The predictability of corrosion

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Corrosion cannot be stopped

Can we extend the lifetime of this car?

Preventive maintenance

When should that maintenance be planned?

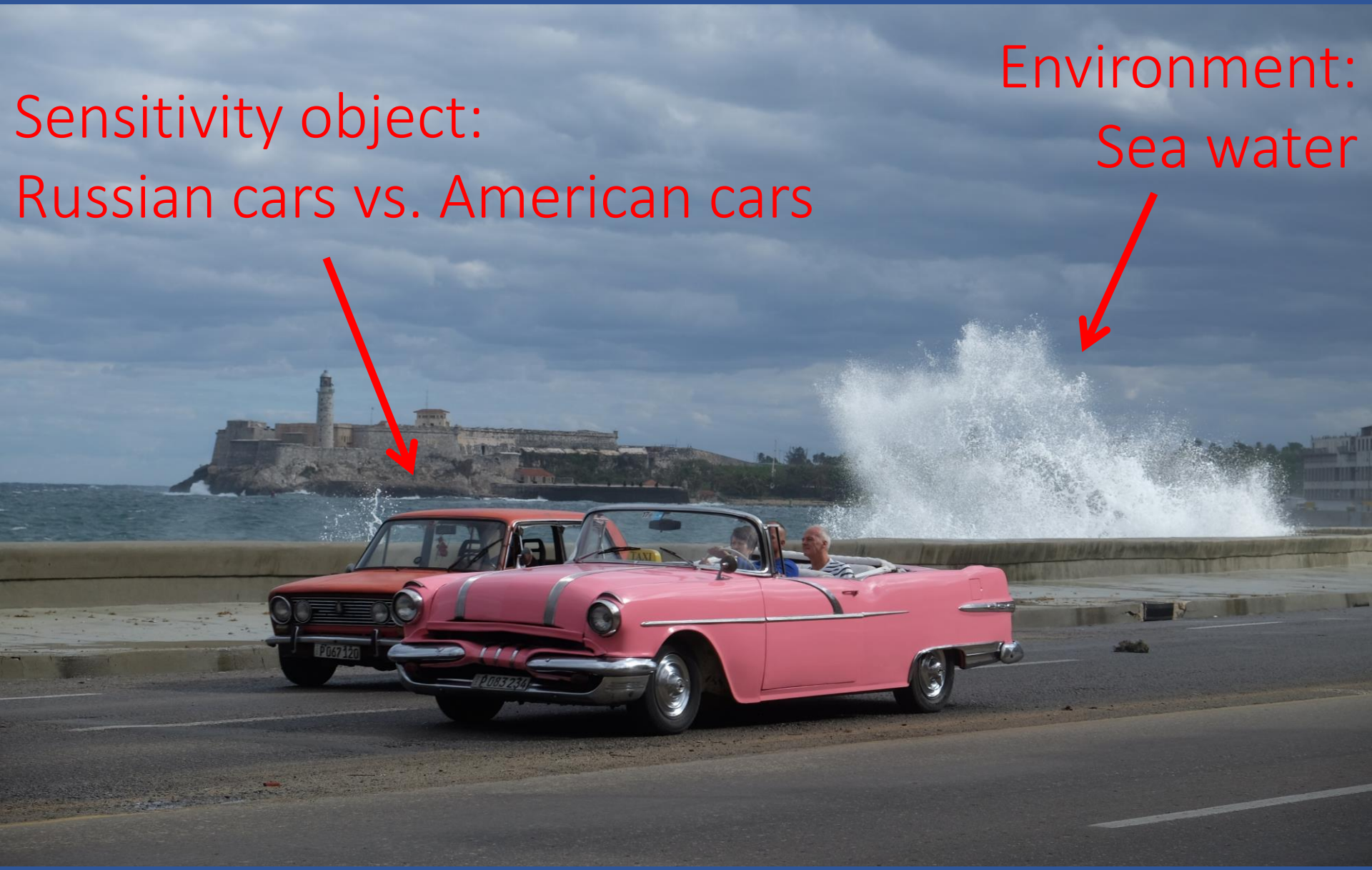
Solution: Protective coatings

Not all zones of the protective coating have the same efficiency

Solution: Change the environment

Some environments can be made less corrosive

Problem: Corrosion rate depends on many factors



Sensitivity of objects & corrosivity of environment is variable

Problem: How to predict corrosivity of environment?

Is our current knowledge sufficient?

Alternative approach to estimate corrosion risk

Degradation of materials
- Reduction of performance
- Reduction of reliability
- Reduction of lifespan

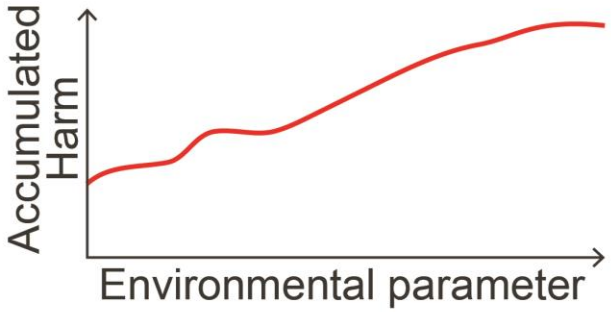
INPUT

Hazard: Continuous exposure to environmental parameters

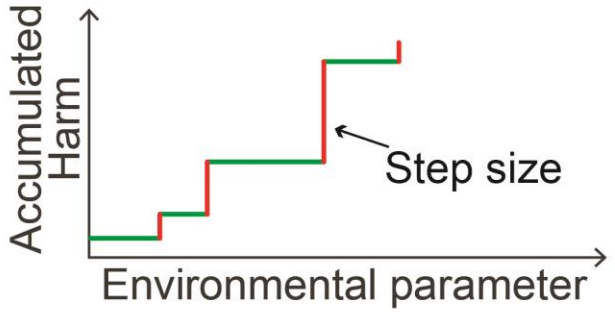
Hazard: Exposure to a series of undesired situations

OUTPUT

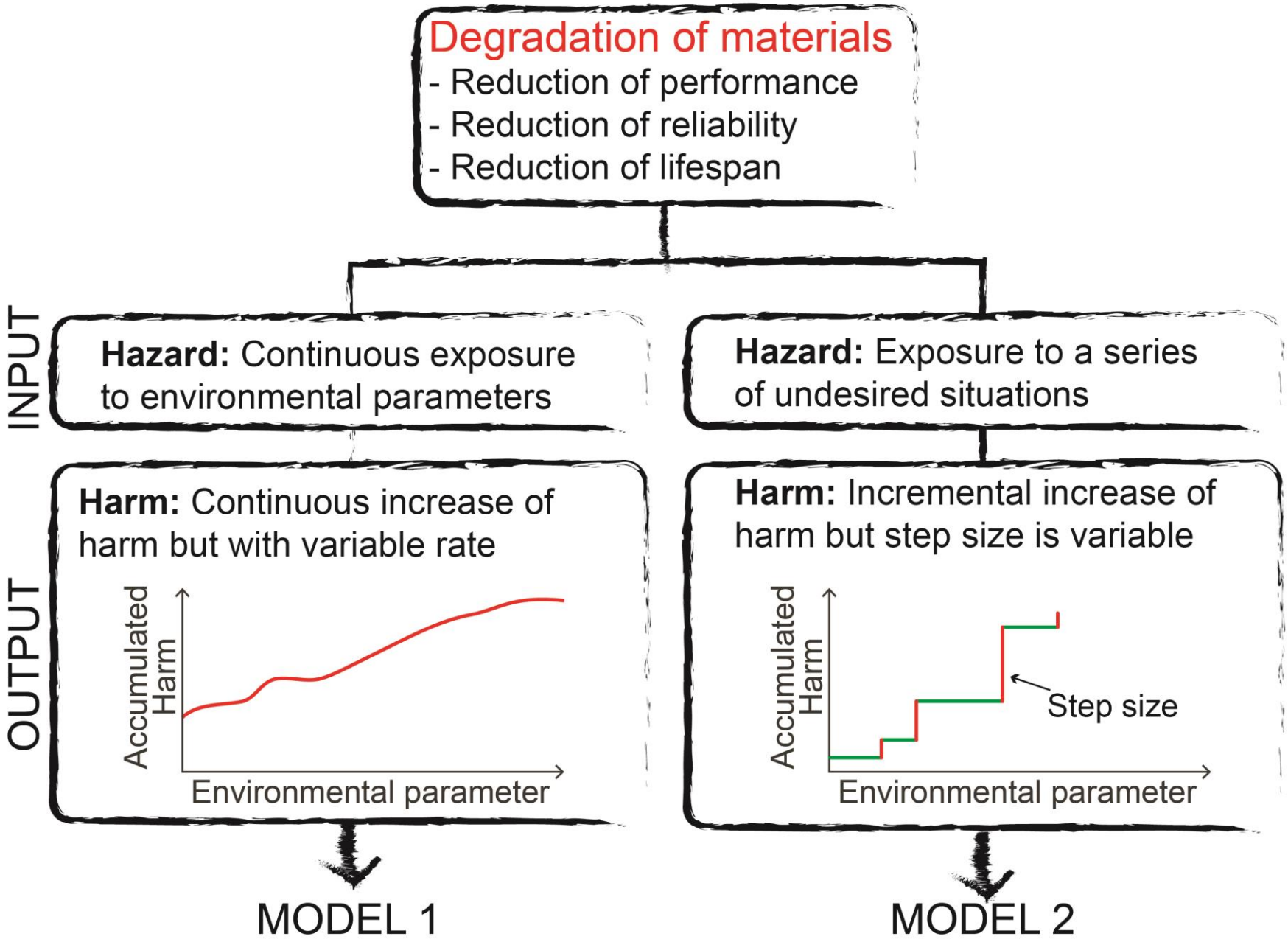
Harm: Continuous increase of harm but with variable rate



Harm: Incremental increase of harm but step size is variable



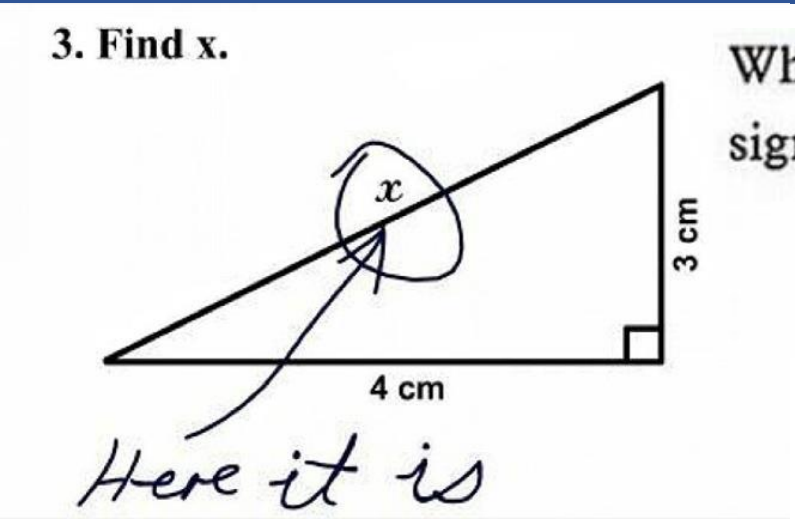
Alternative approach to estimate corrosion risk

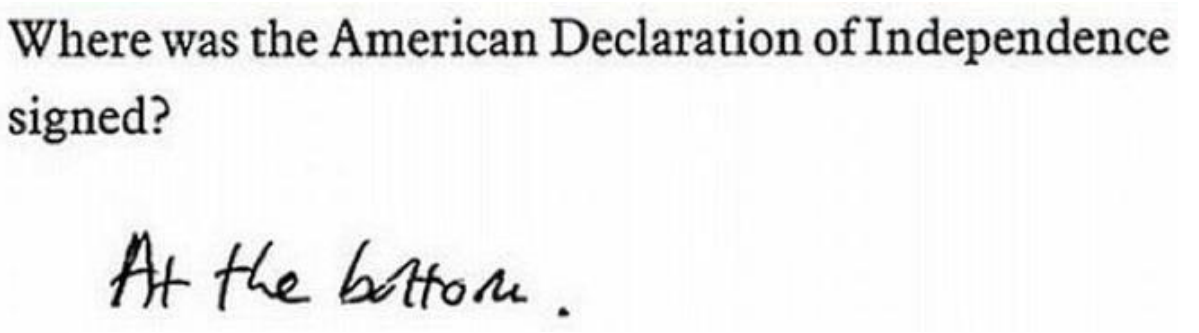


Model 1

Estimate corrosion risk from environmental parameters

Model: Ask experts





1. According to your expertise, what is the highest quantity of a given parameter at which there is no observable corrosion, faintly observable corrosion, or corrosion at an acceptable low rate?

