INFRASTAR

Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

Quantification of the value of monitoring information for deteriorated structures

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I have a truss bridge girder, I don’t know how to design the structural health monitoring and maintenance plan. Can you help me?

Yes, of course , we can help!

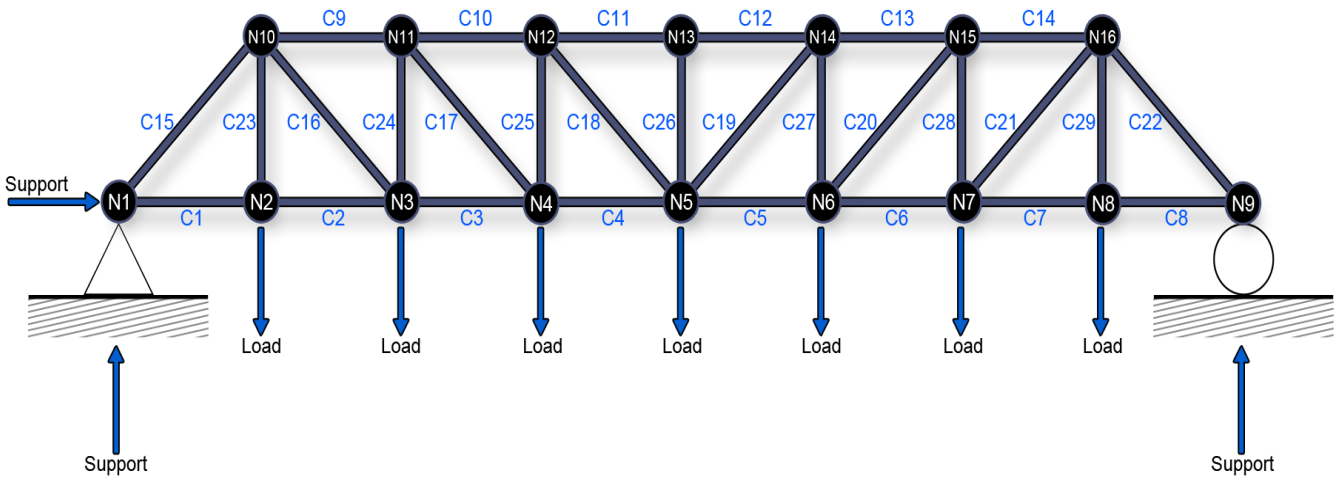
How will you help me?

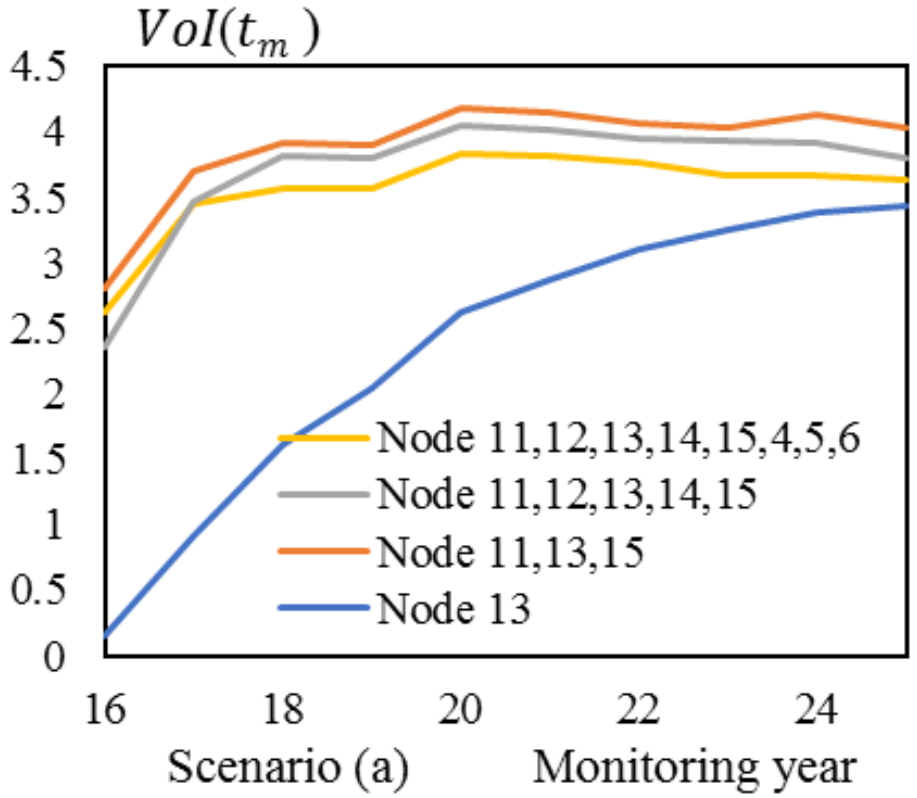
Let Your Investment Be Worthy

Quantification of the value of monitoring information for deteriorated structures!

