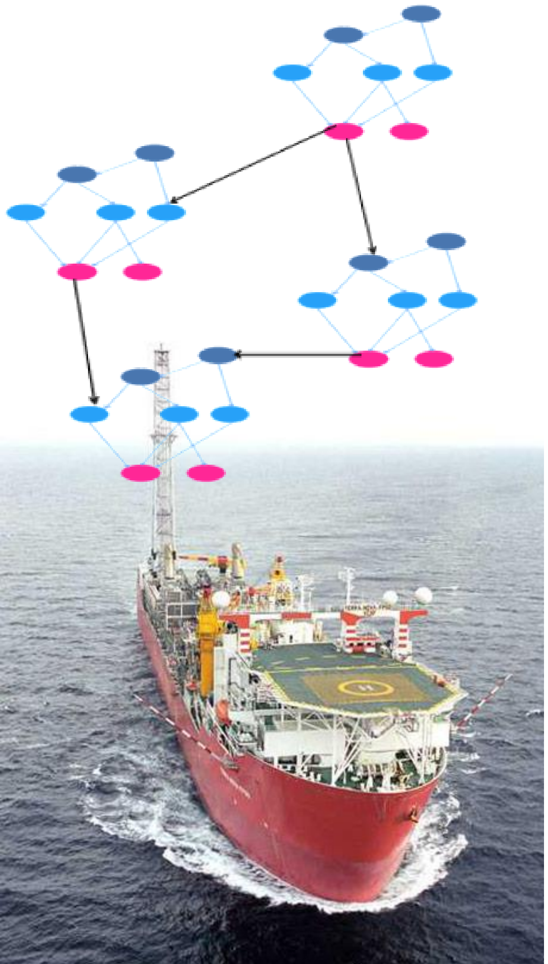
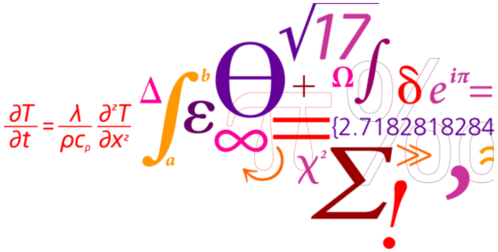
TUDelft, July 4, 2014



Benefits of RBI in Offshore and Marine Applications – Lessons Learnt



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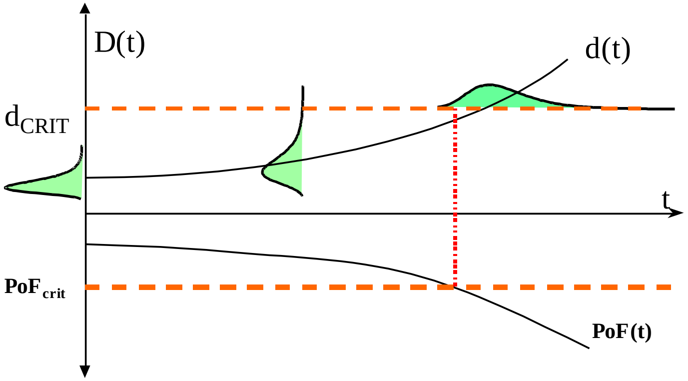
- **The idea behind RBI**
- **Typical applications – offshore and marine**
- **On the value of inspections**
- **Insights from practical experiences**
- **Outlook**

Motivation

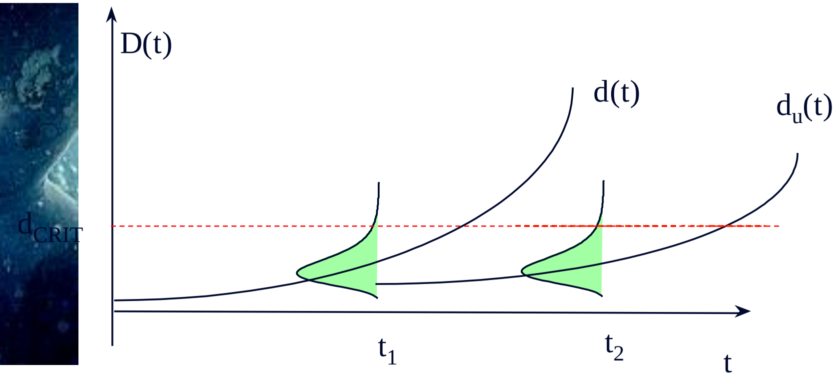
Why inspections and monitoring?