2. According to your expertise, what is the lowest quantity of a given parameter at which the corrosion rate is unacceptable high?

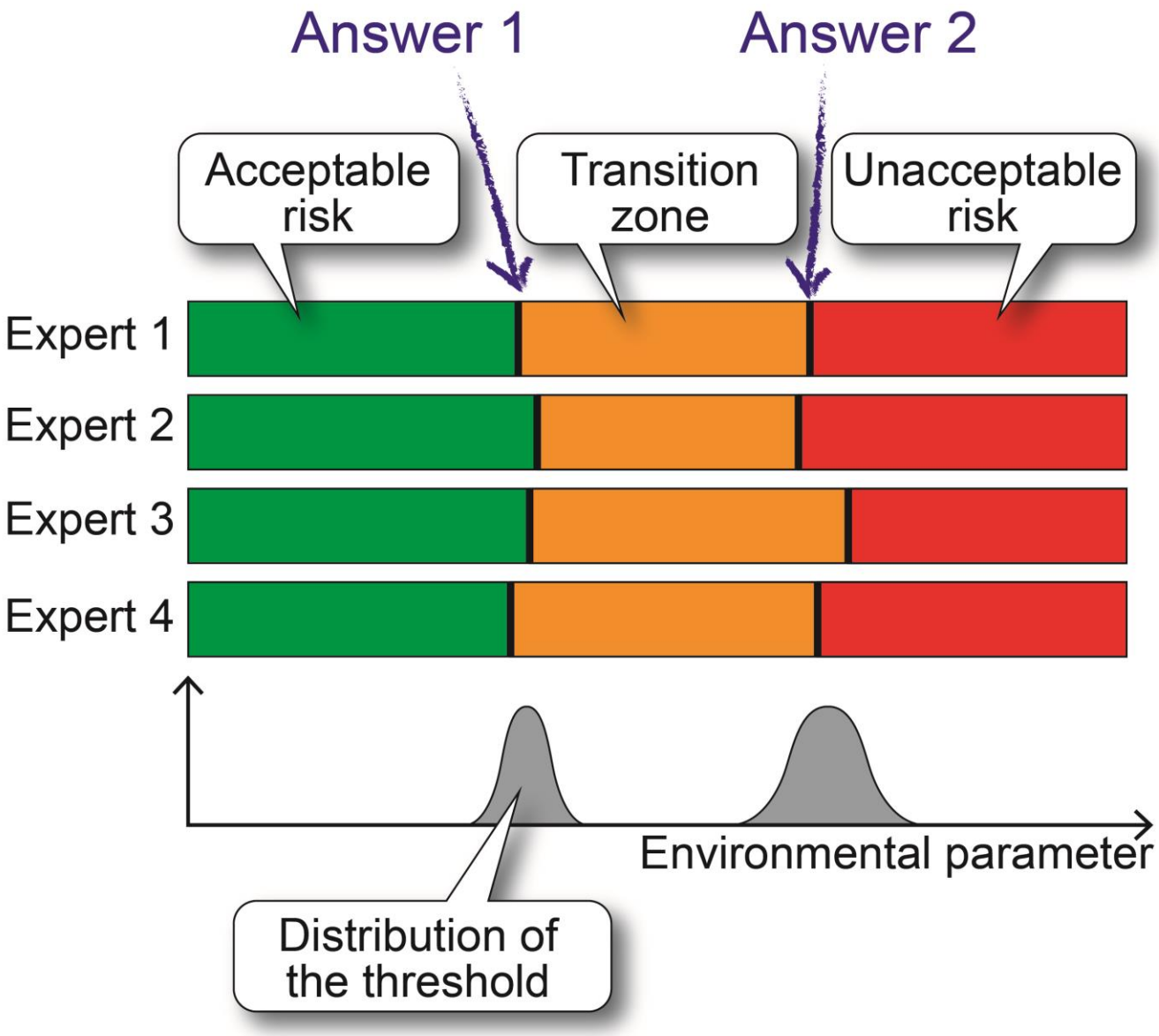
You might think that the questions as not very scientific

Model: No unique answers due to uncertainty

- Meaning of questions is not completely clear
- Expert has insufficient knowledge to give an exact answer
- Knowledge from laboratory experiments is not valid in the real world
- Differences in material sensitivity between similar objects
- Synergetic effects between parameters vary when parameters change
- Experts do not see themselves as experts and refuse to answer the question
- Experts endure cognitive biases

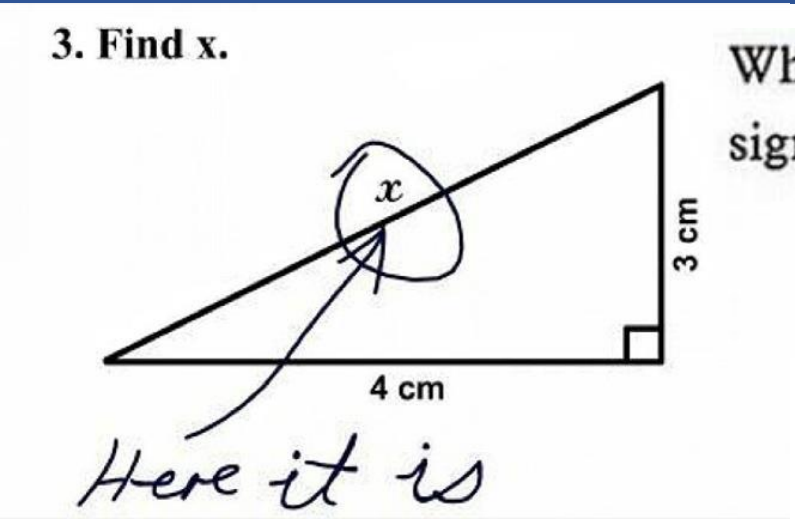
Given the current knowledge, we cannot do better

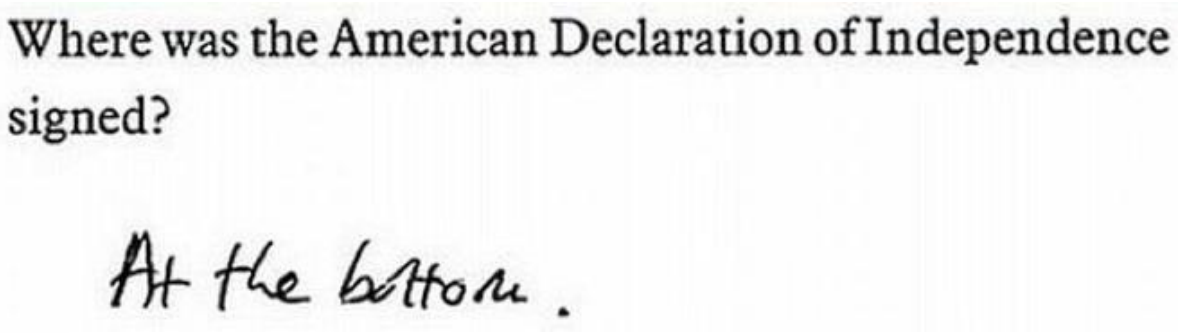
Model: Bring the answers of experts together



Use expert intuition to create a quantitative model

Hypothetical example: Collect all the answers





1. According to your expertise, what is the highest quantity of a given parameter at which there is no observable corrosion, faintly observable corrosion, or corrosion at an acceptable rate?

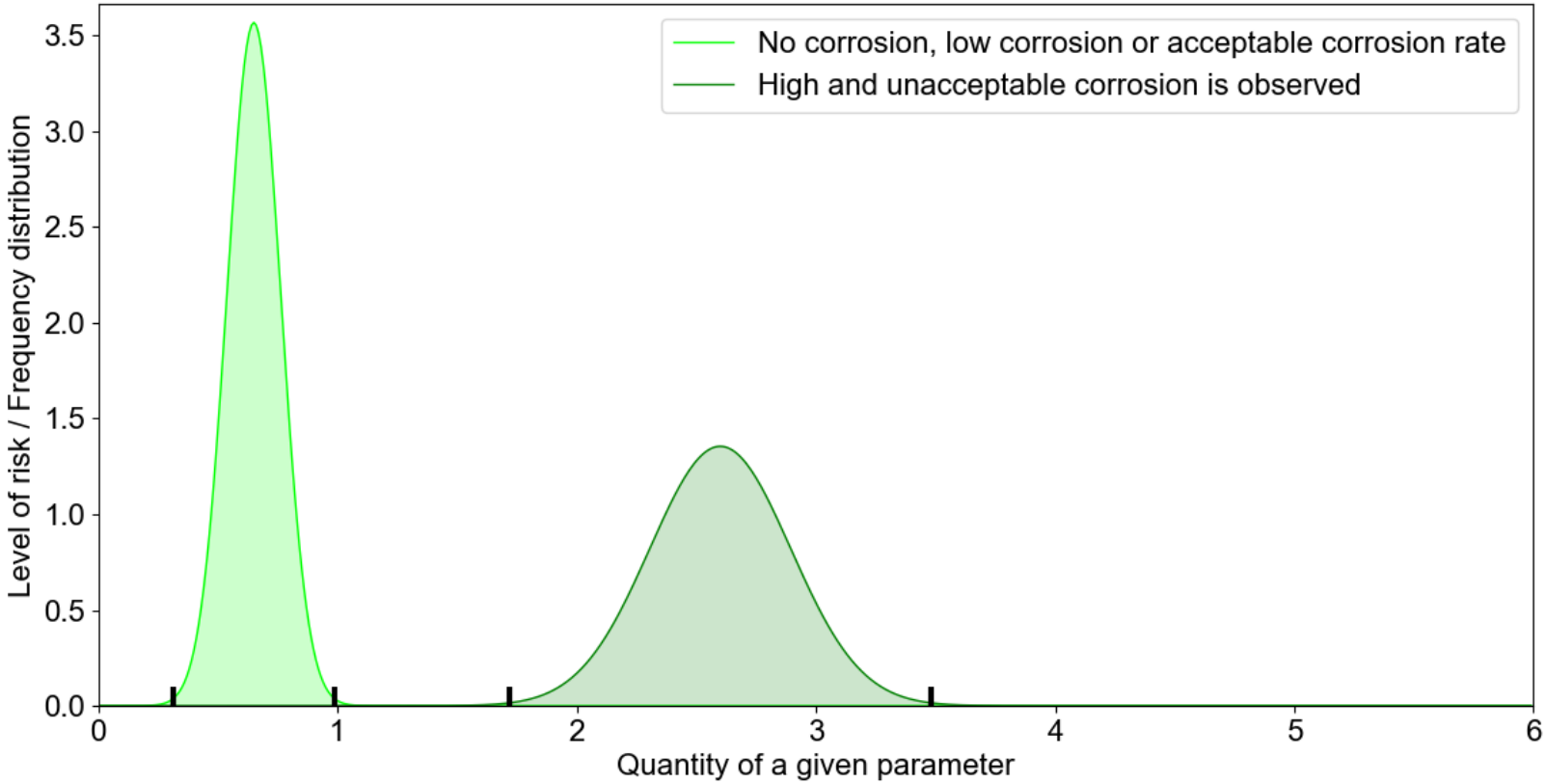
   Answers: 0.5, 0.6, 0,7, 0,8

2. According to your expertise, what is the lowest quantity of a given parameter at which the corrosion rate is unacceptable high?