- Develop efficient monitoring strategies for deteriorated structures.
- Quantification of their utility in terms of risk reduction, expected cost reduction and service life benefits for industrial application and for the value of society.

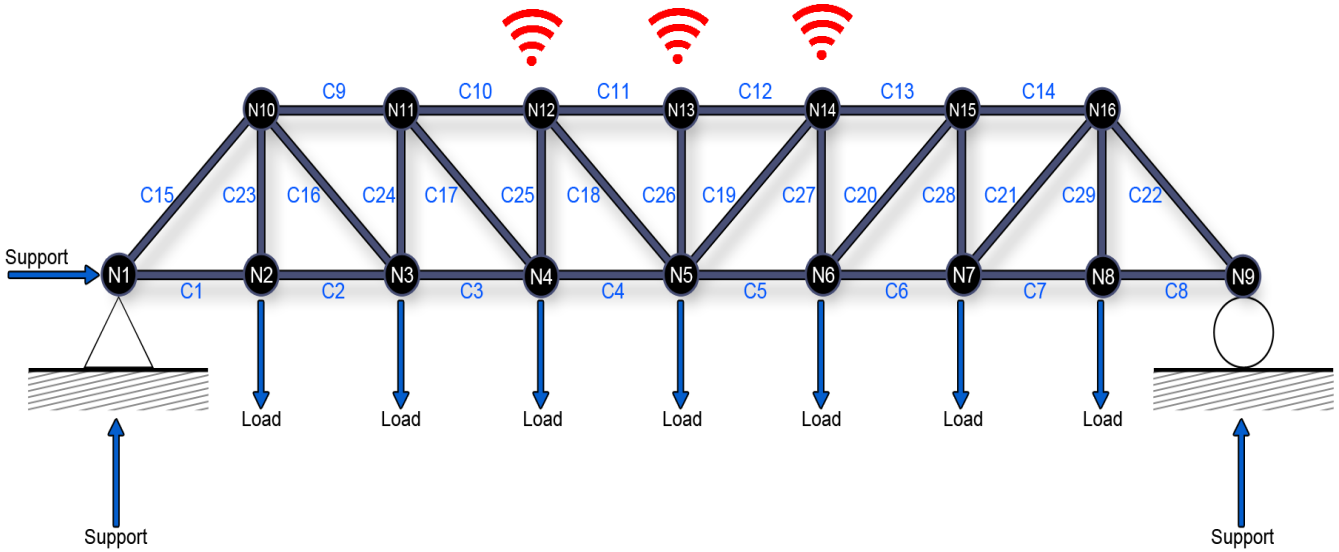
How many sensors should I install?

