Cadent
Your Gas Network

Appendix 9.36
Pipeline Crossings
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 our pipeline crossing assets. A brief overview is provided below.

Overview

Cadent has over 2,000 above ground crossings in various pressure tiers ranging from high pressure (above 7 bar) down to low pressure pipelines. Approximately 90% of asset stock operates at below 7 bar.

The investment driver for crossing inspection and maintenance is to provide robust protection to exposed pipelines (complying with Pipelines Safety Regulations 1996, Reg. 13) from the risk of corrosion, damage and to ensure the risk associated with the public accessing the pipe crossing is reduced / mitigated in line with HSE guidance. Our investment programme is driven by safety requirements.

Following the fatality at Dugdale Bridge in 2014 we have improved our approach to investment in crossings. We enhanced our inspection criteria and undertook a full survey of pipeline crossings, assessing accessibility and asset health. This approach has identified all crossings with a high risk of unauthorised access where suitable protection access deterrent measures (ADMs) are required to be installed. The higher risk crossings will be remediated in RIIO-1 and the lower risk crossings will be remediated in RIIO-2. This document discusses the material elements of the crossings investment which is focused on below 7 bar crossings.

We have also undertaken cost benefit analysis to assess the proposed level of investment, by assessing 3 options. In the CBA the baseline for our assessment is reactive investment only (reactively repair or replace on failure). We assessed a single main option to proactively maintain the structures before failure against the baseline, plus two comparative CBA scenarios to test the sensitivity of the CBA results.

Our analysis shows that our preferred Option (and additional scenarios) are all cost beneficial, delivering benefits through improved safety. Our preferred option (1) is to intervene based on bottom-up identification of crossings requiring intervention following inspection - approach continued from RIIO-1. This option ensures sufficient investment to install ADMs in line with HSE requirements and manage the asset health of the crossings effectively.

Summary of preferred option	£m
RIIO-2 Expenditure - < 7 bar Crossing Interventions	Redacted due to commercial
NPV	sensitivity

Material Changes Since October Submission

No material changes since October

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2. Introduction

The investment case covers the remediations on our above ground pipeline crossings to ensure compliance with Pipeline Safety Regulations and the Occupiers Liability Act. These interventions ensure a safe and reliable supply of gas to our customers.

Above ground crossings are lengths of exposed pipework which run over ground to cross a feature such as a railway or canal.

We have a comprehensive rolling programme of above ground crossing inspections that enables Cadent to make risk-based decisions on critical remediation needed. Remediation typically takes the form of interventions on pipe supports and pipeline protective coatings.

Inspections have also identified specific risks to public safety because there is inadequate deterrent to prevent members of the public accessing the pipe-crossing and therefore putting themselves at risk of injury or death.

Whilst we carry out inspection and remediation on all pipe crossings, irrespective of pipe pressure rating, this document discusses interventions on < 7 barg crossings, covered by lines 38 and 39 in Table 1 below. Of the 2,023 exposed pipeline crossings, 90% are < 7 bar.

Cadent Line Ref	Description	RIIO-2 Total
Line 38	<7bar Above Ground Crossings Interventions	
Line 39	<7bar Access Deterrent Measure (ADM) Interventions	
Total 38 and 39		
Line 34	>7bar Above Groun Redacted due to commercial sensitivity	
Line 35	>7bar Above Ground Crossings Interventions	
Line 36	>7bar Access Deterrent Measure (ADM) Interventions	
Line 37	<7bar Above Ground Crossings Inspections	
Total Other		

Table 1: Summary of the key components within the pipeline crossings investment case

The investment case has been derived from our pipeline inspection results and historic intervention volumes to inform the total investment needed. The inspections are important, allowing us to proactively understand the condition and risks of pipe accessibility, through which we can plan and prioritise intervention investment to protect members of the public and ensure gas security of supply.

3. Equipment Summary

A summary of the pipe-crossings asset base for each network is shown in the following tables. We have included the asset stock for > and < 7 bar pipe crossings.

The asset base has been derived from our CALM Database (June 2018). Feature crossed and crossing length detailed in the CALM data extracts have been validated using the internal ESRI mapping system and Google Maps satellite imagery.

Note:

To show the regional differences within the East of England (EoE) network we have shown East Anglia (EA) and East Midlands (EM) Local Distribution Zones (LDZ) separately.

	Network					
Pipe Pressure	**EA**	**EM**	**Lon**	**NW**	**WM**	**Total**
< 7 bar	233	432	230	574	353	1822
> 7 bar	40	12	12	59	78	201
Total	**273**	**444**	**242**	**633**	**431**	**2,023**

Table 2: Crossing Asset Base per Network

The 201 Crossings at > 7 bar operating pressure have been further broken down by feature crossed in the following table.

	Feature Crossed								
Network	**Canal**	**Ditch**	**Open Ground**	**Railway**	**River**	**Road**	**Stream**	**Other**	**Total**
EA	6	10	1	2	8	0	7	6	**40**
EM	4	0	2	1	1	0	3	1	**12**
Lon	2	1	0	1	3	0	2	3	**12**
NW	8	1	5	0	9	1	16	19	**59**
WM	50	0	1	3	8	5	9	2	**78**
Total	**70**	**12**	**9**	**7**	**29**	**6**	**37**	**31**	**201**

Table 3: Above 7 bar Crossings by Feature Crossed per Network

The 1,822 Crossings < 7bar operating pressure have been further broken down by feature crossed in the following table.

	Feature Crossed							
Network	**Building**	**Open Ground**	**Railway**	**Road**	**Track / Path**	**Other**	**Water**	**Total**
EA	0	3	11	1	1	0	217	**233**
EM	2	21	40	5	10	0	354	**432**
Lon	2	9	39	0	2	6	172	**230**
NW	2	43	72	8	31	0	418	**574**
WM	0	30	48	13	13	0	249	**353**
Total	**6**	**106**	**210**	**27**	**57**	**6**	**1,410**	**1,822**

Table 4: Below 7 bar Crossings by Feature Crossed per Network

The Health Index (HI) survey results for the known < 7 bar pipe crossings are summarised below (January 2019 snapshot) giving the breakdown of the asset health of the assets. HI1 = New condition, HI5 = Priority intervention required. All score definitions are detailed in Table 6.

	Network					
Asset Health Score	**EA**	**EM**	**Lon**	**NW**	**WM**	**Total**
HI1	5	13	3	17	38	**76**
HI2	97	277	84	315	182	**955**
HI3	96	109	95	167	84	**551**
HI4	31	31	39	65	38	**204**
HI5	4	2	3	10	11	**30**
Other	0	0	6	0	0	**6**
Total	**233**	**432**	**230**	**574**	**353**	**1,822**

Table 5: Inspection Survey results for < 7 bar crossings

The pipe crossing health index score information has been used to show the proportions of asset stock in each scoring category in each network that show the asset health of the current pipe crossings.

