RISK-BASED MAINTENANCE OPTIMIZATION OF OFFSHORE WIND SUBSTRUCTURES

Source: https://www.windpowerengineering.com/projects/offshore-wind/drone-inspects-offshore-wind-farm/

Source: https://www.deltares.nl/en/projects/cutting-maintenance-costs-offshore-wind-farms-using-improved-forecasts/

Source: https://motherboard.vice.com/en_us/article/8qxz55/wind-turbine-drone-inspection-will-be-a-6-billion-industry-in-under-10-years

PAT 18 ENERMAR

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Introduction

Pablo is a Maritime Engineer…

Escuela Técnica Superior de Ingenieros Navales

POLITÉCNICA

… specialized in Offshore Renewable Energy…

University of Strathclyde Glasgow

… and Advanced Design of Offshore Structures…

LIÈGE université Sciences Appliquées

UNIVERSITY OF MICHIGAN

CENTRALE NANTES

Universität Rostock Traditio et Innovatio

Now?… PhD in Risk-Based Maintenance of Offshore Wind Substructures

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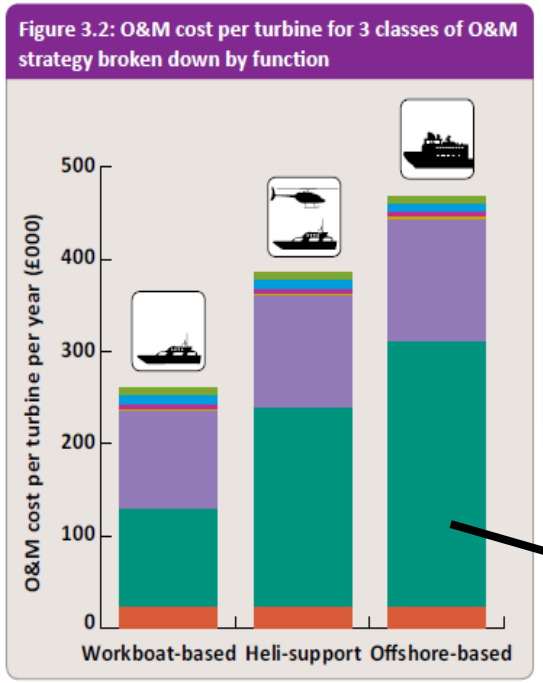
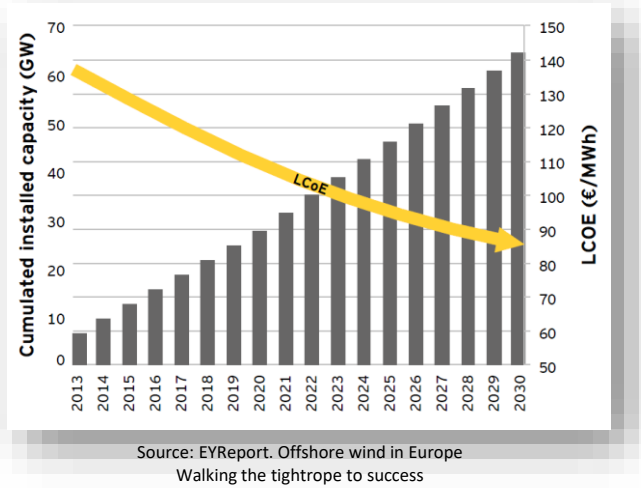
Context: Offshore Wind

Far away from shore

…Complex O&M tasks
Reduce LCOE…



Source: CrownState Report. A Guide to UK Offshore Wind Operations and Maintenance

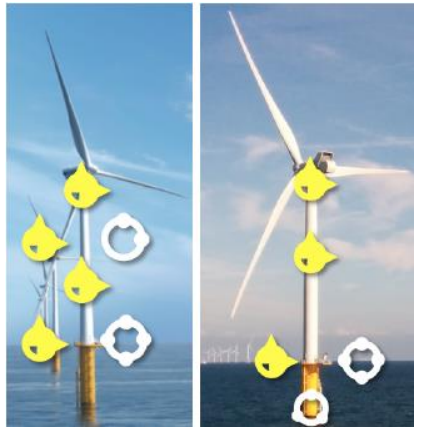


Source: EYReport. Offshore wind in Europe Walking the tightrope to success

Foundation
Maintenance

Information available

….Inspections
Monitoring…



Source: https://www.researchgate.net/figure/Optical-strain-gauges-as-installed-at-a-Belwind-and-b-Northwind

Source: https://www.deltares.nl/en/projects/cutting-maintenance-costs-offshore-wind-farms-using-improved-forecasts

