Ageing infrastructure investment: "Wall of wire" or "wall of confusion"?

WHAT ARE THE ISSUES &

WHAT DO THEY TELL US?

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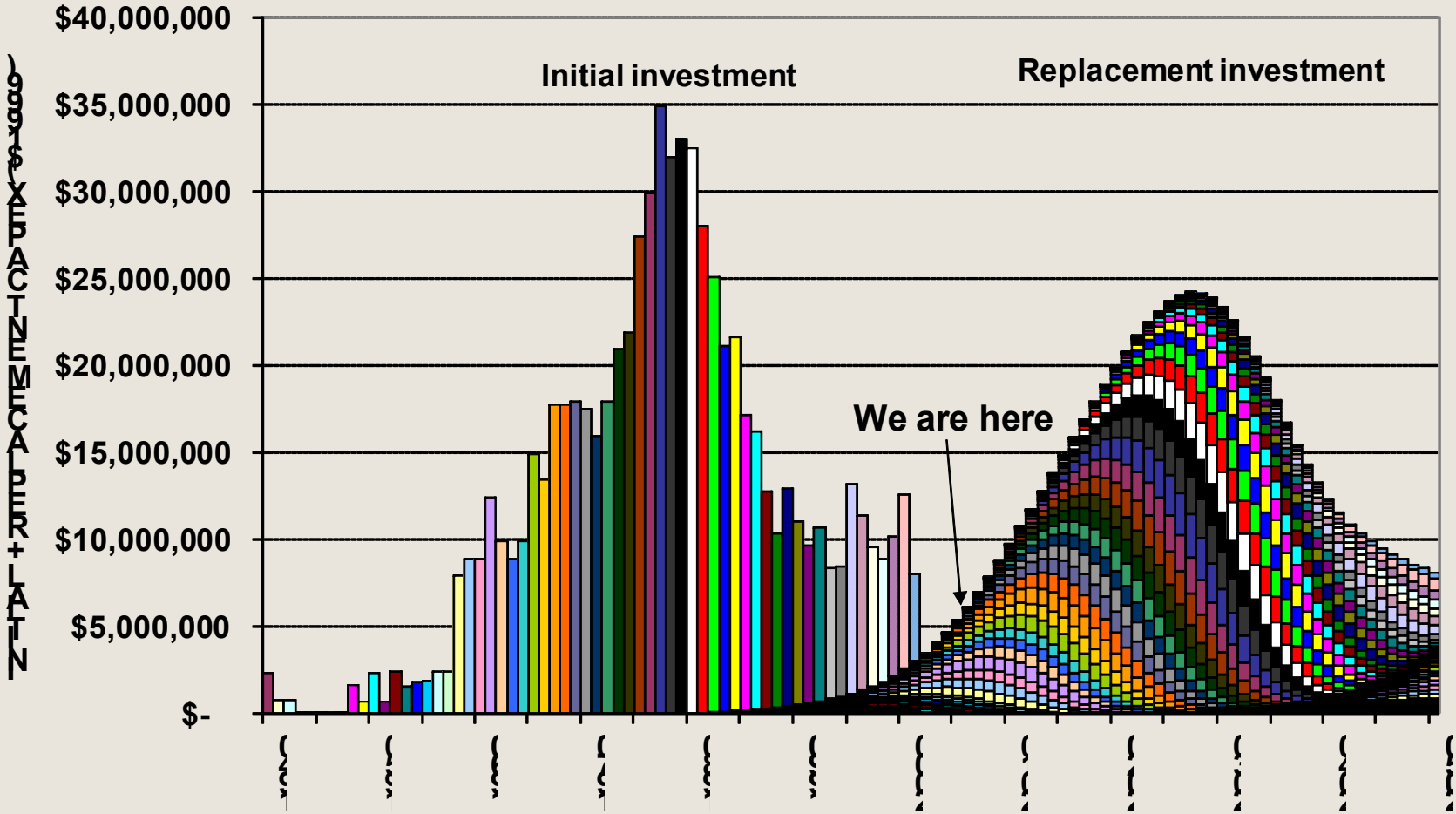
The “wall of wire”



In a nutshell…

- "Wall of wire " debate is confused…
- it does not measure age based renewals…
- It measures probabilty of asset failures
- it is a tool for asset managers targetting *reliability centred maintenance*
- Probability analysis - importance for NZ:
  - Provides guidance on future magnitude and timing of expenditures
  - Allows cost-effective assessment of trade-off between opex and capex
  - Allows quantification of likely future capital requirements to provide comfort for regulators

Ageing assets and probability analysis

Wall of wire

- What it is
- What it is not
- How it is measured
- Implications for expenditures

Probability analysis

- What it is
- What is measures
- Its purpose
- Probability distributions

Probability analysis for NZ

- Why it entered debate
- Failure curves and implications for future expenditures
- Asset age and failure
- Asset age and opex

Asset management as core business

“The wall of wire”

A colourful term…

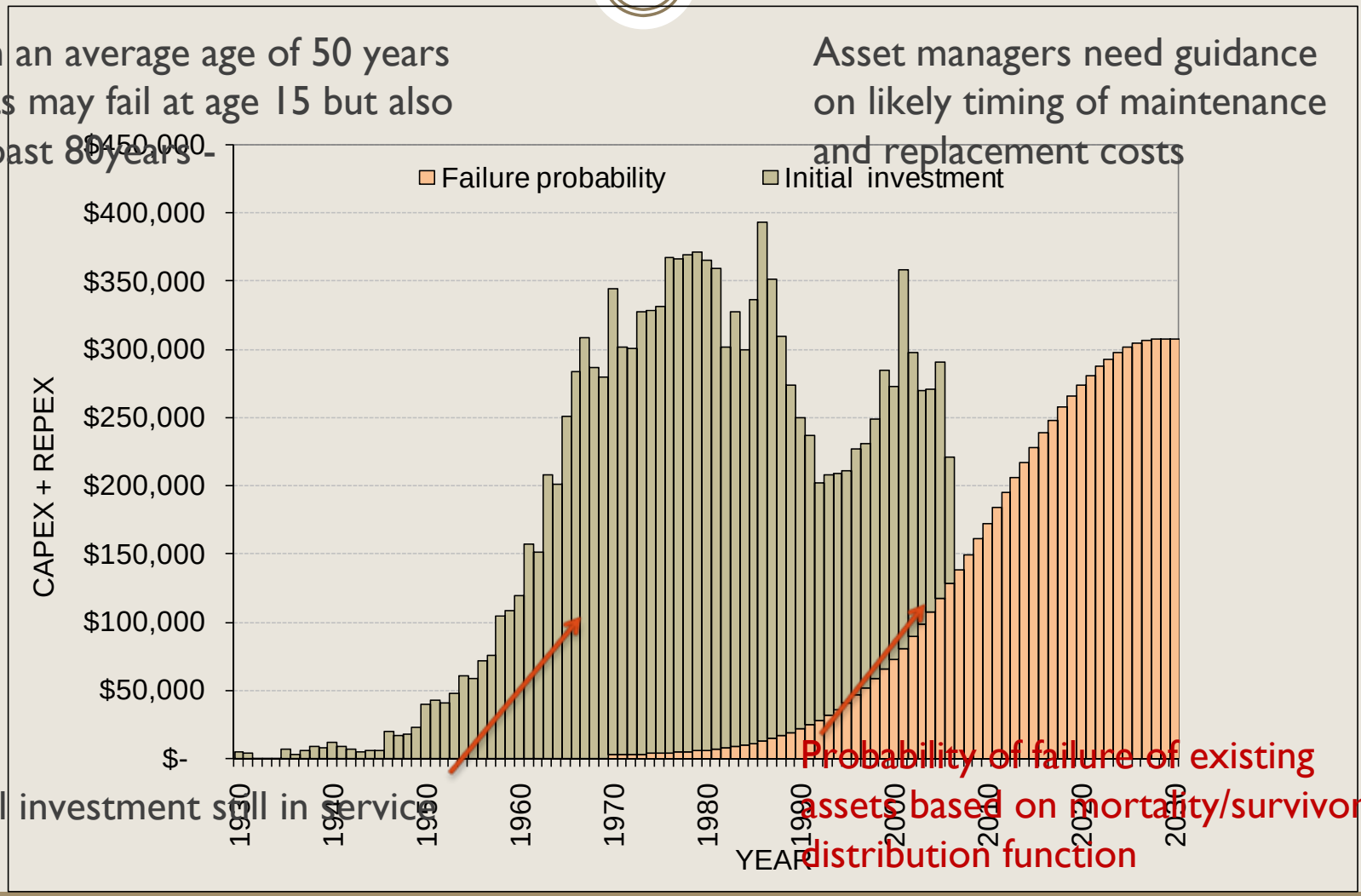
for…

asset mortality analysis

What is the "wall of wire"?