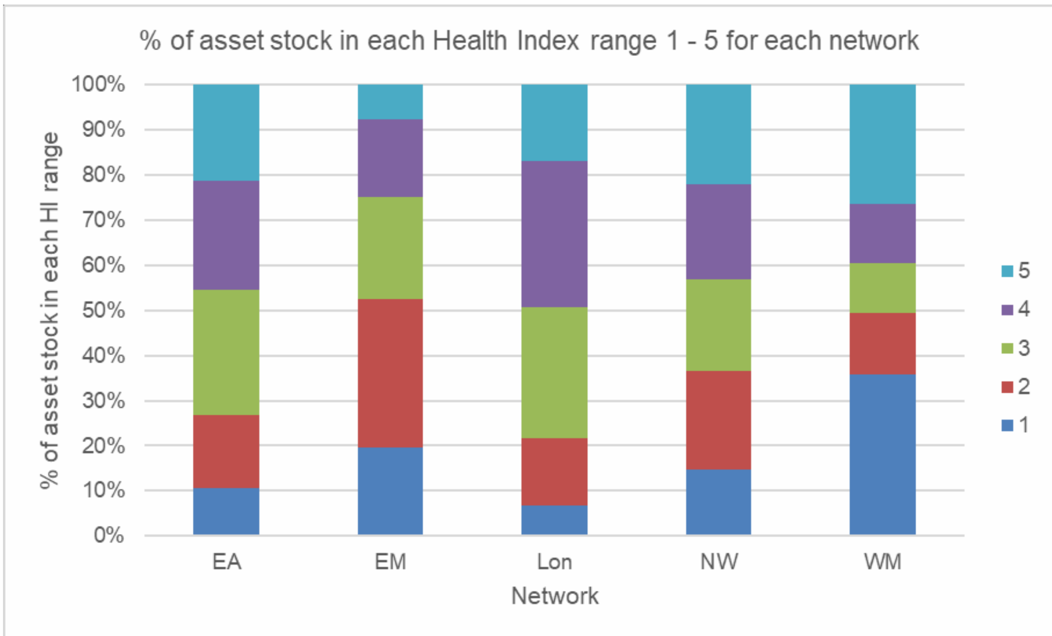

Figure 1: Current asset condition for < 7 bar pipe crossings

In conclusion, East Midlands has crossings in the best condition overall, with approximately 25% of assets in HI4 and HI5 categories and has the lowest percentage of assets in HI5 category (<10%), with most crossings rated at HI2. West Midlands has the greatest percentage of assets in very good health (HI1), yet also has the greatest percentage of assets in very poor health (HI5), requiring urgent intervention.

Some of these will be remediated before the start of RIIO-2 with some of the worst scores restored to HI1 status and some HI3, and HI4 scores moving to the next HI category.

With the exception of East Midlands, approximately 50% of the populations are within HI categories 1, 2 & 3, with the remaining 50% attributed to the HI4 and HI5 categories, showing that overall the assets are deteriorating and requiring investment.

Examples of pipeline crossings

Figure 2: Typical pipeline-crossing construction types

Figure 3: Pipeline crossing with unsuitable access deterrent measure

4. Problem Statement

The investment driver for these investment lines is to mitigate risk caused by asset deterioration and potential for asset failure of our pipeline crossings. In order to provide a safe and reliable service to our customers.

Investment Drivers

The key investment drivers are:

- **Security of Supply:** The failure of a pipeline crossing will lead to an impact on supply.
- **Health & Safety:**
    - The failure of a pipeline crossing will lead to a possible gas-leak and a resulting fire and explosion risk to people in the surrounding area.
    - The lack of adequate access deterrent measures (ADM), could allow trespassers to access the pipeline crossing leading to injury or death.

Cadent has a responsibility to protect assets vulnerable to trespass which could result in damage to the asset or to trespassers per the Occupiers Liability Acts 1957 and 1984. Specifically, 1957 Act – Section 2 "Extent of occupier's ordinary duty", and 1984 Act – Section 1 "Duty of occupier to persons other than his visitors".

Cadent Gas has a legislative obligation under the Pressure Safety Regulations, 1996 (Regulation 13) which states that: *"The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair"*.

An additional driver for inspections and interventions on above ground pipe crossing and associated Access Deterrent Measures (ADM) follows the 'accidental death' of a child at Dugdale Bridge, Burnley in 2014 following a fall from an above ground crossing. National Grid Gas Distribution, prior to Cadent, was served with a Health & Safety Executive improvement notice for this incident which has been complied with. Wider action for all crossings stems from Coroner's recommendations at the inquest and ongoing intervention by the Health & Safety Executive.

Periodic crossing inspections are completed to identify land use changes which occur over time. A crossing where there was no previous requirement for an ADM may be assessed and deemed to require the installation of such a device, as the local situation changes.

Key outcomes

Investment in these pipeline crossings will provide safe and reliable pipeline crossings and associated supporting structures and complies with the requirements of the Occupiers' Liability Act, 1957

Understanding project success

Success is the protection of our pipelines from corrosion, ensuring that the pipeline is operating safely and cannot easily be accessed by the public.

4.1. Narrative Real-life Example of Problem

A 15 metre long, 48 inch diameter, cast iron, medium pressure crossing in North London serves approximately 20,000 customers had been in operation for 31 years when it was assessed with a new and improved inspection methodology in 2015. The inspection found that the pipe crossing was in a fair condition but required re-painting of the structure. No Access Deterrent Measures (ADMs) were fitted which were required as it appeared that the pipe had been used to spray paint on the side of the road bridge running parallel to the crossing. ADM installation was identified as a priority need.

Figure 4: Bow Common Lane pipeline crossing condition at initial inspection

A project was undertaken to remediate the pipework, restoring asset health and installing new ADMs. By undertaking both actions at the same time efficient use of mobilisation effort and resources was achieved. The duration between inspections has now been extended in accordance with improved asset health and ADM installation, from 2 years up to 8 years.

Due to the height of the crossing, scaffolding was used and as the pipeline crosses a canal, engagement with Canals & River Trust was required to obtain access consent.

The remediation and ADM installation cost in the region of **XXXX** (2015 price base).

Figure 5: Bow Common Lane pipeline crossing condition after pipe remediation and fitting of new access deterrent measure

4.2. Spend Boundaries

This investment case specifically refers to the above ground pipework associated with all pipe crossings, coatings, associated pipe supports and access deterrent measures (ADM) where fitted. Where the supporting structure is also owned by Cadent, investment to remediate this supporting structure is also included.

This investment case does not cover crossings that no longer support pipes (pipes have been removed), where Cadent retains the responsibility for maintaining the supporting structure. Any investment to remediate and manage these structures is included in Civil Structures investment case.

5. Probability of Failure

We proactively inspect crossings and identify findings, such as surface damage, grading them accordingly and where necessary remediating before the damage results in a failure. Our < 7 bar pipeline crossings have good performance and we have not had a failure of a pipe crossing requiring emergency action.

