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Literature Review – Decay Curves

- Summary of Findings

  - From a global perspective the research is limited although growing with sophistication over time

  - Most research with this subject matter is coming out of Europe

  - Australia and New Zealand evolved through acceptance of the methodology rather than proving it

 - In the past two decades there has been alignment between research and active application

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History of the Decay Curve

- In 1989 curve developed from measuring pavement decay

- In USA extended to bridges while in Australia it was extended to all other asset classes

- In Australia we replaced time with % effective life and Quality with condition to put all asset groups on same scale

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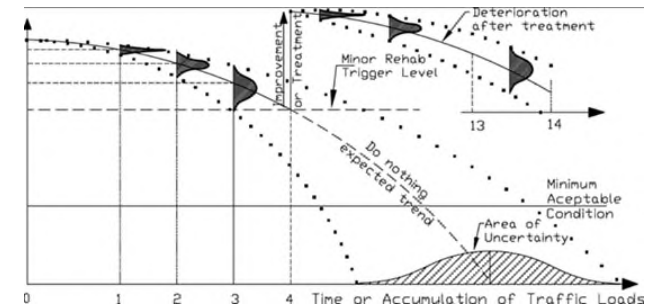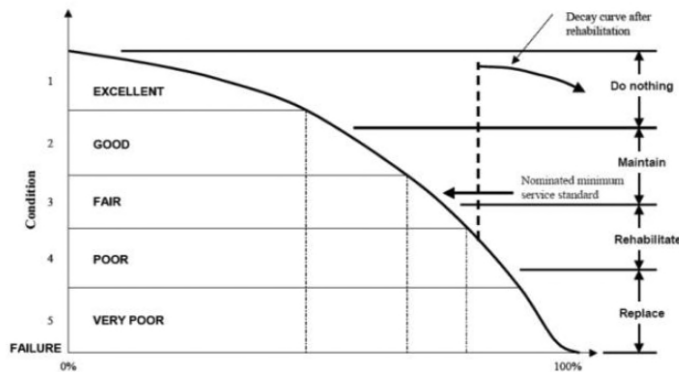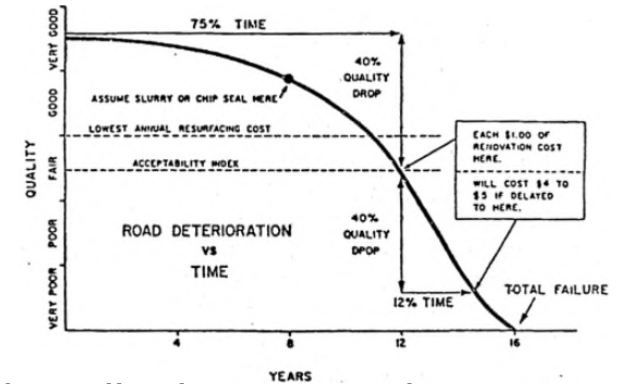
History of Decay Curve
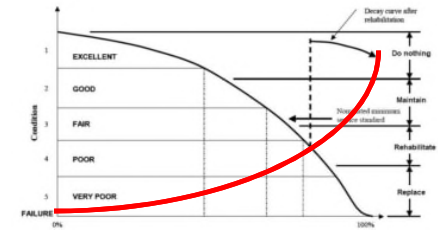
- Added Probability of Failure Curve to chart to incorporate risk into asset management

- At same time (1994) research in Melbourne (RMIT) derives failure equation:

$$y = kx^n \ where \ n \ is \ 1.9 \ to \ 2.1 \ for \ underground \ pipes$$
$$and \ k \ is \ a \ mix \ of \ parameters \ e.g. soil \ condition, location$$

- Use of Multi trigger point analysis to determine long term works programs based on asset decay

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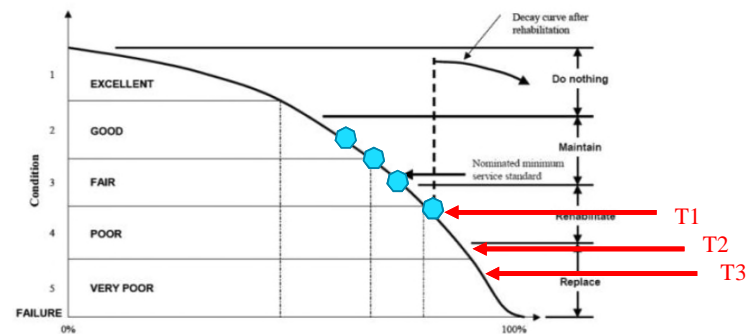
History of Decay Curve

