

Asset Risk Management Dashboard

Calculations Summary

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Abstract

Key calculations used in the Asset Risk Management Dashboard to compare four maintenance strategies through risk and cost analysis.

1 Core Formulas

1.1 Logistic Curve (S-Curve)

$$f(x) = \frac{1}{1 + e^{-\alpha(x-\text{midpoint})}} \quad (1)$$

Models gradual then rapid changes. Used as the foundation for failure rate calculations.

1.2 Likelihood of Failure (LOF)

$$\text{LOF} = \text{min_lof} + (1 - \text{min_lof}) \times f(\text{age_normalized}, \text{lof_alpha}, 0.7) \quad (2)$$

where $\text{age_normalized} = t/T$ (normalized asset age, 0 to 1).

1.3 Risk Calculation

$$\text{Risk} = \text{LOF} \times \text{COF} \quad (3)$$

where $\text{COF} = \text{Replacement Cost (Consequence of Failure)}$.

2 Maintenance Strategy Calculations

2.1 No Fix Strategy

Cost:

$$\text{Baseline} = 0.05 \times \text{replacement_cost} \times \frac{t}{T} \quad (4)$$

$$\text{Catastrophic} = \text{replacement_cost} \quad (\text{at } \approx 90\% \text{ lifespan}) \quad (5)$$

$$\text{Total} = \text{Baseline} + \text{Catastrophic} \quad (6)$$

Risk: Continuous S-curve increase, never resets.

$$\text{Risk}(t) = \text{calculate_lof}\left(\frac{t}{T}, \alpha, \text{min_lof}\right) \times \text{COF} \quad (7)$$

2.2 Fix in Plan (Scheduled Maintenance)

Cost:

$$N_{\text{cycles}} = \left\lfloor \frac{T}{\text{cycle_length}} \right\rfloor \quad (8)$$

$$C_{\text{cycle}} = 0.15 \times \text{replacement_cost} \quad (9)$$

$$\text{Baseline} = 0.02 \times \text{replacement_cost} \times \frac{t}{T} \quad (10)$$

$$\text{Total} = \sum_{i=1}^{N_{\text{cycles}}} C_{\text{cycle}} + \text{Baseline} \quad (11)$$

Risk: Cyclic wave pattern within each maintenance cycle, with peak risk increasing as the asset ages.

$$\text{cycle_pos} = \frac{t \bmod \text{cycle_length}}{\text{cycle_length}} \quad (12)$$

$$\text{wave} = \frac{1 - \cos(2\pi \times \text{cycle_pos})}{2} \quad (13)$$

$$\text{peak_lof} = \text{min_lof} + (0.3 - \text{min_lof}) \times (1 + 0.5 \times \text{age_normalized}) \quad (14)$$

$$\text{LOF} = \text{min_lof} + (\text{peak_lof} - \text{min_lof}) \times \text{wave} \quad (15)$$

2.3 Fix on Fail (Reactive Maintenance)

Cost:

$$\text{Baseline} = 0.01 \times \text{replacement_cost} \times \frac{t}{T} \quad (16)$$

$$N_{\text{failures}} = \max\left(3, \left\lfloor 2 + 3 \times \left(\frac{t}{T}\right)^2 \right\rfloor\right) \quad (17)$$

$$C_{\text{repair}} \sim \text{Uniform}(0.3, 0.5) \times \text{replacement_cost} \quad (18)$$

$$\text{Total} = \text{Baseline} + \sum C_{\text{repair}} \quad (19)$$

Risk: Gradual S-curve buildup between failures, spikes to 1.0 at failure, and resets after emergency repair.

2.4 Fix on Risk (Optimized Maintenance)

Cost:

$$\text{Baseline} = 0.02 \times \text{replacement_cost} \times \frac{t}{T} \quad (20)$$

$$C_{\text{intervention}} = 0.20 \times \text{replacement_cost} \quad (21)$$

$$\text{Interventions} = 4 \text{ at } t_k = (0.3 + 0.15k) \times T \quad (22)$$

$$\text{Total} = \text{Baseline} + \sum C_{\text{intervention}} \quad (23)$$

Risk: Linear growth until a threshold is reached, then resets.

$$\text{growth_rate} = 0.001 \times \alpha \times (1 + 2 \times \text{age_normalized}) \quad (24)$$

$$\text{If LOF} \geq \text{threshold} : \quad \text{LOF} = 1.5 \times \text{min_lof} \quad (25)$$

3 Summary Metrics

3.1 Total Cost

$$\text{Total Cost} = C(T) \quad (\text{cumulative cost at end of lifespan}) \quad (26)$$

3.2 Average Risk

$$\text{Average Risk} = \frac{1}{n} \sum_{i=1}^n \text{Risk}_i \quad (27)$$

where $n = 500$ (number of time points).

4 Key Parameters

- **Replacement Cost:** Base monetary value for all calculations
- **Risk Alpha:** Controls steepness of failure rate curves
- **Min LOF:** Baseline failure rate (infant mortality, default 5%)
- **Cycle Length:** Maintenance interval for Fix in Plan strategy
- **Risk Threshold:** Fraction of COF that triggers intervention (0.1 to 0.9)
- **Cost Curve Alpha:** $= \text{risk_alpha} \times 0.8$

5 Notes

- All calculations use 500 time points for smooth curves
- Random events use seed = 42 for reproducibility
- Costs are cumulative (not incremental)
- Age normalization: $\text{age_normalized} = t/T$ (0 to 1)
- In the Fix in Plan strategy, peak likelihood of failure increases with normalized age to reflect long-term asset degradation