Grading of faults through inspection of the surface condition allows the severity of the pipe crossing condition to be recorded against the criteria below in Table 6. Delamination / peeling of coating are indicators of a deteriorating condition.

Where corrosion of a pipe at a crossing occurs, part of the remedial measures are to remove the corroded surface, reducing the pipe wall thickness. Loss of wall thickness, in the serious cases, may require a reduction in operating pressure. The operating pressure may be restored if the affected section is reinforced by the installation of a surrounding collar, providing increased wall thickness and structural support.

As part of our efforts to focus on above ground pipe crossings as a separate entity from the rest of the pipeline, we have been improving our asset data granularity for improved identification and recording of any future faults on these crossings going forwards into RIIO-2.

If any leak were to occur it should be detected quickly and remedial action taken, as the gas is odourised.

Our < 7 bar pipeline crossing inspection frequencies are based on the previous inspection result and criticality of the pipeline. Cadent uses a risk-based scoring, shown below, to assess the pipeline integrity risk (combination of pipeline, pipe support and support structure integrity) and therefore the need for intervention.

Rating	Definition
HI0	No support or ADM fitted. Note HI0 is not an option for pipework
HI1 (New)	New or as new
HI2 (Good)	Good or serviceable condition. No specific reliability or maintainability issues. More than 10 years remaining life expected.
HI3 (Fair)	Some deterioration in condition or reliability. Maintainability issues that require monitoring and possible replacement in a 5 to 10 year timeframe
HI4 (Poor)	Intervention required within the next 3 to 5 years in order to prevent unacceptable failure rate or maintainability issues.
HI5 (Priority)	Urgent intervention required in order to avoid unacceptable failure rate or maintainability issues.

Table 6: < 7 bar asset health scoring descriptions from Cadent's T/PR/MAINT/5009 document

This table is combined with the pipeline criticality, scored based on the following criteria:

- operating pressure
- pipe diameter
- pipework span length
- pipe material
- vegetation growth density
- structure / feature crossed

And assessed against the following table:

Criticality Index (CI) points rating table	Points
CI 1Very high	>42
CI 2High	21< points score ≤41
CI 3 Medium	5< points score ≤21
CI 4 Low	≤5

Table 7: < 7 bar asset criticality scoring

Resulting in the Inspection Frequency below, through applying the criticality index (CI) and health index (HI):

	Max inspection frequency matrix (years)				
	HI 1	HI 2	HI 3	HI 4	HI 5
CI 1	5	5	3	2	1
CI 2	10	8	5	3	2
CI 3	10	10	8	5	3
CI 4	10	10	10	5	3

Table 8: < 7 bar asset inspection frequencies

Note: Above ground pipework on rail land sites and any pipework which forms part of a complex structure, shall have a maximum inspection frequency of 5 years.

Failure modes

A brief summary of failure modes for pipeline crossings is given below.

Failure of coating

The pipe coating can deteriorate, exposing the pipe wall to air and moisture and causing corrosion damage leading to a pin-hole failure or more serious failure. Loss of pipe wall thickness after remediation of surface damage is a secondary result which may limit pipe operating pressure and increase pipe integrity risk.

Failure of pipe support or support structure

The pipe support or supporting structure could “fail”, thereby putting the gas-pipeline under increased stresses, which again would lead to a pipeline integrity risk.

Failure of Access Deterrent Measures (ADM)

Failure or inadequacy of ADM protection which results in unauthorised access by third parties and members of the public could cause subsequent damage to the crossing and member of the public. This potentially may result in the need to interrupt supplies whilst investigations and repairs to the pipe crossing are conducted.

5.1 Probability of Failure data assurance

We have used the inspections results from the pipeline crossing surveys, from CALM database extracts, June 2018 plus Inspection and Post-Remediation survey result datasets, exported from the dedicated Pipeline Crossings SharePoint system in January 2019. The information contained within is managed and controlled by the Asset Owner and Asset Data Integrity responsible for ensuring correctness.

These datasets have been combined to inform us of the status of our pipeline crossings, determining the requirements for remediation and/ or ADM installations in RIIO-2.

The data set includes all surveys for all < 7 bar pipeline crossings – only 6 pipeline crossings have an unknown health index score, at the time of extract.

We therefore have a high confidence that our probability of failure data is robust.

6. Consequence of Failure

Our pipe crossings are a vital part of our distribution network. Failure of a crossing will have both safety and reliability impacts. Their nature also means that repairs can be both expensive and extended compared to routine pipe repairs. Failures of our pipelines not only means we have failed to meet our duties under the Pressure Safety Regulations but have also failed to manage the safety of the general public and employees.

A number of our pipeline crossings also do not provide adequate access deterrent measures posing a further risk to the general public from mis-adventure, caused by falling from the pipe.

We have used the consequences of a pipeline failure as included in our LTS AIM model for this investment case. In doing this, we acknowledge this will not be valuing the benefit we bring from removing the risk of death due to misadventure from access onto the pipeline crossing itself.

Our LTS AIM model includes the following consequences:

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

In addition, we have considered the avoided costs from avoiding the need to carry out a reactive repair. From our analysis, we have identified that delivering work reactively typically costs 20% more to deliver than a similar planned job.

For this investment case we have chosen to only use:

- Interruptions to supply (properties)
- Fatalities (driven from someone falling from the crossing rather than from gas-leaks & ignition / explosions)
- Avoided costs due to higher reactive costs of repair

For completeness, we have summarised the consequence data (figures per pipeline failure) on the LTS network:

Network	Supply interruption: Properties impacted (nr)	Properties damaged (nr)	Value per property per incident (£)	Fatalities (nr)	Minor injuries (nr)	Level of emissions (kg/m^3)
EoE	732	0.03		0.005	0.005	821.36
Lon	1,198		Redacted due to commercial sensitivity		0.024	1177.26
NW	918				0.013	762.69
WM	772	0.08		0.012	0.012	1539.58
All	838	0.09		0.010	0.010	986.61

Table 9: Consequence of Failure: properties, injury, emissions

In addition to the risks summarised above which could 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.

These costs could substantially exceed the repair costs. The costs of these lower-probability, more-major, costly emergency events have not been included in our CBA. As mentioned above, we have currently applied only a 20% uplift on the costs of proactive work, to cover for this "reactive-response".

7. Options considered

Introduction and approach

Crossings investment has a clear safety mandate. However, within this investment case we have also considered two programme options for the purpose of Cost Benefit Analysis (CBA):

- **Baseline:** Reactively repair or replace upon failure
- **Option 1:** Proactive maintenance before failure

A full discussion of our approach and results of our CBA analysis is included in Appendix 1. We have chosen to use a manual approach to modelling our CBA for this investment case, but have used the consequence of failure from our LTS AIMs model to inform this analysis.