- Enigma developed to use in NZ for network funding – 1996

- First decay curves generated from CCTV, EcoWater – 1998

- Overseas research into sewer prediction models – 1999

- Research into Survival analysis – 2009

- Risk based research – 2010 +
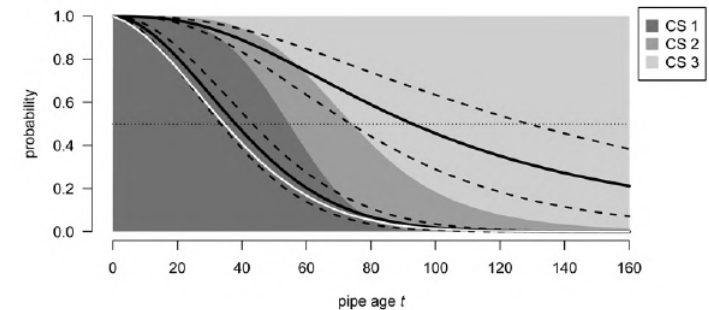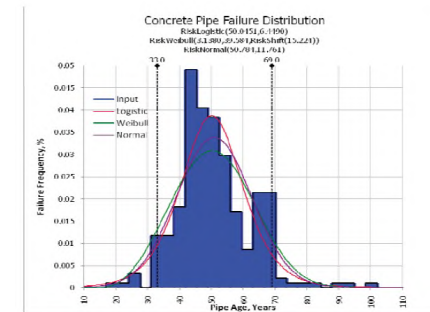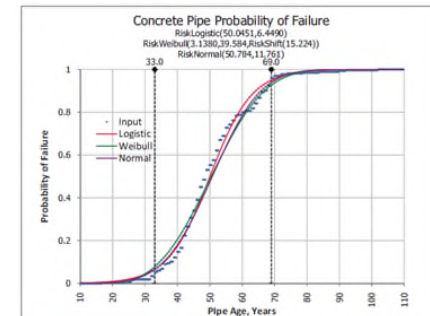
History of Decay Curve

- Review of Sewer Deterioration models (with or without data) – 2013

- Wannon Water develops decay curves from CCTV – 2016

- Sound data on pipe material deterioration - 2017

Table 1: Expected life of flexible sewers

Soil type of backfill	Ground water table	Depth of cover	Expected life (years)
Non-cohesive	Low	Normal	100
Non-cohesive	Low	Too shallow or too deep	90
Non-cohesive	High	Normal	80
Non-cohesive	High	Too shallow or too deep	70
Cohesive	Low	Normal	65
Cohesive	Low	Too shallow or too deep	60
Cohesive	High	Normal	45
Cohesive	High	Too shallow or too deep	40

(a) Based on expert opinions

(b) Markov chain model prediction
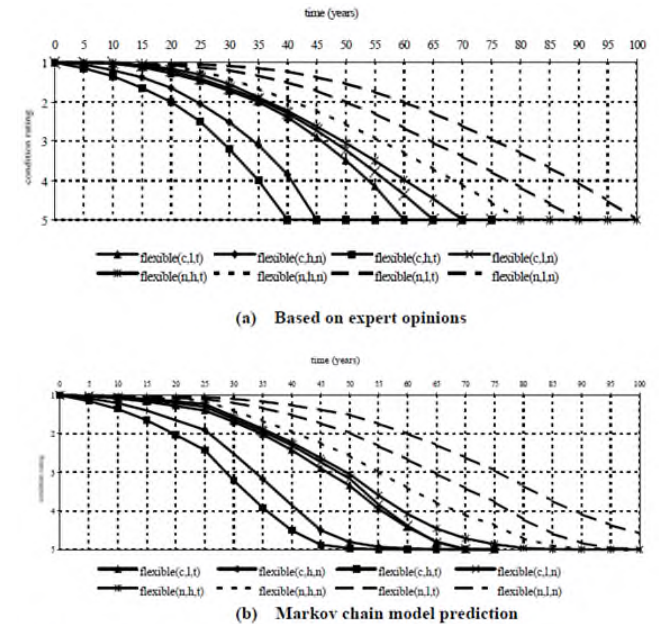
Fig. 3: Comparison of deterioration curves (Markov chain model vs. expert opinions)

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Predictor Model

- Data is sound
  - Continually improve CCTV data
  - Cohorts identified but could be expanded

- Model to be defined
  - Should be based on current decision making
  - Desired decision making should be realistic

- Strategy
  - Highly dependent on outcomes (Review a range of results)

Need to Crawl before you Walk

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Bibliography

- **Enigma7beta, 1997**
- AM software that uses deterioration curves to determine Network modelling outcomes
-
- **Development of Prediction Models for Sewer Deterioration, Abraham and Wirahadikusumah, Purdue University, 1999**
- Discusses the mechanisms of structural failures in sewers.
-
- **Condition Assessment of the West Derwent and associated Lines Asset Management Plan, Hobart Water, Maunsell, 2005**
- Practical application of ODM analysis using condition and likelihood of failure curves.

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Bibliography

- **Prediction of Likelihood of failure of Underground Linear Assets Using Survival Analysis, SEE HYIIK TING, University of Buffalo, 2009**
- Development of survival models to help asset managers better determine the LoF of underground water and sewer pipes.

-

- **Using a Markov Model to estimate Pipe Deterioration, Newnham, Dunedin City Council circa 2010**
- Characteristic deterioration curves can be created based on weighting each path to the current condition by the probability of being in that condition at that point on the path. It has been these characteristic curves which have confirmed that this method captures known behaviour of certain pipe materials and therefore warrants further exploration.

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- **Risk Based Decision Making Tools for Sewer Infrastructure Management, Moustafa Addel Moteleb, 2010**
- Focused on the critical tools that are needed to identify, quantify, and manage risk associated with linear assets, the probability of failure of sewer pipes as well as the impact of such failure.

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- **D 1.2 Review of Sewer Deterioration Models, WassarBerlin,   2013**
- Discusses the models and the factors influencing the models.
-
- **Sewer Deterioration Modelling with Condition Data Lacking Historical Data, Egger, Scheidegger, Reichert and Maurer, Water Research Article, Nov 2013**
- Proposes the combination of a sewer deterioration model with a simple rehabilitation model which can be calibrated with datasets lacking historical information.
-
- **Development of Sewer Decay Curves, Wannon Water, 2016**
- Used CCTV data to develop decay curves based on cohorts
-
- **PAM analytics Predictive Asset Management System, 2016**
- Discusses analytics and survival models used in Asset Management

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Bibliography

- **Optimal Risk-Based Lifecycle Cost scheduling of Water and Sewer Main Replacements, Innovyze 2017**
- Presentation of the use of decay curves and a risk based approach to identify replacement of pipes.

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