With an average age of 50 years assets may fail at age 15 but also last past 80years

Asset managers need guidance on likely timing of maintenance and replacement costs



Initial investment still in service

Probability of failure of existing assets based on mortality/survivor distribution function

What does wall of wire measure?

It does not measure…

- ✖ "wall of wire"
- ✖ "age based replacement"
- ✖ "cliff-edge replacement"
- ✖ "change in investment"
- ✖ only asset replacements
- ✖ certainty

Asset aged 40 years may have a remaining life from zero to 40 years

Managers have no certainty

It does measure…

- ✓ probability of failure of ageing assets
- ✓ each year and trend over time
- ✓ wave of probable expenditure
- ✓ possible trade-off between opex and capex

Enables least cost life cycle asset management

Not certainty, but guidance

Probability of failure *Or,* Asset mortality analysis

Determined by:

- Mathematically derived probability distribution function
- Probability of failure based on empirically derived mortality rates

Probability analysis:
Estimation & distribution functions

- **"THE CAPM OF AGEING ASSET EXPENDITURE ANALYSIS"**
- **WHAT IS IN AN ASSET MANAGER'S INFORMATION SET?**
- **LIFTIME PROBABILITY DISTRIBUTION FUNCTIONS**
  - Weibull
  - Gompertz
  - Gumbel

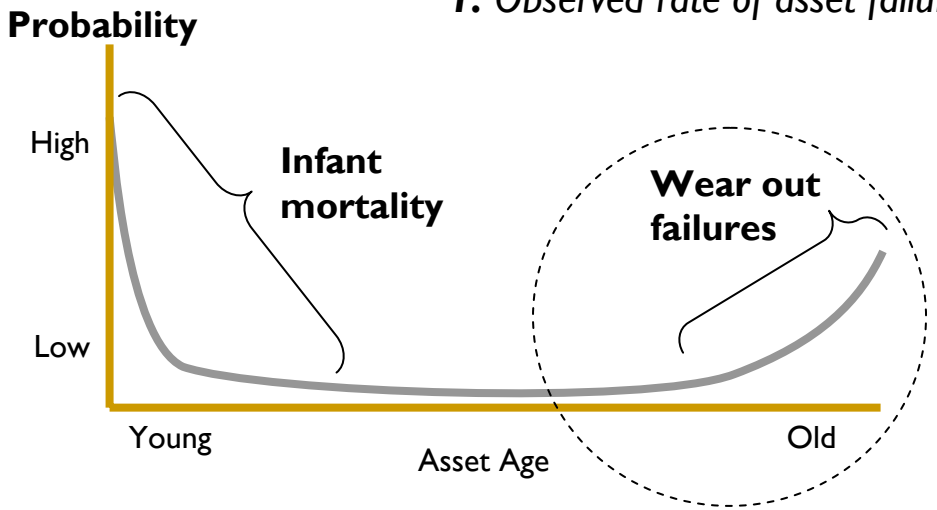
Reliability-based ageing asset theory

Assets more like to wear out when older

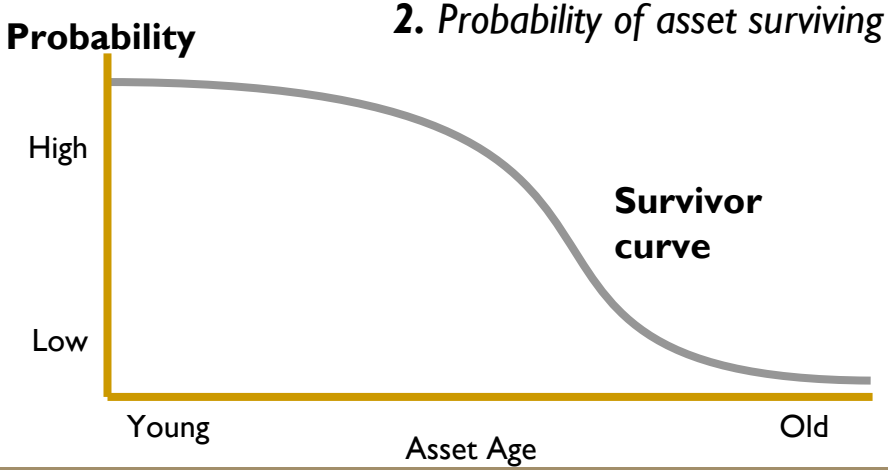
Assets more like to fail when older

Reduces system reliability

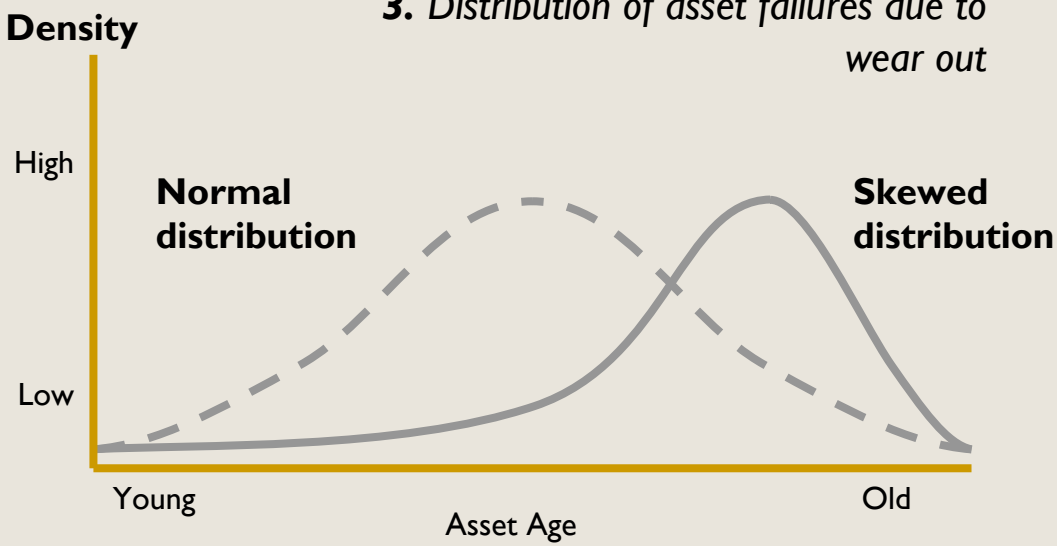
1. Observed rate of asset failures



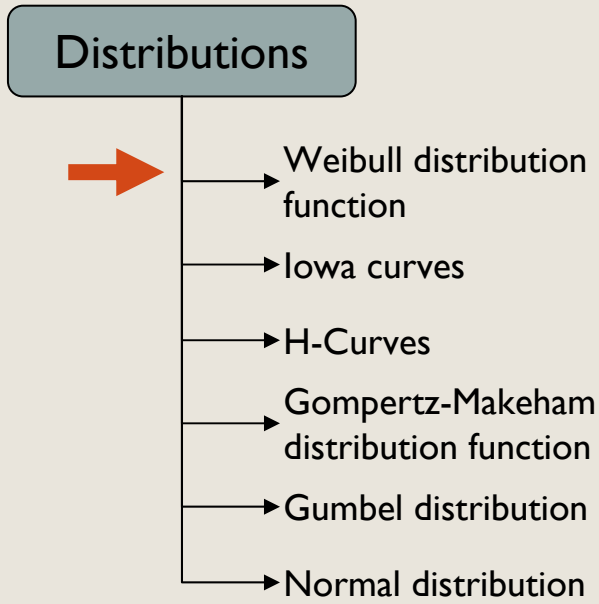
2. Probability of asset surviving



Describing the probability of failure



3. *Distribution of asset failures due to wear out*



Each distribution is capable of describing the failure characteristics of a number of asset types, and the aggregation of assets into networks.