We have carried out two comparative CBA scenarios to test the sensitivity of the CBA results to:

- Removing the willingness to pay (WTP) due to supply interruptions
- Varying the % uplift for carrying out work reactively, i.e. how much more money the same work costs to deliver reactively versus proactively.

We have chosen to model our CBA baseline differently for this investment case.

For areas of investment, such as this one the forecast baseline <u>cannot</u> be assessed due to its highly uncertain nature. In these circumstances, the baseline is set at zero and in the options the *changes* in costs are considered, i.e., we include the costs of reacting to a failure occurring as avoided costs in each option, rather than as absolute levels of anticipated costs in the baseline.

From a pure CBA point of view the two approaches are equivalent – as CBA is all about comparing differences between options.

The discussions set out in 7.1 and beyond are focused on programme-level decisions.

It should be noted that at a project level, for each and every pipeline crossing remediation, we have a detailed risk-based process that is followed to ensure that the most appropriate intervention is chosen at least-cost.

- Assess whether the pipeline (pipeline crossing) is required for network resilience / supply-demand. Look to decommission pipework where there is no longer a need, this removes the long-term liability of the asset.

Where we have confirmed the long-term need for the pipeline crossing, we will then consider options for remediation:

- We will look to restore the pipeline protective coating wherever possible; we generally look to intervene before underlying corrosion begins although this is not always achieved. The coatings used are generally painting systems or protective wrap.
- We will look to repair or remediate pipe supports and brackets wherever possible.
- We consider the need to remediate any civil structure supporting the pipe; this may be owned by a 3rd party, but many pipe-support structures are also managed by Cadent.
- Replacement of key components or more intrusive pipeline repairs or sectional replacements will only be considered where deterioration is so severe a repair isn't viable.
- We also assess the risks posed from unauthorised access due to lack or inadequate access deterrent measures. Again we look at the surrounding area, the height / length of the crossing, the feature crossed and look to provide the least-cost but most appropriate ADM measure to minimise the risk.
    - The options considered are listed in Appendix 3, but include fans, spinners, anti-vandal paint, fencing. Photos of typical ADMs are also included in Appendix 3.

We typically look to remediate or repair wherever possible, so we can retain the asset in operation and minimise the need for network outages. Where extensive quantities of severe deterioration have occurred, the engineer may consider more invasive repairs or sections of new pipework or replacement of other key components. The frequency of our inspections typically ensures deterioration-levels are managed and not allowed to become too severe.

We will always seek to choose the solution-option at a specific location which delivers the best whole life benefits. These individual option choices build into a programme of high-volume, low-cost work. We have assessed the benefits delivered by the programme in the analysis below.

We have an option about when to intervene on a crossing, i.e. at which condition point we would deliver work. Our crossings with a health index category of 5 are judged to be failed or failing and as such require immediate intervention. We would also consider intervening upon category HI4 crossings plus some HI3 rated crossings if an ADM installation was required, due to the high proportion of the intervention costs being associated with mobilisation to conduct work on the crossing – scaffolding, obtaining permits and access, etc. The criticality of the crossing is also a factor, which would determine the need to conduct such an intervention to reduce the risk of supply interruption and crossing failure. Also, time has elapsed since the surveys have been carried out and it is expected that by the time RIIO-2 commences some crossings will have moved to the next asset health category (e.g. from HI3 to HI4) as the asset ages and deterioration progresses.

7.1 Baseline: Reactively repair upon failure

This option assumes that we allow our pipeline crossings to deteriorate leading to a pipeline failure, and therefore the consequences discussed in section 6.

These consequences have been included as avoided costs in Option 1 below.

This scenario considers:

- Avoiding the additional costs from carrying out the repair reactively
- The societal costs of avoiding fatalities from the lack of ADMs
- The willingness to pay / benefits from a supply interruption

7.2 Option 1: Proactive remediation prior to failure

We have derived this option by using our current inspection results to prioritise pipeline crossing interventions throughout RIIO-2 & 3, smoothing delivery throughout the price control periods.

We have two key deficiencies associated with our pipeline crossings:

- The lack of an Access Deterrent Measure, which due to updated risk assessments following the HSE incident at Dugdale Bridge is the primary driver for intervention in RIIO-2
- Severe pipeline integrity risks, which need urgent remediation.

Where we have to intervene on a pipeline crossing to install an ADM, we will also look to carry out any necessary pipeline crossing repairs. The largest cost of intervention is in arranging for access with 3rd party stakeholders and then installing appropriate scaffolding to safely access the crossing. In these situations, we will look to remediate any moderate to severe deficiencies. We would not normally remediate “moderate” deficiencies in other circumstances but recognise that this is a cost-effective approach where other remediation is already taking place.

Where we are not intervening on an ADM, we will look to remediate the highest severity risks in early RIIO-2, with the medium-high risks waiting until later in RIIO-2.

In developing the following strategic approach, we have considered the need to fit ADMs to protect the structure and the public, the asset heath of the pipe crossing and where installed the support structure and existing ADM. Crossing criticality is also factored into when interventions are indicatively proposed.

A primary requirement for intervention in RIIO-2 is installation of ADMs on inadequately protected assets.

Crossings with an ADM score between 21 and 39 are considered to have an elevated risk to the public safety and require appropriate ADM provision to be installed, if not already. Those assets with ADM scores of 40 and above have greater risk than those with scores 21-39, requiring ADMs, and are to be intervened upon in RIIO-1. Therefore, these crossings have not been included in the following strategy decision flow chart that has been used to identify RIIO-2 intervention volumes.

The flow chart below provides direction on which intervention work scope and in which regulatory period is required based on the need for ADM installation and the crossing's asset health rating. By reviewing each < 7 bar crossing against each question, from top left across to the right, the work scope required is defined.