- Failure and inadequate performance of engineered facilities is generally associated with significant consequences
- Design assumptions for engineered facilities are rarely fulfilled during their operational life
- Deterioration processes such as fatigue and corrosion are associated with very significant uncertainties – hard to predict
- Knowledge about actual performance can be utilized to support optimal decisions on operation and maintenance

The Idea Behind RBI

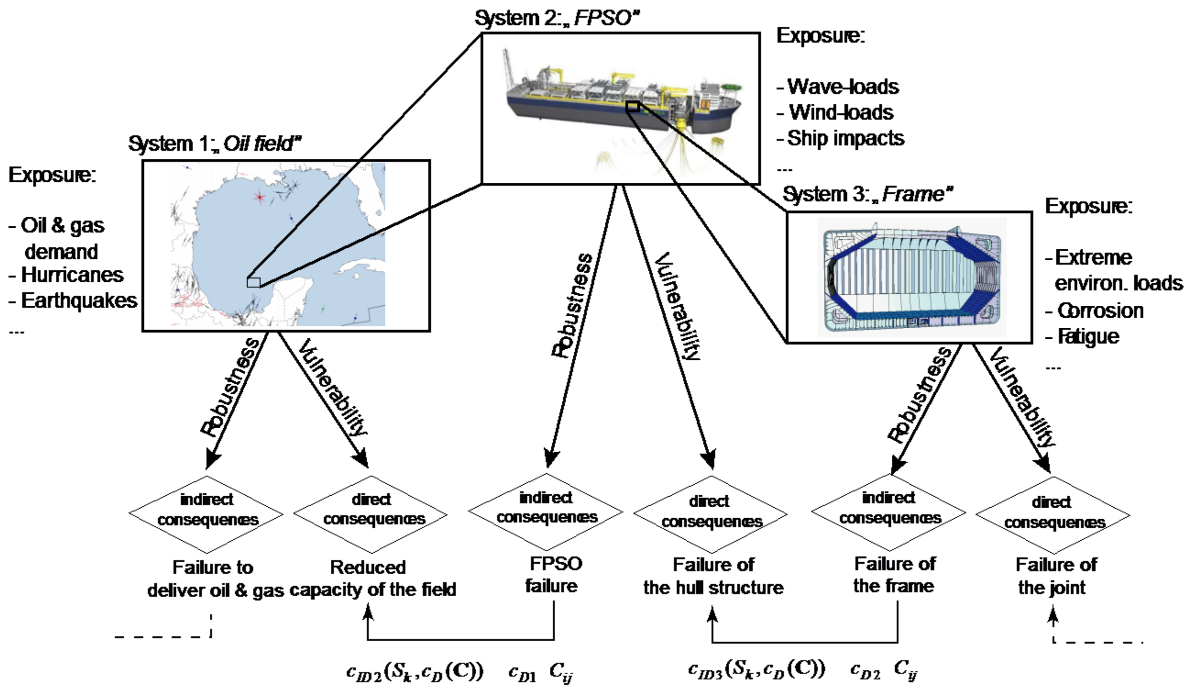
Using risk as a measure of the effect of AIM



- Fundamentally risk is the best knowledge available about the effect of decisions in the face of uncertainty
- Probabilistic risk assessment – utilizing Bayesian probability theory – facilitates consistent treatment of information collected through inspections and monitoring – Bayesian updating
- The Bayesian (pre-posterior) decision theory facilitates that the value (benefit) of information which has not yet been collected can be quantified

The Idea Behind RBI

Using risk as a measure of the effect of AIM



- The risk can be assessed at different scales depending on the decisions which are to be analyzed and ranked

The Idea Behind RBI

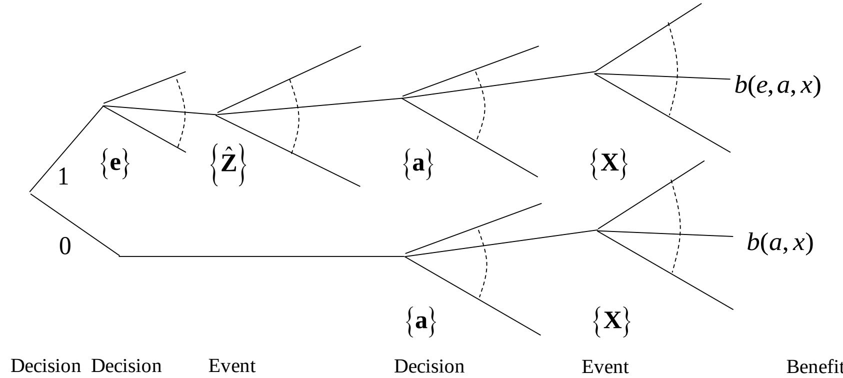
Basic principles to be appreciated

- 😐 A <u>performed inspection</u> does not in itself improve the safety of a structure
- ☺ It improves our estimate of the safety
- ☹ A <u>planned inspection</u> does not in itself improve the safety of a structure
- ☹ It does not improve our estimate of the safety

! To ensure the safety of a structure inspection planning should be performed in conjunction with the maintenance planning !