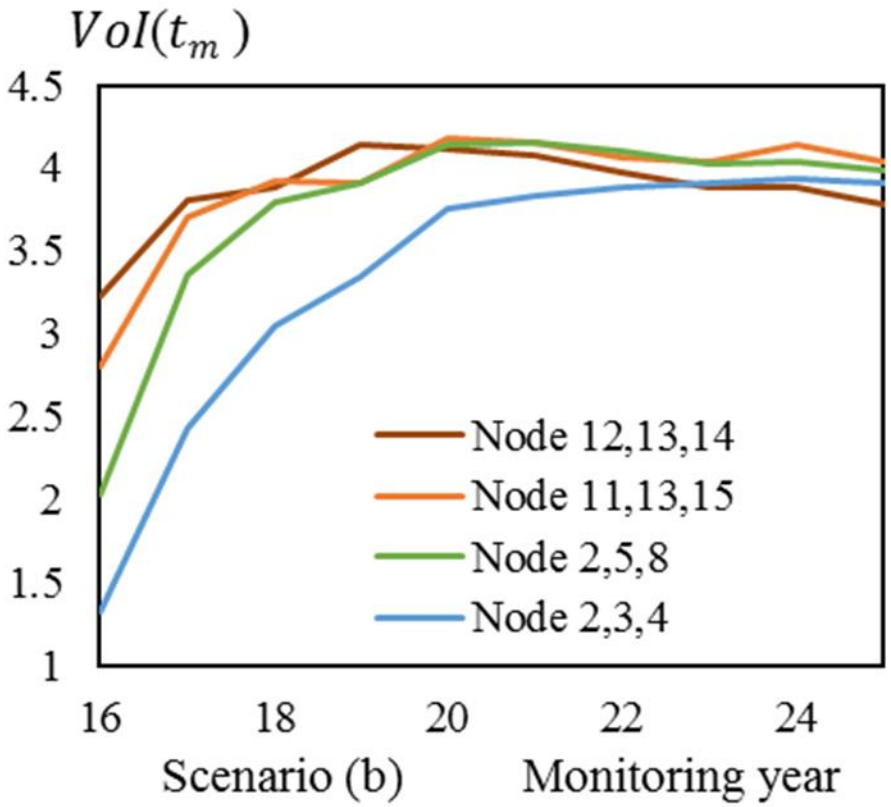




Through Value of information analysis, we recommend you to install three sensors.

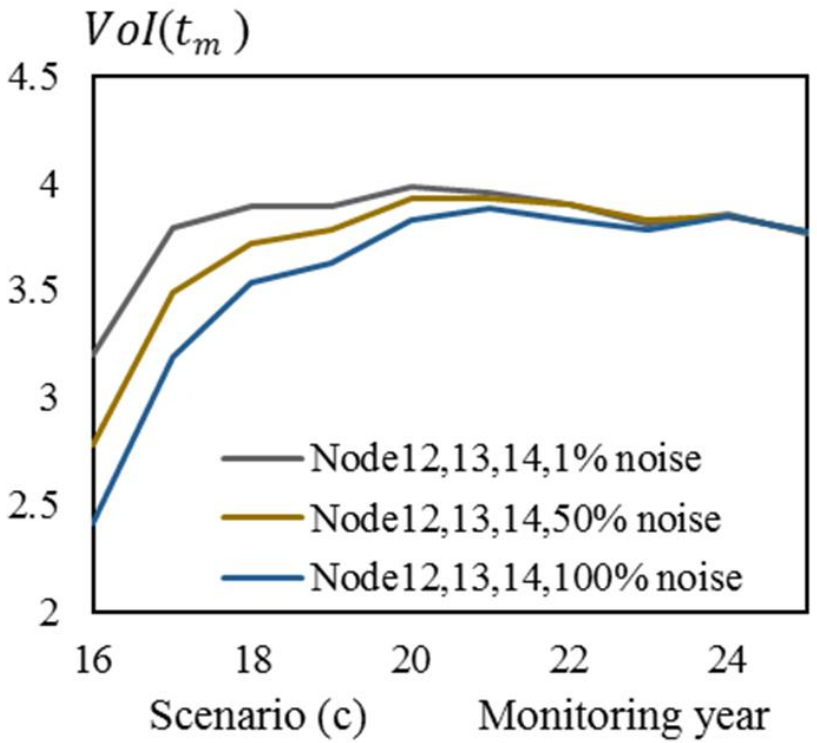
Where should I install the sensors?