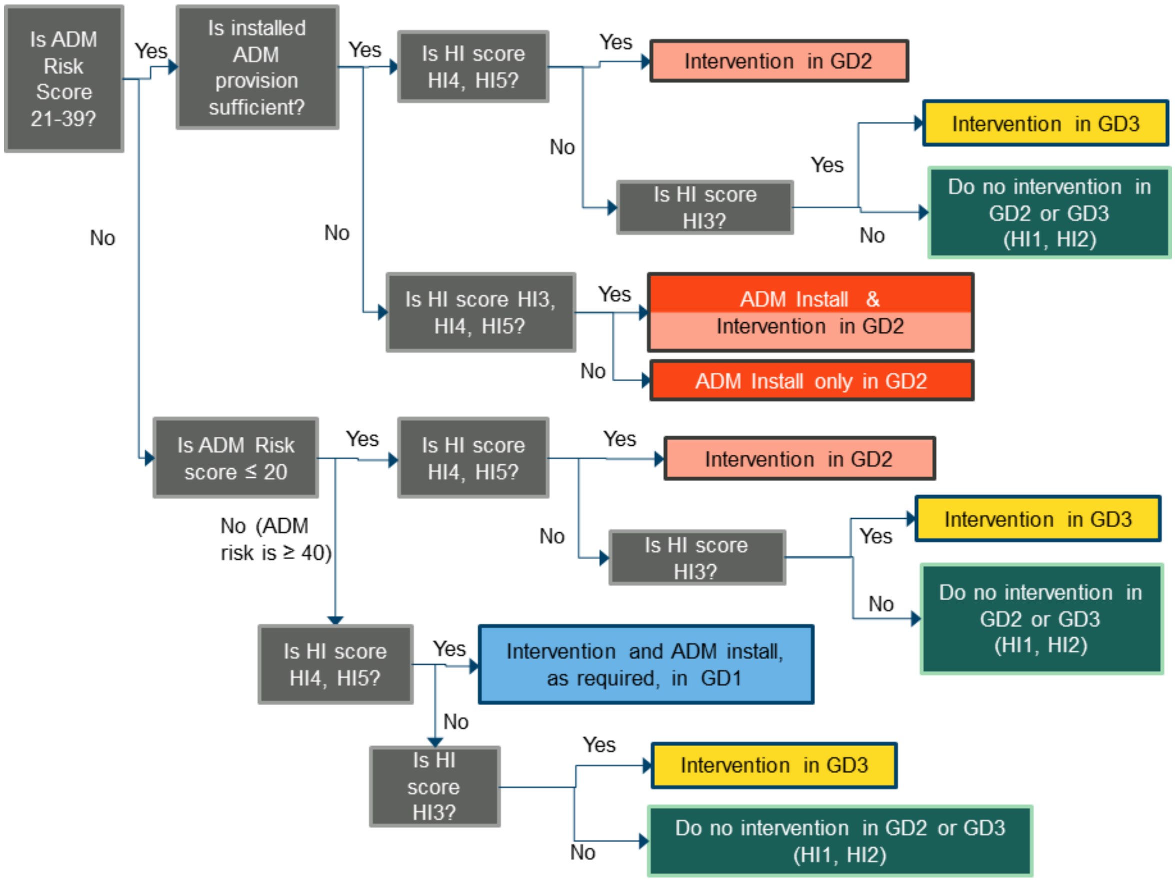

Figure 6: < 7 bar intervention decision flow chart

In summary:

- The need for installation of a required Access Deterrent Measure (ADM), is the initial driver for intervention in RIIO-2, with any remediation required to existing ADM conducted thereafter.
- If an ADM intervention isn't needed, but the pipeline crossing has a Health Index (HI) score of 4 or 5 (i.e. serious or imminent risk) then the intervention is also planned for RIIO-2.
- HI3 pipeline risks are assumed to be intervened in RIIO-3, unless an ADM is being installed and then for cost-efficiency the HI3 risk will be remediated at the same time as the ADM.
- Pipeline crossings with health index scores of 1 or 2 are assumed to need no investment in RIIO-2 or 3.
- A material assumption is that by the end of RIIO-1 all crossings with ADM scores 40 and above are fitted with an ADM and are remediated if they are of HI4, HI5 risk score.

The different work scopes and required intervention dates are summarised in the following chart:

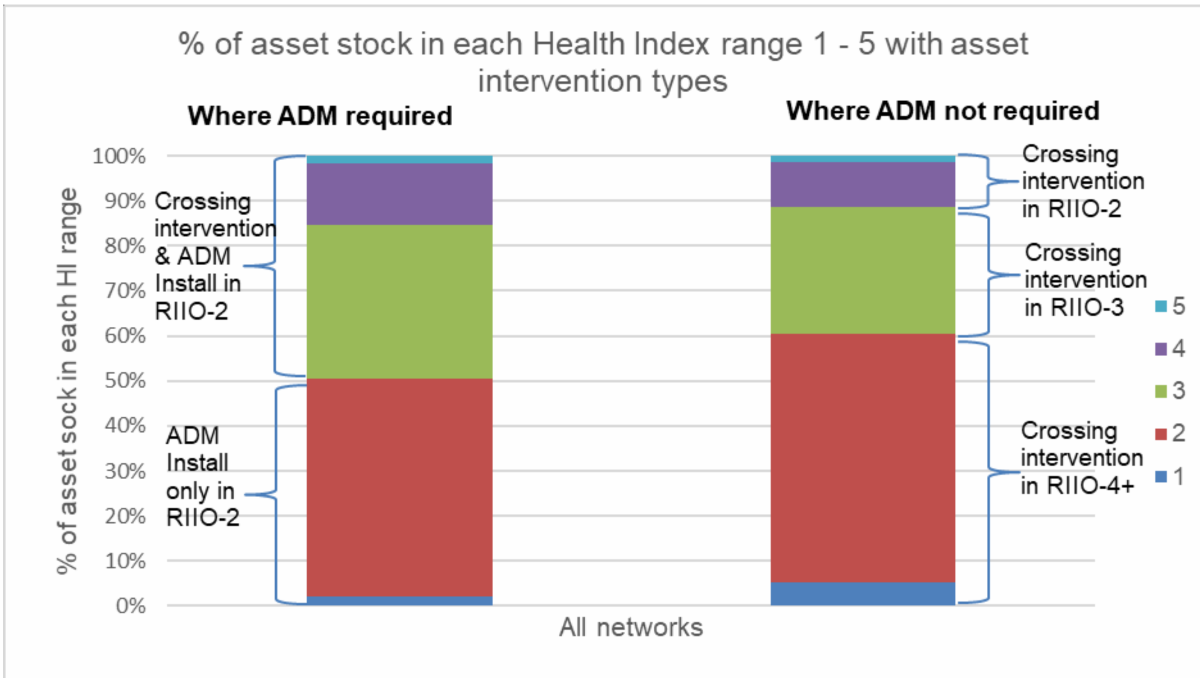

Figure 7: < 7 bar intervention work scopes per health index score throughout RIIO-2 & 3 as % of asset stock

Applying this approach to the survey results, has allowed us to generate the following forward work programme for < 7 bar pipeline crossings for RIIO-2 & 3:

Network	Intervention volumes					
	ADM Install	Crossing Intervention + ADM Install	Crossing Intervention in RIIO-2	Crossing Intervention in RIIO-3	No Intervention or ADM Install	Total
EA	43	54	11	59	66	**233**
EM	114	60	14	64	180	**432**
Lon	29	70	15	51	65	**230**
NW	98	111	27	95	243	**574**
WM	49	37	32	56	179	**353**
Total	**333**	**332**	**99**	**325**	**733**	**1,822**

Table 10: < 7 bar crossing Intervention volumes by work scope and network through to 2031/32

The following table shows < 7 bar intervention work scope per year for RIIO-2:

	Intervention volumes					
	2021/22	2022/23	2023/24	2024/25	2025/26	Total
ADM install	0	13	68	120	132	333
Crossing intervention + ADM install	125	124	68	15	0	332
Crossing intervention in RIIO-2	34	25	19	11	10	99
Total	**159**	**162**	**155**	**146**	**142**	**764**