The Idea Behind RBI

Theoretical Framework



The value of inspections/monitoring may be quantified in accordance with the pre-posterior decision theory:

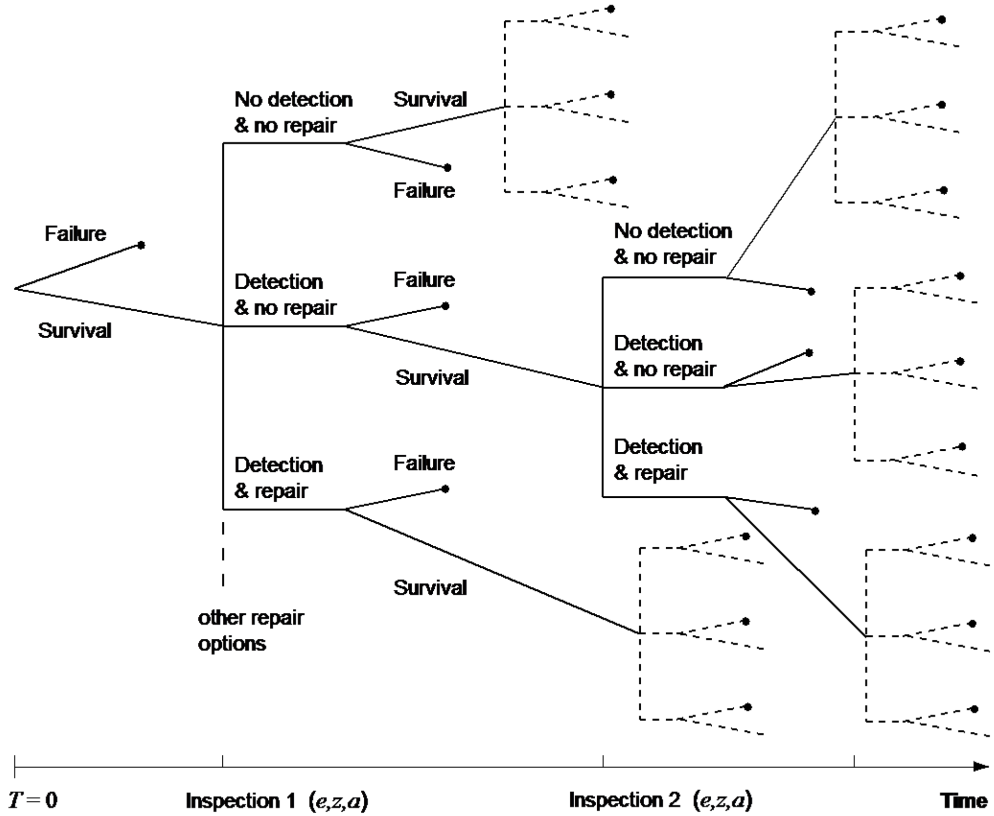
$$V = B_1 - B_0$$

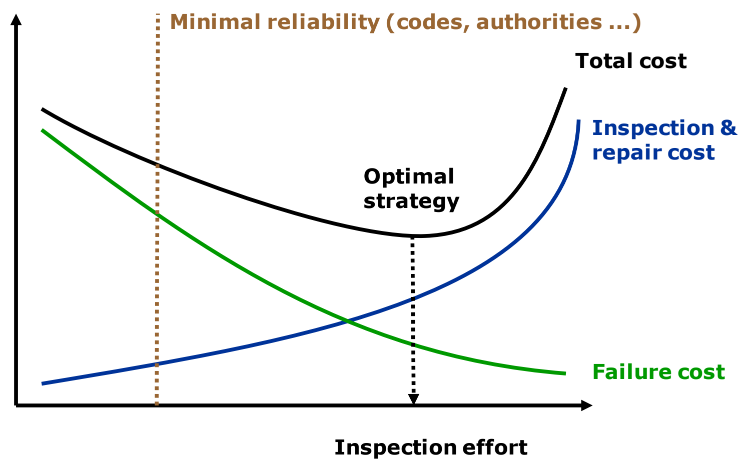
$$V = \max_{s} E_{\mathbf{Z}_E}\left[E_{\mathbf{Z}_A}\left[\max_{\mathbf{a}} E_{\mathbf{X}|\mathbf{Z}_E,\mathbf{Z}_A}\left[B(\mathbf{X}, \mathbf{z}_E, \mathbf{z}_A, s, d(\mathbf{a}, \mathbf{X})) \right] \right] \right] - E_{\mathbf{Z}_E}\left[E_{\mathbf{Z}_A}\left[B(\mathbf{Z}_E, \mathbf{Z}_A) \right] \right]$$

s: Monitoring strategy
X: Random variable representing uncertain monitoring results
$\mathbf{Z}_A$: Random variables representing aleatory uncertainties
$\mathbf{Z}_E$: Random variables representing epistemic uncertainties
d( ): Decision rule defining the adaptive action