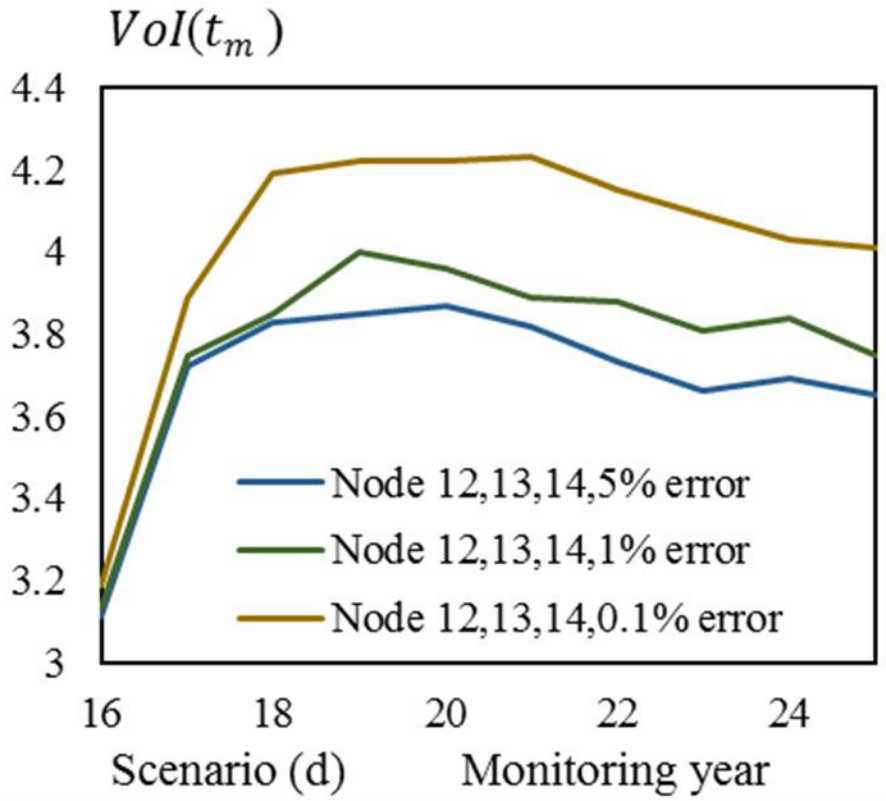




You should install the sensors in the middle.

I have many sensor providers, how to choose the best sensors?





You should choose sensors with measurement noise and type I error as low as possible.

