; both repairs & replacements included	Various; both repairs & replacements included
Safety Compliant	Option was discounted as it would result in failure to comply with Pressure Safety Regulations.	Compliant	Option was discounted as it would result in failure to comply with Pressure Safety Regulations.
Total installed cost	Redacted due to commercial sensitivity		

Table 12: Options Technical Summary table

7.5 Options Cost Summary Table

	21/22	22/23	23/24	24/25	25/26	Total
Baseline	Redacted due to commercial sensitivity					
Option 1						
Option 2						

Note: Rounding-up / down in the above figures results in the totals and individual years not reconciling.

Table 13: Options Cost Summary Table (line 98c only) XXXX

Our RIIO-2 forecasts, as well as adjusting for workload and work mix factors, also include ongoing efficiencies flowing from our transformation activities including from updating and renewing our contracting strategies. Our initiatives are outlined in Appendix 09.20 Resolving our benchmark performance gap. No additional efficiency has been applied to this investment case.

For Pipeline Sleeves our confidence is at Conceptual Design stage with a range of +/-20%.

Deriving our unit costs for sleeve remediation

Based on a review of our RIIO-1 costs and work scope requirements, we have estimated the following likely interventions / remediation costs for an “average sleeve remediation”. On the basis that we cannot forecast the scale or complexity of future interventions for specific sleeves until further investigation is complete, this average remediation cost per sleeve is the most robust approach possible.

The forecast unit costs shown in Table 14 below and are derived from a forecast out-turn cost for a programme of 160 sleeve-remediations (following detailed surveys) during 2018/19. This is a large and current sample size and as such we are confident that the average cost is correct.

Unit Costs (XXXX remediation)	Network		
	EA, EM, NW	Lon	WM
Nitrogen sleeve	Redacted due to commercial sensitivity		
Construction sleeve			

Table 14: Unit costing assumptions for pipeline sleeve remediation

The rationale for the variances are combination of:

- regional variations in labour/contact rates
- varying proportions of pipelines in urban/rural type locations.
- WM having greater proportion of pipelines in canal tow paths (with characteristic site access/maintenance challenges)

8. Business Case Outline and Discussion

We must manage our pipeline sleeves to ensure we comply with our PSR 1996 and HSWA 1974 obligations. We have used CBA, for illustrative purposes, which shows that, even without this regulatory obligation, a proactive approach is the optimum approach. The results of our CBA have been included in Appendix 1.

As such our CBA analysis compares our engineering option 1, against the baseline of replacing pipes once they have failed. In our CBA-option 2 (within the CBA data tables), we have carried out a sensitivity test to assess impact of removing the willingness to pay from supply interruptions within our engineering option 1.

We have not used CBA to compare engineering option 1 to engineering option 2.

8.1. Key Business Case Drivers Description

Our key business case driver for this investment case is to comply with our PSR obligations to effectively manage pipeline integrity risks, through appropriate management of pipeline sleeve deterioration risks.

The CBA shows that avoiding reactive repairs and avoiding fatalities caused by pipeline failure are the primary drivers.

As discussed previously, we have carried out a switching analysis across all potential consequences of pipeline failure, to assess the break-even probability.

8.2. Business Case Summary

Within this investment case we have assessed the following 3 options.

	Baseline	Option 1	Option 2
Description	Reactively fix pipelines upon failure	Target a broadly low risk population by the end of RIIO-2	Hold current (2021) asset risk flat
First year of spend	N/A	Year 1	Year 1
Last year of spend	N/A	Year 5	Year 5
Volume of interventions	Option was discounted as it would result in failure to comply with Pressure Safety Regulations. CBA used to support this decision, discussed below.	90 Nitrogen sleeves remediated 455 Constructions sleeves remediated	22 Nitrogen sleeves remediated 103 Constructions sleeves remediated
Design life		Various; both repairs & replacements included	Various; both repairs & replacements included
Total installed cost		[redacted]	

Table 15: Business Case Summary

We have chosen a RIIO-2 programme which continues the same proactive approach as RIIO-1 (Option 1) as the only feasible option which fully complies with our legal obligations under the PSR and HSWA. Costs will reduce between periods as the bulk of activity has been delivered in RIIO-1.

Our current preferred option is to proactively invest in remediating 545 medium and high risk, pipeline sleeves during RIIO-2.

Option 2 has been discounted because, we would effectively be identifying pipeline-sleeve risks through our survey programme and choosing to delay remediation. In the event that we suffered a pipeline integrity failure as a result of a sleeve, we would not comply with the HSE's test of "as soon as reasonably practicable" which could also be interpreted as a breach under the HSWA 1974 (in respect of an employer's duty to ensure as far as is reasonably practicable that their employees (Section 2) and other persons (Section 3) are not exposed to risks to their health or safety), and under PSR 1996 (Regulation 13 Maintenance).