The Idea Behind RBI

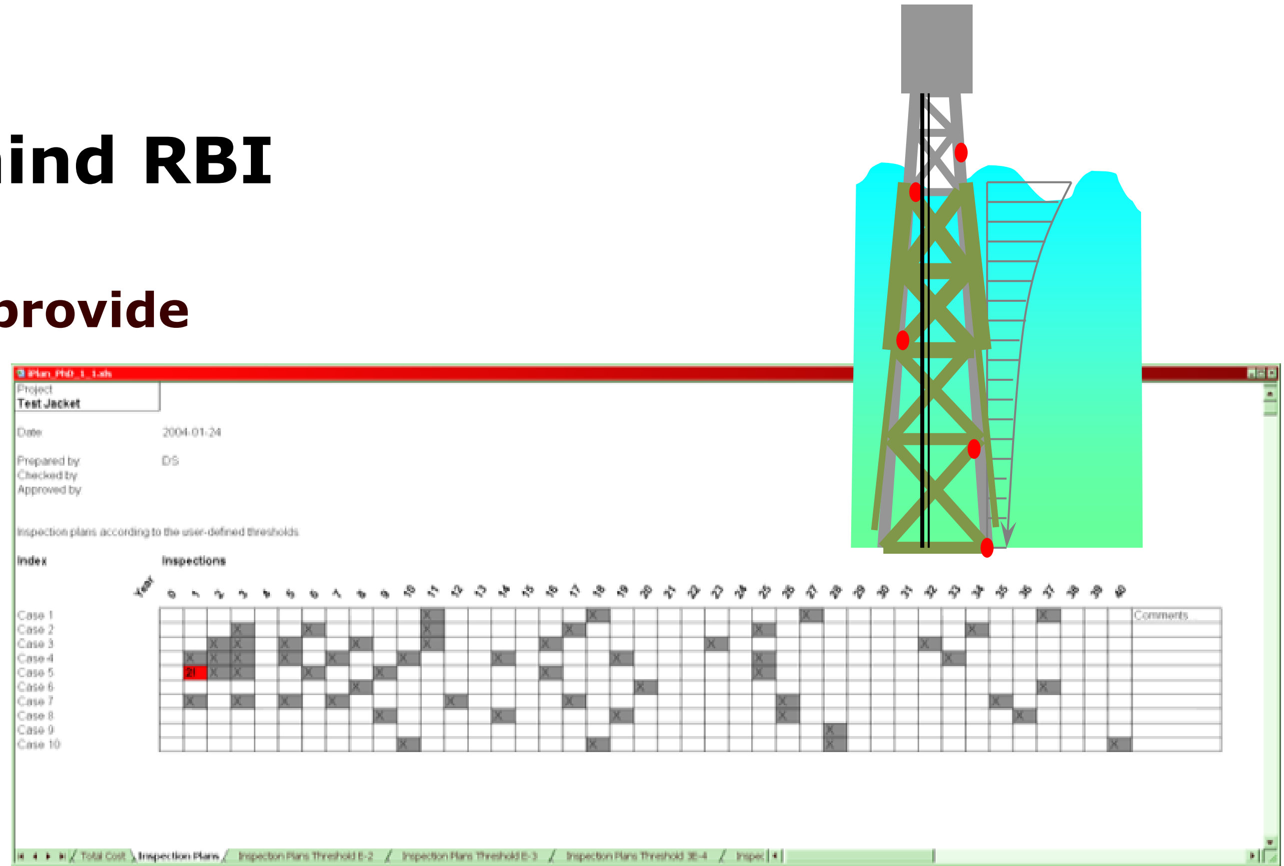
Systematic analysis of decision event trees