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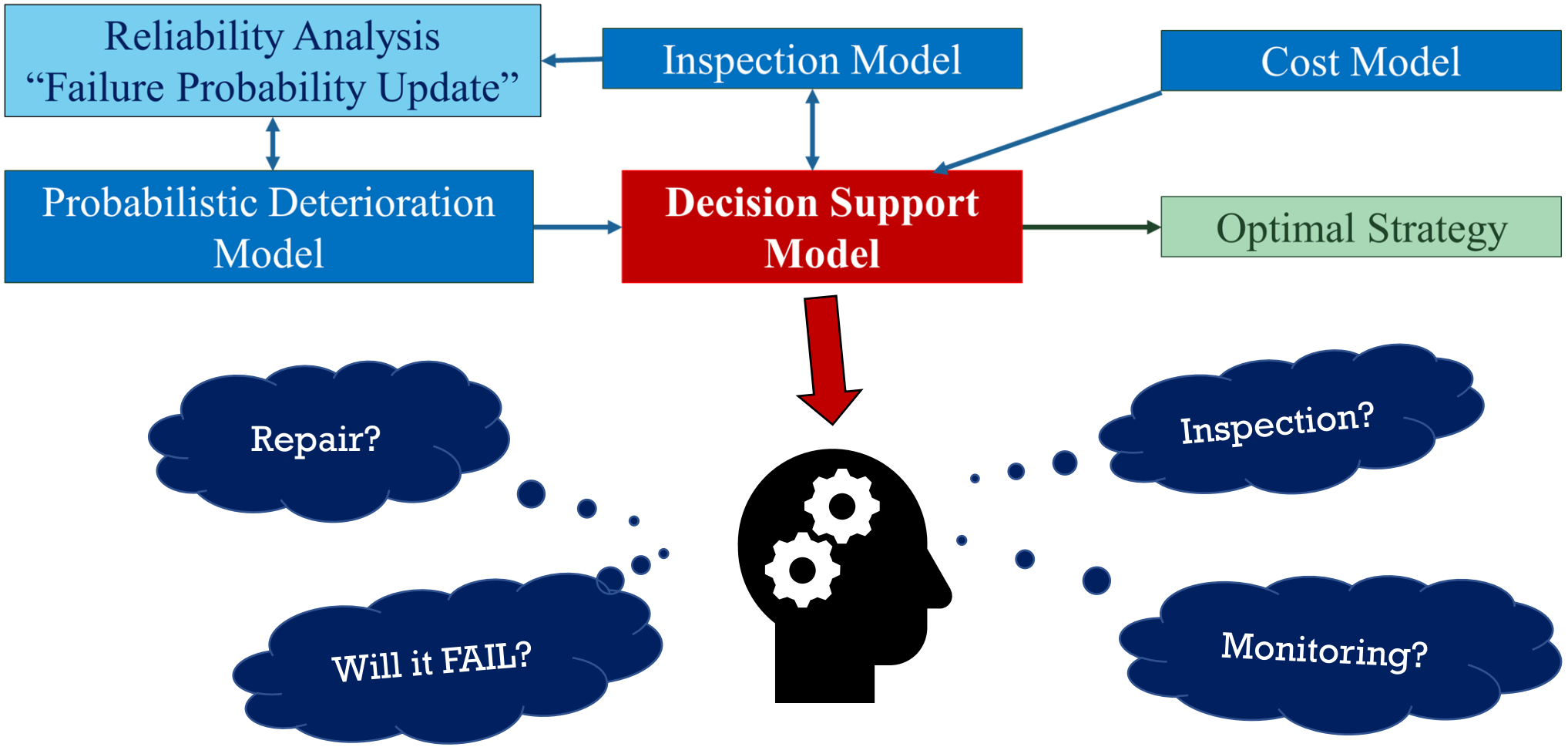
Aim: Decision Support

'Taking the right decision under uncertainty'



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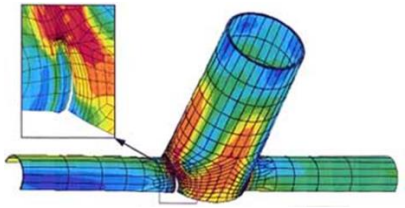
Uncertainties Modeling

Uncertainties?...