The Weibull distribution

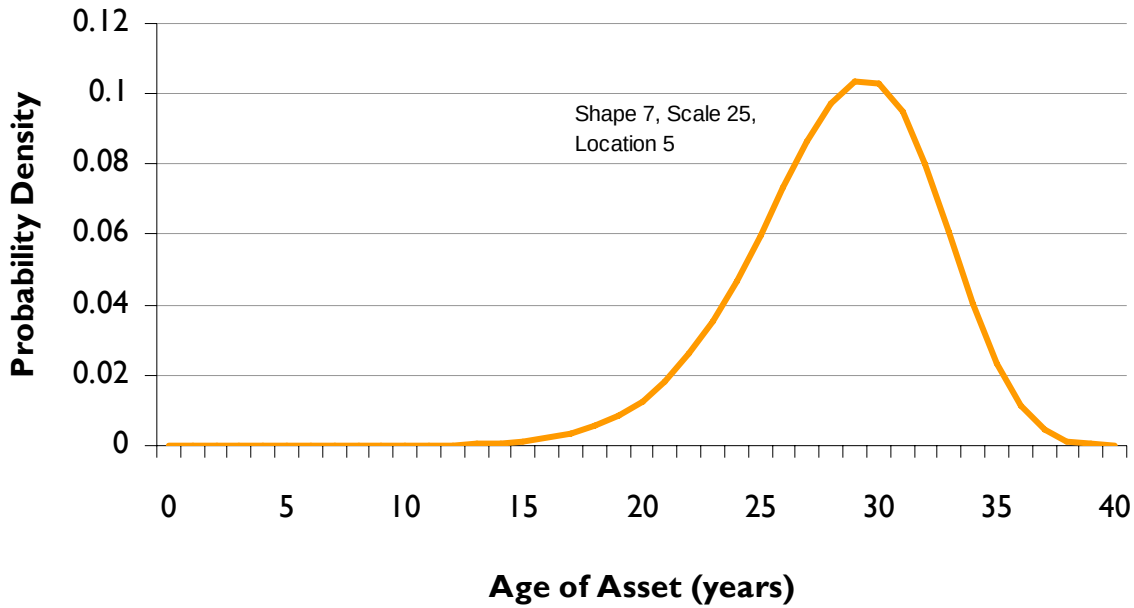
Weibull

- Wallodi Weibull (1939)
- Mathematical formula, similar to the normal distribution
- Fitted to observed failure rates

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}$$

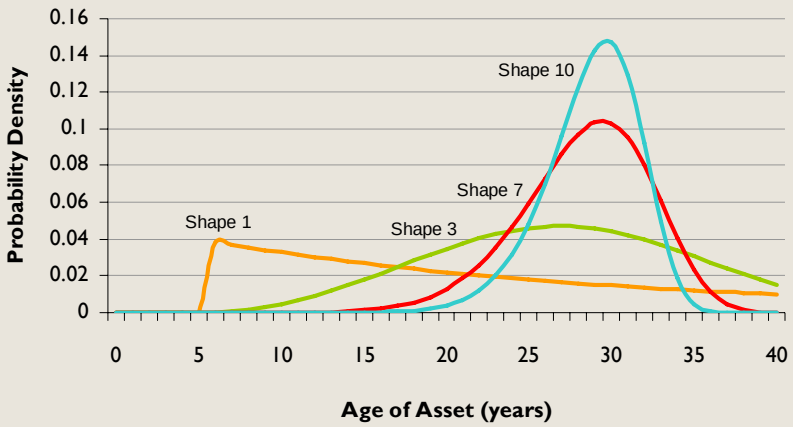
Parameters

- Scale (η) – similar to a mean
- Shape (β) – defines the skew
- Location (γ) – shifts the distribution to the right

