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AusNet Services Revised Revenue Proposal 2017-2022

Review of AusNet Services Transmission safety risk cost

Report to

Australian Energy Regulator

from

Energy Market Consulting associates

April 2017

This report has been prepared to provide the Australian Energy Regulator (AER) with an assessment of AusNet Services (AusNet Transmission Group Pty Ltd)'s Transmission Revenue Review 2017-2022, Revised Revenue Proposal.

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In particular, this report represents findings from a limited scope review. This report is not intended to be used to support business cases or business investment decisions nor is this report intended to be read as an interpretation of the application of the NER or other legal instruments. Opinions stated or inferred in this report should be read in relation to this over-arching purpose.

Except where specifically noted, this report was prepared based on information provided by AER staff prior to 17 December 2016 and any information provided subsequent to this time may not have been taken into account.

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About EMCa

Energy Market Consulting associates (EMCa) is a niche firm, established in 2002 and specialising in the policy, strategy, implementation and operation of energy markets and related network management, access and regulatory arrangements. EMCa combines senior energy economic and regulatory management consulting experience with the experience of senior managers with engineering/technical backgrounds in the electricity and gas sectors.

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Executive summary

Purpose of this report

1. The purpose of this report is to provide the Australian Energy Regulator (AER) with an opinion on the reasonableness of the safety risk calculations and the resultant safety risk costs proposed by AusNet Transmission Group Pty Ltd (AusNet Services) in its Revised Revenue Proposal (RRP). The assessment contained in this report is intended to assist the AER in considering the prudency and efficiency of AusNet Services' capital expenditure, as an input to its Final Decision.

Findings from our review

AusNet Services' safety obligations require compliance with the ALARP principle

2. We consider that:

(i) AusNet Services has acted in accordance with its safety-related legislative and other obligations by undertaking quantitative risk-based cost-benefit analysis to determine the optimal approach and timing for risk management actions, consistent with the 'as low as reasonably practicable' (ALARP) and 'so far as practicable' (SFAP)[1] principles for risk management;

(ii) It is necessary for AusNet Services to consider safety risk (of explosive failure of assets identified as 'at risk') during normal operations, as well as the elevated safety risk during brownfields replacement projects. Recognition of the different levels of risk that apply during normal operations and during brownfields replacement is necessary in assessing the justification for replacement, brownfield versus greenfield replacement, and in determining the economically justified timing of such

[1] The AER refers to SFAP, whereas AusNet Services uses several terms in the documentation we have been provided which we interpret as being equivalent to SFAP, namely: 'as far as practicable', 'so far as is reasonably practicable', and 'so far as is practicable.' Unless we are directly quoting AusNet Services, we use the term SFAP. We note that the Electricity Safety Act 1998 (Vic) requires major electricity companies to minimise hazards 'as far as practicable' (refer to Section 98). The Occupational Health and Safety Act 2004 (Vic), Section 21 (1) uses the term 'so far as is reasonably practicable'. AusNet Services uses the terms 'so far as is practicable', 'so far as is reasonably practicable', and 'as far as practicable' in its Asset Renewal Planning Guideline (AMS 10-24, pages 8-9) and 'as soon as practicable' in its Risk Management Policy & Framework (page 26).

replacement. Actions to assess and address those risks should be based on complying with the ALARP and SFAP principles both during normal operations and during any replacement project; and

(iii) In assessing the likelihood of the consequence (fatality) occurring, AusNet Services should account for the level of exposure of persons to the hazard, cognisant of any risk controls that mitigate the level of exposure.

To the extent that AusNet Services' safety risk-cost drives replacement timing, its analysis tends to bias it towards premature replacement[2]

3. We consider that AusNet Services' application of its safety risk cost analysis contains modelling approaches and assumptions that are poorly supported and, to the extent that safety risk cost was to drive replacement decisions, would tend to bias those decisions towards early replacement because:

(i) AusNet Services mixes the concepts of failure rates and replacement rates. It bases its failure rate projections on replacement rates (proactive and reactive).

(ii) The number of observed failures over a 20-year period equates to failure rates that are an order of magnitude less than AusNet Services has assumed in its modelling, taken over all Terminal Station assets. AusNet Services has not used this data to evidence failure rates for assets with condition ratings of 4 or 5 – being those that it proposes to replace.

(iii) AusNet Services has assumed what we consider to be an inadequately justified, relatively high rate of increase in asset failure risk with age, and has not provided evidence to support this. The rate of increase in asset failure risk has a direct effect on the optimal timing.

(iv) AusNet Services has been overly conservative by assuming that a fatality will result from explosive failure of the plant considered in every instance. In doing so, it has failed to properly consider its own explosive failure statistics, industry statistics and the physical factors (including its own controls) that significantly reduce the probability of a fatality arising from an explosive failure.

(v) By conflating risk parameters during normal operations with risk parameters during the replacement project period, AusNet Services has not properly specified the risk-costs in different years in its analysis of replacement options. Optimum timing cannot be determined without modelling this distinction.

(vi) AusNet Services has not adequately justified a key aspect of its selection of [redacted] as the consequence cost for the purposes of its safety risk cost assessment.

(vii) AusNet Services' counterfactual 'do nothing' option assumes that it would not replace any of the relevant assets for 45 years. The high (and unrealistic) risk inherent in this scenario leads to a high 'residual value' of risk cost which dominates the overall risk cost calculation of this option, biasing the justification for risk mitigation.

4. Finally, we note that safety risk-cost is not the dominant risk-cost in AusNet Services' analysis. Supply risk-cost appears to be considerably greater and appears to be the main driver in its assessment of replacement timing.

[2] EMCa has been asked to assess only safety risk cost as a component of AusNet Services' analysis. As noted below, safety risk cost does not appear to be the dominant driver of replacement timing in AusNet's analysis.

1 Introduction

1.1 Purpose of this report

5. The purpose of this report is to provide the AER with an opinion on the analysis and modelling of the asset safety risk cost by AusNet Services, as presented in AusNet Services' RRP, and which responds to matters raised by the AER in its Draft Decision.

6. The assessment contained in this report is intended to assist the AER in its own analysis of the capital expenditure allowance as an input to its Final Decision on AusNet Services' revenue requirements.

1.2 Scope of requested work

7. The AER has sought an opinion on the reasonableness of the safety risk calculations as proposed by AusNet Services and its response to these calculations as modified by the AER (in its Draft Decision) to determine an expected safety risk cost for the purposes of assessing the economic efficiency of relevant components of AusNet Services' proposed capital expenditure. In particular, the AER has requested that consideration be given to:

- The reasonableness of the parameters (variables) used in the expected safety risk cost equations – are the parameters reasonably defined and is the set of parameters used sufficient to reasonably estimate the expected safety risk cost;
- The reasonableness of the evaluation of the parameters used to determine the expected safety risk cost;
- The reasonableness of any explicit or implicit assumptions used in the calculation of expected safety risk cost that may have a material bearing on the determination of expected safety risk cost; and
- The nature of the Occupational Health & Safety (OH&S) obligations faced by AusNet Services and, in particular, the implications of the principles of grossly disproportionate, 'as low as reasonably practical' (ALARP), and 'so far as practical' (SFAP) principles in the context of the economic analysis.

8. Our review is intended to identify material issues that may impact on the reasonableness of the safety risk calculations as proposed by AusNet Services and its response to these calculations as modified by the AER.

9. Based on discussions with the AER, our assessment of the nature of the OH&S obligations faced by AusNet Services is confined to safety-related obligations in the context of the proposed safety-related capital expenditure.

10. This advice and the assessment that we have undertaken is based on a limited scope review in accordance with the terms of reference provided by the AER. It does not take into account all factors or all reasonable methods for determining an expenditure allowance in accordance with the National Electricity Rules (NER). We understand that the AER will establish a capital expenditure allowance for AusNet Services based on assessments undertaken by its own staff.

1.3 Our approach

11. In undertaking our review, we

- Identified relevant supporting information, including reference to AusNet Services' Regulatory Proposal (RP) and Revised Revenue Proposal (RRP) as relevant to assist our understanding of the safety risk cost calculation, and the AER's own analysis in its Draft Decision;
- Considered the parameters and methodology of the safety risk cost calculation, as proposed by AusNet Services, assessment of the economic analyses prepared by AusNet Services, and from our experience as asset managers, financial and economic advisors within Transmission and Distribution Network Service Providers and as advisors to Network Service Providers and regulators; and
- Considered the modelling, assumptions and sensitivity of the economic analysis undertaken by AusNet Services for four terminal station replacement projects.[3]

12. We undertook an onsite review meeting with AusNet Services staff and the AER to confirm our understanding of the materials provided, and requested further information arising from our assessment and the onsite discussion.

13. We have then considered the reasonableness of the selection of parameters and application of those parameters by AusNet Services in its determination of asset safety risk cost, and its impact on the conclusions reached by AusNet Services in regards to the justification for and timing of replacement projects at the four terminal stations.

14. The limited nature of our review does not extend to advising on all options and alternatives that may be reasonably considered by AusNet Services, however we have included additional observations in some areas and which we trust may assist with future assessments of this type.

1.4 Structure of this report

15. In section 2, we present background information to provide context to our review.

[3] West Melbourne, Springvale, Fisherman's Bend, and Templestowe Terminal Station replacement projects

16. In section 3, we describe our assessment of the nature of the safety-related obligations faced by AusNet Services and which are relevant to its proposed safety-related expenditure for replacements at the four terminal stations.

17. In section 4, we review the reasonableness of the input variables and assumptions used by AusNet Services in its risk cost analysis.

18. In section 5, we consider the reasonableness of the risk cost calculations used in the economic modelling by AusNet Services.

2 Background

2.1 Introduction

19. This section is intended to provide context to the assessment which follows. We set out a summary of relevant aspects of the AusNet Services' RP and RRP, related to its asset and risk management approach focusing on the assets for which we have been asked to provide advice, and for which it has developed safety risk costs. We have also provided a high-level summary of the AER's Draft Decision pertaining to the safety risk cost assessment presented in AusNet Services' RP, as a precursor to our assessment of AusNet Services RRP methodology and assumptions for safety risk cost.