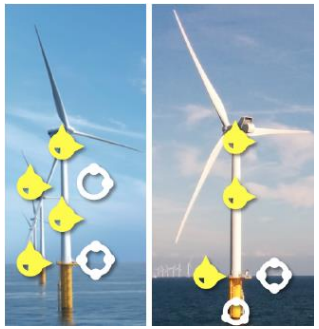
Physical

Source: https://www.theguardian.com/sustainable-business/microsoft-walmart-google-renewable-energy-wind-farm-solar

Model



Statistical



Measurement

Structural Reliability: Bayesian Inference

KNOWLEDGE → KNOWLEDGE → KNOWLEDGE

Design | Production | Operation | Decommissioning

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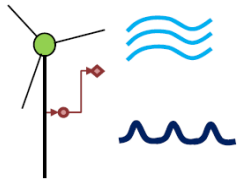
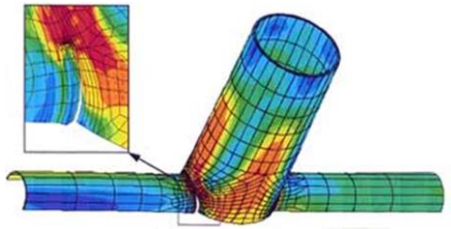
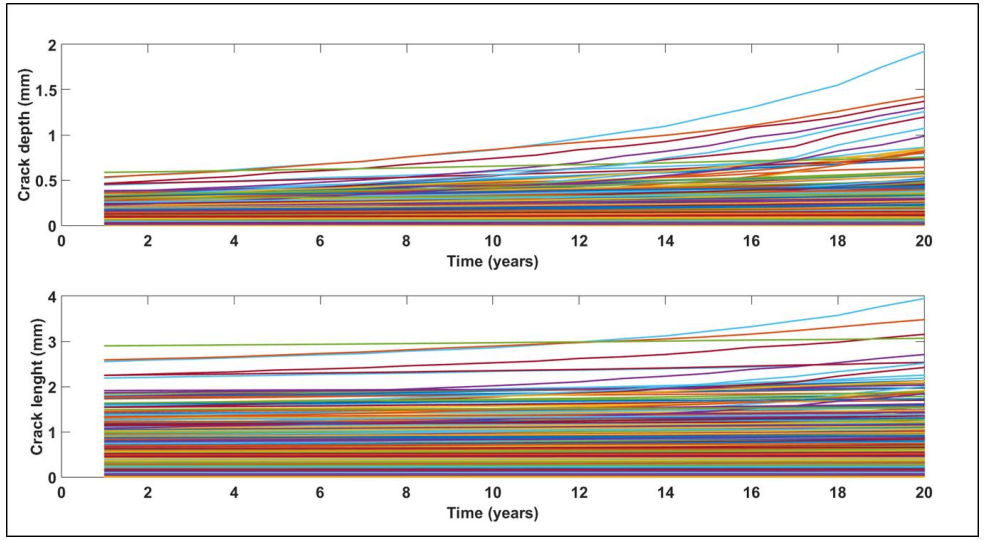
Deterioration Model - Fatigue