The Idea Behind RBI

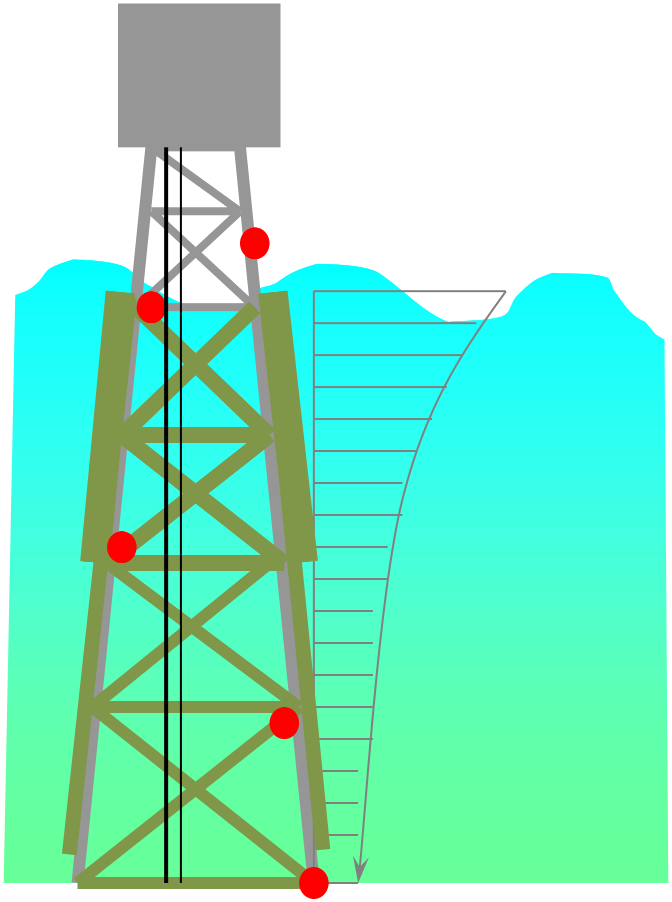
What can RBI provide



- What
- How
- Where
- When

to inspect/monitor

Typical Applications - Offshore and Marine



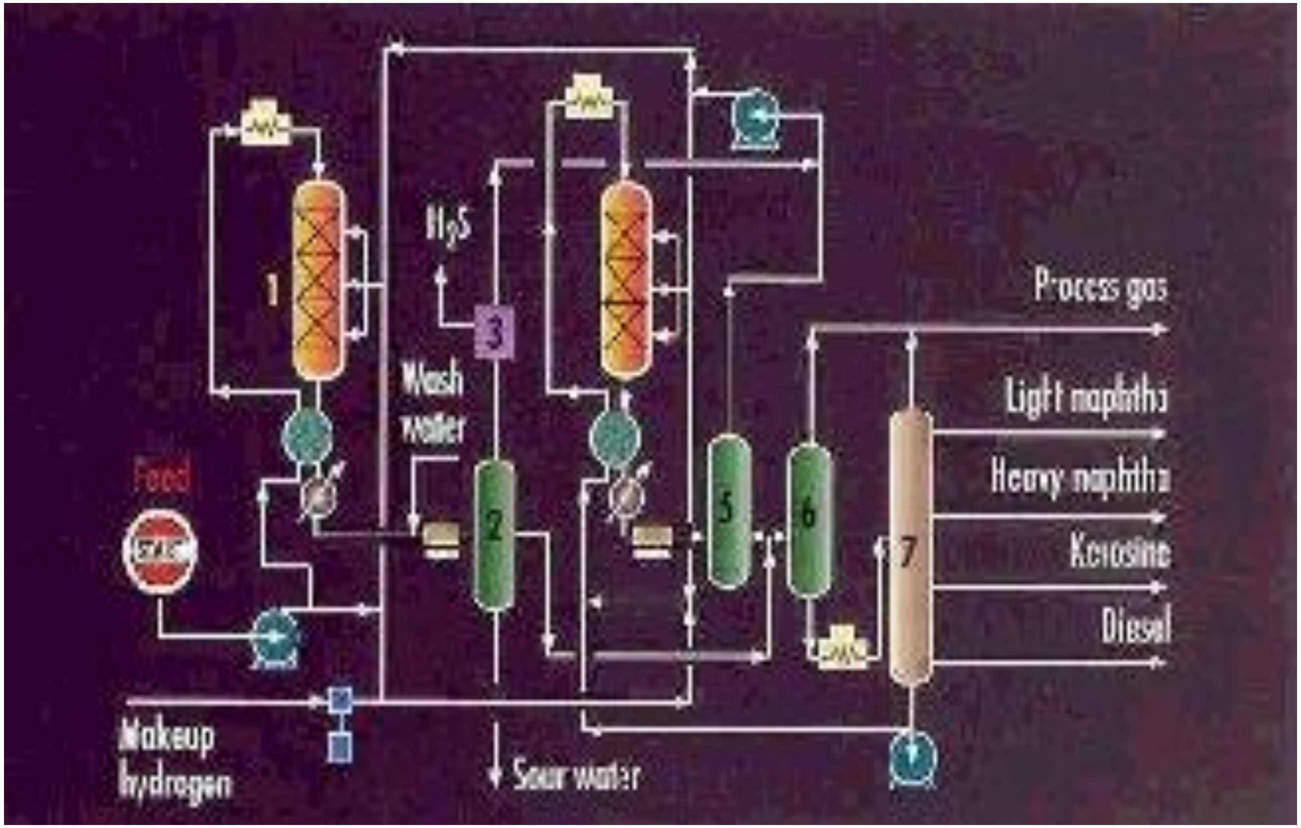
Jacket structures

Inspection Focus

- Fatigue
- Excessive Marine Fouling
- Scour
- Corrosion Protection
- Impact damages