   Answers: 2.3, 2.5, 3

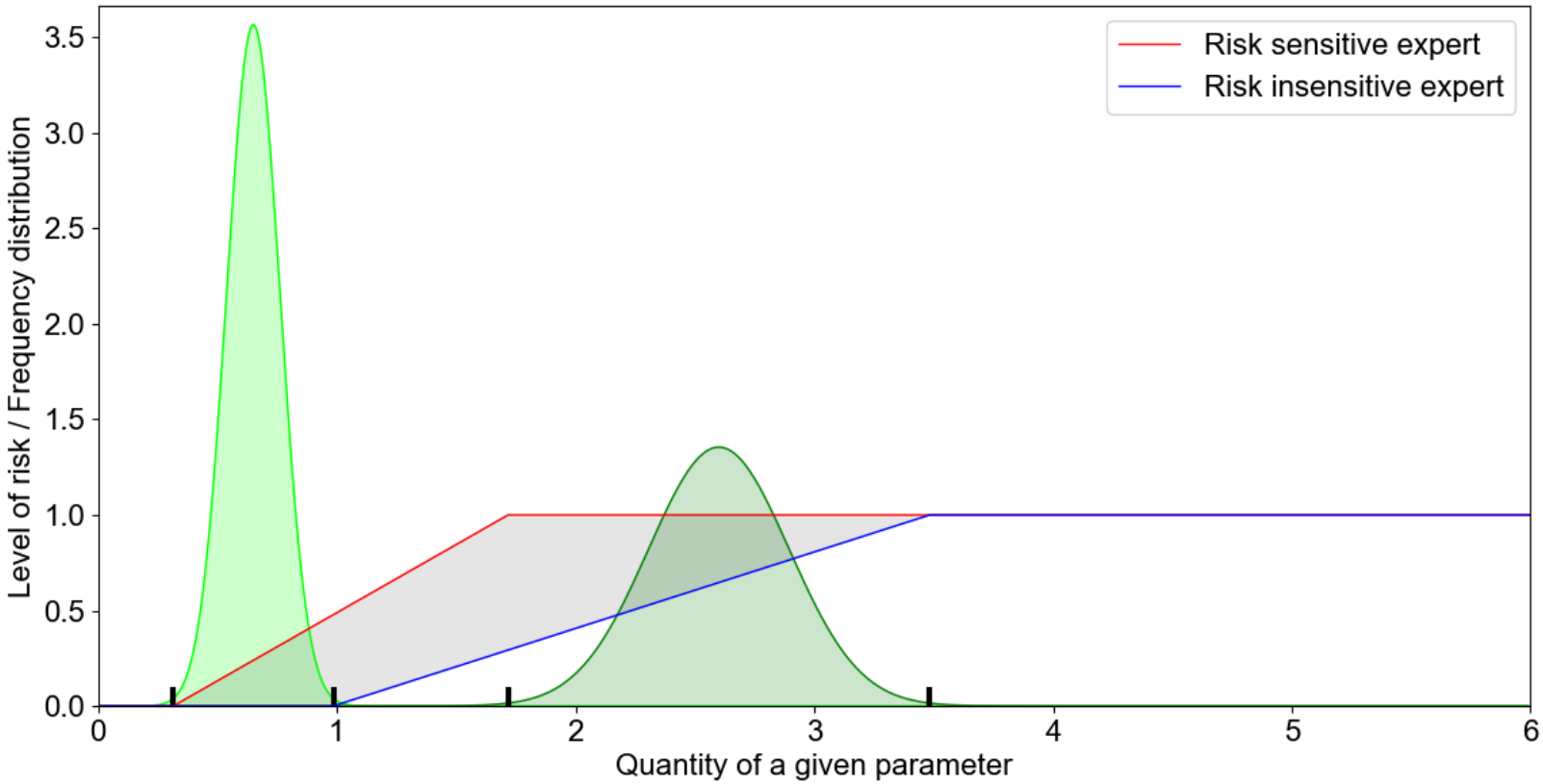
Answers can be found in literature

Hypothetical example: Statistical processing



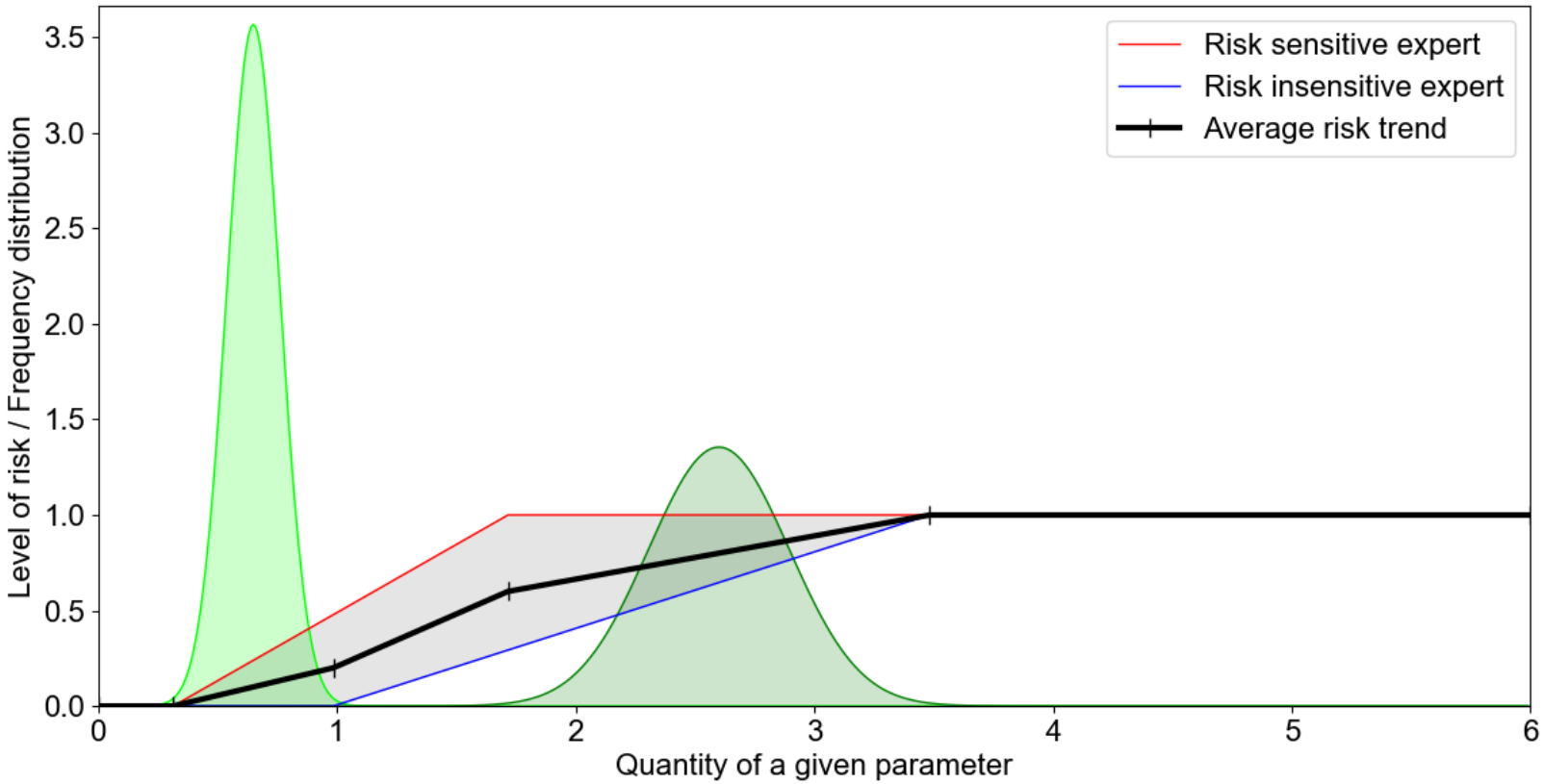
Answers contain information about the risk that corrosion occurs

Hypothetical example: Determine risk relation



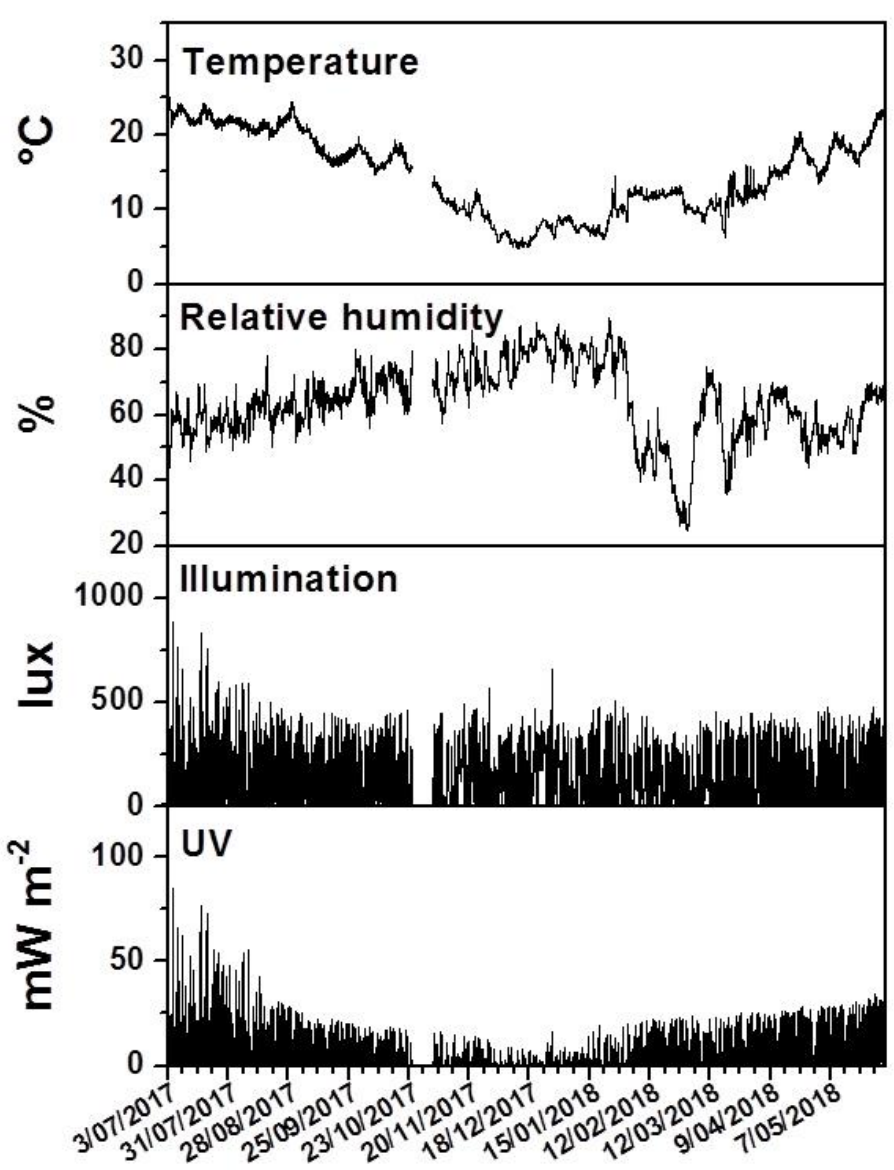
Determine the nodes of the risk vs. parameter relation