2.2 Summary of AusNet Services risk management approach

Risk management policy and framework

20. AusNet Services advised that it has adopted the risk management process in AS/NZS ISO 31000:2009 Risk management – principles and guidelines ('ISO 31000'). It has developed a risk matrix, which denotes risk levels of I – IV, as shown in Figure 1 below. Level I is the highest risk level.[4]

21. We understand that AusNet Services based its risk matrix and the risk levels on both the guideline for such matrices in the ISO 31000 standard and AusNet Services' interpretation of its obligations under relevant legislation.[5] Level I and II risks identified by AusNet Services require action plans and can only be tolerated with the approval of the Managing Director.[6]

[4] AusNet Services, *AMS 10-22 Risk Management* – CONFID, page 6

[5] Technical and occupational health and safety standards (such as the relevant provisions of the *Occupational Health and Safety Act 2004,* and the *Electricity Safety Act 1998)*, policies, work practices and procedures

[6] AusNet Services, *RM 001-2006 Risk Management Policy & Framework, v4.0,* page 9

Figure 1: *AusNet Services risk matrix*

Consequences	A	B	C	D	E
5	II	II	I	I	I
4	III	II	II	I	I
3	III	III	II	II	I
2	IV	III	III	II	II
1	IV	IV	III	III	III
	Likelihood				

Source: AusNet Services ESMS - Formal Safety Assessment for the Electricity Transmission Network, 1D ESMS 20-02

22. AusNet Services' Risk Management Policy and Framework identifies that all options for treating risk will be considered and will include: (i) avoiding the risk; (ii) changing the likelihood; (iii) changing the consequences; (iv) sharing risk; and (v) tolerating risk (i.e. without further treatment).[7]

Evaluating, analysing and treating risks

23. AusNet Services' risk analysis process involves estimating 'Control Effectiveness' and using the AusNet Services' risk rating tables to arrive at the current level of risk. It also estimates the 'Potential Exposure' for each risk and uses it as a measure to focus and plan control assurance activity. The Potential Exposure is based on the total plausible worst case impact arising from a risk, assuming all current controls fail.[8]

24. AusNet Services has assessed the risks associated with the transmission system and has identified over 100 safety-related risks. No risks are rated as having a residual risk of level I, but six are rated as level II. One of these involves explosive failure of primary plant and AusNet Services has undertaken risk-cost modelling of this to justify a proposed allowance for replacements.[9]

25. Four types of primary plant are identified as being subject to explosive failure: instrument transformers (current transformers (CT), voltage transformers (VT)); circuit breakers (CB); power transformers; and surge arresters. AusNet Services has identified that the worst-case consequence of an explosive failure/fire is a fatality (or fatalities).[10] AusNet Services has documented asset management strategies for the four primary asset types[11] to manage the level II risks.

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[7] AusNet Services, *RM 001-2006 Risk Management Policy and Framework,* page 9

[8] *Ibid, page 9*

[9] AusNet Services, *AMS 10-22 Risk Management* – CONFID, Table 3, page 7

[10] Via high velocity porcelain pieces from the porcelain insulating stacks and/or oil fire from exploding power transformers

[11] AusNet Services, *AMS 10-22 Risk Management* – CONFID, Table 3, page 7

Asset management policy and strategy

26. AusNet Services' Asset Management Policy directs its asset management strategies, objectives and plans and, among other things, highlights its focus on minimising 'so far as is practicable' the hazards and risks to the safety of any person and their property.[12]

27. AusNet Services' Asset Management Strategy "*seeks to deliver optimal electricity transmission network performance at efficient cost by ensuring that all decisions to replace or maintain network assets are economically justified."*[13]

28. AusNet Services applies probabilistic planning methods to determine the economic viability for asset renewal, determining a 'baseline risk' which includes: safety risk, security of supply risk, environmental risk, and collateral damage risk for plant that can fail explosively.[14]

2.3 Summary of AusNet Services risk cost methodology

29. AusNet Services applies a cost-benefit analysis as part of the process to determine its preferred replacement option. The cost is represented by an estimate of the proposed expenditure and the benefits are represented by the avoided cost of risk, on an annualised basis:

> *"The monetised baseline risk is compared with the annualised cost of the asset renewal options to establish whether proactive asset renewal strategies are required to manage the asset failure risk instead of continuing with reactive asset management strategies…"* [15]

30. AusNet Services quantifies the baseline risk based on the probability and consequence of an explosive failure of an asset, as illustrated in Figure 2. The consequence of the worst-case event is assumed by AusNet Services to be a fatality.[16]

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[12] AusNet Services, *AMS 10-24 Asset Renewal Planning Guideline*, page 9

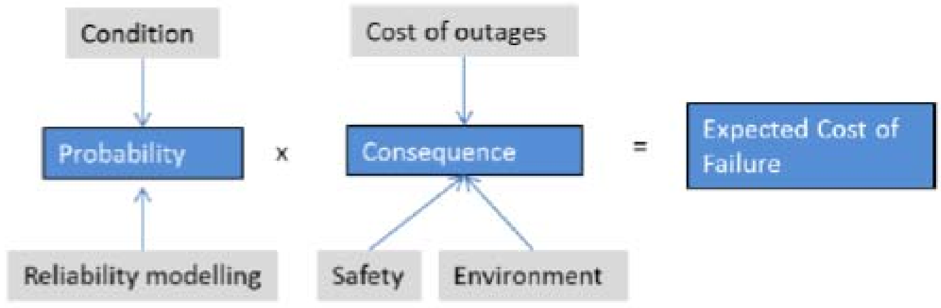
[13] *Ibid, page 9*

[14] *Ibid, page 17*

[15] *Ibid*

[16] AusNet Services – TRR – 5 Dec 2016 capex workshop follow up, page 4: AusNet Services adds a 25% loading in determining the consequence cost to account for the cost of multiple injuries or fatalities in the event of explosive failure of the nominated plant

Figure 2: *AusNet Services' baseline risk calculation*



Source: AusNet Services AMS 10-24 Asset Renewal Planning Guideline

2.4 Summary of AER draft decision

31. In its Draft Decision, the AER determined that AusNet Services' application of quantified risk assessments "*is consistent with good industry practice within the electricity industry*."[17] However, it had concerns with AusNet Services' assumptions that:

- *"Someone is, at all times, in the immediate vicinity of safety related asset failure*
- *Existing controls designed to mitigate safety risk to employees and the public are not effective."*[18]

32. Both concerns relate to assumptions which are part of AusNet Services' modelling of the probability of explosive failure leading to a fatality (which AusNet Services identifies as the worst-case impact). In particular, the AER considers that AusNet Services has overestimated the time that its personnel are exposed to the risk of explosive failure of primary plant by assuming that an explosive failure will result in a fatality.

33. The AER concludes that AusNet Services' estimation of safety risk costs and therefore its forecast asset replacement capex is likely to be overstated. It reduced AusNet Services' proposed replacement capital expenditure related to safety by $99.0 million based on what it considered to be a more realistic assumption of the probability of safety-related risks.[19]

[17] AER, *Draft decision AusNet Services Transmission determination 2017-22, Attachment 6 – Capital Expenditure,* page 6-45

[18] *Ibid, page 6-45*

[19] *Ibid, Table 6.10, page 6-56*

3 Nature of safety-related obligations faced by AusNet Services

3.1 Background

34. This section provides an assessment of the nature of the safety related obligations faced by AusNet Services and, in particular, the implications of the principles of 'grossly disproportionate' consequences and the ALARP and SFAP principles.

3.2 AER's findings

AusNet Services safety obligations

35. The AER in its Draft Decision stated that AusNet Services operates its network "*in accordance with technical and occupational health and safety standards, policies, work practices and procedures designed to minimise hazards and maintain a safe working environment.*" [20]

36. The AER states that AusNet Services estimates the risk consequence of a fatality is based "*on the principle that risks to workers and the public should be minimised to be as low as reasonably practicable (the ALARP principle). That is the risk should be proactively managed until the cost of doing so becomes grossly disproportionate to the benefits.*"[21]

37. In accordance with the requirements of the ALARP principle, AusNet Services applies a 'disproportionality factor' of three to identify the appropriate cost of preventing a fatality, with a fatality being the worst-case impact arising from the explosive failure of major

[20] *Ibid, page 6-49*

[21] *Ibid, page 6-46*

plant. The AER considered this approach provides a "*conservative but reasonable estimate of the consequences of safety risk, consistent with the ALARP principles*."[22]

38. However, the AER noted that AusNet Services' Risk Management & Policy Framework states that:

> "*Potential exposure will be estimated for each risk in terms of the total plausible worse (sic) case impact arising from a risk assuming all current controls fail.*"[23]

39. The AER considered that this "*may be a legitimate assumption in the context of assessing the maximum possible consequences of safety risks…however in quantifying the actual risk cost and therefore the benefit that might be achieved by eliminating that risk, it is important to also account for the likelihood of the risk materialising. To some extent this depends on the controls in place to manage or mitigate the risk.*"[24]

40. The AER considered that AusNet Services' existing controls have the effect of: (i) reducing the need for employees to work in close proximity to potentially hazardous equipment; and (ii) making the potentially hazardous zone safer. It further concluded that the combined effect of AusNet Services' safety controls should be incorporated in the risk analysis and support its conclusion that AusNet Services' assessment of the probability of explosive failure leading to at least one fatality is overstated. [25]

3.3 AusNet Services' response

41. In its RRP, AusNet Services restated its interpretation of its legislative and regulatory safety obligations:

- "*AusNet Services is required to eliminate, where practicable, the risk of an incident before it occurs – this is the effect of legislative and regulatory requirements which oblige AusNet Services to maintain a safe workplace, safe systems of work, a safe electricity supply and the safety of staff and the public (e.g. Occupational Health and Safety Act 2004 (Vic); NEO and NER; Electricity Safety Act 1998 (Vic)). This goes beyond an obligation to mitigate the risks when the incident actually occurs. This is an important point of distinction that has not been considered in the Draft Decision.*"[26]
- "*AusNet Services' current approach explicitly meets this requirement by assuming that each explosive failure has a consequence attached to it. This ensures that explosive failures are eliminated where the benefits of elimination exceed the cost (i.e. to the extent practicable). Any change to this assumption would need to be closely examined to ensure this obligation continued to be met.*"[27]
- "*Protect its workers at all times, including (and explicitly) when decommissioning the network, and … to have regard to the severity of the hazard in question. As explosive failures are very severe hazards, particularly during major replacement*

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[22] *Ibid, page 6-47*

[23] Ausnet Services, *Risk Management Policy & Framework,* page 9

[24] AER, *Draft decision AusNet Services Transmission determination 2017-22, Attachment 6 – Capital Expenditure,* page 6-49

[25] *Ibid, page 6-51*

[26] AusNet Services, *Revised Revenue Proposal 2017-22,* page 34

[27] *Ibid, page 34*

projects when many workers will be on site, AusNet Services is explicitly required to minimise, as far as practicable, the risk of an explosive failure occurring during a replacement project."[28]

42. We understand that AusNet Services holds the view that the governing Electricity Safety Act 1998 (Vic) imposes the requirement to comply with the 'as far as practicable' (AFAP) principle, not the ALARP principle as determined by the AER.[29] AusNet Services referred to advice it received from GHD, an engineering consulting firm, which considers that "*AFAP is generally what legislation requires i.e. the regulatory mandate and takes precedence over ALARP*."[30]

43. AusNet Services also quoted AS 5577:2013 Electricity network safety management systems ('AS 5577') clause 4.3.2 (e), which states:

> "*Risk treatment, including where reasonably practicable the elimination of the source of risk and where elimination is not reasonably practicable, the identification of treatments or controls so that residual risks are reduced to as low as reasonably practicable*."

