Asset criticality modelling in electricity distribution networks

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Introduction

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- Better understanding of EDB investment decisions
- Resilience and reliability risk.
- Asset criticality modelling approach.
- Asset criticality modelling results
- Reliability and hazard risk
- Conclusions
- Next steps

Better understanding EDB investment decisions

- Open letter in Nov 2017 set out our priorities in the EDB sector.
- Key priority - to better understand network performance and linkage to asset management practice. Working with industry bodies.
- An asset criticality framework allows more granular understanding of the investment/quality linkages.
- Advantages of an asset criticality framework include:
  - Provide estimates of asset outage impact on SAIDI/SAIFI and customer costs;
  - Informs replacement/renewal decision making and timing of investment;
  - Prioritise expenditure across asset fleet on a normalised basis;
  - Identify key assets and prioritise expenditure for greatest impact;
  - Ability to consult/make decisions on a range of investment/quality options.

Reliability, hazard and resilience and risk

- Need to delineate between reliability, hazard and resilience risk.
  - Reliability risk concerned with expected single asset outage events.
  - Hazard risk concerned with safety and single asset high impact events
  - Resilience risk concerned with unexpected outage events that generally involve multiple assets and are usually due to external factors.
- Reliability event probabilities are based on historical events and contain aspects of asset outage frequency and duration.
- Hazard events usually assigned event return periods (RP’s could be ≈ < low 100’s years).
- Resilience type events (HILP) are non-uniform in their impact - event durations need to be estimated (RP’s generally ≈ > low 100’s years)
- RP’s used as an tool to test economic mitigations.

Risk framework in decision making

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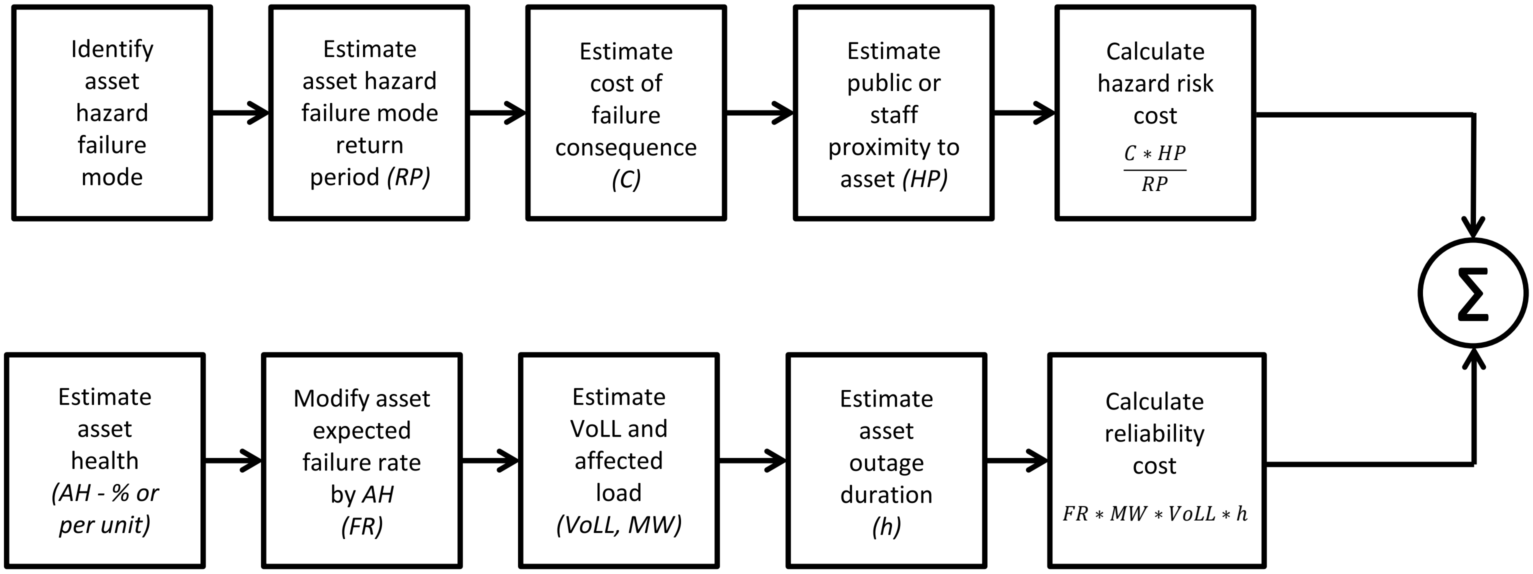
Hazard risk cost*