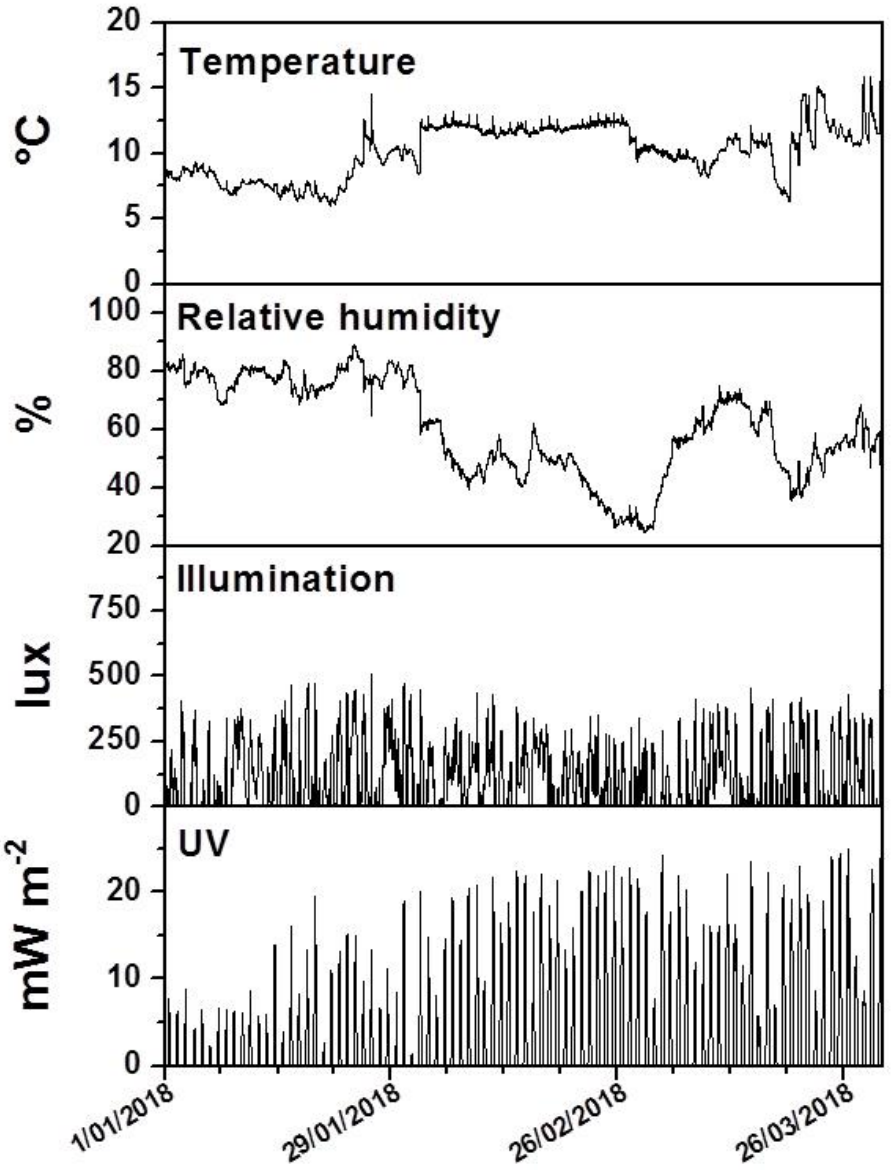
Hypothetical example: Determine average risk



Effects of synergetic effects are considered in the risk trend

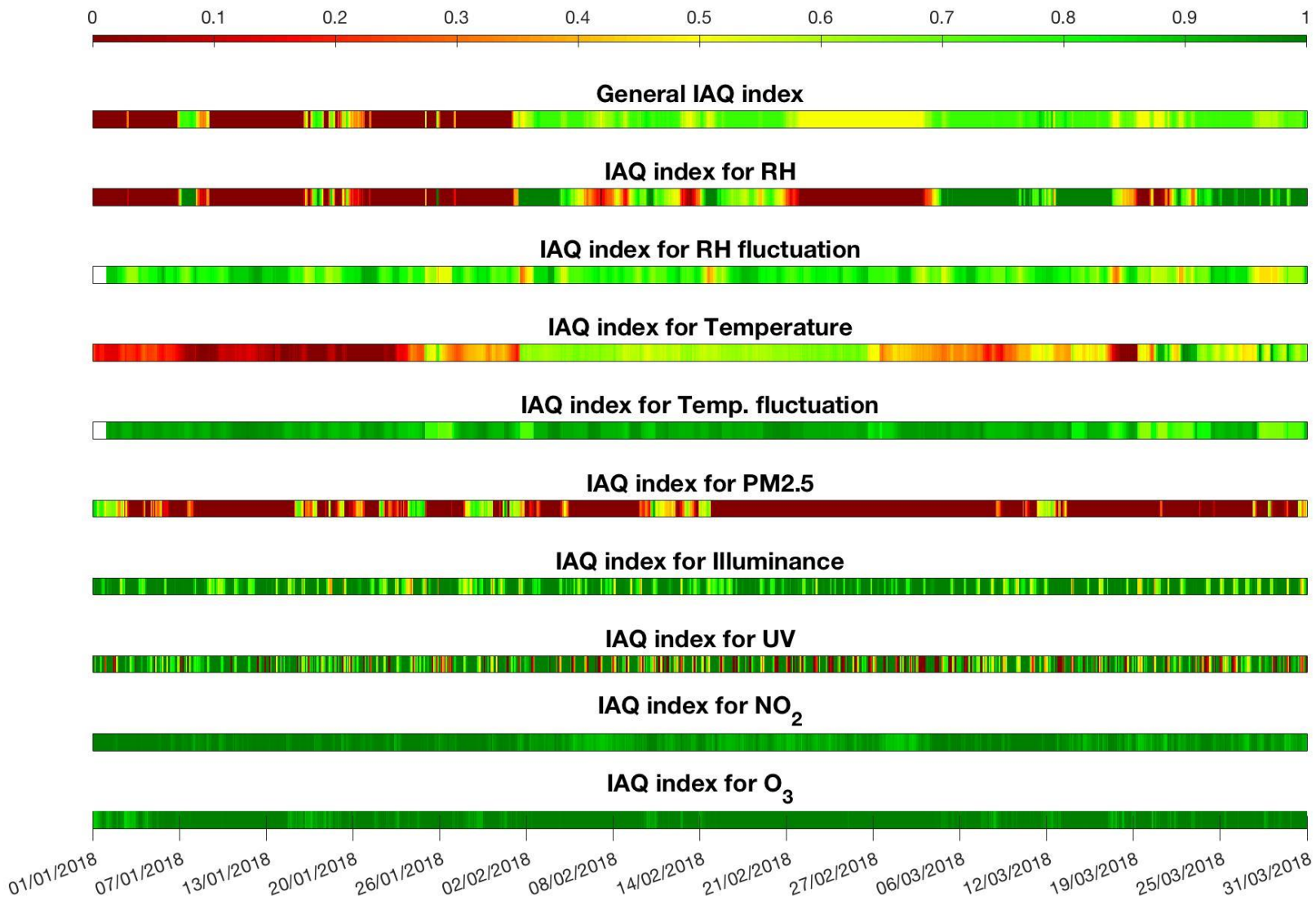
Real case: Air quality in the church of Aalst





Monitor environmental parameters over time

Real case: Air quality in the church of Aalst

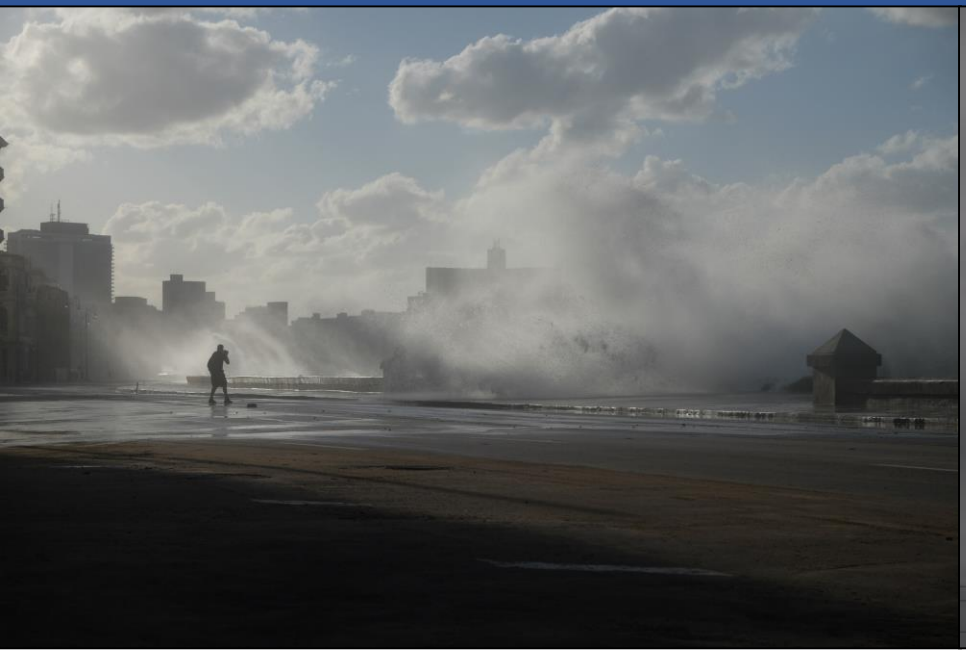


Convert measurements into risk assessments

Model 2

Consider environment as a series of randomly occurring stressful moments

Model: Behaviour of the environment



- A hazard generates a series of N stressful moments (undesired situations)
- Every stressful moment is characterized by an apparent force (stressor)
- The apparent force triggers a stress response in objects

Describe environment by N situations each with a random stress

Model: The protection shield

- There can be a protection shield between the objects and environment
- Small stresses below a constant threshold value will not affect the objects
- That threshold describes the fragility of the protection shield