Table 11: < 7 bar crossing Intervention volumes by work scope and financial year during RIIO-2

The length of crossing and feature crossed was then used to estimate the total cost of interventions. (Unit costs in section 7.1 applied to the work-volumes shown below):

	Intervention Type					
Feature Grouping	ADM Installation (RIIO-2)		Intervention + ADM Install (RIIO-2)		Crossing Intervention (RIIO-2)	Crossing Intervention (RIIO-3)
	Volume	Total Cost (£k)	Volume	Total Cost (£k)	Volume	Volume
Water & Others-Up to 9.9m	199		141		33	139
Water & Others-10m to 24.9m	70		107		23	85
Water & Others-25m and greater	37		Redacted due to commercial sensitivity	[redacted]	[redacted]	52
Railway Up to 9.9m	3		[redacted]	[redacted]	[redacted]	3
Railway 10m to 24.9m	7		18		16	26
Railway 25m and greater	17		25		14	20
Total	**333**		**332**		**99**	**325**

Table 12: A summary of intervention volumes & costs, by work-scope & complexity and scale of crossing

The spend profile of < 7 bar crossing capital expenditure over the RIIO-2 investment period can be found in Appendix 2.

7.3 Options Technical Summary Table

The following table summarises the two programme-options considered for this investment case.

	Baseline	Option 1
Option title	Reactively repair pipeline following failure of pipeline crossing	Proactively remediate pipeline crossing / ADM prior to failure
First year of spend	Not a true option: The costs of reacting to failure are included as benefits (i.e. costs avoided) in Option 1.	2020/21
Final year of spend		2025/26
Volume of interventions		333 ADM-only installs 332 combined installs: ADM installs with pipe crossing remediations 99 pipe-crossing remediations. 40% of asset stock receiving an intervention in RIIO-2.
Equipment or investment design life		Coatings between 15-25 years. ADM 30-40 years.
Total installed cost (Total spend request)		ADM installs: **XXXX** Pipe-crossing remediations: **XXXX**

Table 13: Technical Summary Table

7.4 Options Cost Summary Table

As we have only developed a single programme option for this investment case, we have not repeated the cost profile in this section. Refer to Appendix 2 below for the proposed spend profile for Option 1.

Unit costs used to derive investment case

The following table sets out the unit costs used for the pipe-crossing interventions.

Based on our historic records, it is clear that the main cost drivers for remediating the pipeline crossing is the span of the crossing itself (size) and the feature crossed. Feature crossed has a major influence on the complexity of 3rd party permits or agreements that are needed; these permits can be costly when gaining agreement with the Highways Authorities or Network Rail.

We have developed average unit costs that are used across all regions, based on our RIIO-1 work delivered, based on span length & feature crossed. These are summarised below:

	Work scope		
Feature Grouping	Crossing Intervention + ADM Install	ADM Install	Crossing Intervention
Water & Others-Up to 9.9m			
Water & Others-10m to 24.9m			
Water & Others-25m and greater		Redacted due to commercial sensitivity	
Railway-Up to 9.9m			
Railway-10m to 24.9m			
Railway-25m and greater			

Table 14: Unit costs used for Pipe Crossing interventions for RIIO-2

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. For Capex activities this seeks a 2.9% efficiency improvement by 2025/26 on the end of RIIO-1 cost efficiency level. We have not applied additional efficiencies to this investment area.

For Pipeline Crossings our confidence is defined as being within Detailed Design stage with a range of +/-10%. Within this estimate are elements such as rail crossings which have a ±20% confidence and areas such as ADM on canal crossings which have ±5%. The overall 10% figure is a weighted average of these elements.

8. Business Case Outline and Discussion

We must manage our pipeline-crossing risks proactively to ensure we comply with:

- Our obligations under the Occupiers Liability Act 1957 & 1984 to protect vulnerable assets to trespass.
- Our HSE improvement notice (4370694, dated 16 May 2014), following an accidental death of a child at Dugdale Bridge following a fall form an above ground crossing.
- To maintain our pipelines to ensure we comply with the Pressure Safety Regulations (Reg. 13), as soon as reasonably practical from discovering a deficiency.

We have used CBA, for illustrative purposes, the results of our CBA have been included in Appendix 1 but summarised below.

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. To achieve this, we have developed a methodology which links asset performance to customer impacts, making use of manually developed Cost Benefit Analysis (CBA).

From our CBA calculations, without the legal mandate, the key investment drivers would be:

- Safety; i.e. the reduction of the risk of a fatality or injury
- Avoided costs; having to pay more to remediate something reactively rather than proactively
- Reliability; avoiding interruptions associated with pipeline failures

8.2. Business Case Summary

We have compared our proposed proactive programme of pipeline-crossing remediation against the baseline option of reactive remediation upon pipeline failure.

As mentioned previously, we have taken an alternative approach to modelling the CBA for our baseline case. This baseline-option cannot be forecast in absolute-terms, due to the high levels of uncertainty. We have included the avoided costs of reacting to a failure in Option 1, and then set our baseline to zero.

The two programme-options considered are summarised below.

<table>
<tr><th>Option title</th><th>Baseline</th><th>Option 1</th></tr>
<tr><td>Option description</td><td>Reactively repair pipeline following failure of pipeline crossing</td><td>Proactively remediate pipeline crossing / ADM prior to failure</td></tr>
<tr><td>First year of spend</td><td rowspan="5">This option has been discounted because we have a legal mandate to install access deterrent measures (HSE improvement) and maintain our pipe crossings PSR 1996 Reg 13)</td><td>2020/21</td></tr>
<tr><td>Final year of spend</td><td>2025/26</td></tr>
<tr><td>Volume of interventions</td><td>333 ADM-only installs
332 combined installs: ADM installs with pipe crossing remediations
99 pipe-crossing remediations.
40% of asset stock receiving remediation in RIIO-2.</td></tr>
<tr><td>Equipment or investment design life</td><td>Coatings between 15-25 years.
ADM 30-40 years.</td></tr>
<tr><td>Total installed cost (Total spend request)</td><td>ADM installs: XXXX
Pipe-crossing remediations: XXXX</td></tr>
<tr><td>NPV relative to baseline £m</td><td rowspan="3">N/A</td><td>NPV = XXXX
Sensitivity analysis:
- Excluding supply interruption WTP: NPV = XXXX
- Reduce reactive cost uplift to 5%: NPV = XXXX</td></tr>
<tr><td>Payback year</td><td>Payback periods for all CBA scenarios range between 2045 to 2053</td></tr>
<tr><td>Ratio NPV to RIIO-2 spend</td><td>XXXX</td></tr>
</table>

Table 15: Business Case Summary

More detailed CBA results are included in Appendix 1 but summarised here. All CBA scenarios for Option 1 have positive NPVs, at a company level, as well as reasonable payback periods, demonstrating that the proactive option is cost beneficial. All CBA results are cost beneficial with an NPV ranging between **XXXX** and **XXXX**, with payback years between 2045 and 2053.