44. We further understand that AusNet Services interpreted this requirement as the "*elimination of the hazard must be given primacy over controlling or treating the risk, if it is reasonably practicable to do so*"[31] and concluded that it "*complies with this legislative requirement by replacing assets that present an uneconomic safety risk*."[32]

3.4 EMCa's assessment

AusNet Services' risk matrix

45. The risk matrix illustrated in Figure 1 illustrates a bias towards rating risks high or extreme, as evidenced by the high proportion of possible risk ratings that are either high or extreme (56%). We have not considered, nor have we been requested to consider, the implications of potential bias in the risk matrix on the capital expenditure forecast.

46. We consider that the assignment of risk as Level II, or High risk, for major plant explosive failure risk is reasonable based upon AusNet Services' risk matrix definitions. AusNet Services describes the treatment of Level II risks as being "*managed through implementation of the strategies in the relevant Asset Management Strategies.*"[33]

ALARP versus AFAP

47. AusNet Services appears to purport that that it is held by its governing legislation to a higher obligation under the AFAP principle than under the ALARP principle to support its view that elimination of the hazard must be given primacy over controlling or treating the risk, if it is practicable to do so.

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[28] *Ibid, page 45*

[29] Or, alternatively, the 'so far as is reasonably practicable' (SFAIP) principle

[30] *Ibid, page 35*

[31] AusNet Services, *Revised Revenue Proposal 2017-22,* page 34

[32] *Ibid, pages 35-36*

[33] AusNet Services, *AMS 10-22 Risk Management* – CONFID, page 7

48. We refer to the Health and Safety Executive (HSE), based in the United Kingdom, which provides the following guidance:

> "*In terms of what they require of duty-holders, HSE considers that duties to ensure health and safety so far as is reasonably practicable ("SFAIRP") and duties to reduce risks as low as is reasonably practicable ("ALARP") call for the same set of tests to be applied. However, SFAIRP and ALARP are not always interchangeable because legal proceedings will have to employ (for example, in complaints or informations [sic]) the particular term cited in the relevant legislation*."[34]

49. Noting that AFAP is shorthand for SFAIRP, the HSE does not appear to support AusNet Services' (or GHD's) opinion that AFAP takes precedence over ALARP nor even that it is a different and stricter test. Furthermore, the reference AusNet Services makes to AS 5577 also appears to be consistent with the requirements of ALARP.

50. In our view, the common and relevant aspects of the ALARP and AFAP principles are that each requires an assessment of what response to an unacceptable hazard is reasonably practicable and to implement that response. The required practice is to determine what is reasonably practicable by undertaking an economic test where risks should be reduced to a low level, or as low as practicable, incurring expenditure as necessary up to the point at which the expenditure would be grossly disproportionate to the benefit achieved. That is, if it is not disproportionately uneconomic to do so, then the source of the risk should be eliminated. Conversely, if it is not reasonably practicable (i.e. not economically justified) to eliminate the source of risk, then expenditure should still be incurred to mitigate the risk to as low as is reasonably practicable. We can see no meaningful difference between the ALARP principle and the AFAP principle in this regard.

51. AusNet Services has sought to align its practice with the requirements of the ALARP/AFAP principles by using an economic cost-benefit analysis as part of assessing when it is reasonably practicable to replace potentially hazardous items of plant. Replacement is the risk treatment that AusNet Services recommends to eliminate the identified hazard.

52. We consider that AusNet Services' application of a 'disproportionality factor' to estimate the appropriate cost of preventing a fatality is appropriate.

53. Our understanding is that:

- In its Draft Decision, the AER considered that existing controls should be accounted for in estimating the exposure of personnel and the public to the hazard in question. The AER considered that accounting for such controls reduces the exposure to the hazardous event. It stated that as AusNet Services has not taken into account the effect of controls on the level of exposure to explosive failure, it has overstated the exposure level and therefore the likelihood of a fatality from explosive failure of the identified items of major plant; and
- In its RP and RRP, AusNet Services assumes that it should be focussed on assessing when it is economically justifiable to eliminate the risk posed by the poor/very poor major plant items subject to explosive failure by replacement, rather than rely on current or alternative controls.

[34] Health and Safety Executive, United Kingdom, *Principles and guidelines to assist HSE in its judgements that duty-holders have reduced risk as low as reasonably practicable', http://www.hse.gov.uk/risk/theory/alarp1.htm*

54. We consider that AusNet Services is acting in a manner consistent with the requirements of the ALARP/AFAP principle in determining when it is economically practicable to eliminate the Level II risk posed by potential explosive failure of the identified major plant through safety risk cost analysis. AusNet Services considers that the risk of failure has increased to a level where the existing controls may not result in a level of residual risk that is ALARP and therefore, that further risk mitigation measures should be assessed.

55. However, we also consider that in determining the level of exposure to person(s) from explosive failure in its safety risk cost analysis, AusNet Services should take into account the effect of controls it already has in place. In our opinion AusNet Services has not appropriately assessed the level of exposure in its analysis by considering all relevant information available to it. This is discussed further in Section 4.

3.5 Summary

56. We consider that:

(i) AusNet Services is acting in accordance with its safety-related legislative and other obligations by focussing its safety risk assessment on the sub-class of major plant assets that pose the greatest risk of explosive failure;

(ii) It is necessary for AusNet Services to consider the safety risk of explosive failure of identified assets both during normal operations and during brownfields replacement projects and it should comply with the ALARP/AFAP principles[35] at all times;

(iii) It is appropriate for AusNet Services to focus on the highest consequence that it has identified in its risk assessment, which is a fatality;

(iv) In assessing the likelihood of the consequence occurring, AusNet Services should account for the level of exposure of persons to the hazard (and which may vary between the normal operational state and during brownfields replacement), cognisant of any risk controls that mitigate the level of exposure;

(v) AusNet Services' approach of seeking to eliminate the hazard as the first preference by replacing the hazardous assets is consistent with its safety-related legislative and other obligations, subject to it being economically justified; and

(vi) By undertaking risk-based cost-benefit analysis to determine the appropriate course of action, AusNet Services is acting in a manner consistent with good electricity industry practice.

[35] Which we consider to be equivalent for the relevant aspects of this assessment

4 Assessment of input variables and assumptions

4.1 Introduction

57. In this section, we will assess the reasonableness of the variables and assumptions that underpin AusNet Services' determination of its baseline safety risk cost.

58. We consider each of the factors in turn by providing a summary of the relevant issues identified in the AER's Draft Decision and AusNet Services' response to the Draft Decision in its RRP, and then our assessment of the issues raised. We conclude the section with a summary of our assessment.

4.2 AER's findings

59. The AER identified several concerns with AusNet Services' derivation of asset failure rates.

Asset condition was overstated

60. The AER's analysis of AusNet Services' power transformer condition data suggested that its mapping of individual asset condition scores to the discrete condition index scale appeared to be biased towards assigning a higher condition score (which equates to a poorer condition).[36]

Asset residual life was understated

61. The AER observed that AusNet Services had estimated significant reductions in residual life of (among other things) switchyard, substation and transformer assets. The AER did not consider this to be plausible.[37]

[36] AER Draft Decision, *AusNet Tx – Attach 6 – Capital expenditure – July 2016*, pages 6-61 to 6-62

[37] *Ibid*, pages 6-65 to 6-66

Asset failure rate was not determined appropriately

62. Whilst the AER considered that the use of a health index and the identified techniques used to measure the health of major asset types are both consistent with good industry practice, it identified some issues with AusNet Services' application of the information to determine the asset failure rate, specifically:

- "*AusNet Services analysis adopts one annual failure probability based on failure data for each type of asset and this failure probability is then applied to all asset failure modes. However, different failure modes (e.g. explosive failure, downed conductor) will result in different consequences and therefore different estimated risks.*
- *The asset type failure probability is derived by calibration using historical data. However, the calibration process relies on an annual data point rather than employing a best fit estimator across the historical data set.*"[38]

63. The AER considered that AusNet Services should provide additional information to substantiate that its asset failure rates and consequences reasonably align with failure modes.

Hazard zone occupancy rate is omitted/overstated

64. The AER determined that AusNet Services' equation for determining the safety risk cost overstated the likelihood that a fatality would result from explosive failure of plant by omitting explicit recognition of the Hazard Zone Occupancy ('HZO') rate as a key factor. It represented its alternate equation for quantifying safety risk as shown in Figure 3, where the AER represents the HZO rate as being a realistic estimate of the likelihood that a person will be in the vicinity of a transmission network asset when it fails.