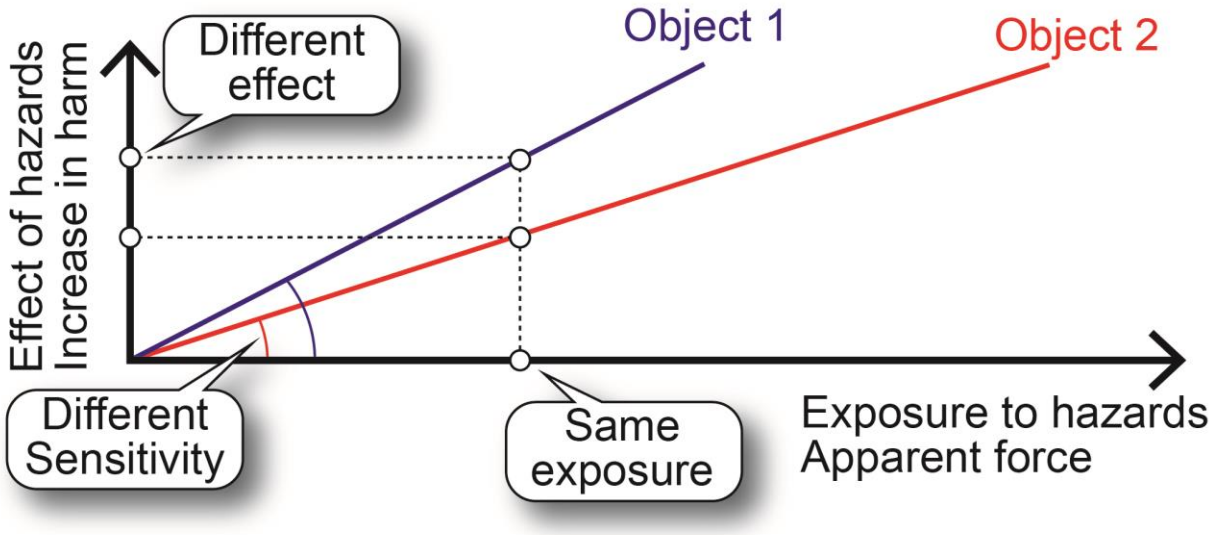
Fragility of protection shield is described by 1 threshold value

Model: Consequence for objects

- Set of M objects is exposed to the same environment
- The object is characterized by a sensitivity towards stress
- The object is characterized by resilience: applied stress has no long-term effect when it is below the resilience threshold

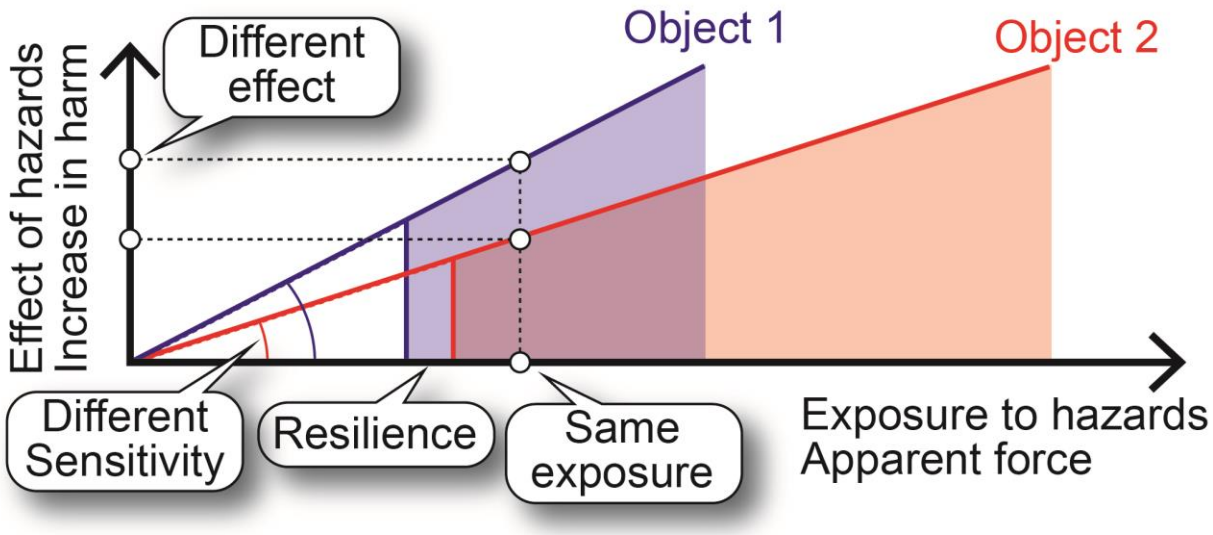
M objects have random sensitivity and resilience

Model: Increment in harm vs. environmental stress



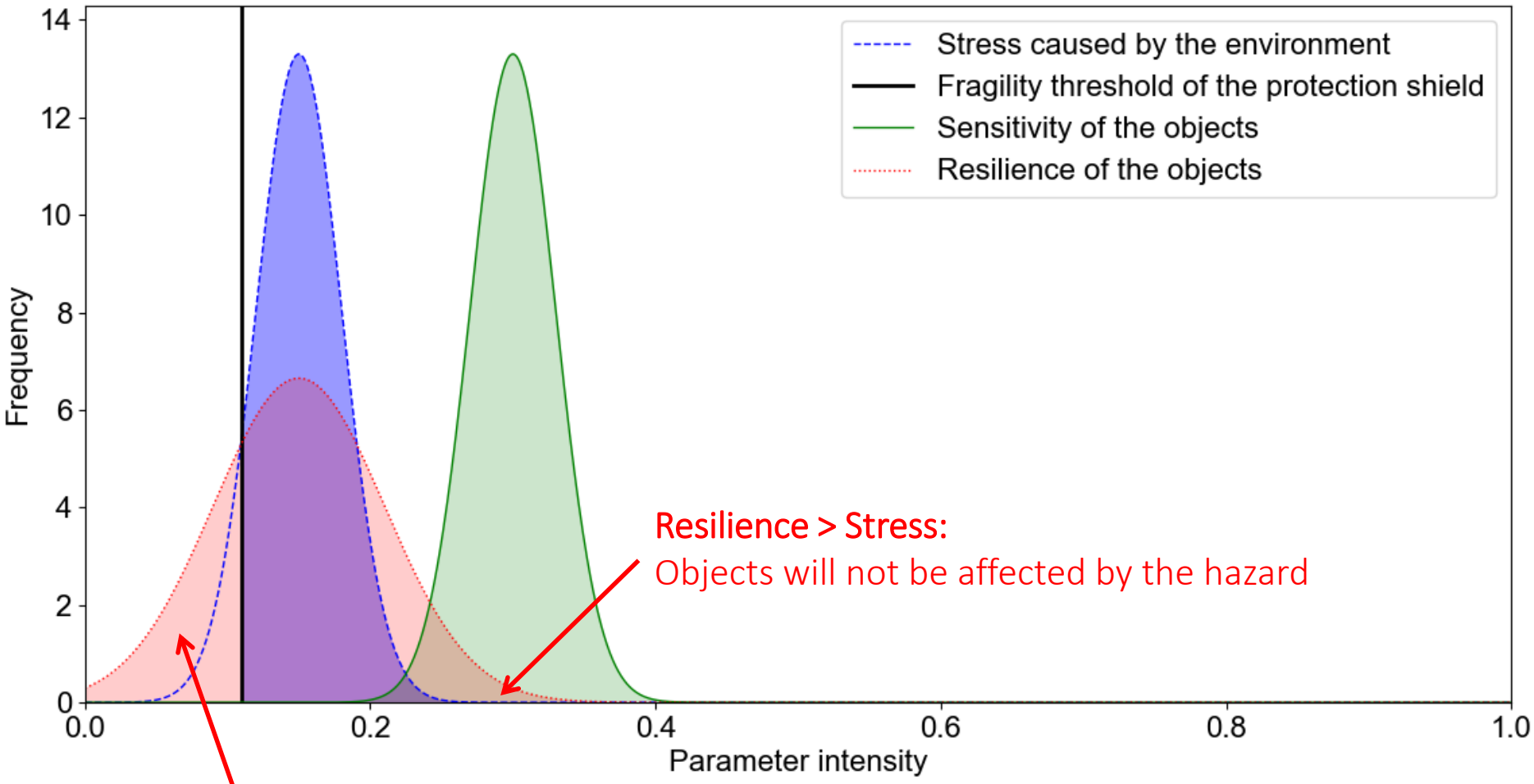
M objects have random sensitivity

Model: Increment in harm vs. environmental stress



M objects have random resilience

Hypothetical example: Description of the model

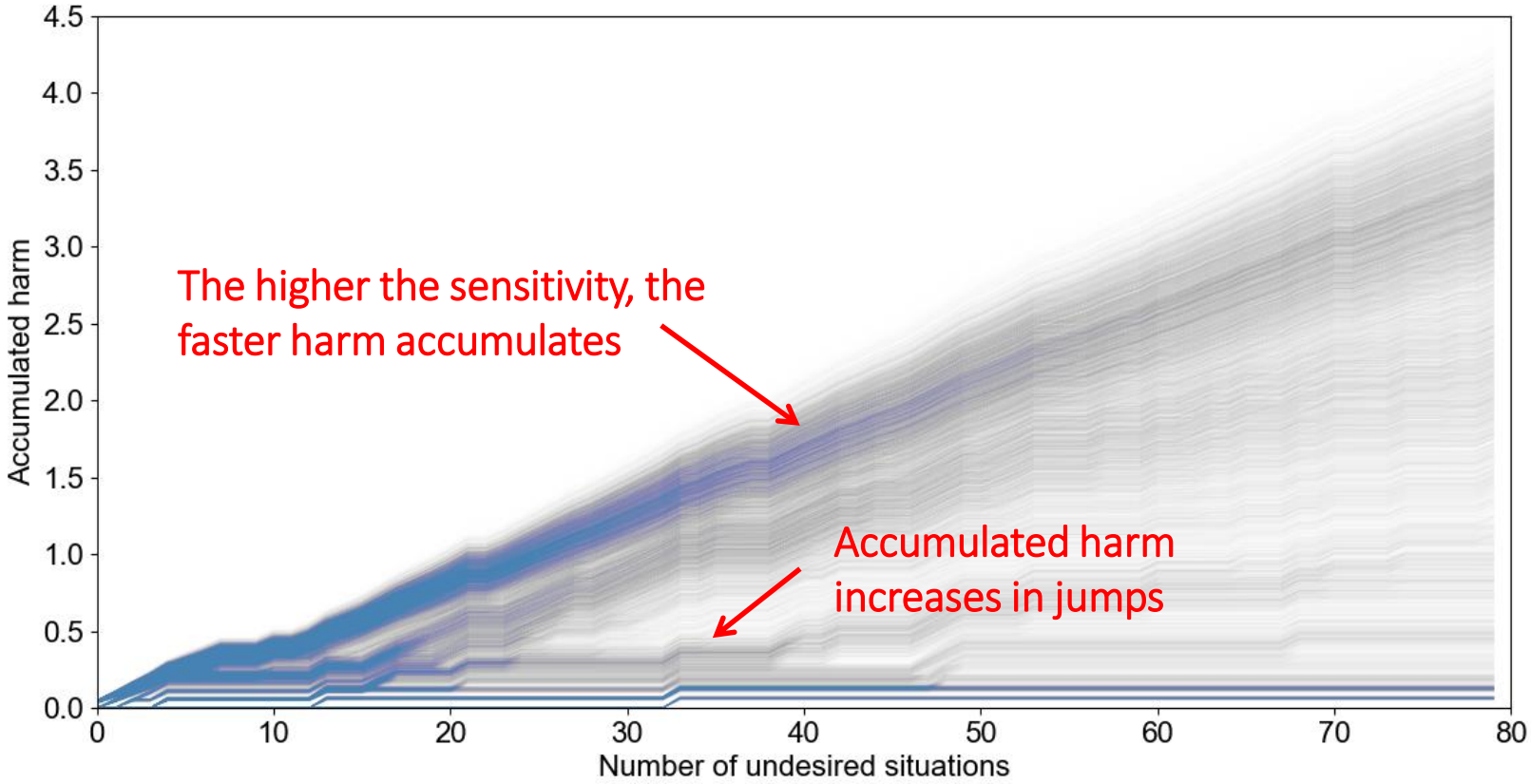


Resilience > Stress:
Objects will not be affected by the hazard

Resilience < Minimum stress:
Objects will be affected by all undesired situations