Typical Applications - Offshore and Marine

Process Equipment

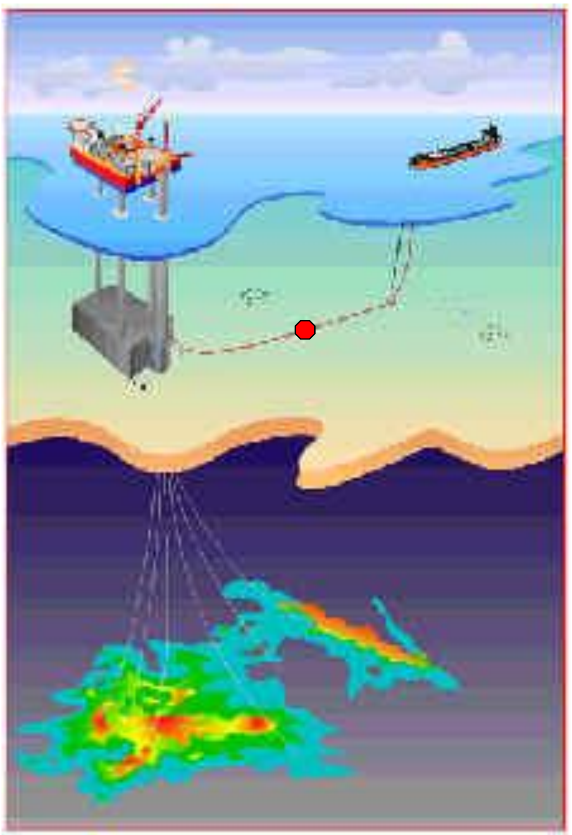


Inspection Focus

- ↑ Corrosion
- ↑ Erosion
- ↑ Fatigue

Typical Applications - Offshore and Marine

Pipelines



Inspection Focus

- Fatigue
- Scour (free span)
- Corrosion
- Impact damages/dropped objects

Typical Application of RBI

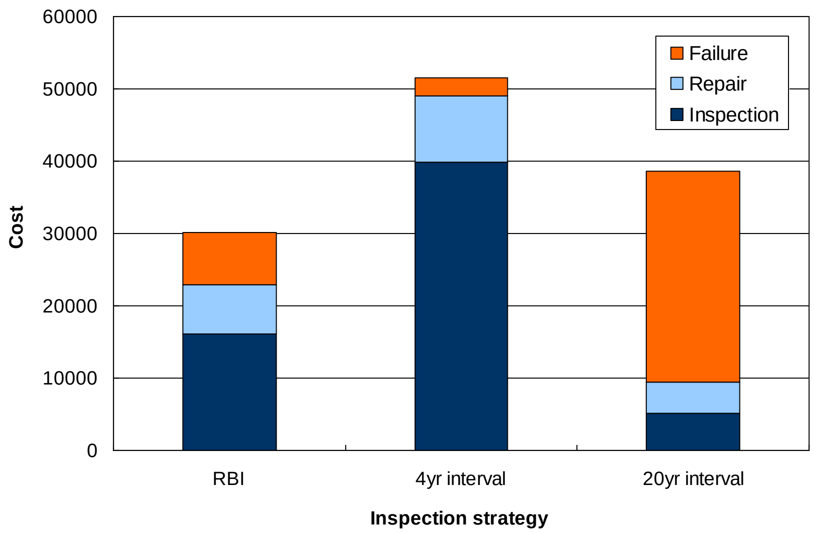
Experience on applied RBI – offshore and marine

- 100+ jacket structures in the Gulf of Mexico
- Xxx Mærsk Oil and Gas jackets in the Danish North Sea
- 15 jackets in the Gulf of Thailand
- 4 FSO/FPSO (Norway/Nigeria/Brazil)
- As basis for the design of FPSOs in the Mexican part of the Gulf of Mexico
- As basis for the design of semi-subs in the Mexican part of the Gulf of Mexico