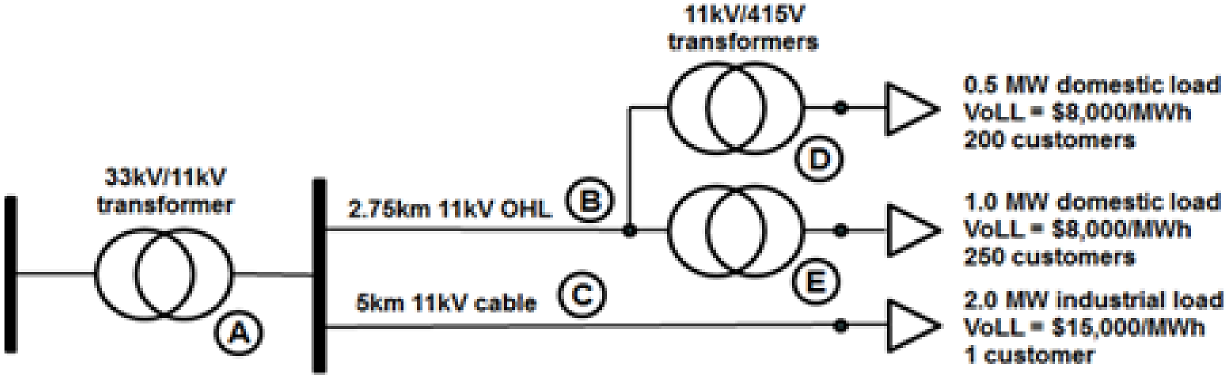


Reliability risk cost

*** Note: This is an example only. We are not H&S experts. Please refer to relevant H&S advisors/Worksafe as appropriate.**

Asset criticality modelling approach

- To test how to do this we used a small theoretical test network.

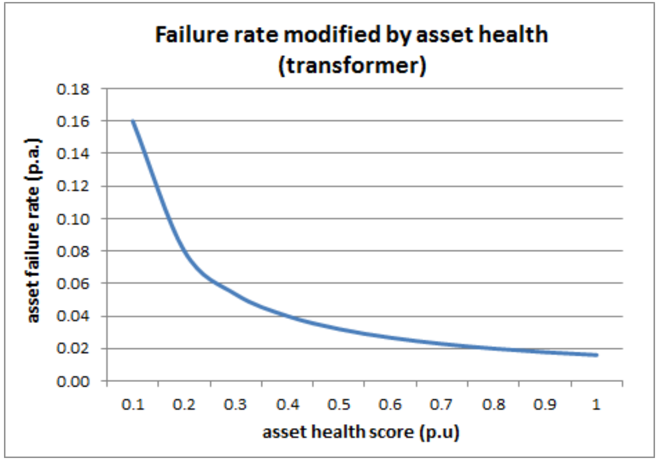


- Modelling includes estimates of asset health, customer numbers, customer load and the value of Lost Load (VoLL).
- Uses outage rate information from a 2015 CIRED paper.
- Asset criticality can be calculated based on quality (SAIDI) and customer outage cost similar to overseas jurisdictions.