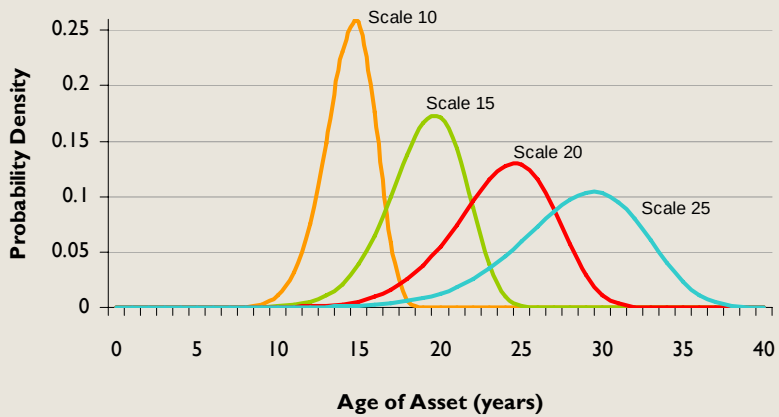


Changing the Weibull parameters

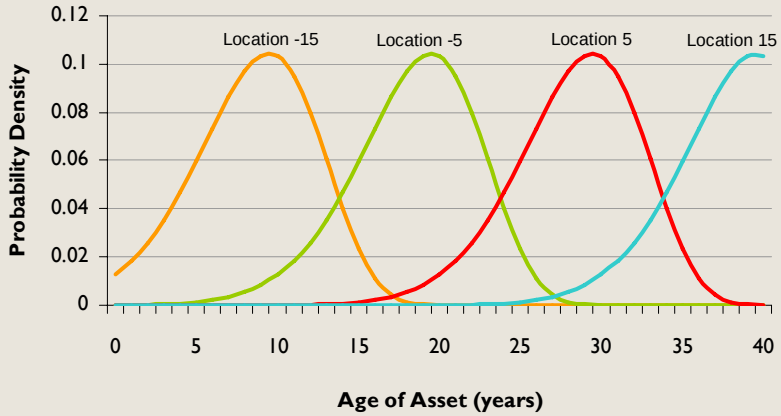
Changing Shape Parameter



Changing Scale Parameter



Changing Location Parameter

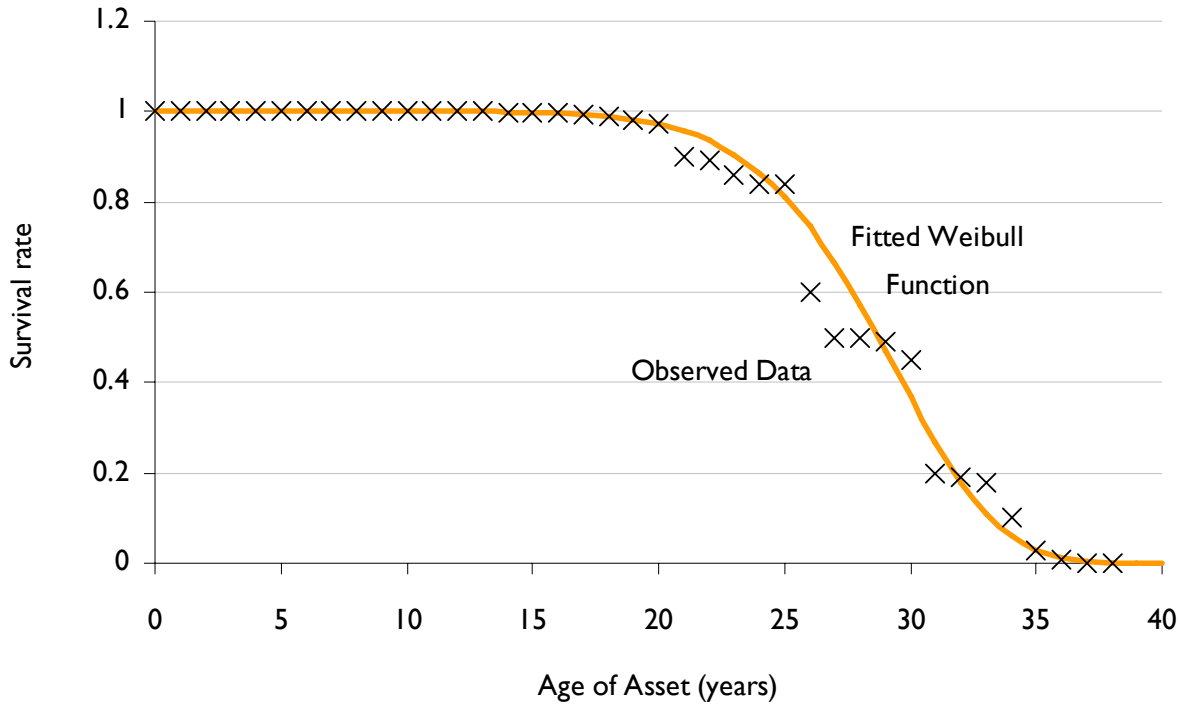


Different assets are modelled by different Weibull distributions

Example Assets:

Asset Description	*Scale*	*Shape*	*Location*
Our example	**25**	**7**	**5**
33 kV pin insulators, Australia	**42.8**	**3.54**	**8**
Wooden distribution poles, Tasmania	**43**	**3.6**	**5**
Wooden distribution poles, Queensland	**96**	**4.17**	**0**
Concrete distribution poles, Queensland	**114**	**4**	**20**
Wooden distribution poles, Canada	**44.07**	**4.21**	**0**
XLPE 15 kV cables, United States	**61.21**	**5.69**	**0**
HMWPE 15 kV cables, United States	**66.3**	**8.39**	**0**

Survivor curve:



Who uses reliability-based aging asset theory?

Industries:

- Electricity Industry
- Water Industry
- Gas Industry
- Drug Industry
- Many Other Industries

Used by:	***Used for:***
US Army	Asset Reliability
Insurance Companies	Risk of Insurance Claims
Accountants	Depreciation
Drug Companies	Risk of Recall
Network Operators	System Reliability

Probability analysis
& New Zealand

WHY DID IT ENTER DEBATE

FAILURE CURVES & IMPLICATIONS FOR FUTURE EXPENDITURES

NZ INVESTMENT AND PROBABILITY OF FAILURE

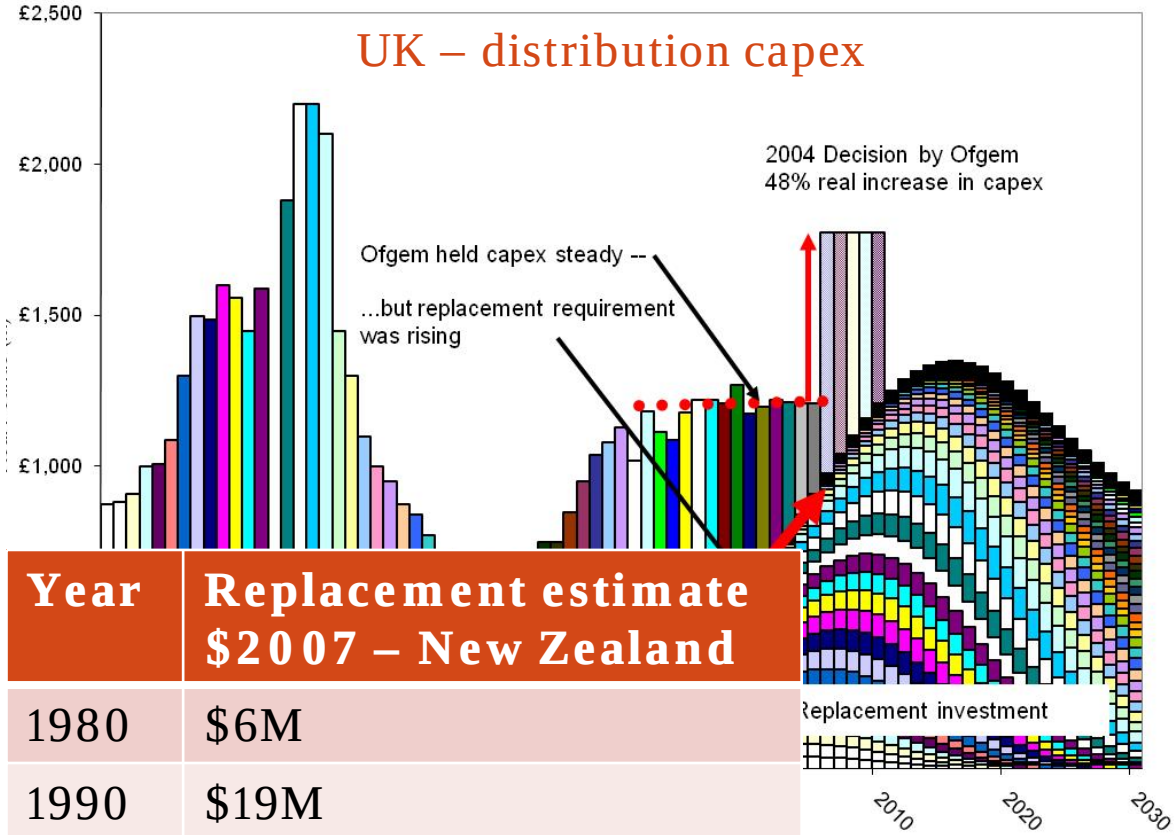
WHY DID IT ENTER DEBATE?