Figure 3: *AER proposed risk quantification equation*

Safety risk cost = Asset failure rate x Probability of safety related failure x Hazard zone occupancy rate x Risk consequence

Source: AER, Draft decision – AusNet Tx – Attach 6 – Capital expenditure – July 2016, page 6-47

65. The AER considered that (i) AusNet Services implicitly assumed a HZO rate of 100% by assuming a person will be in the equipment hazard zone at all times, and that (ii) this is equivalent to assuming a fatality will occur with certainty if there is explosive failure of an asset. The AER considered that this is an unrealistic assumption and has the effect of over-estimating the cost of the safety risk. The AER proposed an alternate estimate of the likelihood that a person is in the vicinity of a safety related asset failure, referred to as the HZO rate, of 1% based on its own analysis, and concluding that this is likely to represent a more realistic assumption.[39]

66. The AER also considered that the controls that AusNet Services does employ mitigate, but do not eliminate, the probability of safety-related asset failure occurring and the likelihood of people being in the hazard zone should explosive failure occur. Accordingly, the AER considered that such controls should be accounted for by AusNet Services in its analysis.

[38] *AER, Draft Decision, page 6-61*

[39] *Ibid, pages 6-46 to 6-49*

Risk consequence cost likely to be reasonable

67. In its Draft Decision, the AER accepted that AusNet Services' use of redacted as the risk consequence cost attributed to a fatality for the purposes of its economic evaluation was likely to be reasonable in the context of AusNet Services proposed baseline risk calculation and the values used in it.[40]

4.3 AusNet Services' RRP response

Asset condition

68. AusNet Services does not appear to address the AER's determination that the condition scores attributed to power transformers was biased towards poorer ratings in its RRP, other than to note that it had provided oil test results to the AER which it considers adequately[41] demonstrates the poor condition of the nominated power transformers and the need for replacement of them.

69. In its supporting documentation[42] AusNet Services reiterates that the condition assessment (including mapping the asset condition data to one of the five condition ratings) is based on the knowledge and advice of AusNet Services' specialists.

70. There has been no apparent change to the condition levels assigned to the plant included in the reliability modelling in its RRP.

Asset failure rate including explosive failures

71. AusNet Services does not directly respond to the AER's comments on its approach to determining the asset failure rates denoted above, but it did point out that:

   (i) There is an increased risk of asset failure during the brownfields replacement work period due to:

      - The risk of an explosive failure increasing exponentially later in an asset's life; and
      - An increased switching activity during replacement projects.[43]

   (ii) The controls that reduce the probability of explosion of the assets lead to decisions to replace the assets before they fail and have been factored into its economic analysis; and most of the risk controls listed by the AER do not reduce the safety consequences of an explosive failure.[44]

Hazard Zone Occupancy Rate

72. AusNet Services acknowledged that the AER's introduction of a HZO rate is "*one way its approach to valuing safety risk could be refined*", but "*adjusting this element alone would not be appropriate*."[45] Therefore, it did not adopt the AER's approach to determination of

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[40] *Ibid, page 6-46*

[41] AusNet Services *Revised Revenue Proposal 2017-22,* page 42

[42] AusNet Services, *AMS 10-54 Circuit Breakers – CONFID; AMS 10-64 Instrument Transformers – CONFID; Power Transformers Oil Filled Reactors – CONFID; Appendix 1A Asset Life Evaluation- CONFID*

[43] AusNet Services, *Revised Revenue Proposal,* 2017-22, page 45

[44] *Ibid,* pages 55-56

[45] *Ibid,* page 31

the baseline safety risk cost (i.e. by including a HZO rate as a factor in determining the probability of an explosive failure of asset(s) causing a fatality).

73. Nonetheless, AusNet Services stated that it considers that its implicit assumption that the HZO rate is 100% may understate the risk because its safety risk cost assessment does not account for:

(i) The 30-50 workers who will be located within hazard zones in working hours over several years during end-of-life brownfield replacement projects; and

(ii) The risk to the general public, noting that there are public areas within the proximity of each of the terminal substations for which major refurbishment work is recommended.[46]

74. AusNet Services provided an alternative HZO rate analysis based on the equation in Figure 4, expressed as a percentage of total hours per year:[47]

Figure 4: *Hazard zone occupancy rate calculation*

$$\textbf{Hazard Zone Occupancy Rate} = \Sigma_{activity}\frac{\textbf{(hours of occupation x no. people on the site)}}{\textbf{Total hours per year}}$$

Source: AusNet Services, Revised Revenue Proposal 2017-22, page 44

75. AusNet Services determined that the HZO rate could be up to 820% at West Melbourne Terminal Station and Springvale Terminal Station (large, complex replacement projects) and 342% at both Fisherman's Bend and Templestowe Terminal Stations (both less complex replacement projects) during the brownfields construction phase. These rates were derived by including the expected number of people on site during the brownfields construction phase at each site, but not the general public.[48] GHD further estimates that the public exposure rate (i.e. the time that a member of the public occupies a terminal station hazard zone, on average) is 47.44% of the year.[49]

76. AusNet Services rejected the AER's determination of a 1% HZO rate primarily on the basis that the calculation should only focus on the later part of the assets' lives, when AusNet Services claims that the risk of explosive failure increases exponentially. AusNet Services claims that the HZO rate in the past is not relevant.[50]

Risk consequence

77. In its RRP, AusNet Services advised that the redacted risk consequence cost: (i) did not represent the higher range recommended in other sources (being between red [redacted] and (ii) did not include other costs resulting from explosive failure, such as project disruption, incident investigation, emergency management costs, cost of accelerating replacement of like plant, and increase in supply risk. AusNet Services proposed that it had not sought to increase the assumed cost of a fatality in its RRP on the basis that other parameters (such as Hazard Zone Occupancy) are not altered,

[46] *Ibid*, page 32

[47] *Ibid*, page 44

[48] *Ibid, page 44*

[49] AusNet Services, *Revised Revenue Proposal 2017-22*, Appendix 3A – Report From GHD_Confidential

[50] AusNet Services, *Revised Revenue Proposal 2017-22*, pages 44-45

thereby maintaining a '*reasonable and balanced*' approach when the parameters are considered together.[51]

Overall

78. AusNet Services advised that it operates on the basis that terminal stations are safe to access at any time and that its methodology reflects this operational requirement. Further, it does not expect that a more refined approach to its assessment of the safety risk cost would result in a lower cost than it has applied.[52]

79. AusNet Services also submitted that its approach to monetising safety risk should be considered as an overall package and that it is the reasonableness of the overall approach that must be considered, not an individual assumption in isolation.[53]

80. It further advised that "*if the value of costed safety risk were lowered, deferring projects, it would not allow AusNet Services to meet its legal obligations for the safety of its workforce and the general public. It would make on-site (brownfield) replacements infeasible, and therefore, necessitate more expensive options (such as greenfield replacements), increasing the long term cost to customers.*"[54]

4.4 EMCa's assessment

4.4.1 Asset failure rate variable

81. In this sub-section, we consider each of the components of AusNet Services' derivation of its asset failure rate variable which is used in its reliability modelling.

Condition Score

82. AusNet Services appears to derive a condition score for each of its assets based on the results of its condition assessment process, which is in turn dependent on data derived from its condition monitoring programs. We understand that AusNet Services deploys a range of condition monitoring techniques that are broadly representative of good industry practice and that it is pursuing enhancements to current practices.[55]

83. AusNet Services appears to use two approaches to determine a condition score. The first approach is enunciated in its asset management strategy documents in which condition score descriptions are provided to guide the score allocation. The condition data/information from the condition monitoring program(s) for the asset need to be matched to the most appropriate condition score description. For example, the guiding description for a C5 score for instrument transformers is:

> "*Failure mechanisms may be known through autopsies and laboratory investigations from removed units. Major failures may have occurred and there will be a history of replacements. Enhanced monitoring, such as oil dissolved gas analysis (DGA) or RF scanning may be scheduled. There may be safety concerns over the risk of*

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[51] *Ibid, page 49*

[52] *Ibid, pages 31-32*

[53] *Ibid, page 48*

[54] *Ibid, page 24*

[55] AusNet Services, *AMS 10-13 Condition Monitoring – Non Confidential*, pages 9-18

major failure such that site access restrictions are implemented. There are no longer like spares available."[56, 57]

84. In our experience, this is a common approach in the electricity industry.

85. A second approach is described in AusNet Services' Dependability Management document in which a weighting or importance factor is applied against health indicators derived from the condition monitoring program to determine a total weighted asset score. The condition score is assigned depending on the range into which the total weighted asset score falls.[58]

86. Whilst weighting condition assessment scores by an importance factor may be valid in terms of directing expenditure to the most important assets from an overall perspective, if it is based on factors other than safety risk, then including it in the process for determining the condition score introduces an inappropriate bias to the safety risk cost calculation. It is beyond the scope of our report to assess whether this bias is built into the approach or the impact of this bias.

87. It is not clear from the information provided which of the approaches to assigning a condition score AusNet Services has been applied to determine the scores for the asset classes subject to explosive failure.

88. The AER determined from its review of the condition information for power transformers and AusNet Services' assignment of condition scores, that there appeared to be a bias towards allocating a higher condition score (indicating poorer condition) than is appropriate. AusNet Services has not provided additional information to counter this finding in its RRP.

89. We also note that in its Asset Management Strategy documents, AusNet Services identifies the assets that are at the highest risk of explosive failure (i.e. manufacturer type/voltage level) based on historical performance. We would expect to see this also lead to the highest risk assets being appropriately identified as C4 or, more likely, C5.

90. In the absence of further detailed analysis, we consider that:

(i) AusNet Services condition monitoring techniques are broadly aligned to good industry practices;

(ii) AusNet Services' general approach to determining a condition score based on the results of its condition monitoring and mapping them based on condition descriptions is broadly aligned with common industry practice. Whilst we consider that this approach should enable AusNet Services to assign the appropriate condition score to the assets in question, we did not undertake an independent review of any bias that may be present in this approach. Also, we note that AusNet Services did not (in its RRP) rebut AER's assessment (in its Draft Decision) of a bias towards allocating higher-than-appropriate condition scores;[59]

[56] AusNet Services, *AMS 10-64 Instrument Transformers – CONFID,* page 13

[57] We cannot determine AusNet Services' definition of 'Major Failure' from the information provided, but from various references in its document AMS 10-24 '*Asset Renewal Planning Guideline',* it appears to assume that assets that suffer major failure may be repairable

[58] AusNet Services, *AMS 20-11 Dependability Management* – CONFIDENTIAL, page 28-29

[59] Based on its consideration of AusNet Services information pertaining to one asset category – transformers

(iii) Based on our understanding of AusNet Services' calculated weighted condition assessment approach, we are concerned that it may introduce a bias towards overstating the asset failure rate;

(iv) Overall, there may be a bias towards overstating the condition score of the assets in question which, as discussed below, is likely to lead to an over-estimation of safety risk.