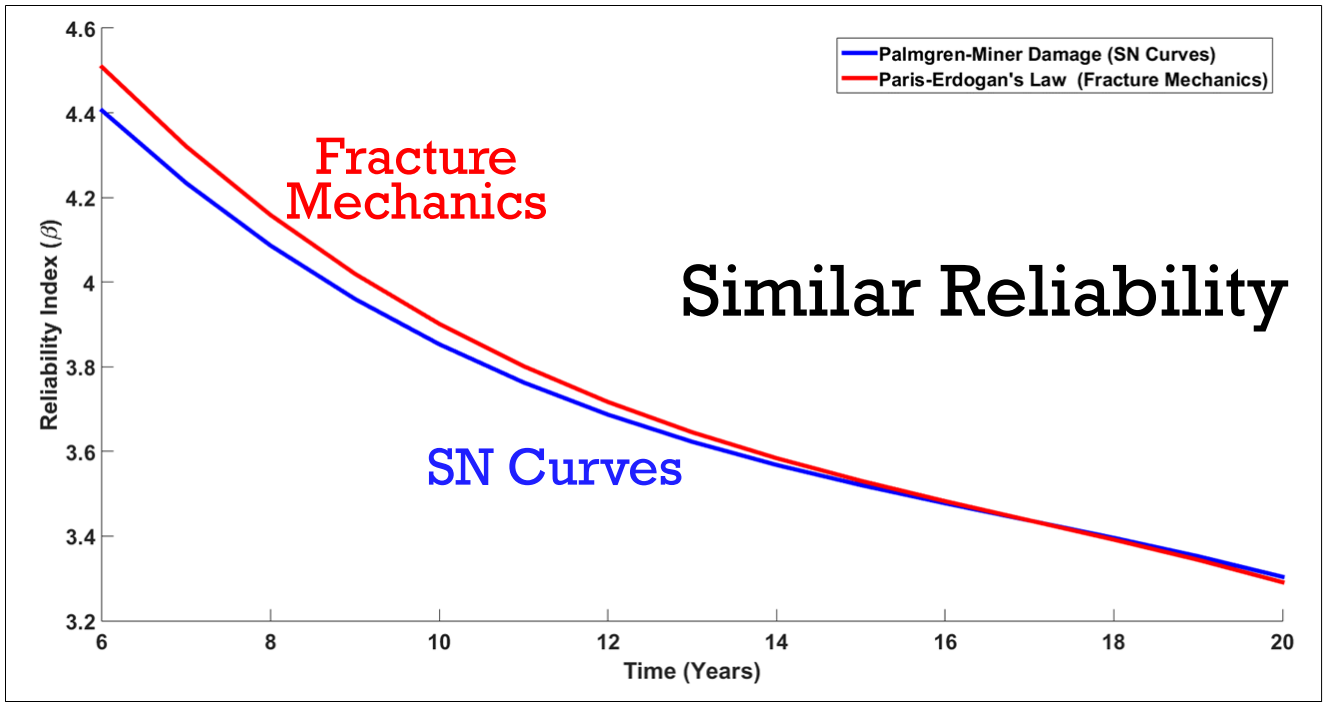


Why fatigue? ⟶ Combined action of wind & waves ~10^8 cycles/lifetime

Fracture Mechanics Calibration







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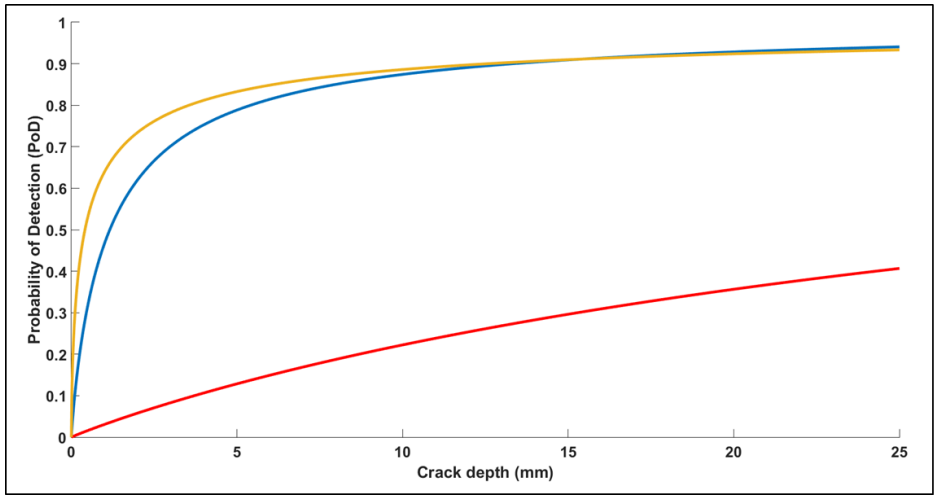
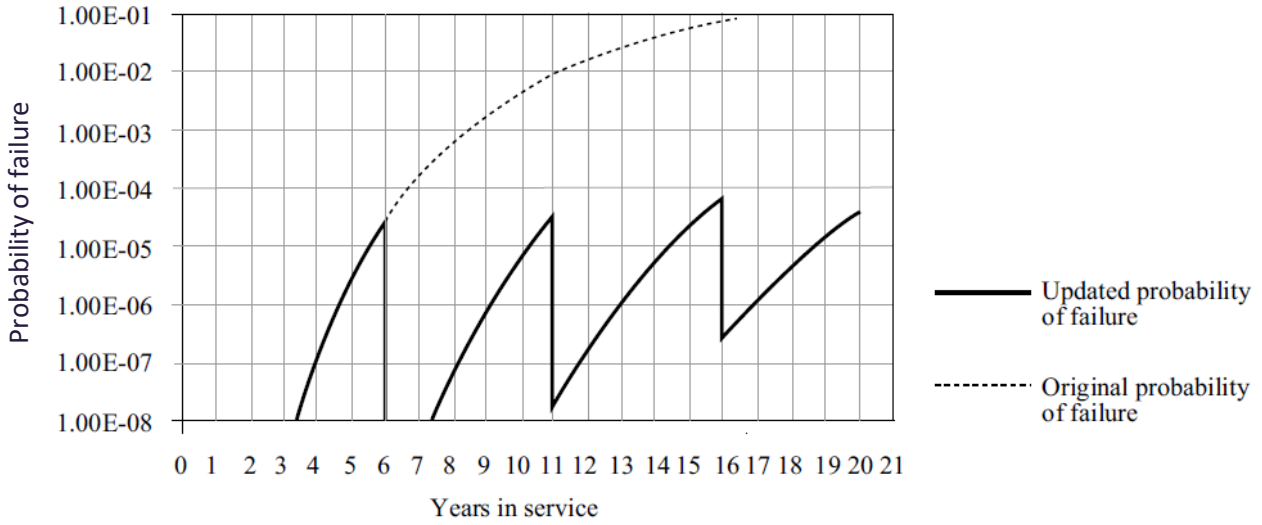
Updating Reliability - Inspections

Optimization: RISK = **Probability** * Consequence





Inspection technique:

- Ultrasonic
- Eddy current
- Visual

Inspection result:

- No detected
- Detected & repair
- Detected & no-repair

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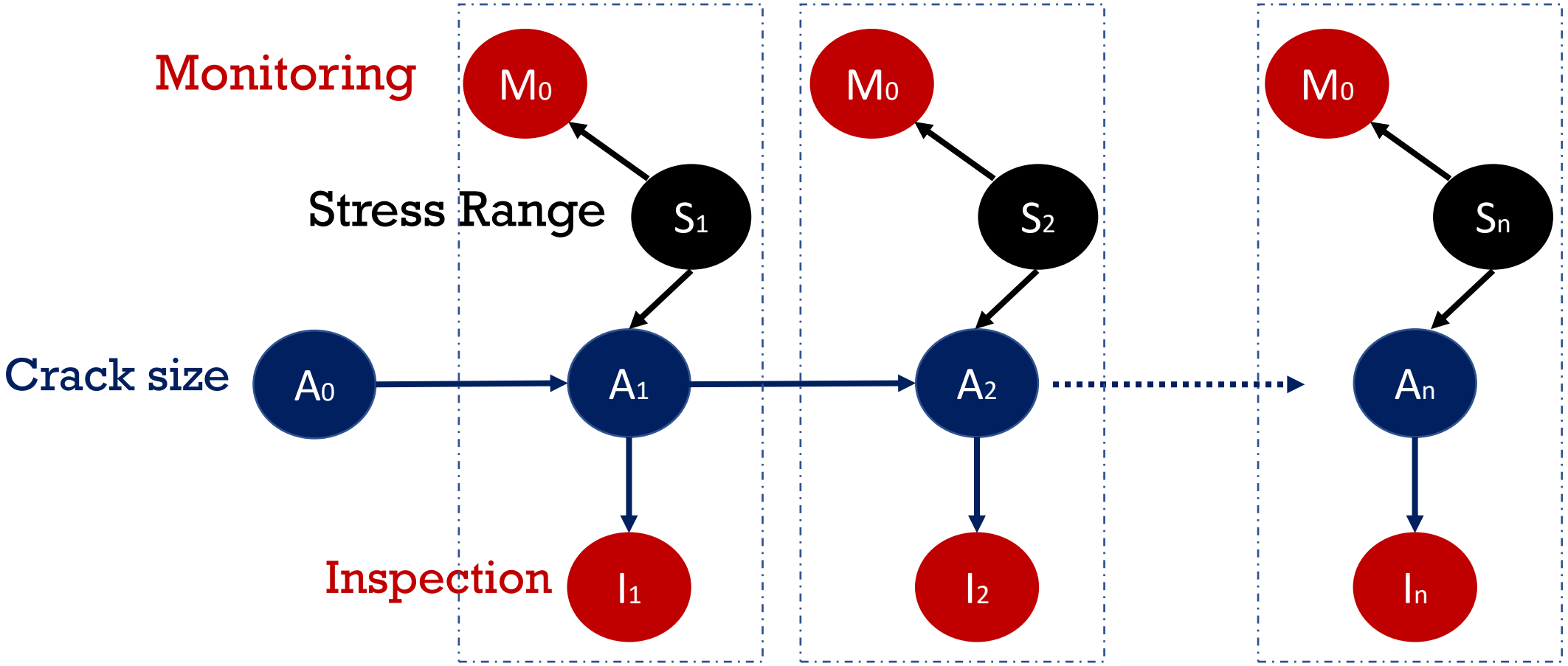
Utilizing Monitoring Data

Optimization: RISK = **Probability** * Consequence

'Dynamic Bayesian Network (DBN)'