On the Value of RBI

Quantifying the value of RBI

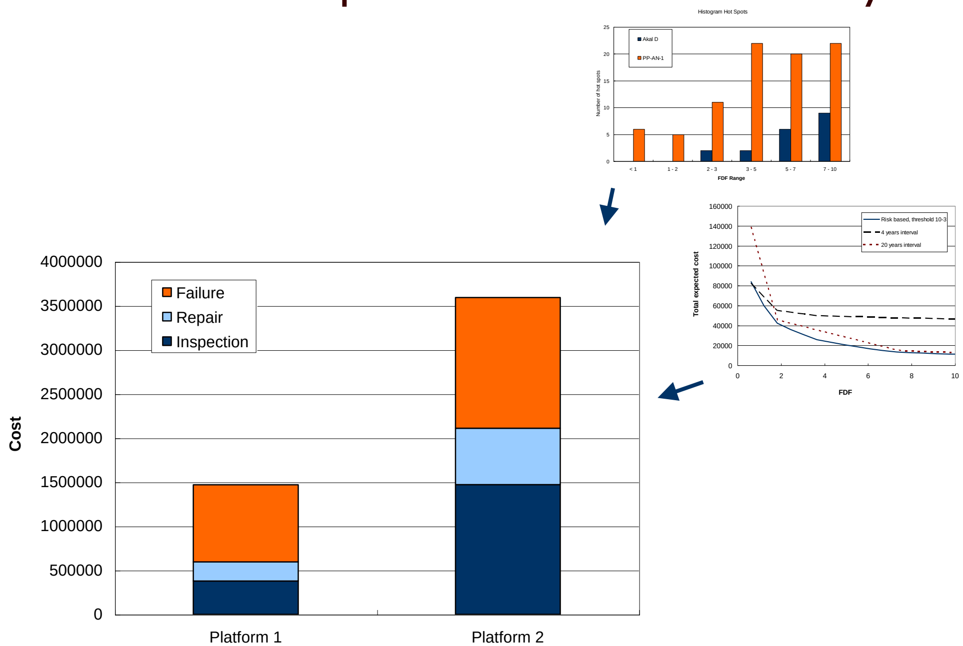
- A simple approach is to compare the expected value of the service life integrity management costs for a structural detail with given deterioration characteristics corresponding to different strategies