Remaining Service Potential

91. AusNet Services allocates a Remaining Service Potential (RSP) to each of the five condition scores. RSP represents the extent to which an asset can provide a future economic benefit to electricity consumers and represents the assumed percentage of remaining life of an asset. AusNet Services bases its RSP allocations on the concept of Advanced Straight Line Asset Management (SLAM) methodology, customised to reflect the remaining service potential applicable to AusNet Services' Assets.[60] The five RSP values range from 95% for C1 assets to 15% for C5 assets, as shown in Table 1, below.

92. AusNet Services has provided insufficient information in support of the RSP allocations that it has applied to each of the five condition scores. However, based on our experience, we consider that the five RSP values are likely to be reasonable.

Characteristic Life

93. AusNet Services determines the Characteristic Life for an asset population/fleet (i.e. similar assets) from the equation in Figure 5. AusNet Services advises that it has data collected over a 15-year period.[61] The Characteristic Life as defined by AusNet Services is equivalent to the average useful life (i.e. the average operating life of the asset, which is when AusNet Services deems that it needs to be replaced or when on average it is likely to suffer major failure. This is very different from determining the Characteristic Life based on explosive failure data alone and differs from the definition in AusNet Services cited reference for related aspects of its failure rate determination. [62] AusNet Services advised that it uses the Date Disposed because it does not have a 'run to fail' strategy – instead it seeks to find the optimal time to replace the assets before they fail.

Figure 5: *Characteristic life*

$$\eta = \frac{\sum_{i=1}^{n} Date\ Disposed - Install\ Date}{n}$$

Where:
η = Characteristic Life (eta)
n = number of disposed assets

Source: AusNet Services, AMS 20-11 Dependability Management – CONFIDENTIAL, page 28

94. As we understand AusNet Services approach, it is not seeking to predict future major 'failure rates' of the at-risk asset classes in its analysis - it is predicting future 'replacement rates' based on its historical replacement of assets. Whilst we consider that seeking to predict the best time to replace assets (i.e. before they fail) is consistent with

[60] Edgerton, D. 2009. *Depreciation of Infrastructure Assets,* Local Government Association of South Australia, page 24, as referenced by AusNet Services, *AMS 20-11 Dependability Management – CONFIDENTIAL,* page 29

[61] *Ibid,* page 28

[62] In O'Connor and Kleyner, *Practical Reliability Engineering,* 5th Edition, page 78, the Characteristic Life is defined as the time by which 63.2% of the population will fail

AusNet Services' asset management strategy, it is not valid to use unadjusted replacement/disposal data as a proxy for failure data.[63]

Conditional Age

95. The Conditional Age is one of two parameters that AusNet Services uses to scale a Weibull distribution, from which it derives asset failure rates. AusNet Services derives the Conditional Age from the equation in Figure 6.

Figure 6: *Conditional Age calculation*

$$\text{Condtional Age} = \eta - (\eta \times \text{RSP\%})$$

Where:
RSP% = Percentage of Remaining Service Potential
η = Characteristic Life (eta)

Source: AusNet Services, AMS 20-11 Dependability Management – CONFIDENTIAL, page 29

96. Table 1 shows the assigned RSP to each of the condition score and the derived Conditional Age for each condition score, assuming a Characteristic Life of 45 years (by way of example).

63 We have continued to use the expression 'failure rates' in the rest of the report, whilst noting that AusNet Services is seeking to predict the future 'replacement rate' which varies with the assigned condition and asset class

Table 1: Conditional Age for AusNet Services asset condition classifications assuming a Characteristic Life of 45 years

Condition score	RSP%	Conditional Age (years)
C1	95	2.25
C2	70	13.5
C3	45	24.75
C4	25	33.75
C5	15	38.25

Source: EMCa representation of AusNet Services' information in Table 2 of its document AMS 20-11 Dependability Management, page 7

Asset failure rate

97. As the basis for deriving the expected failure rate, r(t), for the asset classes for which it undertakes reliability modelling, AusNet Services uses a classic wear-out curve (based on a two parameter Weibull distribution as shown in Figure 7) the outputs of which it then calibrates to reflect its historical data. The value of β is referred to as the 'shape' parameter and η is referred to as the 'scale' parameter.[64] As AusNet has determined the Characteristic Life of assets (η, or scale parameter) based on the age of assets when they were proactively replaced, not when they explosively failed, the 'asset failure rate' AusNet Services has determined is in reality an estimate of the replacement rate.[65]

Figure 7: *Failure rate*

$$r(t) = \frac{\beta t^{\beta-1}}{\eta^{\beta}}$$

Where:

t = Time
η= Characteristic Life (eta)
Beta (β)=Shape Parameter

Source: AusNet Services, AMS 20-11 Dependability Management – CONFIDENTIAL, page 6

98. AusNet Services uses a software package called Availability Workbench (AWB) to, among other things, derive the instantaneous failure rate from the imported shape and scale parameters.[66] β is fixed at 3.5 and η is the Characteristic Life for the individual asset.[67]

99. As shown in Figure 8, the failure rate with β = 3.5 increases exponentially with time and implies a very rapid increase in probability of failure from one year to the next.

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[64] *Ibid*, page 6

[65] AusNet Services, *AMS 20-11 Dependability Management – CONFIDENTIAL, page 7*. AusNet Services also refers to the 'instantaneous failure rate' as being equivalent to the 'hazard rate' on page 6 of this document. AusNet Services' cited reference text (*Practical Reliability Engineering*) defines the hazard rate as the instantaneous probability of the first and only failure of the item. This does not appear to be consistent with AusNet Services application of the term 'failure rate'.

[66] *Ibid*, page 13

[67] AusNet Services refers in AMS 20-11 to O'CONNOR, P. & KLEYNER, A. 2011. Practical Reliability Engineering. 5 ed. Hoboken: Wiley as the source of the selected β

Figure 8: *Failure rates with variation of β (illustrative)*

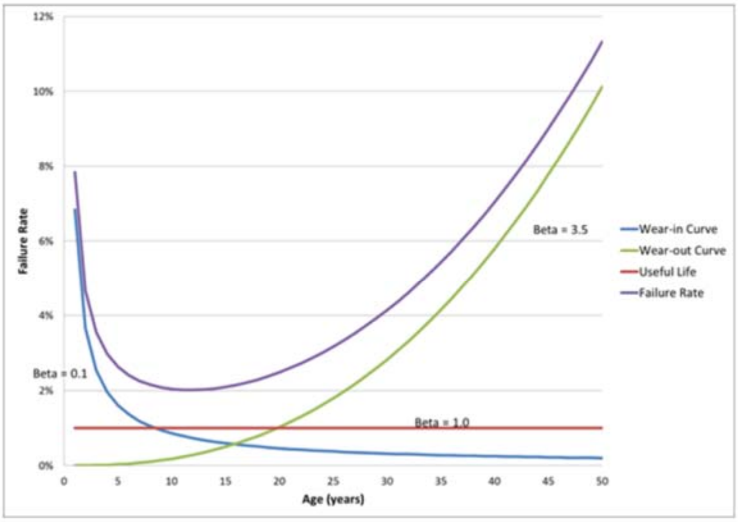


Figure 1 - The Bathtub Curve

Source: AusNet Services, AMS 20-11 Dependability Management – CONFIDENTIAL, page 7

100. Whilst Figure 8 is illustrative, β = 3.5 is representative of an 'aggressive' failure rate. AusNet Services has applied a constant β value of 3.5 to all asset classes in its reliability modelling. It states that its selection of β is "*consistent with a wear out pattern represented by a normally distributed probability density function*."[68] AusNet Services has not demonstrated that the failure data for the assets under consideration are consistent with a normal distribution. We note for example, that the ages of instrument transformers suffering major failure in the Cigre international reliability study do not appear to follow a normal distribution.[69]

101. AusNet Services calibrates the results of the resulting failure rate curve. From the information we have been provided, AusNet Services' 'failure rate' calibration appears to have been based on a single point average of its historical data, with the historical data comprising a mixture of asset failures and proactive asset replacements.[70] It appears from the example provided,[71] that the outputs of the model are scaled by +56% to align with the single point average annual failure plus proactive replacement amount. We consider that a more appropriate calibration approach is for AusNet Services to use the 15 years of annual data for each asset class and to confirm that the selected 2-parameter Weibull distribution represents a reasonable fit.[72] Given this will involve a relatively small data set, there are likely to be very broad confidence bounds for the results. Combining its results with those from other Australian utilities and/or using the results from international studies (such as the Cigre work) may provide AusNet Services with a more robust basis for deriving the β values for its asset populations.

[68] *Ibid*

[69] Cigre, *Final Report of the 2004-2007 International Enquiry on Reliability of High Voltage Equipment*, October *2012, Part 4 – Instrument Transformers*, Table 4-109, page 73

[70] AusNet Services, *AMS 20-11 Dependability Management – CONFIDENTIAL,* page 28

[71] *Ibid, page 7*

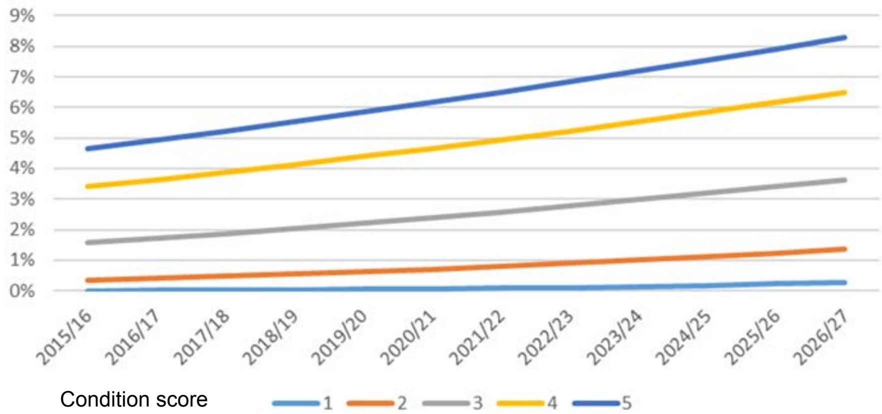
[72] Noting that a location parameter, γ, is used in the three parameter Weibull function, where γ is the expected minimum life. It is possible that a three parameter Weibull distribution represents the best fit, as was the case for another DNSP's evaluation (but for a different asset category to those being considered here)

102. We are also concerned that if AusNet Services does not remove assets from the population that were replaced proactively for reasons other than they were in very poor condition (C5), the resultant average Characteristic Life derived for the population of at-risk assets as used for 'failure rate' calibration approach is likely to be biased towards overestimating the failure rate.