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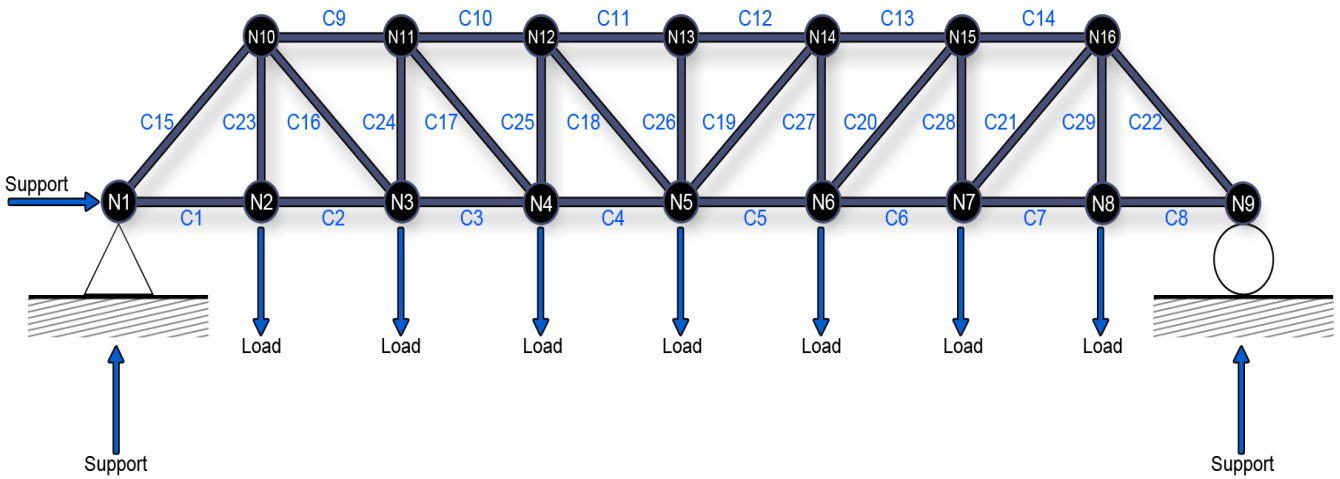
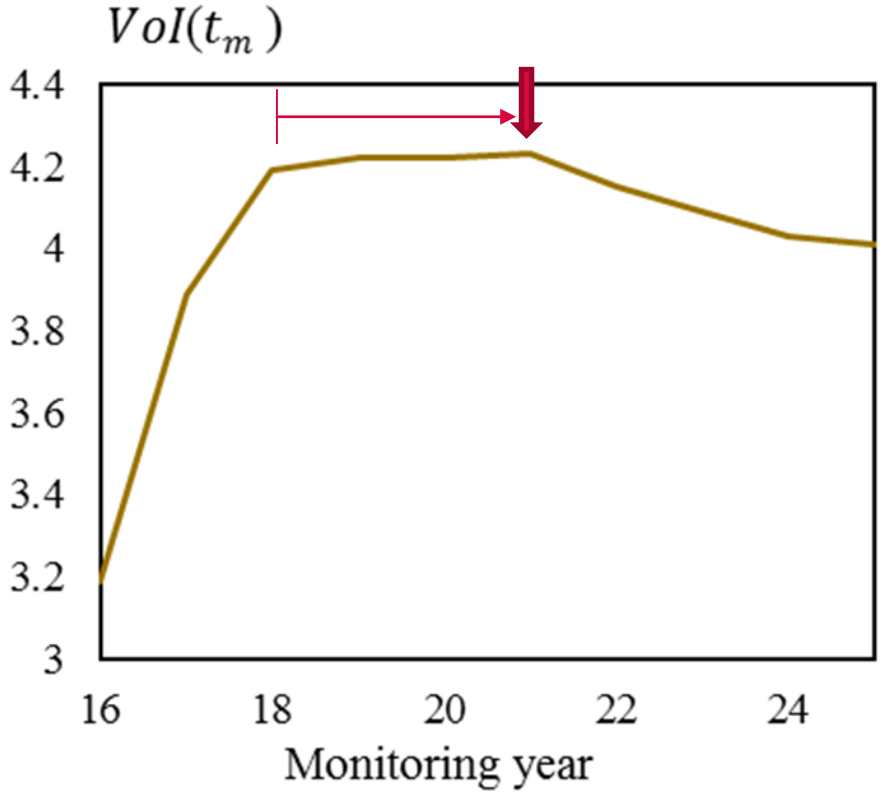
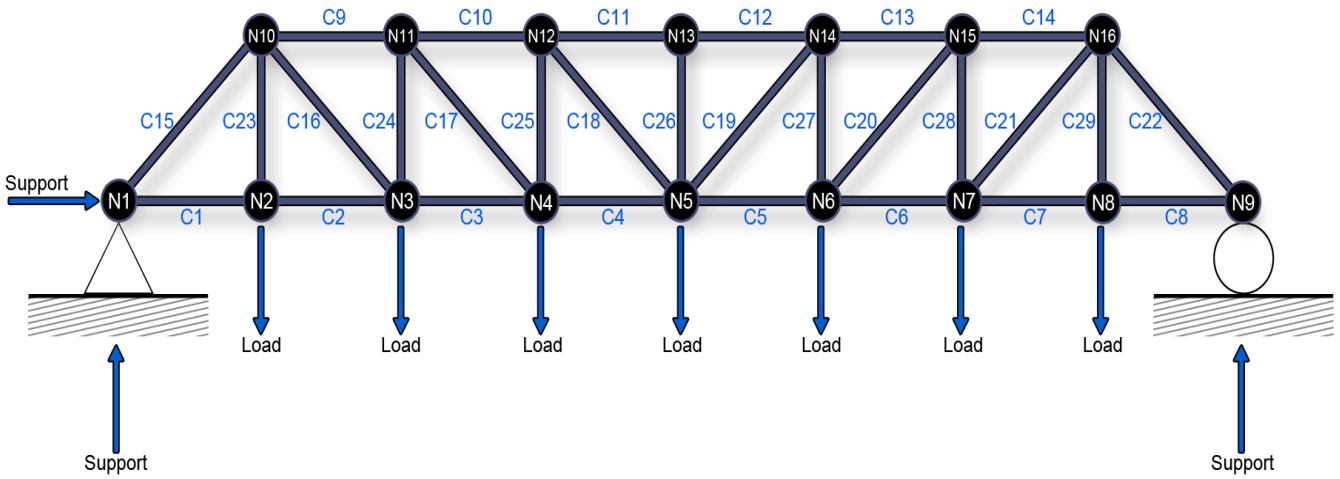
When should I do monitoring?