To demonstrate that the past was not a guide to the future

Past expenditures were setting basis for future allowances

…But - Ageing assets were new phenomenon and not captured in past trend -

Threshold effectively imposed price cap – no allowance for ageing asset base

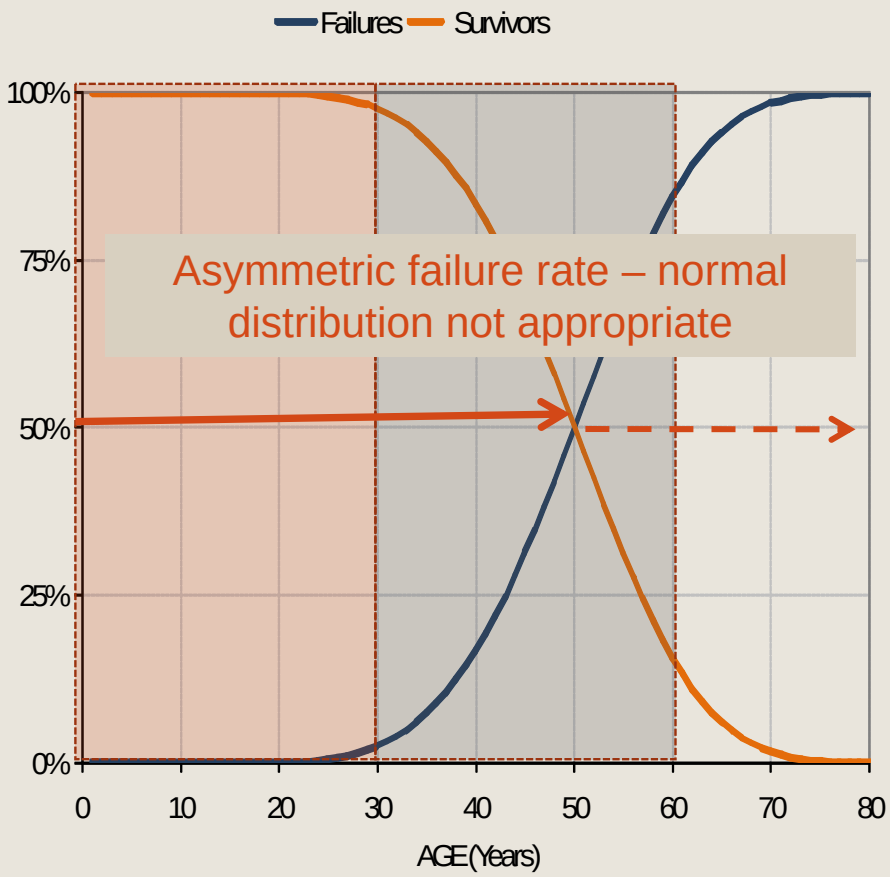


Year	Replacement estimate $2007 – New Zealand
1980	$6M
1990	$19M
2000	$62M
2010	$152M

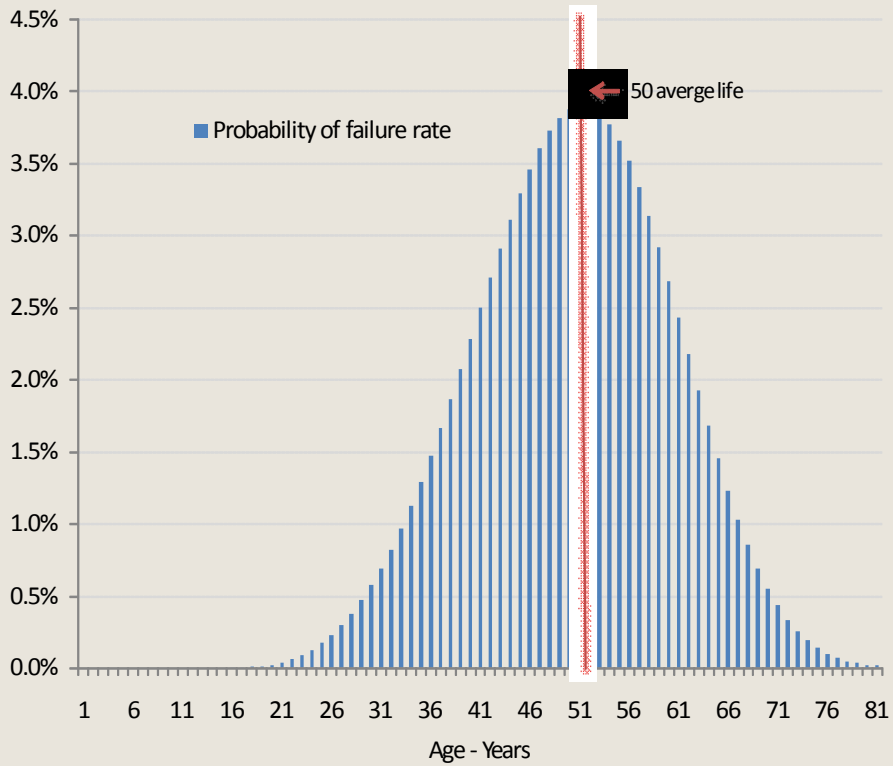
"…Commission has decided that past trend in capex will be used as the starting-point…" …ESC, Victoria

Failure curves & implications for future expenditures

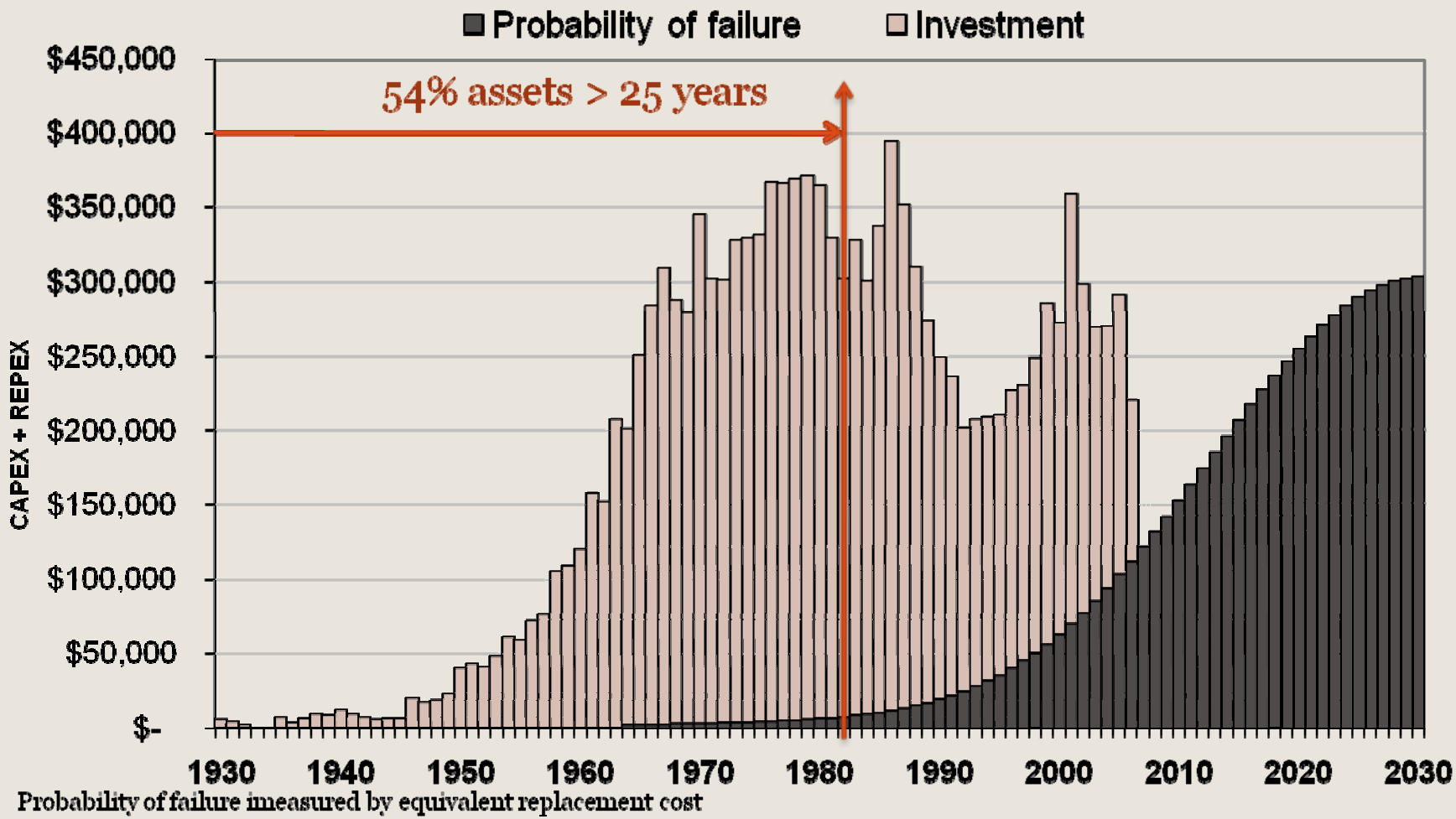
Network assets – Average 50 years: 20 → 80