103. In lieu of such analysis, we consider that sensitivity studies using lower and higher β values are necessary to demonstrate that the 'failure rates' derived from the fixed β of 3.5 do not have a material impact on the outcome of the economic analysis. Since AusNet Services is using these distributions to assess the optimum replacement timing, the slope of the failure rate curve with time is important.

104. AusNet Services' approach to deriving expected major failure rates (i.e. by including replacement rates) results in strongly increasing expected failure rates for power transformers, circuit breakers and instrument transformers (CTs and VTs) with poor (C4) or very poor (C5) condition scores. Figure 9 illustrates the results for power transformers used for the West Melbourne Terminal Station (WMTS) project. The curves are of a similar shape for circuit breakers, current transformers and voltage transformers.

Figure 9: *Power transformer major failure rates with condition score*



Source: EMCa analysis of AusNet Services' information in WMTS Economic Model TRR Aug 2016_AER_CONF

105. In summary, we consider that AusNet Services has provided insufficient information to confirm that it has selected an appropriate β for its derivation of expected failure rates and that on balance the results are likely to be biased towards indicating earlier replacement (because of the relatively high fixed β). In making its case, we would have expected to see broader reference to technical literature, relevant reliability studies (including for example the international review by Cigre which SP AusNet and Transgrid participated in),[73] and to the experience and approach of other utilities.

4.4.2 Explosive failure variable

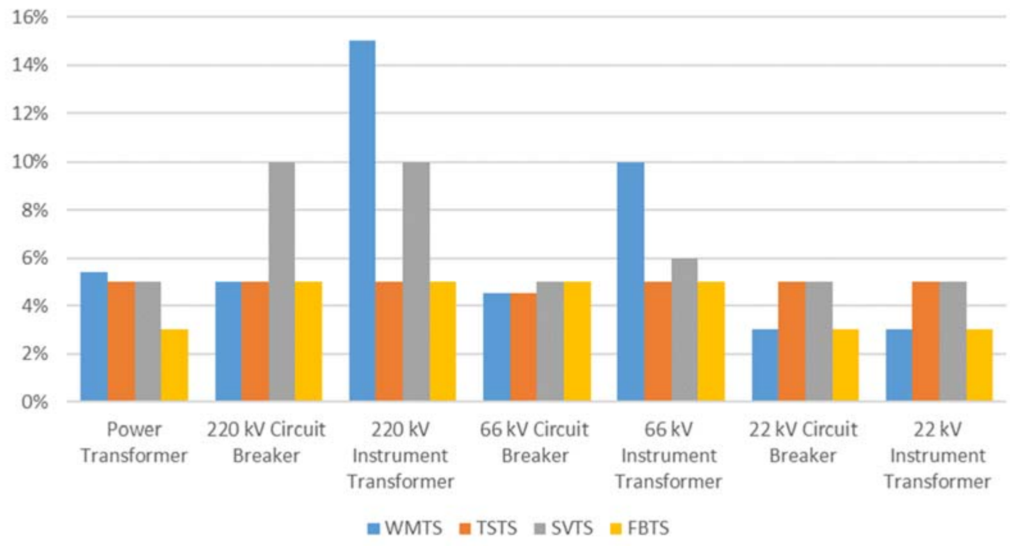
106. We understand from discussions with AusNet Services[74] that it has derived explosive failure to major equipment failure ratios for 66kV and 220kV instrument transformers and

[73] Cigre, *Final Report of the 2004-2007 International Enquiry on Reliability of High Voltage Equipment*, October 2012, Part 1,

[74] Meeting at AusNet Services' premises on 5 December 2016

circuit breakers from an international study on the reliability of HV equipment.[75] The source of the ratios for 22kV equipment and for power transformers shown in Figure 10 is unclear.[76]

Figure 10: *AusNet Services' explosive failure to major failure ratio assumptions*



Source: EMCa analysis of information in AusNet Services economic models

Comparison with recorded explosive failures

107. Figure 11 illustrates the actual number and temporal distribution of explosive failures AusNet Services has recorded over the last 21 years, including the most recent explosive failure of a CT at Richmond Terminal Station in 2016. On average, there has been an explosive failure approximately at a rate of 0.86 p.a. over this period. This equates to an annual failure rate of approximately 0.018% per device for AusNet Services' population of circuit breakers, instrument transformers, and power transformers.[77] This is an order of magnitude less than the annual explosive failure rate assumptions used in AusNet Services' economic models. For example, for condition 5 220kV CTs, the explosive failure rate in AusNet Services' model ranges from 1.00% in 2015/16 to 2.19% in 2026/27.[78] AusNet Services has not provided sufficient evidence of the reasonableness of the explosive failure rates projected for assets in the various asset classes.

108. AusNet Services' own data shows poor correlation between age and explosive failure. Although the 18 failures represent a small sample, the results from the international study conducted by Cigre show a similarly low correlation.

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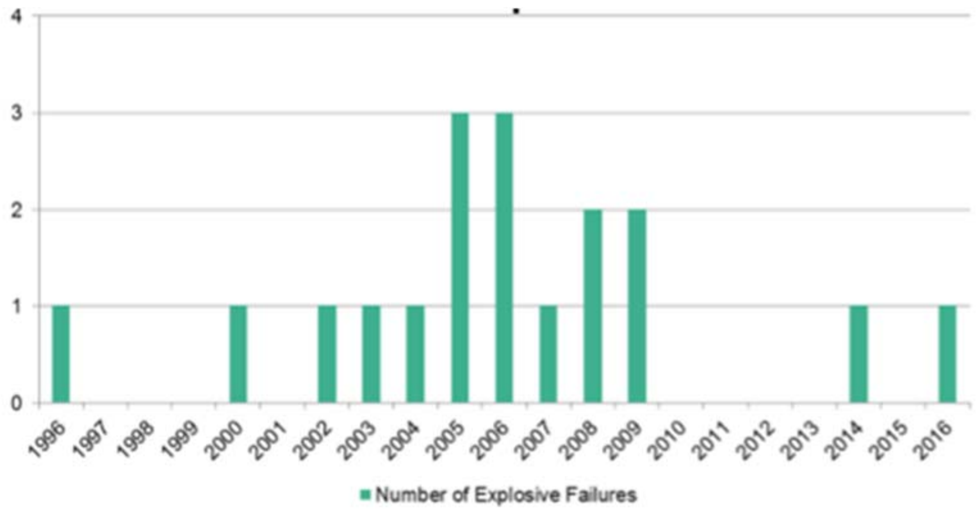
[75] The Cigre study presents Fire and Explosive failure probabilities (i.e. not explosive failures alone) for various asset classes and voltage levels. It does not include analysis of power transformer reliability nor does it include equipment rated at less than 60kV

[76] Although AusNet Services includes the assumed ratios of explosive failure to major failure for 22kV equipment in its economic models for all four terminal stations, it only has 22kV equipment at WMST (and then only until 2021)

[77] Based on AusNet Services' aggregate IT, CB, and power transformer population of 4600 devices as advised by AER

[78] Based on the CT explosive failure to major failure ratio of 15% for 220kV CTs used in AusNet Services economic models (e.g. WMTS Economic Model TRR Aug 2016_AER_CONF) - the ratio is less for lower voltage instrument transformers

Figure 11: *Number of explosive failures – AusNet Services' transmission network*



Source: AusNet Services, 2017-2022 Revenue Reset – Slide pack presentation to AER Board 14 October 2016

Temporal and voltage variation of explosive failure risk

109. AusNet Services has used a simplified approach to modelling the probability that a major plant failure is an explosive failure by using a constant ratio. It assumes that there is no change in the ratio of explosive failure to major failure over time. For instrument transformers, we consider this to be a reasonable approximation for the purposes of its modelling.[79] AusNet Services does not provide sufficient information to confirm the reasonableness of the approximation for other asset classes.

110. In its modelling, AusNet Services varies the assumed ratios of explosive failure to major failure with voltage within an asset class. This is consistent with the findings in the Cigre international reliability study.

111. However, overall AusNet Services has not provided sufficient information to confirm that the explosive failure ratios that it has applied to the assumed failure rates in the three asset classes are reasonable.

4.4.3 Fatality rate variable

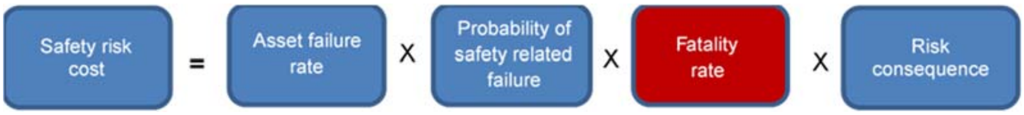
112. In this sub-section, we consider the applicability of the HZO rate variable that the AER introduced in its Draft Decision to account for the likelihood that someone will be in the vicinity of a transmission network asset when it fails. The AER introduced this variable because it considered that AusNet Services was being overly conservative by implicitly assuming in its reliability modelling that explosive failure would cause a fatality. We consider that the AER's approach can be extended by considering other factors that reduce the likelihood that a fatality occurs, noting that just because a person is in a hazard zone, it is not certain that a fatality will occur if primary plant fails explosively. We therefore suggest that reference to a HZO rate in the AER's proposed safety risk cost formula, may be replaced with 'fatality rate', as shown in Figure 12.[80] The 'Asset failure rate', 'Probability of safety related failure', and 'Risk consequence' variables in Figure 12

[79] Based on our review of data in Cigre, *Final Report of the 2004 – 2007 International Enquiry on Reliability of High Voltage Equipment',* 2012, TB512 – Part 4, Table 4-108

[80] Strictly, the probability and consequence of an injury arising from explosive failure should also be assessed and included in the safety risk assessment. However, as the consequence cost for an injury is l kely to be an order of magnitude lower than the consequence cost of a fatality, and AusNet Services has not included it in its analysis, we have not considered it further in our assessment

use the same nomenclature and definitions as applied by AusNet Services (and the AER[81]) in their respective safety risk cost equations.