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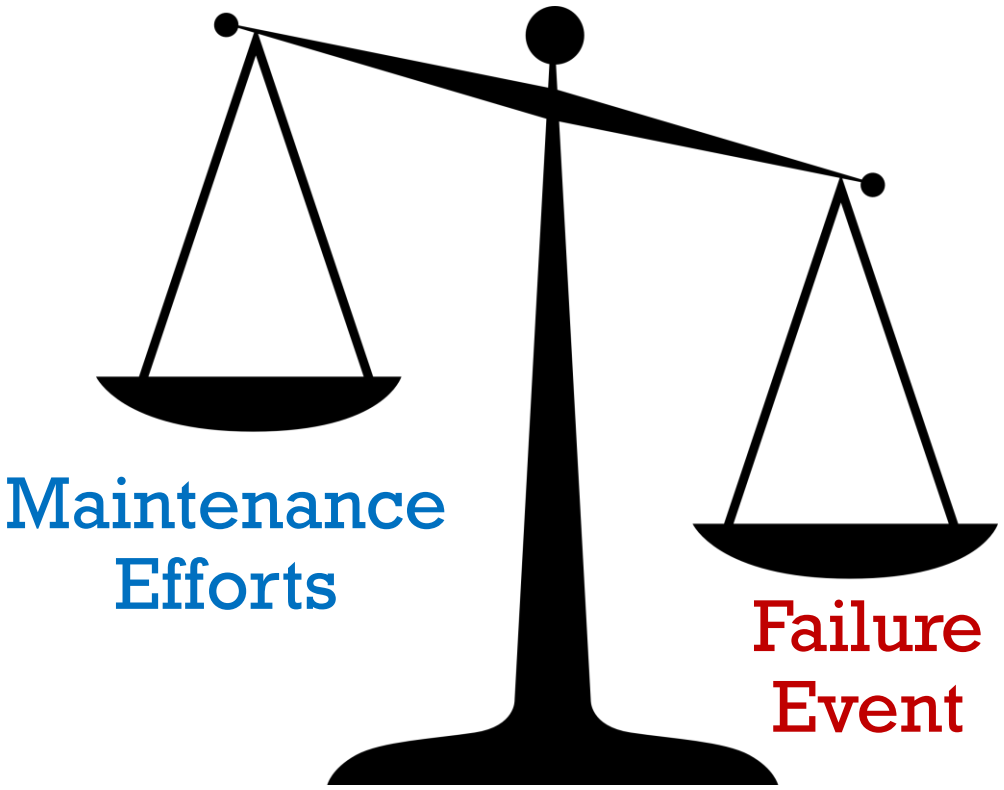
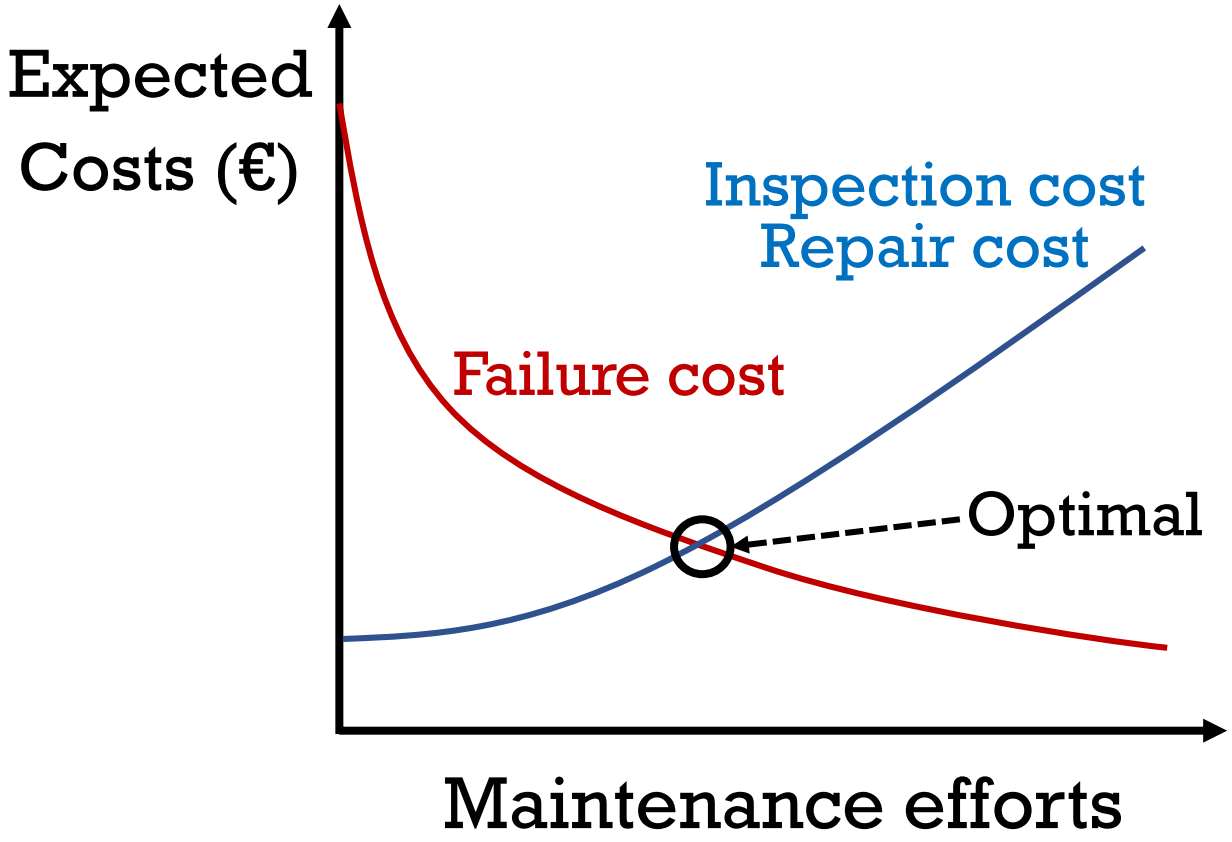
Cost Optimization