Failure rates - Annually



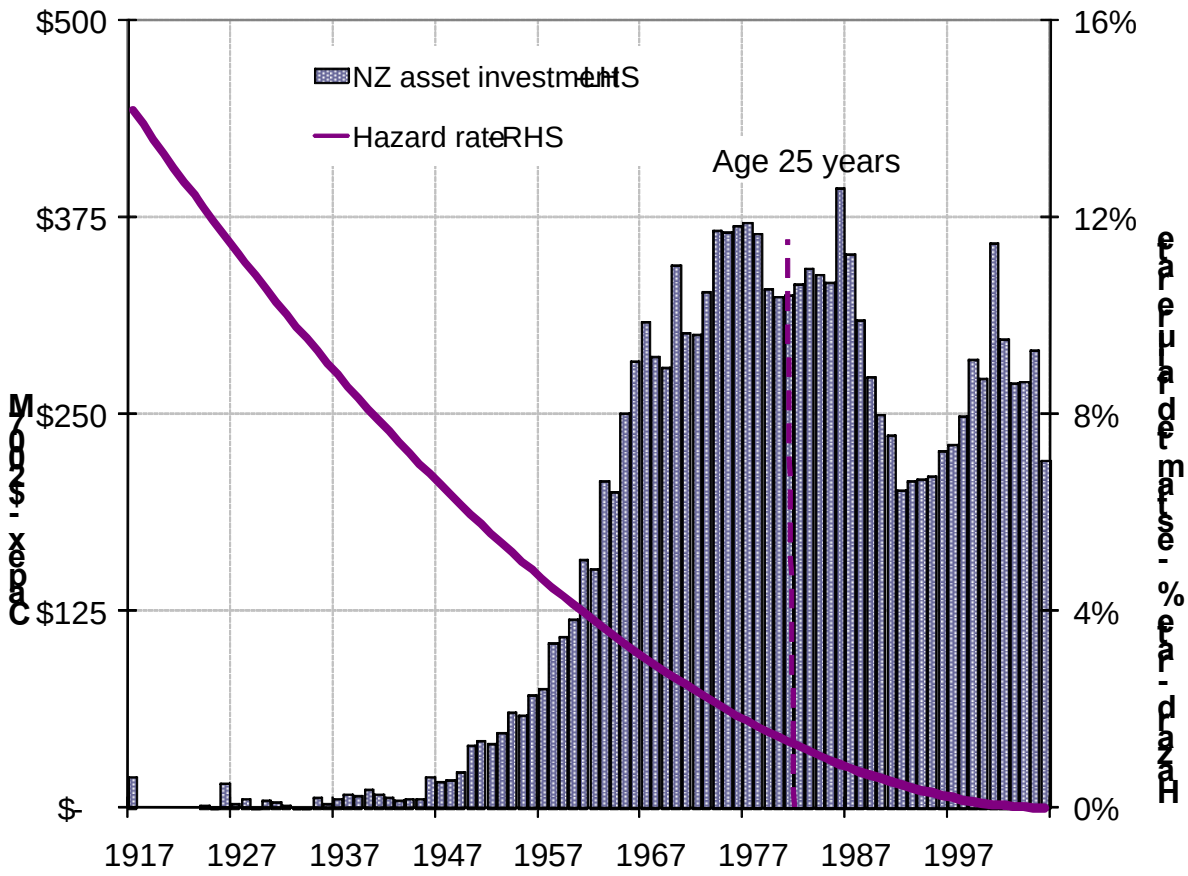
New Zealand – Initial investment & probability of failure



Failure rate differs with asset age

Older assets have higher failure rates

Maintaining weighted average asset age of 25 years provides balance between too much expendiutre or too much unreliability