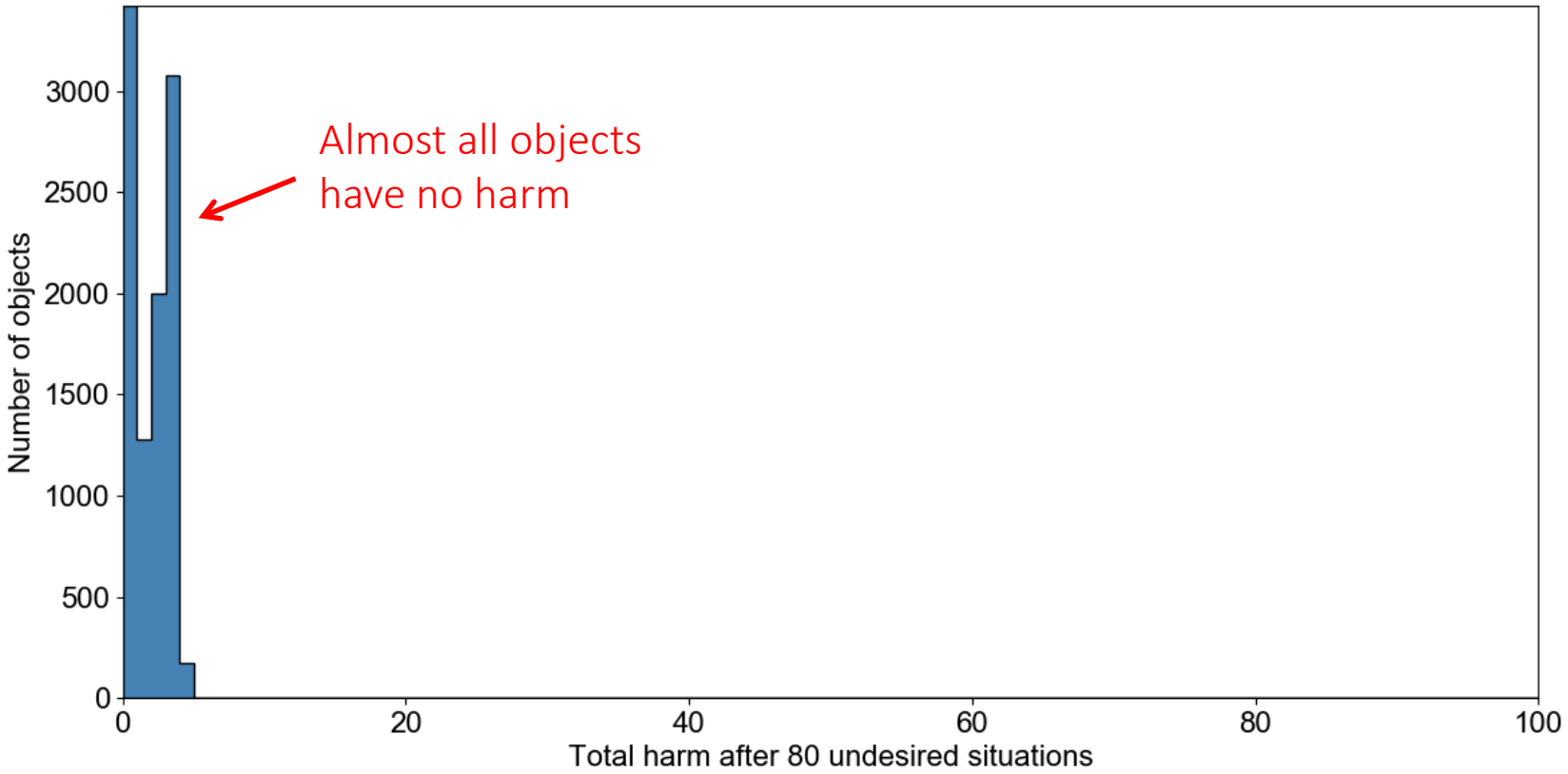
Sensitivity, resilience and stress are random variables