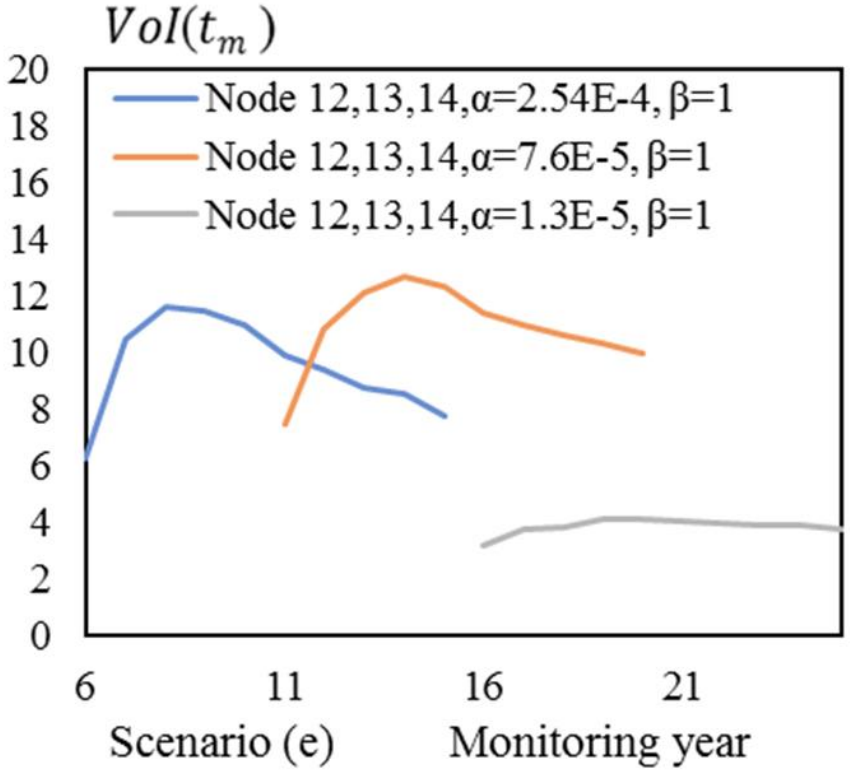




You should monitor at year 21 with the highest VoI, but with flexible employment year from 18 to 21.

I have other truss girders abroad under different deterioration environment, does the same monitoring strategy apply ?