We have used CBA for illustrative purposes only to demonstrate that a proactive approach to pipeline-sleeve maintenance is optimum. We recognize that we have an obligation under our Pipeline Safety Regulations to maintain our pipes and allowing them to fail prior to intervention would leave us open to prosecution from the HSE. We have however included this CBA for completeness.

Our CBA switching analysis has looked at how many reactive failures we would need for the proactive option to be the most cost-beneficial. This **baseline option of reacting upon failure**, assumes that we don't invest in maintaining any of these pipeline sleeves in the remaining years of RIIO-1, and all of RIIO-2 & RIIO-3. The results of the CBA switching analysis tells us that we would only need 1.7% of these 545 poor condition pipeline sleeves, to deteriorate to such a level within a 12 year period, to cause a pipeline integrity failure, for the proactive option to be cost beneficial.

Our engineering judgement suggests that with no-investment for 12 years, it is highly likely that at least 9 (1.7%) of these 545 pipeline sleeves will have degraded significantly with resulting gas-leaks and pipeline failures.

Therefore, the cost-benefit analysis demonstrates that our proposed proactive programme of work (Option 1) is the optimum approach. Option 1 also ensures that we are remediating our pipeline sleeve risks as soon as reasonably practicable, to manage pipeline integrity risk.

9. Preferred Option Scope and Project Plan

9.1. Preferred option

Option 1 above sustains our current approach to proactively target the higher and medium risk sleeves (as defined by the UKOPA framework) and so manage the condition and risk profile of our pipelines. This option enables us to progressively reduce the UKOPA risk profile of our pipeline sleeve population in a reasonably practicable way which we consider to be in accordance with our obligations under both the HSWA 1974 ((in respect of our duty as an employer to ensure as far as is reasonably practicable that our employees (Section 2) and other persons (Section 3) are not exposed to risks to their health or safety), and also PSR 1996 (in respect of Regulation 13 which requires the operator to maintain the pipeline to secure its safe operation and to prevent loss of containment).

Specifically, we aim to remediate the population of high and medium risk sleeves (as forecast at the end of the RIIO-1 period) in RIIO-2. We have forecast that we will need to undertake c545 sleeve remediations during RIIO-2. This is based on the projected position at the end of RIIO-1 and an assumption that we will be able to re-classify 5% of these higher risk sleeves as a result of the survey work we propose (i.e. by completing or amending data sets).

Our proposals anticipate a reduced workload during RIIO-2 in comparison with RIIO-1 (i.e. c 545 sleeves -v- c780 sleeves remediated in RIIO-1) with this trend continuing in to RIIO-3 when we estimate we would remediate c10% of the overall population over the period due to ageing factors (i.e. 200 sleeves, or 40pa, remediated).

9.2. Asset Health Project Spend Profile

Our preferred option (Option 1) results in the expenditure summarised below for each network during RIIO-2.

	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	Redacted due to commercial sensitivity					
Lon						
NW						
WM						
Total						

Table 16: Forecast investment in RIIO-2: Preferred Option

9.3. Investment Risk Discussion

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.33 - 001	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
09.33 - 002	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing	Low	Established marketplace - ability

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
		overall programme costs.		to manage the known commodity market
09.33 - 003	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
09.33 - 004	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.
09.33 - 005	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.
09.33 - 006	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.
09.33 - 007	Increased Environmental impacts upon design requirements	Increased costs and programme impact	Low	Constant review of site impacts and legislative changes Constant reviews of current / future installations

Table 17: Risk Register

9.4. Regulatory Treatment

This investment will not be processed through the NARMs reporting tool.

Cost variance for low materiality projects such as this will be managed through the Totex Incentive Mechanism (TIM).

This investment is accounted for in the Business Plan Data Table 2.04 Maintenance within the Non Routine Maintenance Sub Table under the LTS Pipeline Section under the Sleeves: Nitrogen & Other line.

Appendix 1. Basis of calculation for CBA

The following section sets out our approach to CBA, the assumptions made in deriving the benefits for each technical option, and the results of the CBA shown in the data tables.

Approach to CBA

We have used 'switching analysis' to assess the optimum option for this investment area, because of the uncertainty we have around the probability of a pipeline failure, as a result of pipelines with reduced depth of cover (and therefore damage from 3rd party land use). As stated in Section 6, we have used the consequence of failure from our LTS AIMS model to inform this manual CBA calculation.