Optimization: RISK = Probability * **Consequence**





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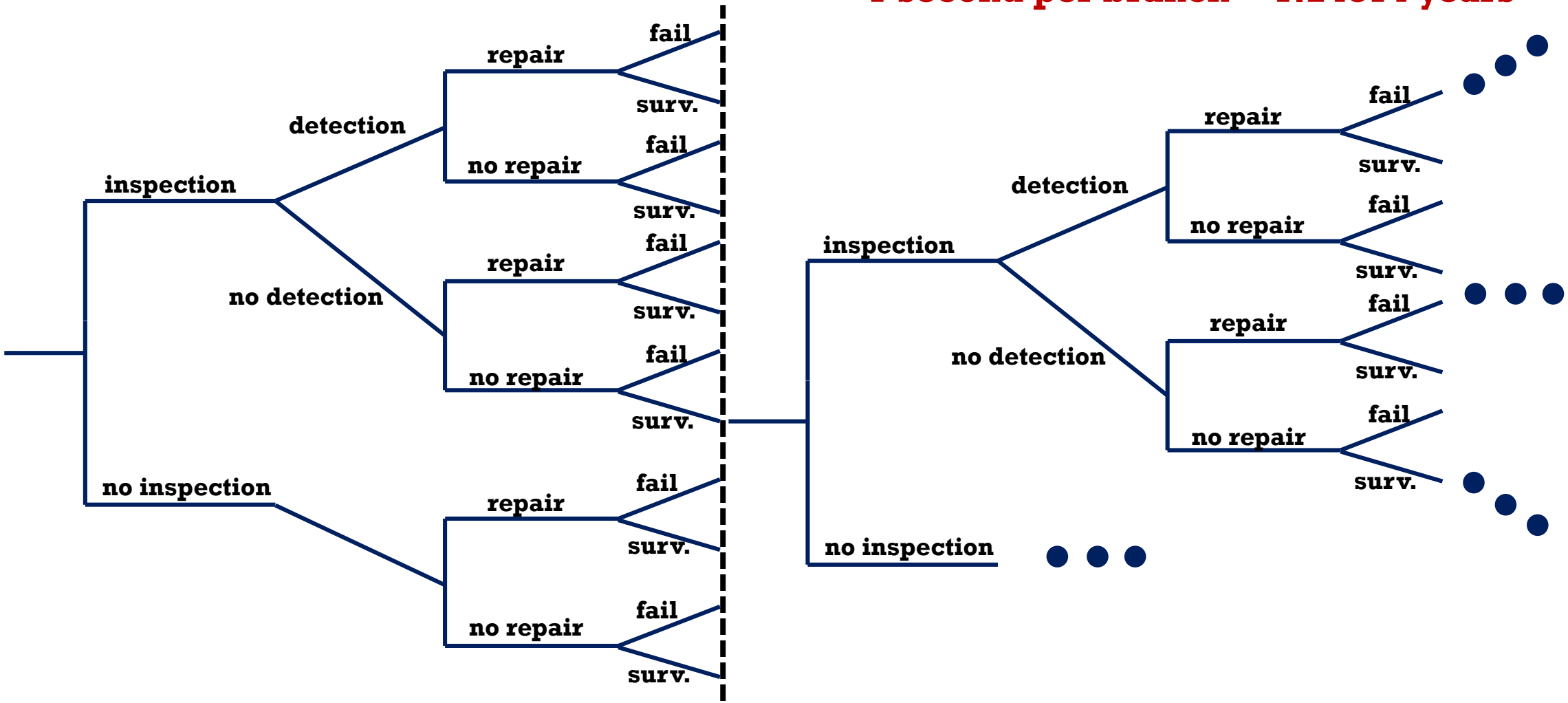
Decision Problem (II)