Asset health modifying asset outage rates

- Used simple method to model asset health (AH) survivor curve effects.
- Using CIRED data we assumed ‘expected failure rates’ and then used 1/x function to model declining asset health effect.
- For the 33/11kV transformer assumed failure rate (FR) was 1.6 faults per annum per 100 units. AH decline then increases modelled FR.

asset health (per unit)	modified failure rate
0.1	0.1600
0.2	0.0800
0.3	0.0533
0.4	0.0400
0.5	0.0320
0.6	0.0267
0.7	0.0229
0.8	0.0200
0.9	0.0178
1	0.0160



Asset and network SAIDI

- SAIDI measure of average outage duration for each network customer.
- We wanted to test how to calculate asset outage risk on a per annum basis
- Will allow understanding of network total outage risk, enable asset prioritisation across fleet, and investment/quality linkage to be made.
- For Asset A we tested asset outage SAIDI probabilistically using:
  - asset health (compare AH estimates of 30% and 90%)
  - number of customers connected (451) and total network customers (25,000)
  - asset outage duration estimate (hours converted to minutes for SAIDI calculation)
  - asset failure rate (expected failure rate of 0.016 faults per annum)
- For asset A (33/11kV transformer):
  - At 30% asset health estimate - SAIDI was **0.831 minutes per annum**
  - At 90% asset health estimate - SAIDI was **0.277 minutes per annum**

Asset and network customer cost

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- We wanted to also test how to calculate asset outage risk cost on a per annum basis
- Will allow understanding of cost based asset prioritisation, normalises fleet on a $ basis, allows use of NPV analysis to make investment decisions depending on risk.
- For Asset A we tested asset outage cost probabilistically using:
  - asset health (compare AH estimates of 30% and 90%)
  - customer connected load (for simplicity used average value for yr) and Value of Lost Load.
  - assumed outage duration (hours)
  - asset failure rate (expected failure rate of 0.016 faults per annum)
- For asset A (33/11kV transformer):
  - At 30% asset health estimate – outage cost was **$32,256 per annum**
  - At 90% asset health estimate - outage cost was **$10,752 per annum**

Asset criticality modelling – two assets

- Compared Asset A with the overhead line (Asset B)
- Asset A supplies cable and overhead line, but due to outage rate differences and assumptions here about outage duration Asset B may be more critical asset.
- This is just an example but shows systematic modelling approach may be useful to staff and decision makers.

Asset	SAIDI (mins)			EUE cost ($)		
	AH 30%	AH 90%	Δ	AH 30%	AH 90%	Δ
Asset A - 33/11kV transformer	0.831	0.277	**0.554**	$32,256	$10,752	**$21,504**
Asset B - 11kV overhead line	8.49	2.83	**5.66**	$94,336	$31,445	**$62,891**

Scenario 1 (assets A and B – asset health 30%)

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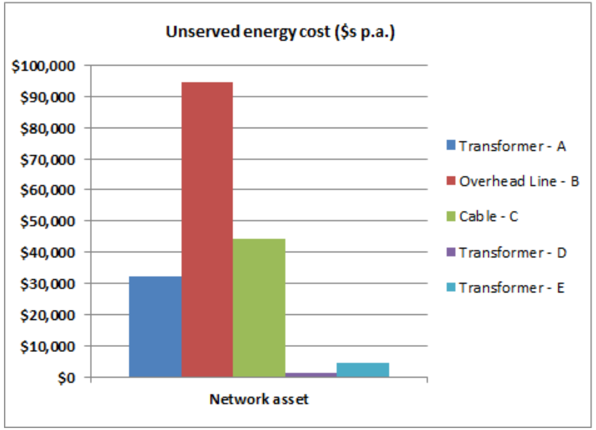
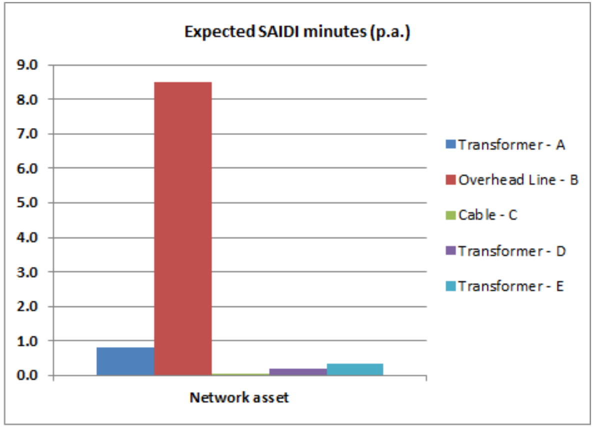
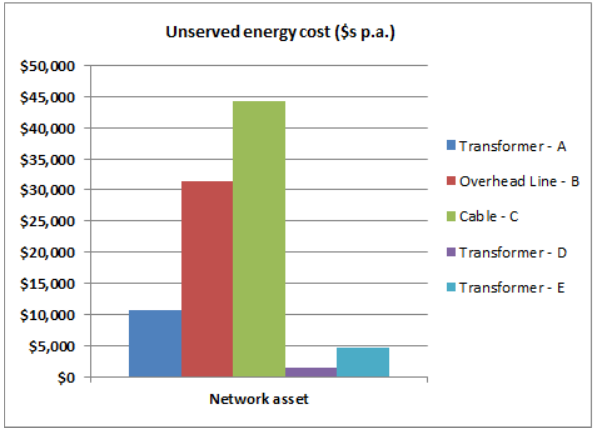
Asset	Customers	Load (MW)	Outage duration (h)	Unserved Energy (MWh)	Average VoLL cost ($/MWh)	Asset health (AH)	Asset failure rate at start of life (FR)	Asset failure rate weighted by asset health (FR)	Expected EUE cost pa ($s)	Expected SAIDI minutes (pa)
Transformer - A	451	3.5	14.4	50.4	$12,000	30%	0.01600	0.05333	$32,256	0.831
Overhead Line - B	450	1.5	12.8	19.2	$8,000	30%	0.18425	0.61417	$94,336	8.490
Cable - C	1	2	9.4	18.8	$15,000	70%	0.11000	0.15714	$44,314	0.004
Transformer - D	200	0.5	14.4	7.2	$8,000	60%	0.01600	0.02667	$1,536	0.184
Transformer - E	250	1	14.4	14.4	$8,000	40%	0.01600	0.04000	$4,608	0.346