We have used the switching analysis to help us identify the probability of failure that would make the programme breakeven – the switching point. We have then used expert judgement to assess whether this switching point is a reasonable minimum probability of failure. Taking an extreme case as an example, a break-even probability or failure rate for the identified stretch of pipe of 1 in 2 years would not be reasonable whereas 1 in 500 years clearly would.

Switching analysis, as set out the in HM Treasury Green Book, is a form of sensitivity analysis that identifies the input values required to change the cost-benefit analysis results.

> *'A switching value refers to the value a key input variable would need to take for a proposed intervention to switch from a recommended option to another option or for a proposal to not receive funding.* *(HM Treasury Green Book, p33)*

As set out in the Green Book, this approach is particularly useful where there are significant future uncertainties, making specification of accurate risk scenarios problematic. It is the most appropriate approach to Cost-Benefit Analysis in this area as we are able to model the consequences of a pipeline failure using our AIM models, however the probability of the failure is very uncertain.

We have modelled the following CBA scenarios within the CBA data tables, the results of this analysis are discussed in Section 8.

Option (In CBA Template)	Modelled Costs	Modelled Benefits
Option 0: Reactively replace pipe failures	N/A Costs of reacting to failure are included as benefits (i.e. costs avoided) in relevant Options below	N/A No activity is being undertaken
CBA Option 1: Targeted Proactive repair	RIIO-2 costs as submitted. (Line 98c).	Private and social costs avoided by the option: • Reactive Costs • Interruptions to supply • Transport disruption • Property Damage • Emissions • Health & Safety These are set at the breakeven failure rate level. Avoided societal costs associated with traffic disruption

Option (In CBA Template)	Modelled Costs	Modelled Benefits
CBA Option 2: Scenario to test Sensitivity of Option 1 to interruptions to supply valuation	RIIO-2 costs as submitted. (Line 98c.)	As above without Interruptions to Supply

Table A1: CBA options analysed within CBA data tables

Our CBA model has not been used to assess our engineering Option 2, and therefore assess that the optimum level of pipeline sleeve remediation is optimum. The level of intervention to manage pipeline sleeve risk has been based on expert opinion.

Calculating the Benefits for Option 1

Annual avoided Reactive Costs

(Annual rate of reactive repair) * (Cost of reactive repair)

The cost of reactive repair is assumed conservatively to be the 1.2 times that of proactive repair. This is because evidence shows that emergency reactive costs are substantially above planned proactive costs (in the region of 40 to 60% higher). Further our experience of reactive pipeline repair that may occur as a result of pipeline failure is that it is in the region of XXXX which is substantially above the reactive repair.

The annual rate of reactive repair is the failure rate, the breakeven value of which is assessed via Switching analysis.

These avoided reactive costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

The calculation at the company level is:

Failure rate x 1.2 x XXXX

Annual value of interruptions to supply

(Annual rate of interruption to supply) * (Number of properties affected) * (WTP to avoid interruption) * (Volume of interventions)

The annual rate of interruption to supply is the failure rate, the breakeven value of which is assessed via Switching analysis.

The number of properties affected is forecast via the AIM model and the WTP to avoid an interruption of the likely length of 24 hours to 1 week is XXXX . As the AIM model is for LTS and the sleeves relate to a wider range of pipelines, the failure of which may affect a lower number of properties than the LTS pipelines, we have taken only 10% of the properties affected in the AIM model as conservative estimate of properties affected.

Region	Number of Properties affected by any failure in LTS AIM model
EoE	732
Lon	1,198
NW	918
WM	772
All	838

Table A2: Properties affected by a pipeline failure by region

The calculation at the company level is:

Failure rate x 0.1 x 838 x XXXX x 545 (volume sleeve interventions)

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

Annual value for transport disruption

Our sleeves are often underneath transport features such as roads or railways. (Annual rate of disruptions to transport network) * (Number of days affected) * (Social cost of transport disruption) * (Volume of interventions)

The annual rate of interruption is the failure rate, the breakeven value of which is assessed via Switching analysis.

The number of days affected is forecast by the AIM model and set out in the table below.

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
ALL	0.0054	0.0000	0.0015	0.0055	0.0183

Table A3: Transport disruption (days affected per failure)

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

Severity	Value
Transport disruption: Minor road	Redacted due to commercial sensitivity
Transport disruption: A road (modelled - average A roads)	
Transport disruption: Motorway	
Transport disruption: National rail (critical routes)	
Transport disruption: National rail (other routes)	

Table A4: Avoided costs for transport disruption (per day of disruption)

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

The social cost of rail disruption is based on a conservative analysis of Department of Transport data and a conservative assumption for a single day of disruption.

Annual value for property damage

(Annual rate of property damage) * (number of properties affected) * (Social cost of property damage) * (Volume of interventions)

The annual rate of property damage is the failure rate, the breakeven value of which is assessed via Switching analysis.

