Ageing infrastructure investment: “Wall of wire” or “wall of confusion”?

WHAT ARE THE ISSUES & WHAT DO THEY TELL US?

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Wellington

Margaret Beardow, Principal Benchmark Economics
Eli Grace-Webb, Analyst Castalia Strategic Advisors
The “wall of wire”

Initial investment

Replacement investment

We are here

BENCHMARK ECONOMICS AND CASTALIA
In a nutshell...

- “Wall of wire“ debate is confused…
- it does not measure age based renewals…
- It measures probability of asset failures
- it is a tool for asset managers targeting *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

<table>
<thead>
<tr>
<th>Wall of wire</th>
<th>Probability analysis</th>
<th>Probability analysis for NZ</th>
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</thead>
<tbody>
<tr>
<td>• What it is</td>
<td>• What it is</td>
<td>• Why it entered debate</td>
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<tr>
<td>• What it is not</td>
<td>• What is measures</td>
<td>• Failure curves and implications for future expenditures</td>
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<td>• How it is measured</td>
<td>• Its purpose</td>
<td>• Asset age and failure</td>
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<tr>
<td>• Implications for expenditures</td>
<td>• Probability distributions</td>
<td>• Asset age and opex</td>
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### 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 80 years. Initial investment still in service. Asset managers need guidance on likely timing of maintenance and replacement costs.

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

**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

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

Managers have no certainty

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?
- LIFETIME PROBABILITY DISTRIBUTION FUNCTIONS
  - Weibull
  - Gompertz
  - Gumbel
Reliability-based ageing asset theory

1. Observed rate of asset failures

Assets more like to wear out when older
Assets more like to fail when older
Reduces system reliability
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

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

Wallodi Weibull (1939)

Mathematical formula, similar to the normal distribution

Fitted to observed failure rates

Parameters

- Scale ($\eta$) – similar to a mean
- Shape ($\beta$) – defines the skew
- Location ($\gamma$) – shifts the distribution to the right

Parameters

Shape 7, Scale 25, Location 5

Probability Density

Age of Asset (years)
Changing the Weibull parameters

Changing Shape Parameter

Changing Scale Parameter

Changing Location Parameter
### Example Assets:

<table>
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<tr>
<th>Asset Description</th>
<th>Scale</th>
<th>Shape</th>
<th>Location</th>
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<td>Our example</td>
<td>25</td>
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Different assets are modelled by different Weibull distributions.

**Survivor curve:**

![Survivor curve graph](image)
Who uses reliability-based aging asset theory?

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

**Used by:**
- US Army
- Insurance Companies
- Accountants
- Drug Companies
- Network Operators

**Used for:**
- Asset Reliability
- Risk of Insurance Claims
- Depreciation
- Risk of Recall
- 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

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

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<th>Replacement estimate</th>
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<td>2000</td>
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<td>2010</td>
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UK – distribution capex

2004 Decision by Ofgem
48% real increase in capex

Ofgem held capex steady –
…but replacement requirement was rising

Replacement investment
Failure curves & implications for future expenditures

Network assets –
Average 50 years: 20 → 80

Asymmetric failure rate – normal distribution not appropriate

Failure rates - Annually

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New Zealand – Initial investment & probability of failure

54% assets > 25 years

Probability of failure measured by equivalent replacement cost
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 expenditure 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

Older assets require a higher level of opex than younger assets

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Managing asset based businesses

ASSET MANAGEMENT AS CORE BUSINESS

ROLE OF PROBABILITY ANALYSIS IN ASSET MANAGEMENT

FAILURE ANALYSIS AND EXPENDITURE PLANNING
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

Objective: Maintain system reliability

Determine optimal system reliability

Reliability-based ageing asset theory

Decision over assets

Maintenance

Refurbishment

Replacement

Cost of outages or failures

Life cycle costs of assets

Criticality of assets

Operational Expenditure

Capital Expenditure

Trade off
Networks are different:
Asset Management as core business

**Asset investment / revenue**

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**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

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Thank you