These CBA results have been presented in the CBA data tables as follows:

- **CBA Option 1:** Our proactive targeted programme, with costs included from avoiding failures and therefore supply interruptions, reactive costs to remediate the crossings and the social cost of a fatality.
- **CBA Scenario 2:** A scenario to test the NPV of engineering option 1, removing supply interruption willingness to pay values.
- **CBA Scenario 3:** A scenario to test the NPV of engineering option 1, to reducing the additional remediation costs from a reactive failure, we used a 5% uplift for this scenario.

In conclusion, Option 1 is the preferred option for our RIIO-2 investment case, as it is the only option that would ensure compliance with

- The HSE improvement notice for ADMs
- The Occupiers liability act, to deter the public from potentially harmful trespass
- Legal obligations under the PSR 1996 (Reg 13) to maintain our assets

The results of our CBA also show that, even without this legal mandate, this proactive approach is cost beneficial.

9. Preferred Option Scope and Project Plan

9.1. Preferred option

Our preferred option is Option 1 – Engineering Volumes Option.

Option 1

Based on the preferred option the following table summarises the proposed intervention volumes for RIIO-2:

Intervention Volumes						
Network	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EA	24	24	21	20	19	**108**
EM	39	39	37	37	36	**188**
Lon	24	24	23	22	21	**114**
NW	50	50	50	43	43	**236**
WM	22	25	24	24	23	**118**
Total	**159**	**162**	**155**	**146**	**142**	**764**

Table 16: Option 1 Total Intervention volumes in RIIO-2

9.2. Asset Health Project Spend Profile

The associated investment levels for RIIO-2, based on the above intervention volumes are set out below (Rounded to the nearest x):

Costs (£m)						
Network	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EA						
EM						
Lon			Redacted due to commercial sensitivity			
NW						
WM						
Total						

Table 17: Option 1 Total Intervention Expenditure in RIIO-2 in £m

9.3. Investment Risk Discussion

There are no material delivery risks for this investment case. Work is high volume, low cost, and is delivered within our operational sites.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.36 - 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
09.36 - 002	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
09.36 - 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
09.36 - 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.
09.36 - 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.
09.36 - 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.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.36 - 007	Access issues to network Rail assets and trackside working (increased volume of this activity in RIIO-2)	BAPA access agreements to network rail assets	Low	Continue working relationships with Network rail and manage expectations - early engagement with contractors to manage RAMS etc…

Table 18: Risk register

10 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 within the LTS Pipelines section under the ≥7 bar Special Crossings line and within the Distribution Mains Section under the <7 bar Special Crossings line.

Appendix 1. CBA approach and basis of calculation

Approach

This section sets our approach to CBA for this investment case. A full cost benefit analysis has been undertaken to ensure value for money. Our approach is compliant with HM Treasury's Green Book and the relevant Ofgem guidance. We have followed the Ofgem approach, spreadsheet and societal benefit values and calculations.

Table A1 sets out the options assessed using CBA modelling, together with the costs and benefits used for each. We have also completed a number of CBA scenarios to test the sensitivity of the CBA for differing avoided costs & benefits.

Our approach to defining the baseline is the option where we do not invest proactively in our assets, but we do inspect and maintain assets in line with our obligations, and repair assets under a fix on fail strategy. This is the absolute minimum investment we can make in our assets. Other options are then considered which represent increments of investment over and above the baseline.

However, for areas of investment, such as this one the forecast baseline cannot be assessed due to its highly uncertain nature. In these circumstances, the baseline is set at zero and in the options the *changes* in costs are considered, i.e., we include the costs of reacting to a failure occurring as avoided costs in each option, rather than as absolute levels of anticipated costs in the baseline.

From a pure CBA point of view the two approaches are equivalent – as CBA is all about comparing differences between options.

Option (In CBA Template)	Modelled Costs	Modelled Benefits
Options:		
Baseline: 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
Option 1: Targeted Proactive repair	RIIO-2 costs as submitted. (Lines 38 & 39).	Private and social costs avoided by the option: • Reactive Costs (+20%) • Interruptions to supply • Health & Safety
Scenarios:		
Option 2: Scenario to test Sensitivity of Option 1 to interruptions to supply valuation	RIIO-2 costs as submitted. (Lines 38 & 39)	As Option 1 without Interruptions to Supply
Option 3: Scenario to test Sensitivity of Option 1 to level of avoided costs	RIIO-2 costs as submitted. (Lines 38 & 39)	As Option 1 with lower avoided reactive costs.

Table A1: Basis of Calculations in CBA Template

Calculating the Benefits

In addition to the benefits modelled above, it is likely that some of the pipeline crossings would also cause transport disruption on failure and or during any reactive fix. We have not included this in the cost benefit modelling at this stage as the level of any disruption varies significantly on a case by case basis. This conservative approach means that the benefits of the programme can be considered to be a minimum as they could actually be significantly higher in some cases.

The benefits of the RIIO-2 expenditure have been assumed to commence at the end of RIIO-2 and to last 23 years in line with average asset lives. This is a reasonable assumption to make for this project as the investment consists of a mix of refurbishment with a design life of 15 years and ADM with a much longer asset life.

<table>
<tr><th>CBA Benefit</th><th>CBA basis of calculation</th></tr>
<tr><td>Annual Avoided Reactive Costs</td><td>(Annual rate of reactive repair) * (Cost of reactive repair)
The failure rate is assumed to be 5% per year which is a reasonable assumption as these are high priority crossings with HI4 or HI5 classifications, and only HI3 if there is no effective ADM at present.
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). The substantial costs of access (such as scaffolding & other payments for access e.g. to Network Rail) are required for either reactive or proactive intervention and once these have been incurred it is cost-effective to undertake the full scheme.
The calculation at the company level is:
0.05 * 1.2 * XXXX= XXXX
For the Sensitivity test Scenario (Option 3) this is:
0.05 * 1.05 * XXXX= XXXX</td></tr>
<tr><td>Annual value of Interruptions to Supply</td><td>(Annual rate of interruption to supply) * (Number of properties affected) * (WTP to avoid interruption) * (Volume of crossings targeted)
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 LTS Pipeline 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 Crossings 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 1% of the properties affected in the AIM model as a conservative estimate of properties affected.
<table><tr><th>Region</th><th>Number of Properties affected by any failure in LTS AIM model</th></tr><tr><td>EoE</td><td>732</td></tr><tr><td>Lon</td><td>1,198</td></tr><tr><td>NW</td><td>918</td></tr><tr><td>WM</td><td>772</td></tr><tr><td>All</td><td>838</td></tr></table>The calculation at the company level is:
0.05 * 0.01 * 838 * XXXX* 764 = XXXX</td></tr>
<tr><td>Annual Probability of Fatality</td><td>Very sadly a fatality occurred at one of our pipeline crossings at Dugdale Bridge in 2014. We have used this to calculate the probability of a fatality that is avoided by implementing effective ADM.
665 Crossings have been identified for ADM upgrade via the prioritisation process set out above. The average crossing age is 49 years. Assuming that they have the same risk of fatality as Dugdale that is 1 in 49 years i.e. 2%.</td></tr>
</table>