Figure 12: *Proposed safety risk cost equation*



Source: EMCa

113. The likelihood of a fatality from impact by a projectile (from the exploded plant) in this case is primarily determined by:

(i) The probability that a person in the hazard zone is hit by a projectile(s) from the explosive failure; and

(ii) The probability that the person suffers fatal injuries from impact of the porcelain projectile(s) (i.e. as opposed to being not fatally injured or not injured).[82]

114. The probability that any one person is hit by a projectile will vary with the HZO rate. The higher the number of people in the hazard zone at any particular time, the higher the probability that any one of the people in the hazard zone will be hit by a projectile. The Fatality rate in Figure 12 is the rate that would apply in the event of an explosive failure, and taking account of the possibility of there being more than one person in the hazard zone on some occasions.

115. Some of the other factors that will influence whether a person in the hazard zone may be impacted by a projectile from an explosive failure are likely to include: (i) the point of failure; (ii) mode of failure; and (iii) location of asset relative to other assets in the terminal station (i.e. other assets may provide some level of shielding). And, further, the factors that will influence the probability of the person(s) that is impacted by the projectile suffering fatal injuries are likely to include: (i) the location of the impact on the person(s); and (ii) the size, weight and velocity of the projectile.

116. These factors combine to significantly reduce the likelihood of a fatality arising from an explosive failure. Whilst there is elevated risk during the complex brownfields construction phase, AusNet Services has not provided evidence to support its economic modelling assumption that explosive failure of the designated plant will directly result in a fatality. As far as we are aware, a fatality caused by explosive failure of outdoor major electrical plant in a terminal station has not occurred in Australia in the last 20 years.[83]

HZO rate

117. The HZO rate was introduced by the AER in its Draft Decision and is represented as an estimate of the likelihood that a person will be in the vicinity of a transmission network

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[81] As reproduced in Figure 3, the AER has sought to represent the factors that AusNet Services descr bes in its approach to quantifying safety risk in AMS 10-24, *Asset Renewal Planning Guideline,* October 2015, pp 27-28

[82] The probability of multiple fatalities from the single explosive event could also be approximated, but this is l kely to be an order of magnitude less than the probability of a single fatality and therefore we have not considered it further

[83] AusNet Services has recorded 18 explosive plant failures in the last 20 years event without a fatality or an injury.

asset when it fails.[84] The AER expressed it as a rate, because the HZO varies over time depending primarily on the extent of construction and maintenance activity on the site.

118. AusNet Services' internal investigation of explosive failure of CTs has led it to conclude that the maximum radius porcelain pieces (from an exploding asset) reach is dependent on the voltage level, ranging from 75 metres (220kV) to 100 metres (500kV).[85] AusNet Services has identified the hazard zones at several of its terminal substations and determined that some hazard zones extend outside the boundaries of the terminal station corresponding with these calculated distances.[86]

119. The HZO rate varies over time at each site depending on the scale and scope of work that is being undertaken. There is a distinct step change in the HZO rate between normal operations (relatively low HZO rate) and a brownfields construction phase (much higher HZO rate than normal operations). The HZO rate will vary with the complexity and duration of the construction phase work.

HZO rate during normal operations

120. The AER estimated an average HZO rate during normal operations of 1% based on AusNet Services personnel (whether contractors or staff) being present at the terminal station and assuming that these personnel would be within the hazard zone whilst at the terminal station. The AER invited AusNet Services to provide a revised assessment based on its own experience. AusNet Services provided an estimate of 17% in its RRP although it claimed the operational phase HZO rate as irrelevant.[87] AusNet Services did not explicitly consider the HZO rate contribution from exposure of members of the public in the proximity of the hazardous equipment.

121. We have reviewed AusNet Services' approach to derive its HZO rate estimate of 17%. AusNet Services estimates that every year at every terminal station, personnel will be on site on average 982 hours per annum for 'operations, routine inspection and maintenance activities and 475 hours per annum to complete planned refurbishment.[88]. This is in addition to the forecast 'major replacement projects at WMTS, SVTS, TSTS, and FBTS.

122. Based on our experience and the results of our assessment of another utility's HZO equivalent[89], we consider 17% to be conservatively high.

HZO during brownfields construction (or 'project risk')

123. In its RRP AusNet Services estimated the HZO rate at 820% at WMTS and SVTS, and 342% at FBTS and TSTS during the major replacement project construction phases. This suggests that an average of eight people will be on site and within the hazard zone of each piece of hazardous equipment seven days a week for the four years of the

[84] *AER Draft decision - AusNet Tx - Attach 6 - Capital expenditure - July 2016*, page 6-47

[85] AusNet Services, *FINAL AusNet Transmission Revised Revenue Proposal_21 Sept 16 CONF,* page 41

[86] Or would do so in the absence of any shielding

[87] AusNet Services *Revised Revenue Proposal_21 Sep 16 CONF,* pages 45, 47

[88] AusNet Services *Revised Revenue Proposal_21 Sep 16 CONF,* Table 3.5. page 47

[89] Information from Powerlink, as discussed in the following subsection

project at WMTS and SVTS and more than three people on average will be in a hazard zone on average 24 hours a day / seven days a week at FBTS and TSTS.[90]

124. AusNet Services therefore implies that the probability of explosive failure leading to a fatality could be eight times higher than it included in the current economic models for WMTS and SVTS and over three times higher than it included in the current models for FBTS and TSTS, being 100%. However, if AusNet Services considers this to be a valid assumption, it is unclear why it has not followed through and re-cast its analysis accordingly.

125. By way of comparison, we have considered the calculations of the number of field personnel on site during periods of significant work activity by another Australian transmission utility, which shows a HZO rate of 19%.[91] On this basis, AusNet Services' HZO rate calculations for the four terminal stations would appear to be excessively high.

126. As discussed further below, some of the risk controls AusNet Services has adopted reduce the HZO rate during the construction phase and this too should be taken into account.

Existing risk controls

127. AusNet Services has a number of risk controls in place that need to be considered in evaluating the risk exposure during normal operations and during brownfields replacement projects, including de-energising equipment during planned refurbishment, maintenance and testing, and the use of portable and fixed electromagnetic frequency and radio frequency devices to provide warning of any increased risk of impending failure of at risk assets. [92]

128. Risk controls are not a substitute for timely replacement of at-risk equipment, but the combined effect of the risk controls deployed by AusNet Services is likely to result in a risk exposure of less than 100% of any 'unmitigated risk' assessment.

4.4.4 Risk consequence

129. AusNet Services has derived a risk consequence cost of redacted use in its economic modelling through a four step process: (i) deriving a value of statistical life (VSL), (ii) adding a 25% loading to account for the potential for multiple injuries or fatalities; (iii) applying a disproportionality factor of 3 for workers, and (iv) rounding upwards. We discuss each of these steps below.[93]

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[90] *Ibid, page 44;* AusNet Services assumed that each worker would spend on average 70% of their time on site in a hazard zone in deriving its HZO rate estimates

[91] Powerlink, *AER Site Visit – 6 Asset Risk Framework,* May 2016, slide -CONFIDENTIAL. The utility presented its calculations of field personnel present at 12 substations. From discussions with the utility we understand that the site access records were for substations at which there had been recent significant work activity. The highest average annual site occupancy rate was 27% (over a five-year period). As we do not have access to the utility's derivation of an equivalent to the hazard zone occupancy, we have applied the 70% ratio that AusNet Services applied in its derivation (refer to the preceding footnote). The highest annual site occupancy rate of the projects considered by the utility was 40%, which equates to an average hazard zone occupancy of 27% in that one year

[92] AusNet Services *Revised Revenue Proposal_21 Sep 16 CONF,* pages 56-57

[93] AusNet Services – TRR – 5 Dec 2016 capex workshop follow up, pages 4-5

Value of Statistical life

130. The Australian Government's VSL guidance note (2014 version) states that "*based on international and Australian research a credible estimate of the value of statistical life is $4.2m, and there are complicating assumptions used to derive these estimates so a sensitivity analysis should be undertaken as part of the cost-benefit analysis.*"[94]

131. AusNet Services has based its VSL on the 2008 version of the same Australian Government's guidance note which recommends use of $4 million ($2007). AusNet Services then escalates this figure at 3% p.a. to derive a VSL of $4.8 million ($2013).

132. AusNet Services also advises that in AS/NZS7000 – Overhead Line Design – Detailed Procedures ('AS/NZS 7000'), a VSL is nominated at $10 million. [95] However, it applies a VSL of $4.8 million in its derivation of the risk consequence cost.

133. We do not have access to the reasoning behind the $10 million figure used in AS/NZS 7000 but we note that the Australian Government guideline refers to a VSL range of $3m to $15m in studies relevant to Australia.

134. We consider that the latest available Australian Government nominated VSL of $4.2 million ($2014) represents a reasonable basis for derivation of the risk consequence cost.

Loading factor

[redacted]

136 [redacted] We consider that the likelihood of multiple injuries or fatalities should be established through consideration of the factors we discuss in section 4.4.3.

137 [redacted] we consider that the Australian Government's 2014 guideline VSL of $4.2 million presents a reasonable basis for determining the consequence cost of a fatality.

Disproportionality factor

138. AusNet Services advises that it estimated the risk consequence cost "*based on a methodology established in several government studies including by the UK's Health and Safety Executive and the New Zealand Government. The methodology estimates direct safety benefits and escalates this by a disproportionality factor of three to form an appropriate cost of preventing a fatality.*"[96]

139. Also of relevance is the HSE guideline, which states:

[94] Australian Government, Department of the Prime Minister and Cabinet, Office of Best Practice Regulation, *Best Practice Regulation Guidance Note, value of Statistical Life*, December 2014, page 1

[95] AusNet Services *Revised Revenue Proposal_21 Sep 16 CONF,* page 32, footnote 16

[96] AusNet Services, AMS 10-24 Asset Renewal Planning Guideline, page 27

> *"Although there is no authoritative case law which considers the question, we believe it is right that the greater the risk: the higher the proportion may be before being considered 'gross'. But the disproportion must always be gross.*
>
> *HSE has not formulated an algorithm which can be used to determine the proportion factor for a given level of risk. The extent of the bias must be argued in the light of all the circumstances. It may be possible to come to a view in particular circumstances by examining what factor has been applied in comparable circumstances elsewhere to that kind of hazard or in that particular industry."*[97]

140. On balance, we consider that a reasonable approach is to adopt the disproportionality factor of [redacted] referred to by the UK Health & Safety Executive, [redacted]

Rounding

141. Through the combination of its assumed VSL, [redacted] loading factor and disproportionality factor of 3, AusNet Services has determined a 'cost to prevent worker fatality' [redacted] which it then rounds up to [redacted] for application in its economic modelling as the risk consequence cost. The rounding step accounts for a further 11% loading.