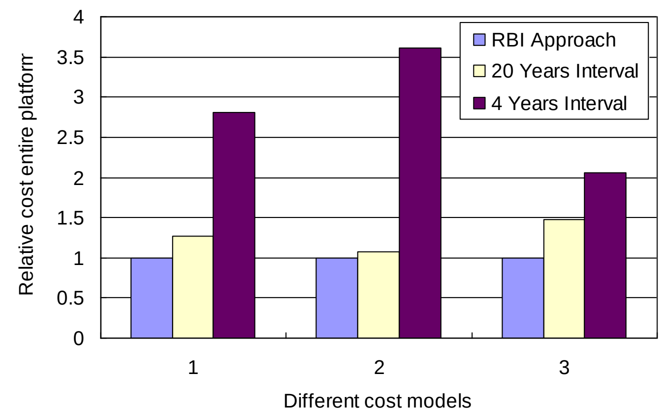


On the Value of RBI

Quantifying the value of RBI

- For an entre platform the risks may be aggregated

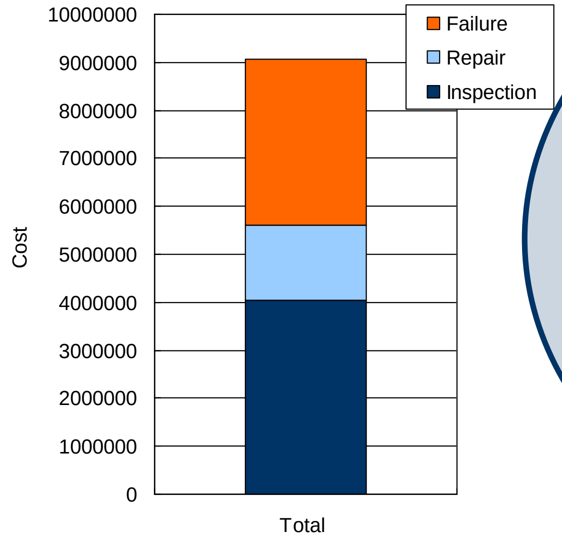


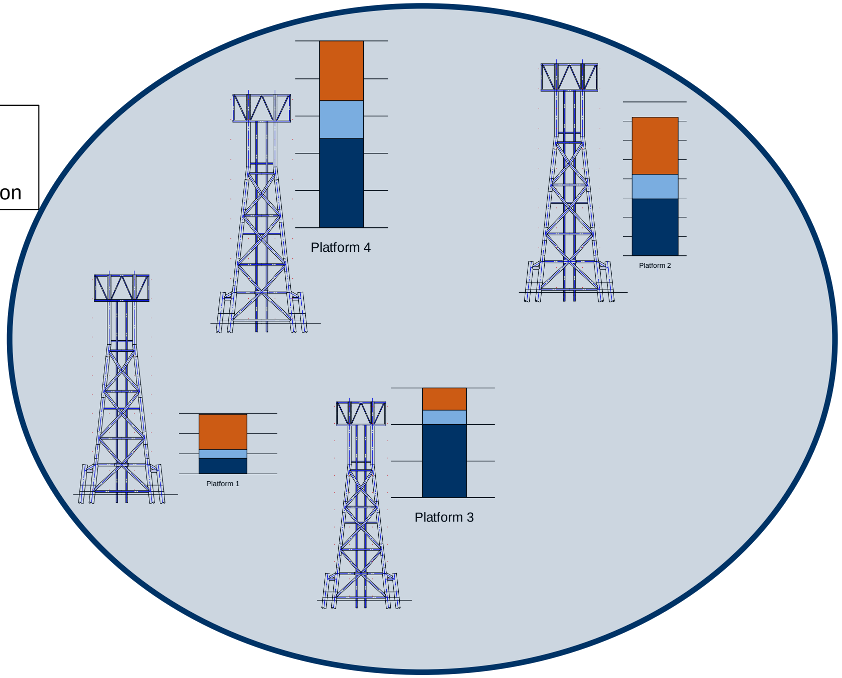


On the Value of RBI

Quantifying the value of RBI

- For a portfolio for structures the risk information facilitates budgeting





Insights Gained from Experience

Issues to be considered carefully

- The representation of the knowledge (uncertainty) concerning the performance of the structures/faclities must be undertaken with care:

  - deterioration processes
  - performance given damage
  - model uncertainties (time/space dependency representations)
  - inspection/monitoring uncertainty
  - modeling of effect of mainenance/repairs

Insights Gained from Experience

Barriers for practical applications

- Availability of adequate and simple tools which might be utilized by engineers without expert knowledge on probabilistic risk modelling and analysis

Outlook

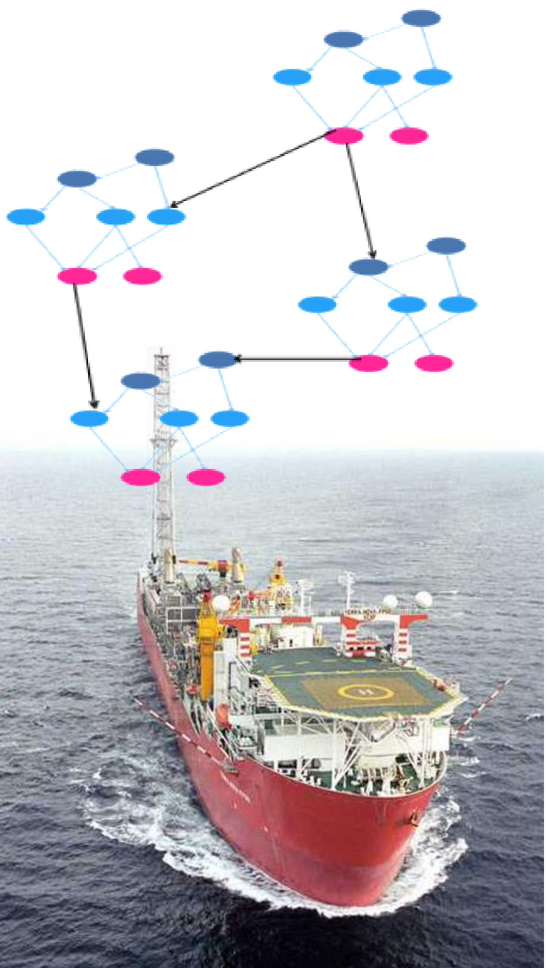
A New COST Action on the Value of Information in SHM

- The JCSS has been granted COST Action 1402 starting in November 2014

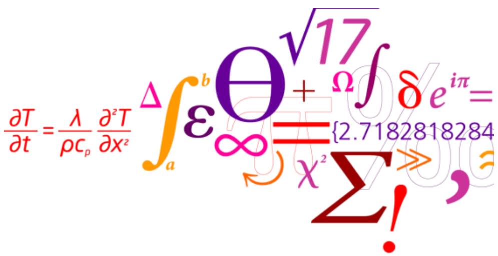
  Main purpose is to:

  - Develop, describe and apply the theoretical framework for the quantification of the value of SHM prior to its implementation for a range of typical structures and best practice optimal SMH techniques/strategies

  - Provide practical guideline for VoI of SHM across different classes of structures



Thanks for Your Attention ☺



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