Hypothetical example: Accumulation of harm



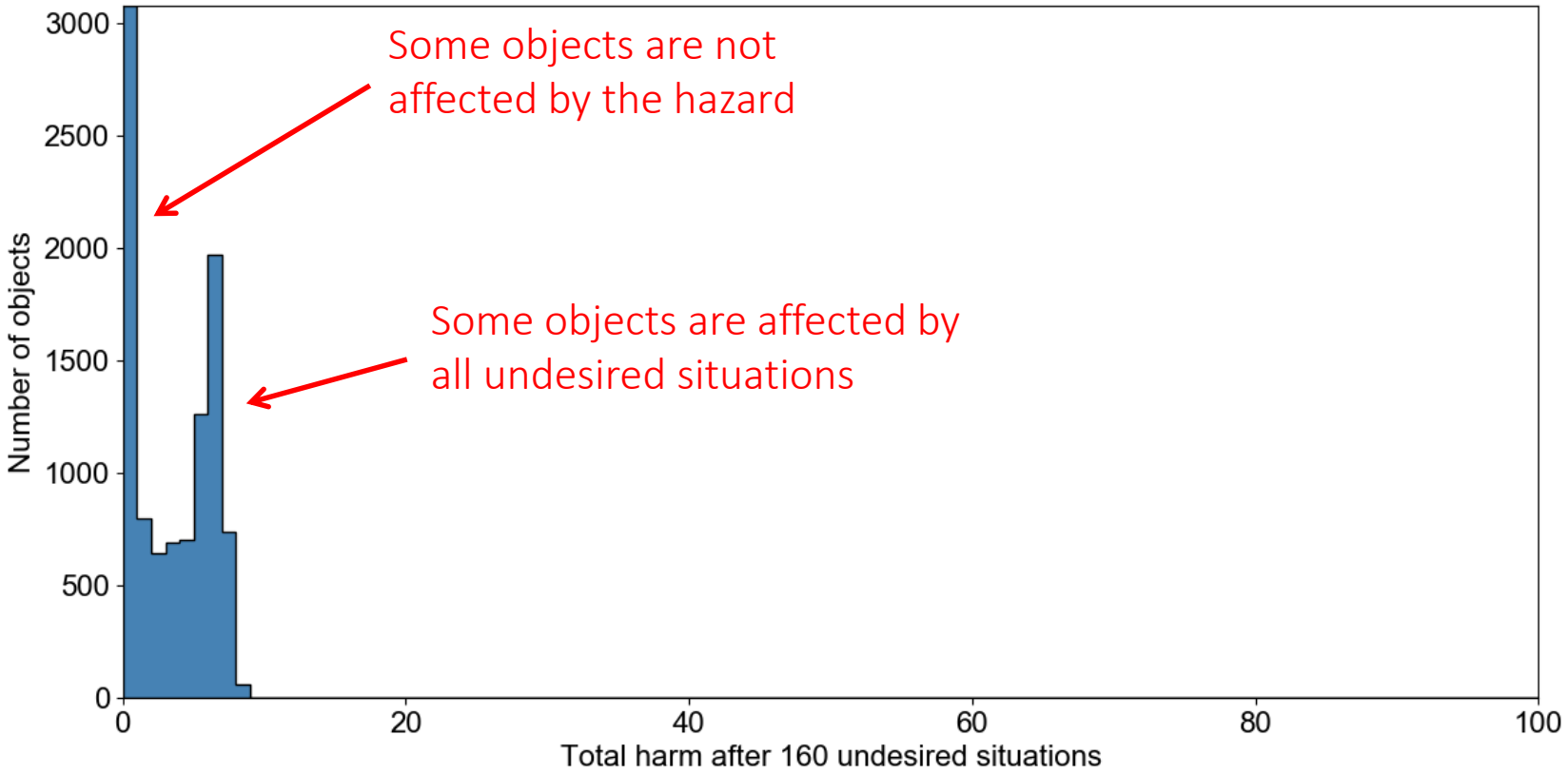
Objects accumulate harm ove time

Hypothetical example: Distribution of harm



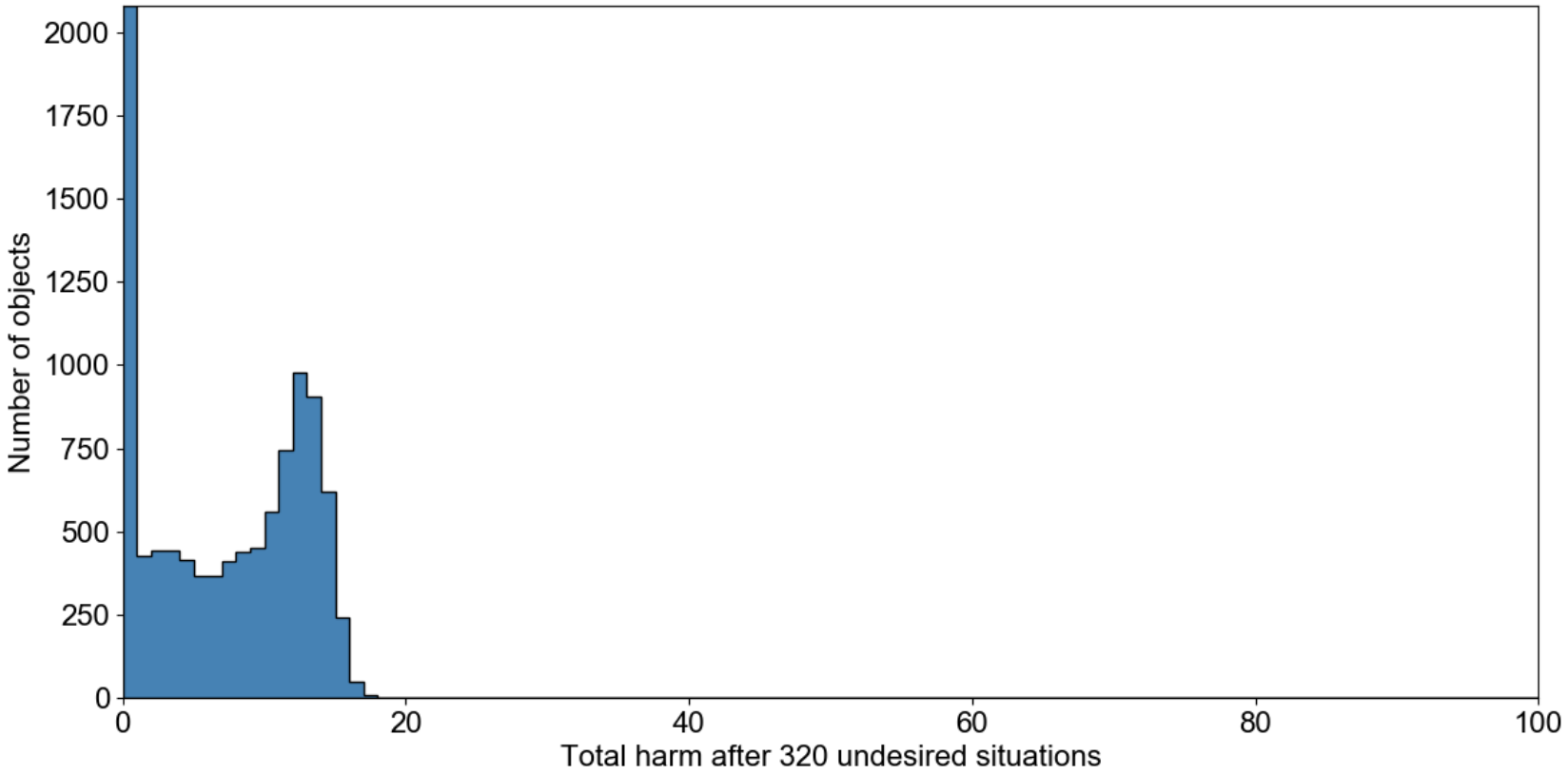
Objects have similar amount of harm

Hypothetical example: Distribution of harm



Set of M objects have random sensitivity and resilience

Hypothetical example: Distribution of harm



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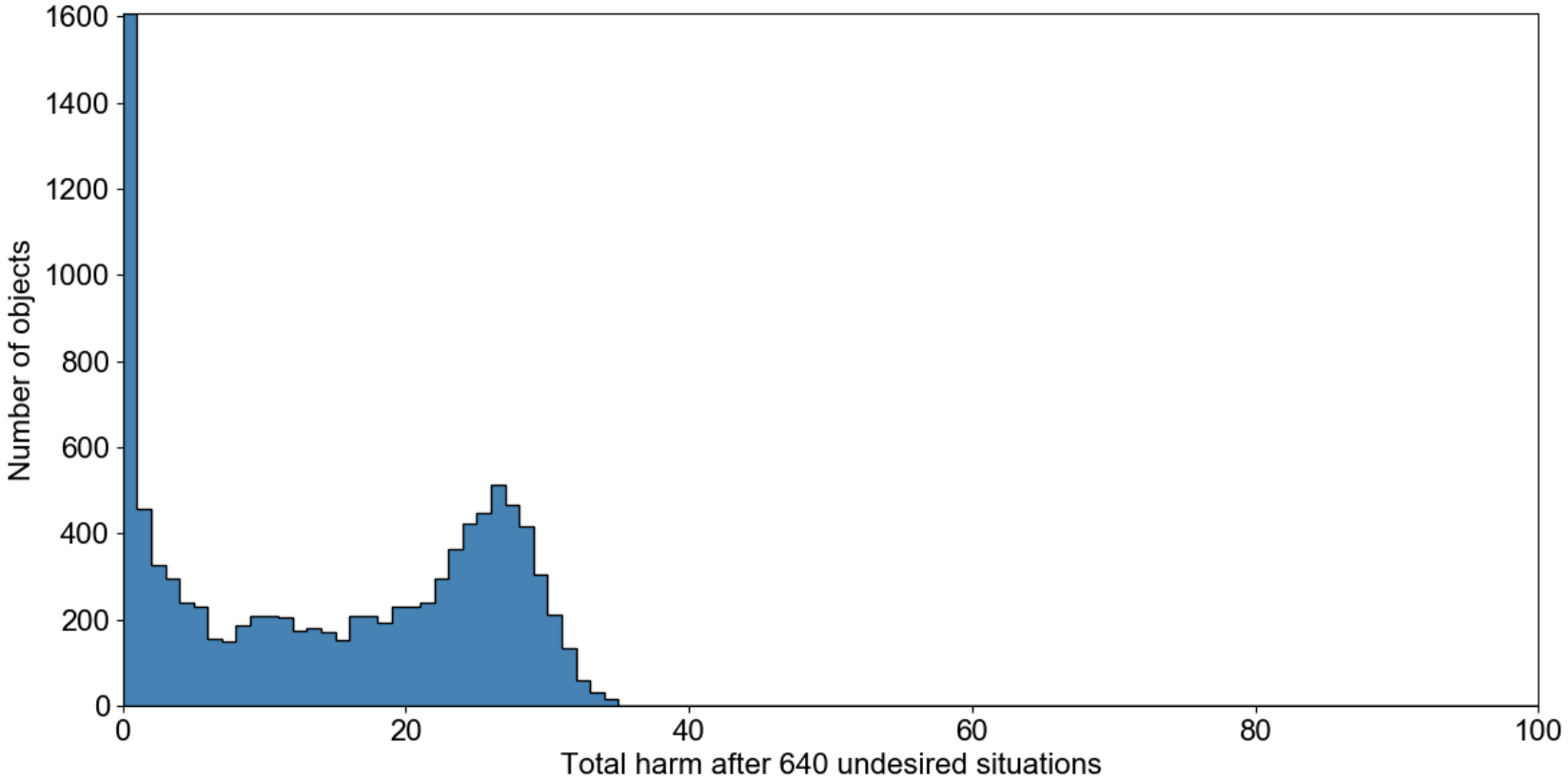
Hypothetical example: Distribution of harm



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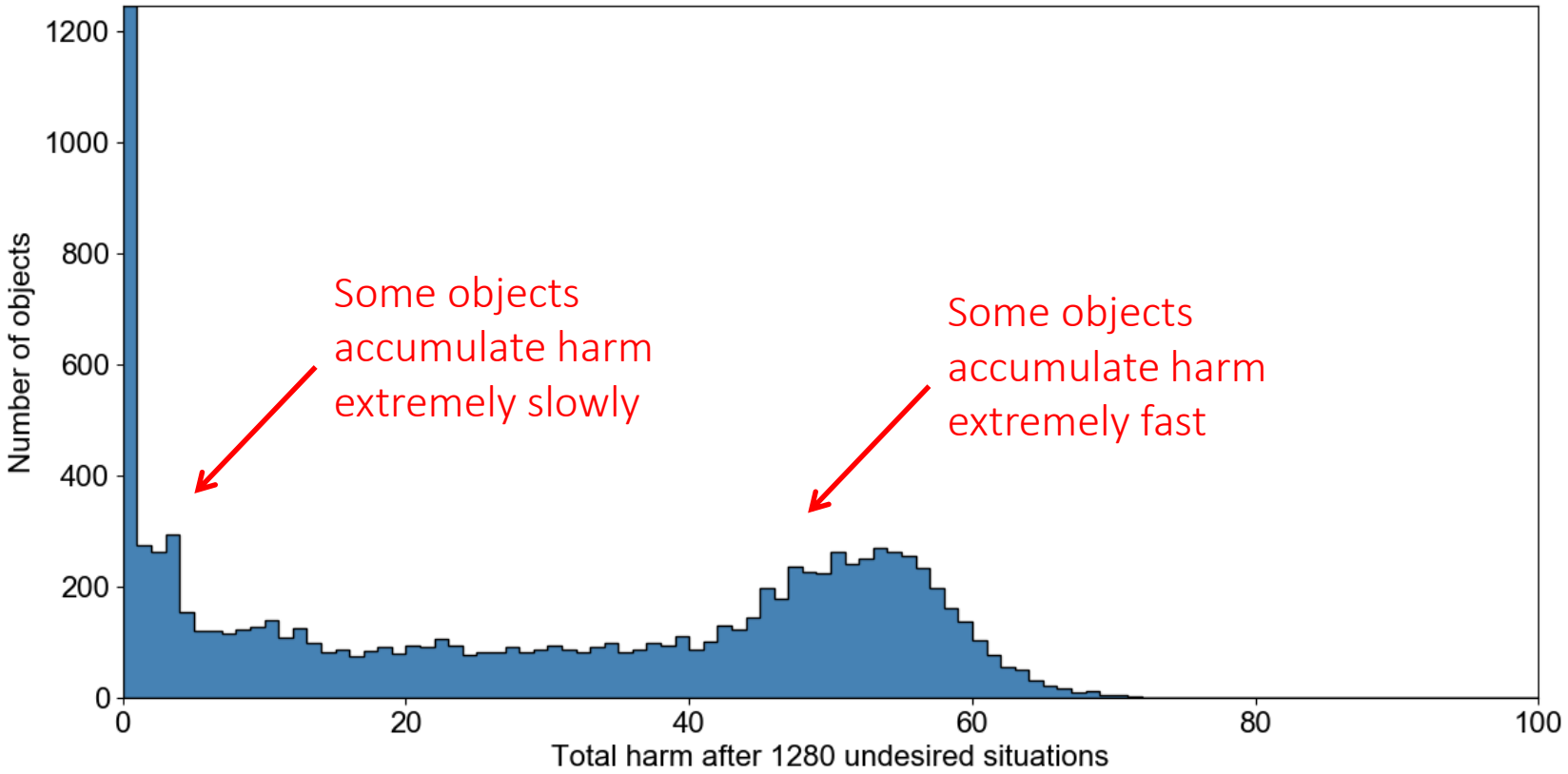
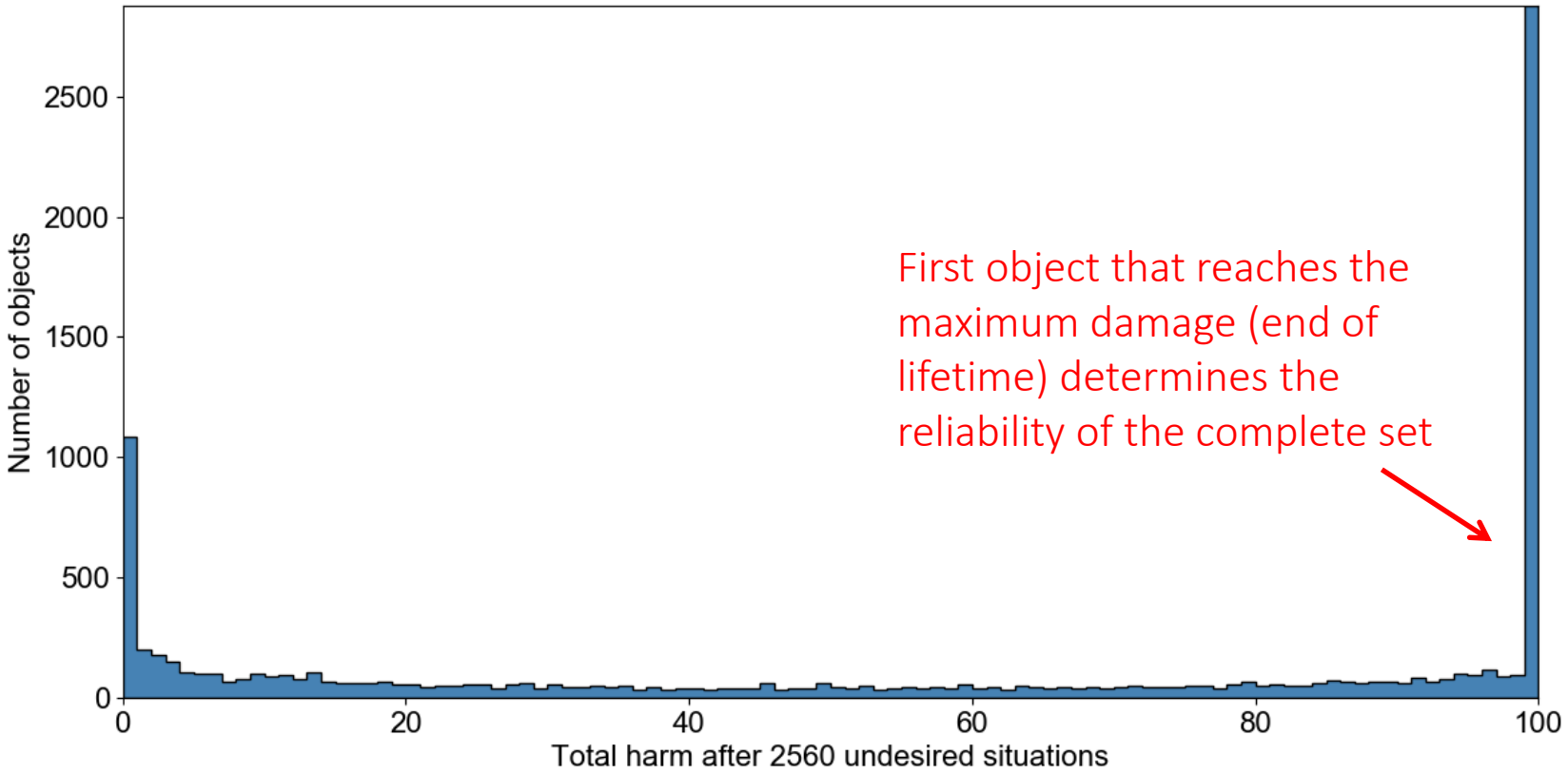
Hypothetical example: Distribution of harm