'Pre-posterior Decision Analysis'…

12^{20}=3.8e21 branches
1 second per branch = 1.24e14 years



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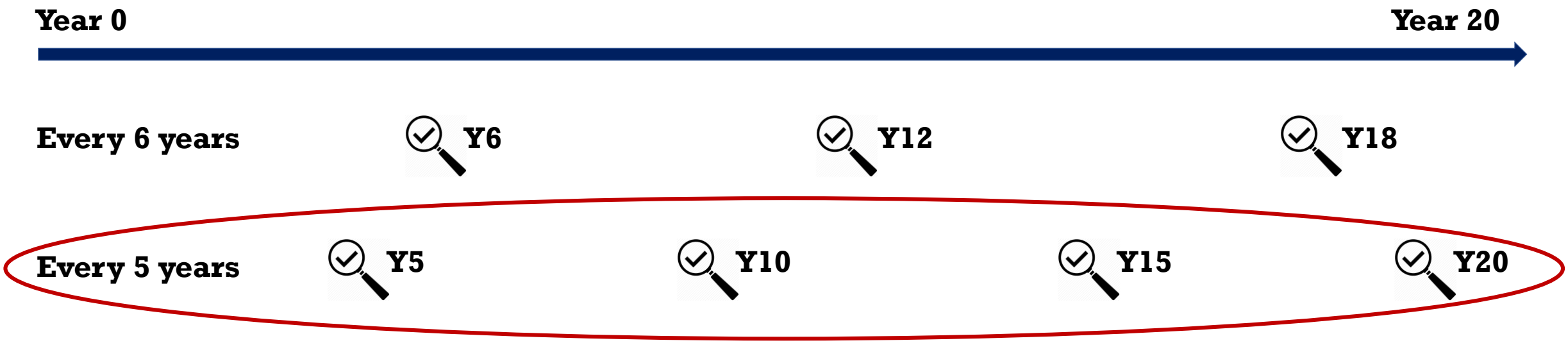
Simplification to Decision Problem

Heuristic Rule: 'Constant intervals of time'



More simplifications…

- Perfect inspections
- Repair if detected

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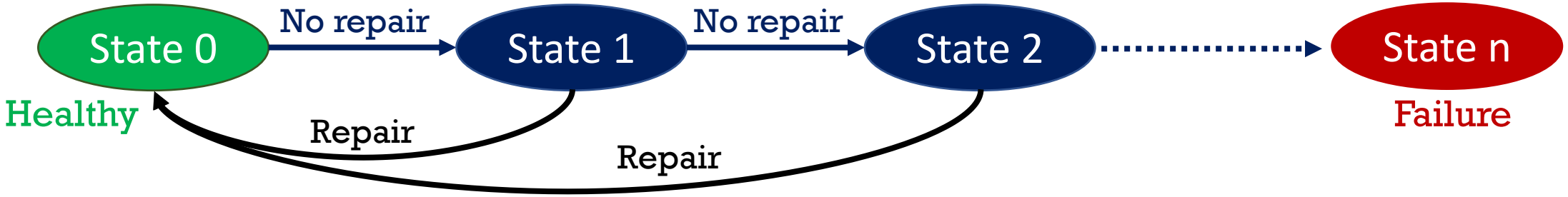
Dynamic Approach for Maintenance Planning

MARKOV Models



Inspection/Monitoring ⟶ Improves the **belief state** ?

Partially Observable Markov Decision Processes (POMDP)

Point-based algorithms ⟶ Reduces **CPU time** significantly

60-states POMDP including 3 combined actions ⟶ Only **0.32 seconds of CPU time**

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System Effects for Planning

Where to perform inspections?

Past…

Components analyzed separately

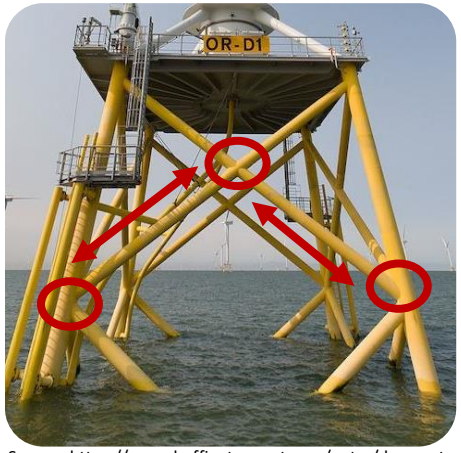
Future…

Considering **Dependencies**

Shared epistemic uncertainty

- Similar manufacturing
- Similar loading

'Lower costs can be attained'



Source: https://www.huffingtonpost.com/entry/deepwater-offshore-wind-farm_us_581a311fe4b0c43e6c1d9715

Source: https://www.telegraph.co.uk/business/2016/12/13/first-us-offshore-wind-farm-opens-rhode-islands-coast-ge-turbines/

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Impact: Life extension

Fixed-Offshore Wind Farms…

Year 0 — **Year 20**

Source: https://corporate.vattenfall.co.uk/projects/

… Lifetime Reassessment

Life extension

… Utilize gathered data

Inspections / SCADA

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Impact: Desing Optimization

Floating Offshore Wind Farms…

Year 0 → **Year 20**

Source:
https://www.marinelog.com/index.php?option=com_k2&view=item&id=26727:france%E2%80%99s-first-wind-farm-to-feature-floating-wind-turbines&Itemid=257

… Probabilistic Design

Reduce Safety Design Factor

… Utilize information

Optimize resources

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Conclusion

- **Decision support under uncertainty**
- Utilizing available DATA
- Engineering: Optimization of the resources!

*Contact me for more info ☺

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