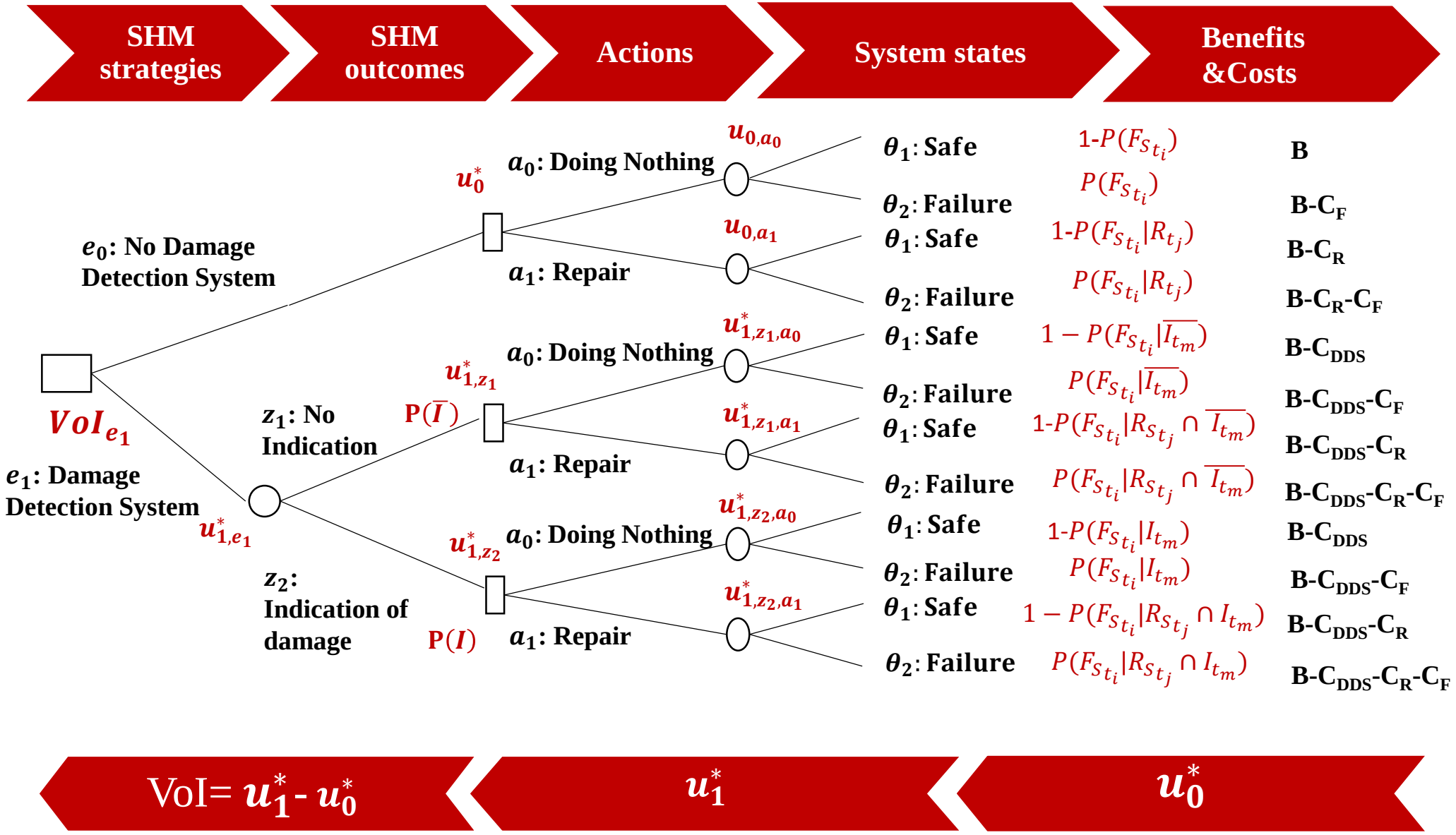




No, you should do monitoring earlier if the deterioration is higher.

How to do Value of information analysis?

That’s a secret ☺


SHM strategies
SHM outcomes
Actions
System states
Benefits &Costs
u_{0,a_0}
u_0^*
a_0: Doing Nothing
θ_1: Safe
1-$P(F_{S_{t_i}})$
B
θ_2: Failure
$P(F_{S_{t_i}})$
B-C_F
u_{0,a_1}
e_0: No Damage Detection System
a_1: Repair
θ_1: Safe
1-$P(F_{S_{t_i}}|R_{t_j})$
B-C_R
θ_2: Failure
$P(F_{S_{t_i}}|R_{t_j})$
B-C_R-C_F
u^*_{1,z_1,a_0}
θ_1: Safe
$1-P(F_{S_{t_i}}|\overline{I_{t_m}})$
B-C_{DDS}
a_0: Doing Nothing
u^*_{1,z_1}
θ_2: Failure
$P(F_{S_{t_i}}|\overline{I_{t_m}})$
B-C_{DDS}-C_F
u^*_{1,z_1,a_1}
θ_1: Safe
1-$P(F_{S_{t_i}}|R_{S_{t_j}} \cap \overline{I_{t_m}})$
B-C_{DDS}-C_R
VoI_{e_1}
z_1: No Indication
P($\bar{I}$)
a_1: Repair
θ_2: Failure
$P(F_{S_{t_i}}|R_{S_{t_j}} \cap \overline{I_{t_m}})$
B-C_{DDS}-C_R-C_F
e_1: Damage Detection System
u^*_{1,e_1}
u^*_{1,z_2,a_0}
θ_1: Safe
1-$P(F_{S_{t_i}}|I_{t_m})$
B-C_{DDS}
u^*_{1,z_2}
a_0: Doing Nothing
θ_2: Failure
$P(F_{S_{t_i}}|I_{t_m})$
B-C_{DDS}-C_F
z_2: Indication of damage
P(I)
u^*_{1,z_2,a_1}
θ_1: Safe
$1-P(F_{S_{t_i}}|R_{S_{t_j}} \cap I_{t_m})$
B-C_{DDS}-C_R
a_1: Repair
θ_2: Failure
$P(F_{S_{t_i}}|R_{S_{t_j}} \cap I_{t_m})$
B-C_{DDS}-C_R-C_F
VoI= u_1^*- u_0^*
u_1^*
u_0^*

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Have you done any other field case studies?

Case study on wind turbine along the highway under ice condition

Case study in COWI on Great Belt Bridge in Denmark

Case study on Crêt de l'Anneau Viaduct in Switzerland

EPFL

COWI

AALBORG UNIVERSITY
DENMARK

LIÈGE université

Case study on offshore windturbine

Thank you for your attention

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Stay tuned http://infrastar.eu