142. Whilst the derived risk consequence cost is by its nature an estimate, we consider that for application in economic modelling, the additional 11% from rounding has not been justified by AusNet Services and results in further conservatism in the calculation of risk consequence cost.

Sensitivity Studies

143. Mindful of the advice in the Australian Government's guideline, we consider that it would be prudent for AusNet Services to incorporate a higher value of risk consequence cost as part of sensitivity analyses in its economic modelling.

4.5 Summary

144. AusNet Services is not predicting future major failure rates of the at-risk asset classes in its analysis - it is predicting future replacement rates based on past replacement of assets.

145. With respect to the variables and assumptions that underpin AusNet Services safety risk cost modelling, we consider that:

(i) AusNet Services' approach results in explosive failure rates that are an order of magnitude higher in its model than from its own data and much higher than data from a large industry survey. AusNet Services has provided insufficient information to confirm that it has selected appropriate explosive failure to major failure ratios for the three at-risk asset classes;

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[97] Health and Safety Executive, UK, *Principles and guidelines to assist HSE in its judgements that duty-holders have reduced risk as low as reasonably practicable'*, http://www.hse.gov.uk/risk/theory/alarp1.htm

[98] Health and Safety Executive, UK, *HSE principles for Cost Benefit Analysis (CBA) in support of ALARP decisions*, noting that the disproportionality factors are presented as rules of thumb, and the factor of three is applied to risks of workers and a factor of 10 is applied for high risks to members of the public. AS5577 does not nominate disproportionality factors.

(ii) AusNet Services has in its RRP continued to implicitly assume that an explosive failure of an item of plant will result in a fatality without accounting for the mitigating factors that will reduce the likelihood of a fatality. We recommend adoption of a 'fatality rate' variable in AusNet Services derivation of the safety risk cost. The fatality rate should be separately estimated for normal operations and for the eventual replacement project, taking account of the independence or overlap of hazard zones relevant to the different equipment at the site;

(iii) The [redacted] for the purposes of the quantified risk-cost analysis is not adequately supported and is higher than the amount that would be supported by reference to the Australian Government guideline for the VSL for a single fatality. We consider the use of a disproportionality factor of three to be reasonable.

(iv) AusNet Services' derivation of asset condition scores is based on condition monitoring techniques that are broadly aligned with good industry practice, but we are concerned that if it applies the 'calculated weighted condition assessment approach' it may introduce a bias towards overstating the Conditional Age of assets. This would in turn lead to overestimating the 'major failure rate'; and

(v) AusNet Services has provided insufficient evidence to confirm that the Weibull function curve with the assumed β and η values used to forecast future failure rates is calibrated adequately to its actual data or to any other relevant data source.

5 Assessment of expected safety risk cost methodology

146. In this section, we present our assessment of the reasonableness of the methodology applied by AusNet Services in its economic model for determining the expected safety risk cost and supporting proposed timing for replacement expenditure.

5.1 AusNet Services' safety risk cost methodology

147. In its economic model, AusNet Services has determined a risk cost by the summation of risk costs associated with safety, environmental, collateral plant damage, supply, and operating and maintenance costs. Our comments relate only to the methodology used for derivation of safety risk cost.

148. AusNet Services defines the safety risk cost as the arithmetic product of: (i) probability of major failure; (ii) probability of the major failure being an explosive failure; and (iii) safety risk consequence.

149. In the economic models used to support AusNet Services' proposed expenditure for four of its terminal station replacement projects, AusNet Services derives the safety risk cost of the terminal station by:

(i) Determining the condition score of each individual 'at risk' asset (i.e. power transformers, circuit breakers, and instrument transformers) in the terminal station;

(ii) Assigning an asset failure rate to each individual asset based on the condition score and assumed major failure rates for that condition score and asset class;

(iii) Determining the asset failure rate for the asset class from the arithmetic sum of the asset failure rate for each individual asset in that asset class (e.g. for the power transformer asset class, AusNet Services sums the asset failure rate of individual power transformers to give the power transformer failure rate);

(iv) Determining the asset class safety risk cost from the product of (i) the arithmetic sum of asset failure rate for each asset class, (ii) the proportion of major failures that result in an explosive failure, and (iii) the assumed consequence cost of [redacted]

(v) Aggregating the safety, environmental and collateral plant damage risk costs at an asset class level;

(vi) Determining the terminal station risk cost from the arithmetic sum of the asset class risk costs of safety, environment, collateral plant damage, supply, and operations and maintenance; and

(vii) Then, separating the safety risk cost from the environmental and collateral plant damage for the terminal station. The reduction in the annual safety risk cost is treated as a benefit (i.e. avoided risk) which is compared with the cost of various options, including the cost of asset replacement. The optimal time for asset replacement is when the annual benefit exceeds the annualised cost.

5.2 EMCa's assessment

AusNet Services' economic model

150. We consider it appropriate that AusNet Services has developed an economic model that seeks to provide a quantitative analysis of the cost of risk to support the economic assessment of options for replacement. However, the analysis of safety risk undertaken by AusNet Services is likely to introduce a conservative bias towards premature replacement due to the following factors:

(i) Selection of input parameters that are likely to be conservative (as discussed in the previous section); and

(ii) Estimating failure rates at a terminal station level (i.e. population of assets) and individual asset class level that appear to be higher than the failure rates being experienced by AusNet Services, and are not supported by AusNet Services in its supporting documentation. This tends to cast a level of doubt on the methodology applied by AusNet Services in the treatment of aggregated risk for a terminal station in its model (as discussed in the previous section).

Definition of safety risk consequence

151. As discussed earlier, the definition of safety risk cost in the formula used by AusNet Services assumes that the consequence associated with a major failure event being explosive is a certain fatality, and has adopted a consequence cost of redacted Without consideration of other risk exposure factors, AusNet Services has conflated the consequence of an event (explosive failure) with the actual consequence which it has costed (which is not an explosion, but rather is a fatality). This leads it to assume in its modelling that an explosion will cause a fatality, which we consider to be incorrect, as discussed in Section 4.

Use of the HZO rate in options analysis

152. We consider that the HZO rate during normal operations should be used in the first instance in the safety risk calculation as part of the options analysis to determine when asset replacement is economically justified. In assessing a brownfields replacement option, the extra safety risk cost associated with the brownfields construction phase should be accounted for in determining what controls should be introduced during that phase, and the optimum timing. This is likely to be an iterative process.

Influence of other risk costs

153. We have not assessed, nor were we asked to assess, the contribution of the risk costs associated with drivers other than safety. We observe in its economic model, that the risk costs associated with non-safety risks used by AusNet Services, in aggregate, are a more significant determinant of the timing of a replacement option than the safety risk cost.

Poor definition of 'do nothing' option

154. In any comparative analysis, it is essential to properly define the counterfactual.

155. In its economic model, AusNet Services has applied a 35-year residual value of risk cost in year 10 of its analysis, which indicates an assumption that in the assumed counterfactual, AusNet Services would do nothing in that station for 45 years. We consider that this is an unrealistic assumption and has the effect of determining a massively high cost counterfactual, which biases the justification of risk mitigation.

156. We suggest that the counterfactual should be defined along the lines of 'do nothing for the foreseeable future', wherein the foreseeable future could reasonably be defined as 10 years. In other words, in the 'do nothing' option the refurbishment cost would be incurred in 10 years' time. The options to test against this are then the various technologies (AIS, or GIS) and timings within that period. In the factual options and in the counterfactual a residual value term would be required in the final year.

157. We also note that AusNet Services appears to skew its comparative analysis by not having applied a residual value in the 'factual' options, that is option 4 and Option 5 – albeit this would be a much lower number (because the residual costs in the final year are much lower, having rebuilt the station).

Application of sensitivity analysis

158. In its economic model, AusNet Services undertakes sensitivity analysis, by scaling a number of factors. For the safety risk cost, a factor of +/- 25% is used to scale the probability of major failure, which has the result of deferring or advancing the proposed replacement work. It is not clear how AusNet Services has used this sensitivity analysis in its economic analysis, and what reliance it has placed on the accuracy of its individual factors.

159. We observe that the timing of a replacement option using safety risk costs is sensitive to changes in factors, as shown in AusNet Services' sensitivity analyses in the four economic models we were provided for review. Notwithstanding that the safety risk cost does not appear to be the major determinant of the timing of the replacement option, we would have expected to see additional sensitivity analysis to represent the uncertainties in safety risk in the analysis, and to support the conclusions formed by AusNet Services.

160. Similarly, where the analysis suggests that some deferment may be possible, this may present an option for greater levels of expenditure on risk treatments / controls or a more aggressive approach to targeted replacement options.

5.3 Summary

161. AusNet Services' approach to modelling the contribution of each asset 'at-risk' of explosive failure allows identification of the respective contributions to the safety risk cost assumed for each of the at-risk assets at the four terminal stations.

162. We consider that AusNet Services' model has been established in a manner that will not reveal the optimum timing for replacement, for three reasons:

- It is not a realistic counterfactual that AusNet Services will 'do nothing' for 45 years, as is implied by the specification of its counterfactual,
- A residual value should be included in the factual options as well as the counterfactual (do nothing) option, and
- Modelling of replacement options should involve modelling of two states – normal operations and the assumed brownfields replacement project period. While AusNet Services acknowledges that these two states have very different risk characteristics, its model does not account for this.

163. Taking account of the matters above, together with the matters identified in Section 4, points to a safety risk cost that is more likely to be materially lower than AusNet Services' base case.