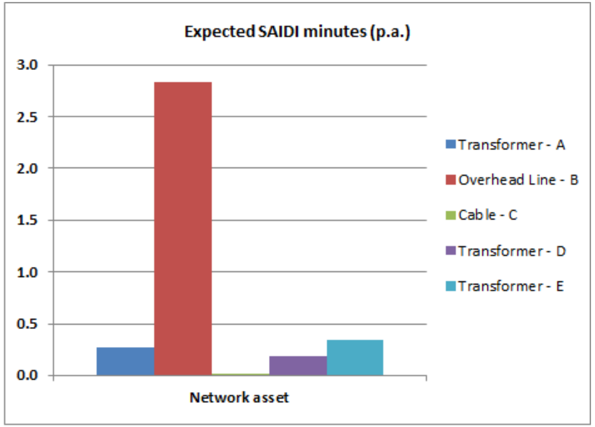




Scenario 2 (assets A and B – asset health 90%)

Asset	Customers	Load (MW)	Outage duration (h)	Unserved Energy (MWh)	Average VoLL cost ($/MWh)	Asset health (AH)	Asset failure rate at start of life (FR)	Asset failure rate weighted by asset health (FR)	Expected EUE cost pa ($s)	Expected SAIDI minutes (pa)
Transformer - A	451	3.5	14.4	50.4	$12,000	90%	0.01600	0.01778	$10,752	0.277
Overhead Line - B	450	1.5	12.8	19.2	$8,000	90%	0.18425	0.20472	$31,445	2.830
Cable - C	1	2	9.4	18.8	$15,000	70%	0.11000	0.15714	$44,314	0.004
Transformer - D	200	0.5	14.4	7.2	$8,000	60%	0.01600	0.02667	$1,536	0.184
Transformer - E	250	1	14.4	14.4	$8,000	40%	0.01600	0.04000	$4,608	0.346