The number of properties affected is forecast by the AIM model and set out in the table below.

Region	Number of Properties Damaged per failure	Value per property
EoE	0.03	Redacted due to commercial sensitivity
Lon	0.26	
NW	0.13	
WM	0.08	
All	**0.09**	

Table A5: Property damage within LTS model

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

Annual Probability of Fatality/Injury

(Annual rate of injury) * (Number of injuries) * (Volume of interventions)

The input to the template in this area is the annual probability and the annual value is calculated within the template.

The annual rate of injury is the failure rate, the breakeven value of which is assessed via Switching analysis.

The number of injuries is forecast via the AIM model as shown in the table below.

Region	Number of Fatalities	Number of Minor Injuries
EoE	0.005	0.005
Lon	0.024	0.024
NW	0.013	0.013
WM	0.012	0.012
All	0.010	0.010

Table A6: Fatalities and minor injuries per annum

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

Annual level of emissions

(Annual rate of emissions) * (Amount of emissions per failure) * (Volume of interventions)

The input to the template in this area is the annual expected amount of emissions and the annual value is calculated within the template.

The annual rate of emissions is the failure rate, the breakeven value of which is assessed via Switching analysis.

The level of emissions is forecast via the AIM model as shown in the table below.

Region	Level of emissions (kg/m3)
EoE	821.36
Lon	1177.26
NW	762.69
WM	1539.58
All	986.61

Table A7: Emissions forecast within AIM model

These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.

CBA results

As part of our switching analysis, due to the uncertainty surrounding the deterioration rate for pipeline sleeves we have assumed that without any investment there will be no failures in RII0-2 followed by a constant rate of failure from the beginning of RIIO-3 for 23 years. It is our engineering judgement that if we do not invest in these assets in the next 10 years then they are almost certain to fail.

The results of the Cost Benefit Analysis at the company level are shown in the table below. As we have used switching analysis the NPV is set at 0.00.

Option Name	PV Expenditure & Costs	PV Environment	PV Safety	PV Other	Total PV	NPV (relative to baseline)
Baseline	Redacted due to commercial sensitivity					
Preferred Option						
Preferred Option Without WTP						

Table A8: Results of Preliminary Cost Benefit Analysis (XXXX)

The annual benefits associated with the breakeven failure rate are set out in the table

Benefit	Breakeven Level per annum
Avoided Cost	Redacted due to commercial sensitivity
or	
Interruptions to Supply	
or	
Transport Disruption	
or	
Property Damage	
or	
Probability of a fatality (injuries/yr)	
or	
Probability of minor injury	
or	
Emissions	

Table A9: Breakeven Level of Annual Benefits (with WTP scenario)

Our CBA switching analysis has enabled us to calculate the pipeline failure rate required under a reactive approach, for the proactive programme to breakeven. The annual breakeven failure rate across the company is 0.3% of the targeted assets failing each year from 2027 to 2049. This is the equivalent of a 1 in 300 year failure rate which is clearly longer than the average life of these assets.

These minimum cost-beneficial/breakeven failure rates translate into the minimum number of pipeline failures required by the end of RIIO-3 for the programme to breakeven (assuming these failure rates continue until 2049) as set out in Table A10.

	EoE	Lon	NW	WM	Company Level
Breakeven Failures by the end of RIIO-3	5	2	1	1	9

Table A10: Breakeven RIIO-3 Failure levels for the Preferred Option: Targeted Proactive

We have tested the sensitivity of these results to the exclusion of the WTP to avoid supply interruptions which raises the company wide breakeven level from 9 to 13.

Our current preferred option is to proactively invest in remediating 545 high and medium risk, pipeline sleeves during RIIO-2.

This **baseline option of reacting upon failure**, assumes that we don't invest in maintaining any of these pipeline sleeves in the remaining years of RIIO-1, and all of RIIO-2 & RIIO-3. The results of this switching analysis tells us that we would only need 1.7% of these 545 poor condition pipeline sleeves, to deteriorate to such a level within a 12 year period, to cause a pipeline integrity failure, for the proactive option to be cost beneficial.

Our engineering judgement suggests that with no-investment for 12 years, it is highly likely that at least 9 of these 545 pipeline sleeves (already identified as medium or high risk) will have degraded significantly with resulting gas-leaks and pipeline failures.

Therefore, the cost-benefit analysis demonstrates that our proposed proactive programme of work is the optimum approach.

As stated earlier, this CBA has been produced for illustrative purposes. Our pipeline sleeve remediation programme is required to ensure we meet our regulatory obligations to maintain our pipeline sleeves under the PSR regulations 1996, and to ensure we are compliant with the HASWA 1974.