Table A2: Approach to calculating benefits for CBA

Results of CBA analysis

The results of the Crossings CBA are set out in Table A3:

CBA Option No.	Option Name	Total NPV (£m)	Cost Beneficial	Payback Year	RIIO-2 Spend (£m)	Ratio of NPV to RIIO-2 spend
Baseline	Baseline		N/A	N/A		
Option 1	Proactive Repair		Cost Beneficial	2045		
Sensitivity Analysis		Redacted due to commercial sensitivity				
Scenario 2	*Preferred Option Without WTP*		Cost Beneficial	2053		
Scenario 3	*Preferred Option Lower Avoided Costs*		Cost Beneficial	2048		

Table A3: CBA results for Pipeline Crossings (£M)

The approach to assessing CBA:

- For each option, we estimate the Total NPV. This is the discounted sum of costs over time relative to our do-nothing position (known as the baseline position). In estimating NPV, we have considered costs over five risk categories: financial, environmental, safety, reliability and other costs.
- All costs are discounted in line with Ofgem's recommended approach, for example financial impacts are discounted using the Spackman approach.
- A positive NPV means an option reduces the profile of costs relative to the do nothing (baseline) position and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial option.
- Payback shows the year when the sum of costs associated with an option is lower than 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; the ratio of NPV to RIIO-2 spend shows how much NPV per £ 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.

The table clearly shows that the Option to proactively repair and refurbish the crossings is cost beneficial, with an NPV of **XXXX** and payback by 2045.

Option 2 tests the sensitivity of this result to the WTP to avoid supply interruptions. Removal of these benefits only reduces the NPV by **XXXX** and does not affect the overall result that the investment is cost-beneficial.

Table A4 shows the drivers underlying these positive results in more detail:

Option Name	PV Expenditure & Costs (£m)	PV Environment (£m)	PV Safety (£m)	PV Reliability (£m)	Total PV (£m)	NPV (relative to baseline) (£m)
Baseline						
Preferred Option						
		Redacted due to commercial sensitivity				
Preferred Option Without WTP						
Preferred Option Lower Avoided Costs						

Table A4: Breakdown of CBA results for Pipeline Crossings (£m)

The table above shows the discounted present value (PV) of costs across the five risk categories.

- Costs are presented as negative values, cost reductions are presented as positive values.
- PV expenditure and costs shows discounted sum of proactive investment (replacement or refurbishment costs) over and above the costs of the baseline. All financial costs are discounted using the Spackman approach.
- PV environment shows the discounted sum of changes in leakage and shrinkage, using the base case cost of carbon.
- PV safety shows the discounted sum of the change in 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 the change in 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 cost changes, as valued using our research into the cost of property damage and transport disruption.

The following table looks at the NPV by network, and also shows that option 1 is cost beneficial at a network level.

Region	NPV (£m)	Cost Beneficial	Payback
EoE		Cost Beneficial	2045
L	Redacted due to commercial sensitivity	Cost Beneficial	2046
N		Cost Beneficial	2044
W		Cost Beneficial	2047
Total		**Cost Beneficial**	**2045**

Table A5: CBA results by region for Option 1

The full cost benefit of the proposed programme including all three types of benefit is set out in Table A4. This is clearly cost-beneficial with an NPV of **XXXX**

The positive NPV result is being driven clearly by each of the three types of benefit included as demonstrated by the sensitivity analysis. The largest benefit is that associated with health and safety protection from the installation of ADM, with a PV of **XXXX**, followed by the benefit of avoiding interruptions with a PV of **XXXX**. Reducing the avoided costs to 105% of planned has a PV of **XXXX**

The results are not sensitive to the inclusion or removal of the value of supply interruptions or the reduction in avoided costs.

Inclusion of transport interruptions would only improve the positive NPV of the targeted programme of interventions.

Therefore, the CBA supports the preferred option of undertaken targeted proactive intervention of our Pipeline Crossings.

Appendix 2. Below 7 bar Crossing Capital Expenditure – interventions and ADM installs – RIIO-2 profile

The following scope of work was then prioritised across RIIO-2 & 3, based on criticality and severity, which generated the following cost profile for pipeline crossing interventions and ADM installations.

	£k investment for < 7 bar pipeline crossing interventions and ADM installs					
Network	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**Total**
EA						
EM						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table A6: RIIO-2 investment costs for < 7 bar crossing interventions & ADM installations by network and year

Appendix 3. Types of Access Deterrent Measure (ADM) Options

Any one of these deterrent methods may be suitable, or these systems may be used in combination to provide the best solution for that crossing:

- Fencing
- Barriers including anti vandal guard fans
- Anti-climb rotational devices
- Anti-vandal paint
- Raptor or spiked guards

See below a comparison table of the different deterrent measures:

	Preferable Method ←					→ Least Preferable Method		
Guidance table for selection for Access Deterrent Measure (ADM)	**Fan / Anti Vandal Guard**	**Anti-Vandal Paint**	**Palisade Fence**	**Welded Mesh Fence**	**Palisade with spikes**	**Rotational Anti Climb device**	**Fence 3m high welded mesh with barbed wire**	**Raptor or Spikes across the pipe span**
Difficulty to climb (Easy, Moderate, Hard)	Moderate	Hard	Easy	Hard	Moderate	Hard	Hard	Moderate
Maintenance (Low, Medium, High)	Medium	Low	Low	Low	Low	Low	Low	Low
Can measure be installed in restricted space	Yes	Yes	No	No	No	Yes	No	Yes
Cost (Low, Medium, High)	Medium	Low	Medium	High	Medium	Medium	High	Low
Risk of Injury to Intruders (Low, Moderate, High)	Low	Medium	Low	Low	Medium	Low	High	High
Position on pipe. (Isolates, Verticals, Horizontals, Span)	Horizontal	All positions	Isolates	Isolates	Isolates	All positions	Isolates	Span
Advantages	Fabricated to fit conditions	Easy installation and low cost	Heavy Duty can act as vehicle barrier	Climb resistant	Heavy Duty can act as vehicle barrier	Difficult to breach and lightweight	Difficult to breach	Strong Visual deterrent
Disadvantage	Only deters access to pipe ends	Shall be used above 2 metres	Gaps between rails	High Cost	Gaps between rails	Injury to intruder	Expensive and difficult to install	Injury to intruder

Table A7: Comparison between the different deterrent measures

Access Deterrent Measure Example Images


Figure A1: Example of Palisade Fencing


Figure A2: Example of Fans and anti-vandal guards

Figure A3: Example of Anti-climb rotational device

Figure A4: Example of Raptor and spikes