Asset criticality – reliability and hazard risk

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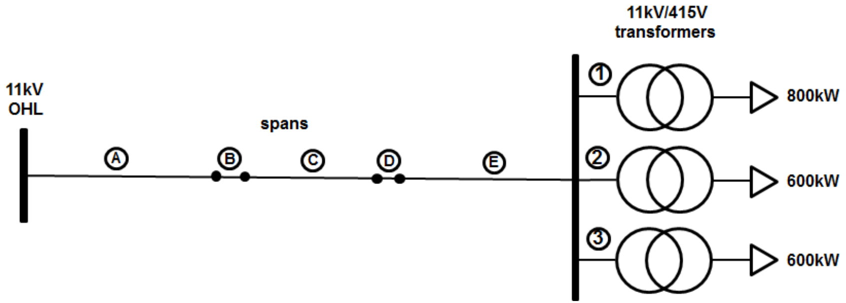
- Two limbs to this:
  - First limb is purely about reliability cost exposure from consumer perspective (using VoLL and lost load)
  - Second limb about hazard cost exposure from public/staff perspective.
- Both limbs involve risk monetisation to allow ranking of critical assets. Monetisation allows all asset risk exposure, regardless of asset type and class, to be normalised.
- Also monetisation allows reliability risk cost and hazard risk cost for each asset to be added together.
- The costs are generally cumulative (some hazard mitigation investment may affect consumer reliability - assume here it hasn’t)

Valuing hazard

- To demonstrate how we might calculate hazard risk costs using another small test network to rank hazards in a qualitative way.



- Focus on hazard cost related to conductor drop on OHL spans A to E. Use OHL outage rate and pro-rate failure RPs for each span length.
- Identify high to low risk spans by event consequence – value the likely injury cost for example (similar to HSE approach in UK).
- Not advocating any particular value for consequence (injury or worse) just seeking industry consistency.

Reliability and hazard – hazard cost

- For each OHL span identify factor representing estimate of human proximity to risk. How often are people likely to be in the vicinity?
- For example:
  - High proximity to risk areas could be CBD and school zones could be quite high.
  - For other areas proximity to risk could be quite low.
  - Use this to help rank relative exposures.
- Multiply consequence cost by estimate of human proximity to hazard event and divide by event return period = hazard risk cost.

Span	Span length (m)	Outage return period (years)	Proximity factor (%)	Hazard risk cost pa ($)
A - rural	2000	7.5	0.2%	$2,144
B - CBD	200	74.6	15.0%	$16,080
C - rural	1000	14.9	0.2%	$1,072
D - school	100	149.3	30.0%	$16,080
E - rural	1700	8.8	0.2%	$1,822

Asset criticality – consolidated cost

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- With reliability costs (using asset criticality method from before) and hazard costs quantified – total asset risk cost can be estimated*
- Based purely on reliability cost transformer 1 most critical asset.
- Factor in hazard exposure then OHL spans D then B are the critical assets.

Asset	Reliability risk cost pa ($)	Hazard risk cost pa ($)	Total risk cost pa ($)
OHL span A - rural	$9,827	$2,144	$11,971
OHL span B - CBD	$983	$16,080	$17,063
OHL span C - rural	$4,913	$1,072	$5,985
OHL span D - school	$491	$16,080	$16,571
OHL span E - rural	$8,353	$1,822	$10,175
Transformer 1	$12,288	$0	$12,288
Transformer 2	$4,608	$0	$4,608
Transformer 3	$2,560	$0	$2,560

* Note we have not included environmental or single asset HILP event costs but these could also be included

Conclusions

- Asset criticality calculation outcomes - quality and customer cost.
- SAIDI calculation method:
  - make analytical investment/quality outcome linkages for decision making and consultation – regulator understands also;
  - EDB understands highest impact assets for focussed investment to meet quality objectives;
  - inform vegetation management strategies.
- Customer cost calculation method:
  - normalise asset fleet on a cost basis;
  - enable NPV analysis to make renewal/replacement trade-offs and timing decisions;
  - allows incorporation of hazard control into investment decision making
- Systematic AC modelling facilitates enduring knowledge management

Next steps

- Continued focus - 2016 AMP review and 2018 upcoming.
- Current AMP review work – we see an inconsistent approach to asset criticality, hazard control and HILP exposures.
- We would like to know more about how asset criticality is informing decision making – reliability and hazard control.
- We will reflect on overseas experiences and begin engagement with EEA to help develop robust, consistent asset criticality modelling.
- Looking for EDBs to more explicitly understand and use asset criticality from reliability and hazard control perspectives.
- We want to understand barriers to implementing a framework like this (and how hazard control and HILP is understood)