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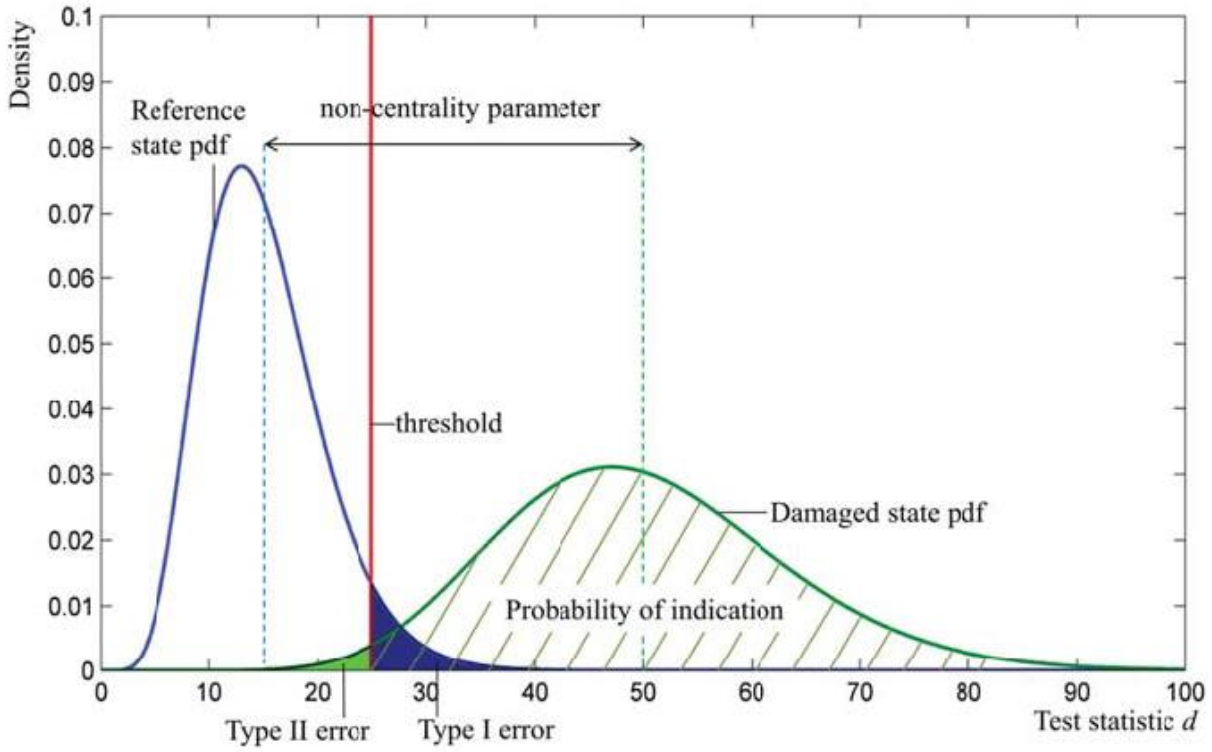
STEP2: Damage Detection System (DDS)

- **A subspace-based test statistic is computed to detect changes (stiffness loss) in vibration measurements**



- Reference state
  Central χ^2 distribution
- Damaged state
  Non-central χ^2 distribution
- Threshold
  Below- healthy
  Above-damaged
- Model-based computation of probabilities of indication for any damage state

Döhler, M., L. Mevel, and F. Hille, *Subspace-based damage detection under changes in the ambient excitation statistics*. Mechanical Systems and Signal Processing, 2014. **45**(1):207-224.

Utility calculation

$$u_0 = \max[u_{0|a_0}, u_{0|a_1}] \qquad u_i = \max[u_{i|a_0}, u_{i|a_1}] \qquad VoI = u_i - u_0$$

$$u_{0|a_0} = \sum_{t=1}^{T_{SL|a_0}} (1 - P(F))B\frac{1}{(1+\gamma)^t} - \sum_{t=1}^{T_{SL|a_0}} P(F)C_F\frac{1}{(1+\gamma)^t} - \sum_{n=1}^{Na_0} C_R$$

$$u_{0|a_1} = \sum_{t=1}^{T_{SL|a_1}} (1 - P(F))B\frac{1}{(1+\gamma)^t} - \sum_{t=1}^{T_{SL|a_1}} P(F)C_F\frac{1}{(1+\gamma)^t} - \sum_{n=1}^{Na_1} C_R$$

$$u_{i|a_0} = \sum_{t=1}^{T_{SL|a_0}} \left(1 - P\left(F|M_{e_i}\right)\right)B\frac{1}{(1+\gamma)^t} - \sum_{t=1}^{T_{SL|a_0}} P\left(F|M_{e_i}\right)C_F\frac{1}{(1+\gamma)^t} - \sum_{n=1}^{N_i} C_M - \sum_{n=1}^{Na_0} C_R$$

$$u_{i|a_1} = \sum_{t=1}^{T_{SL|a_1}} \left(1 - P\left(F|M_{e_i}\right)\right)B\frac{1}{(1+\gamma)^t} - \sum_{t=1}^{T_{SL|a_1}} P\left(F|M_{e_i}\right)C_F\frac{1}{(1+\gamma)^t} - \sum_{n=1}^{N_i} C_M - \sum_{n=1}^{Na_1} C_R$$