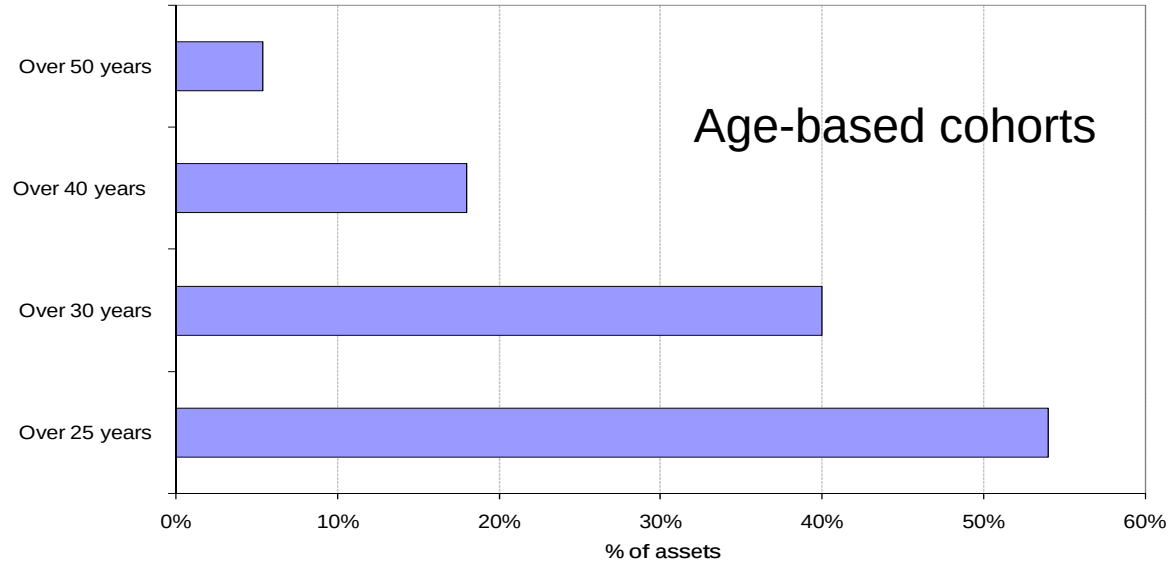
Asset age profile & failure rates

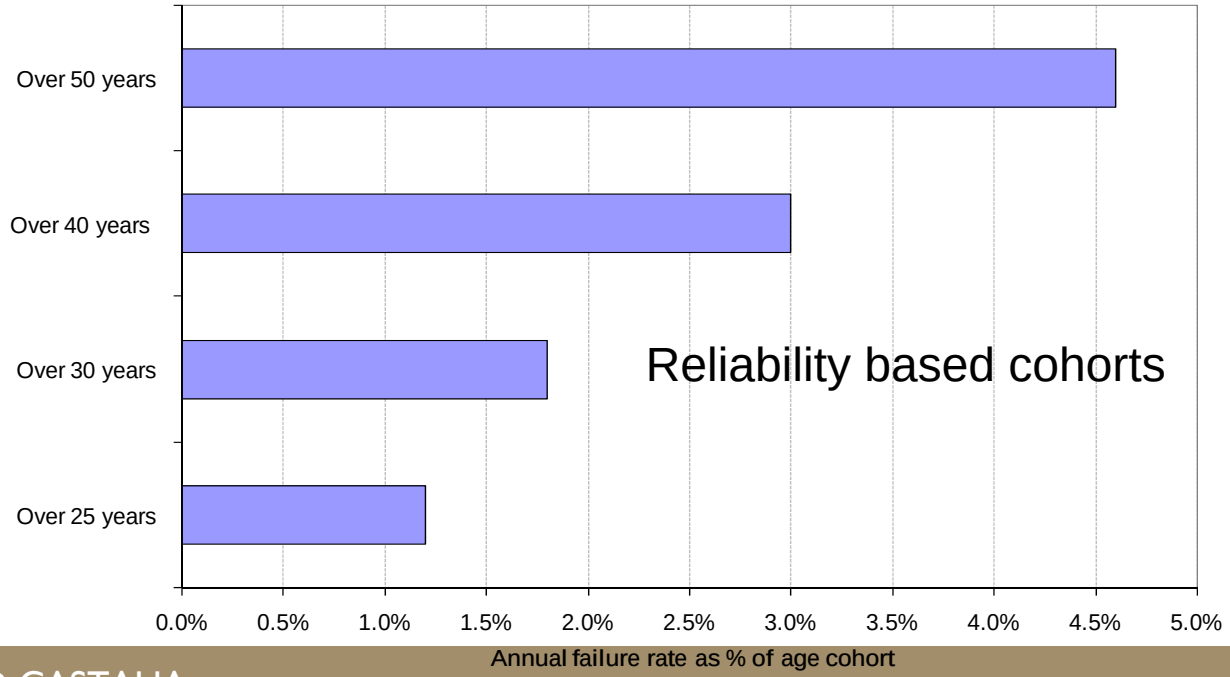
Asset age and failure rates NZ

Assets aged 40 years with average life expectancy of 50 years are not 5 to 10 years from renewal…

…They could fail tomorrow or last another 40 years

Hence probability distribution functions

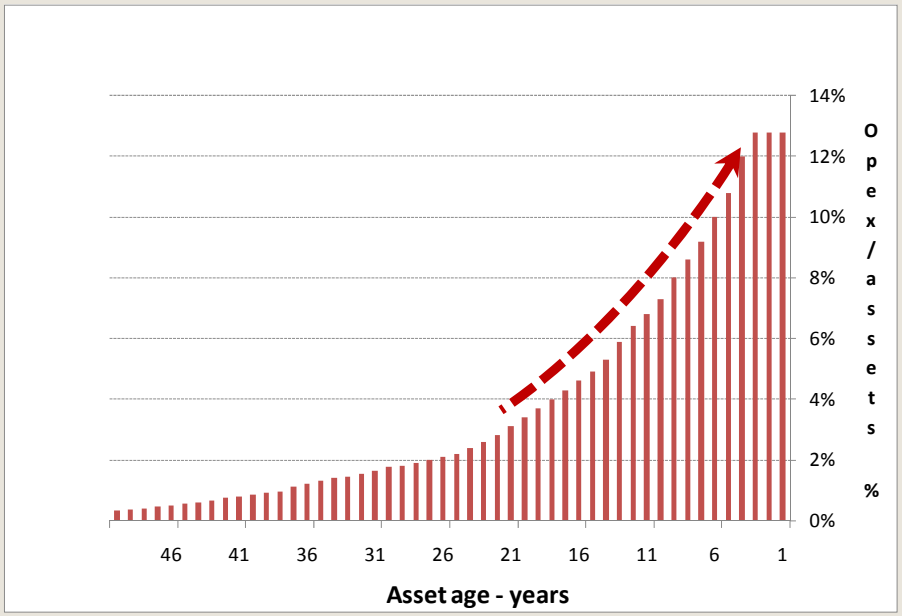




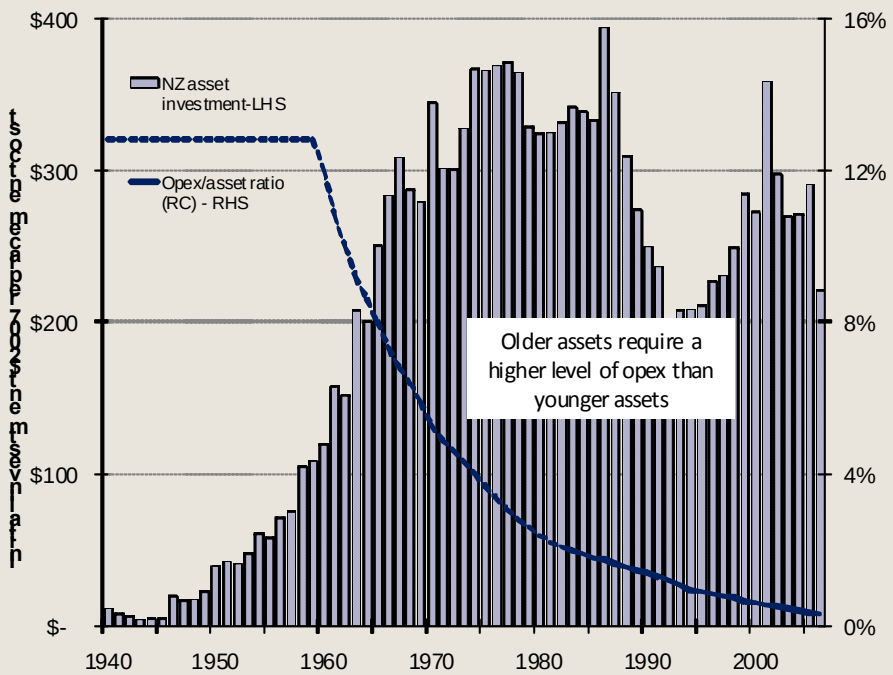
Asset ageing and maintenance expenditure

Opex/assets ratio rises as assets age

Opex/assets 0% – 2% first 25 years
2% to 13% 2nd 25 years



...and NZ has 54% of assets > 25 years



Managing asset based businesses

ASSET MANAGEMENT AS CORE BUSINESS

ROLE OF PROBABILITY ANALYSIS IN ASSET MANAGEMENT

FAILURE ANLAYSIS AND EXPENDITURE PLANING

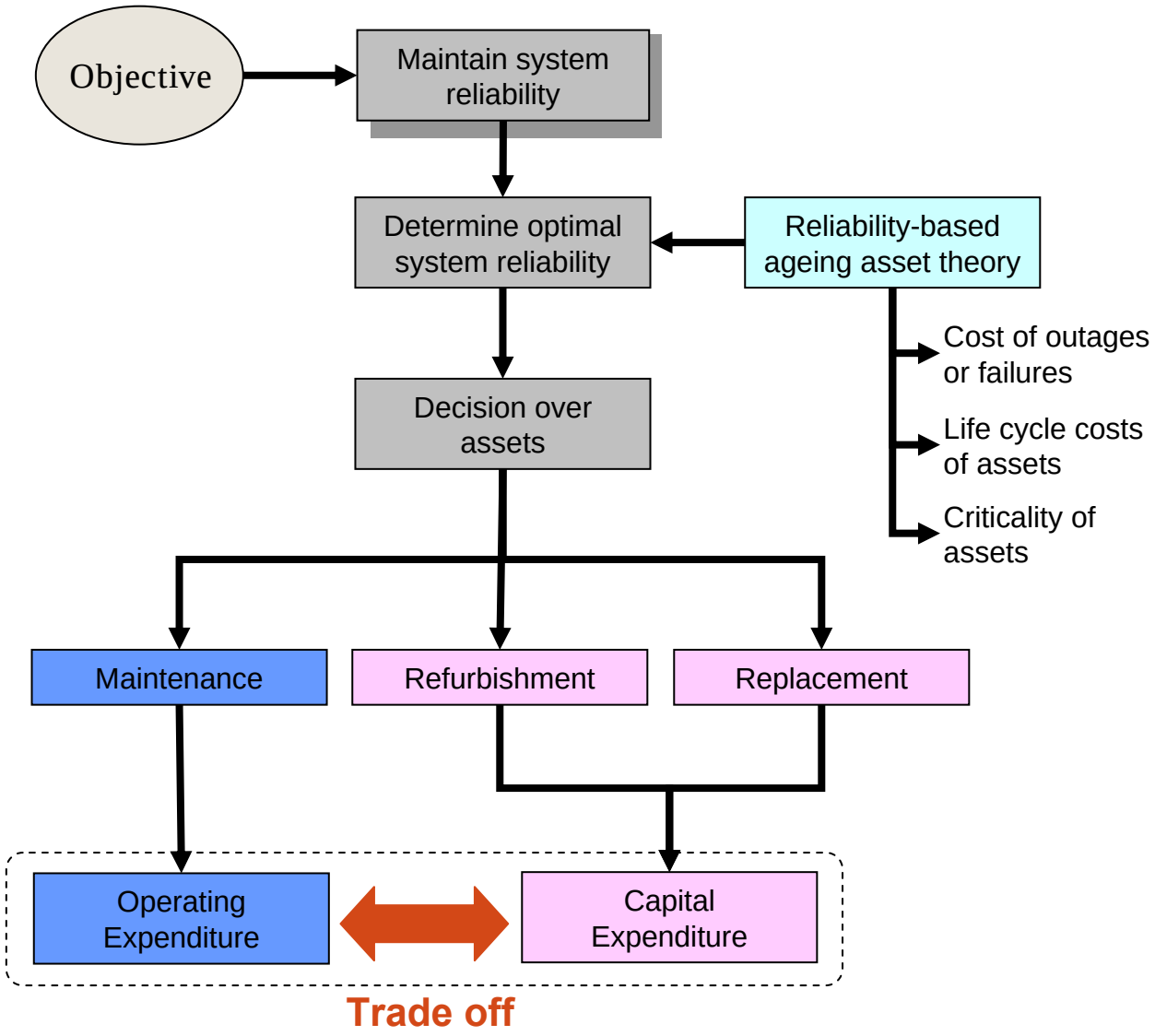
Role of probability analysis in asset management

Objective:

- to maintain system reliability
- at least life cycle cost
- by cost-effective trade-off between maintenance and replacement

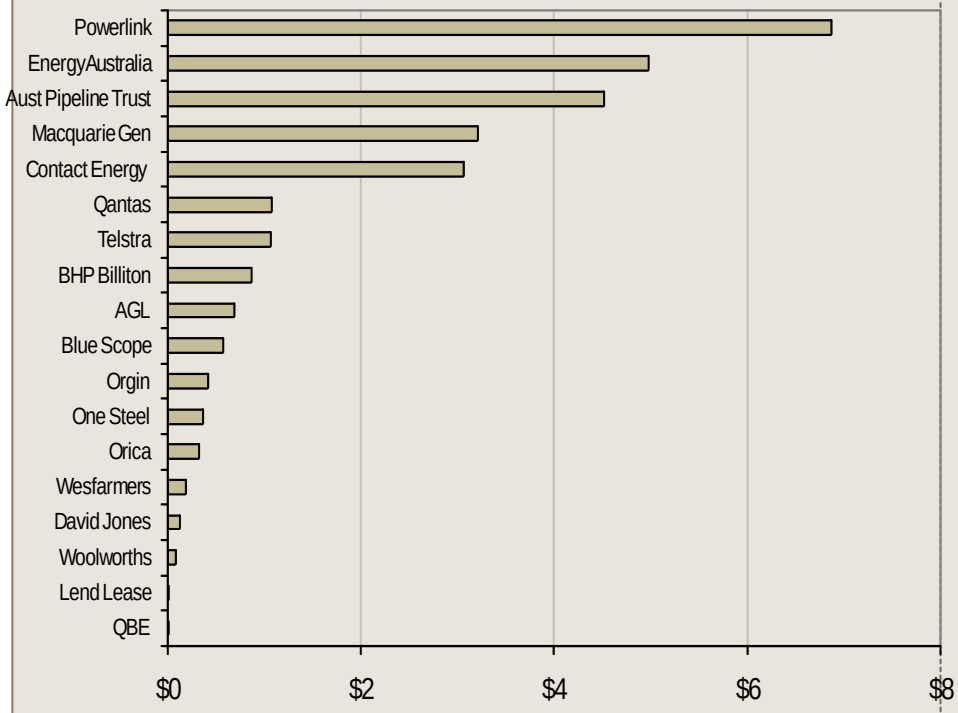
Criteria::

- cost of outages or failure
- life cycle costs of the asset
- criticality of the asset to the network



Networks are different : Asset Management as core business

Asset investment / revenue



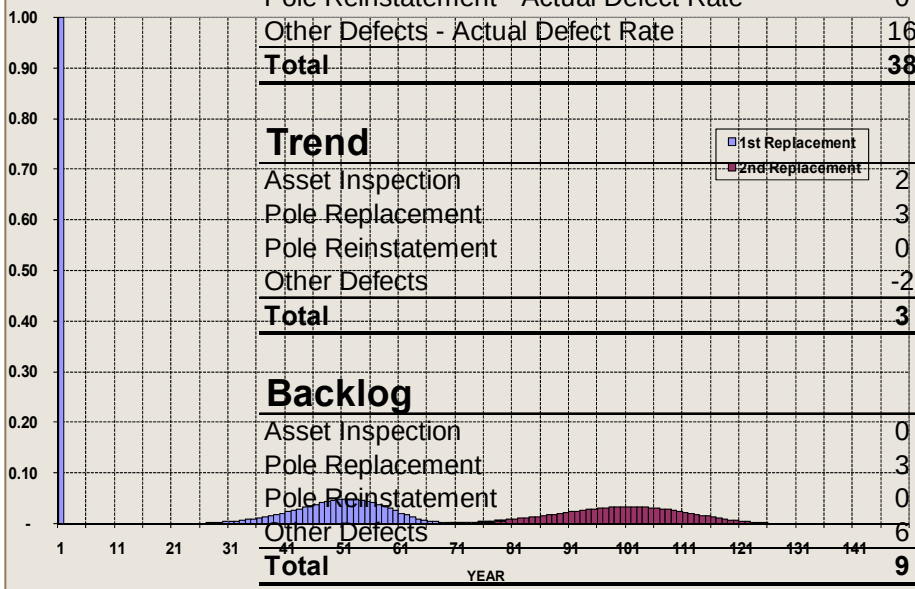
Implications

- Asset management is THE business:
- Objective for asset manager is to maintain system reliability - hence *reliability centred maintenance*
- Criteria:
  - Reliability demanded by consumers
  - Life time cost of assets
  - Criticality of asset
  - Trade-off between opex & capex

Failure analysis for expenditure planning

Lifetime mortality distribution can be estimated many years out

...and facilitates cost-effective planning of maintenance and capital expenditure



Base Workload - Calculated		Regions						
Asset Inspection - 4.5 Years Cycle	11	9	17	12	10	10	9	9
Pole Replacement - Actual Defect Rate	10	10	23	11	13	9	7	14
Pole Reinstatement - Actual Defect Rate	0	0	1	0	0	0	0	1
Other Defects - Actual Defect Rate	16	25	21	50	31	10	11	26
Total	**38**	**44**	**61**	**73**	**54**	**29**	**28**	**51**

Trend		Regions						
Asset Inspection	2	2	1	-1	-1	0	0	-1
Pole Replacement	3	0	9	2	7	-4	-2	-1
Pole Reinstatement	0	0	0	0	0	0	0	0
Other Defects	-2	4	-10	-2	6	-12	0	0
Total	**3**	**6**	**-1**	**-1**	**12**	**-16**	**-2**	**-2**

Backlog		Regions						
Asset Inspection	0	0	1	0	0	0	0	1
Pole Replacement	3	2	3	1	1	1	1	1
Pole Reinstatement	0	0	0	0	0	0	0	0
Other Defects	6	8	7	5	1	2	1	0
Total	**9**	**10**	**11**	**6**	**3**	**3**	**2**	**2**

Additional Resource Requirement	**12**	**16**	**11**	**5**	**15**	**-13**	**0**	**1**

Thank you