Difference between slowest & fastest harm accumulation becomes larger

Hypothetical example: Distribution of harm



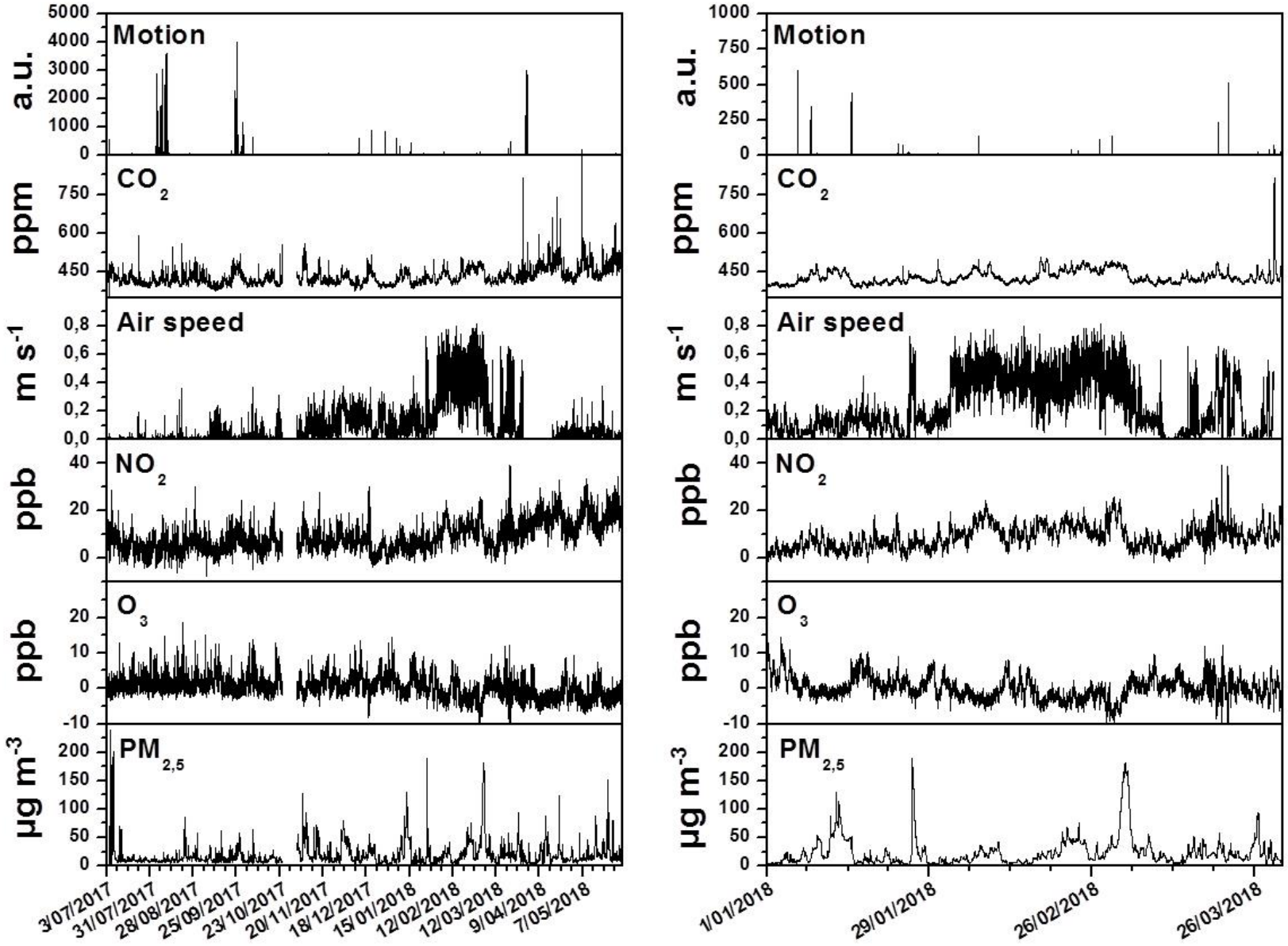
Maximum damage & end of lifetime is reached

Real case: Model resembles a marathon

- Huge amount of people start the marathon
- The leading group becomes smaller over time
- There is only 1 person who will win
- The winner takes it all
- The distance between the slowest & fastest person becomes larger over time

How to use the model in a quantitative way?

Real case: Is this model meaningful?



Environmental parameters show many peaks

Conclusions

Models are based on expert intuition

Model 1: Estimate corrosion risk from environmental parameters

- Model can be calibrated
- Based on expert intuition
- Corrosion rate $\Rightarrow$ risk for unacceptable corrosion
- Visualize periods with enhanced risk for corrosion

Model 2: Consider environment as a series of stressful moments

- Environmental data show many peaks
- Short moments can dominate the majority of harm
- Both models should be considered at the same time
- Evolution of accumulated harm can be predicted

This information is helpful to improve preventive maintenance

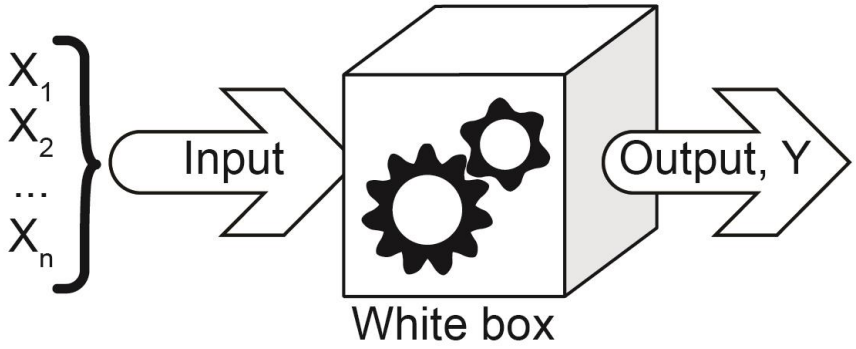
Some literature

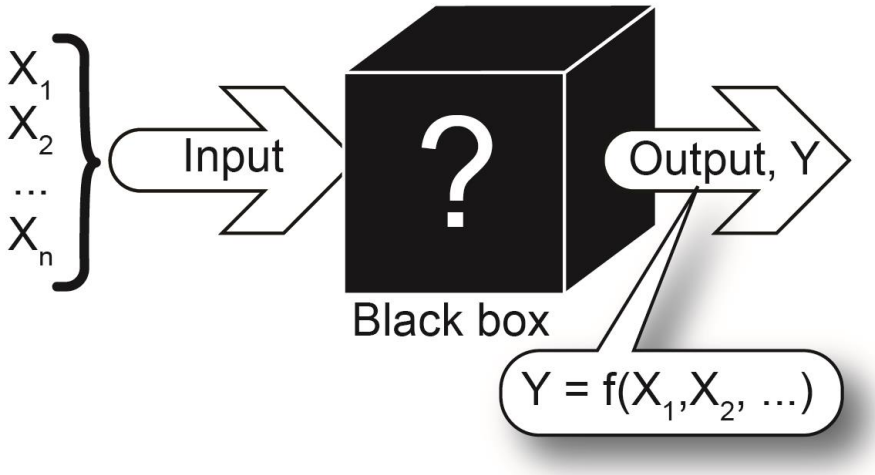
- Anaf W., Leyva Pernia D., Schalm O., 2018, Standardized indoor air quality assessments as a tool to prepare heritage guardians for changing preservation conditions due to climate change, Geosciences, 8:8, 276

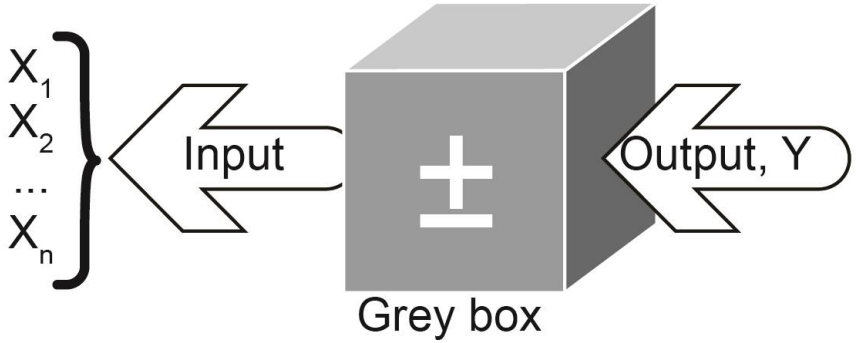
- Anaf W., Schalm O., 2019, Climatic quality evaluation by peak analysis and segregation of low-, mid-, and high-frequency fluctuations, applied on a historic chapel, Building and Environment 148, 286–293

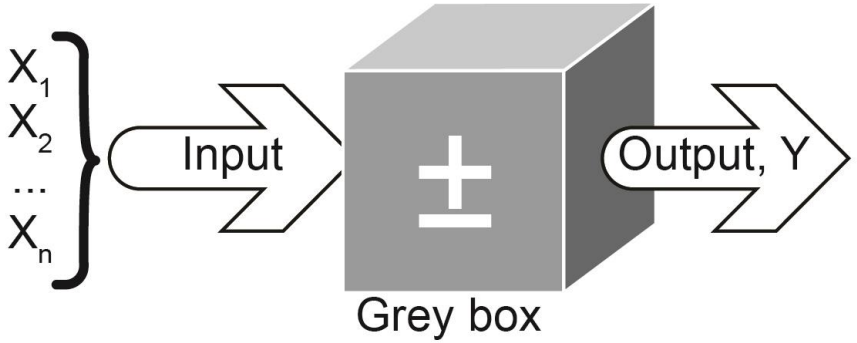
- Schalm O., Cabal A., Anaf W., Leyva Pernia D., Callier J., Ortega N., 2019, A decision support system for preventive conservation: From measurements towards decision making, The European Physical Journal Plus, 134:74

Thank you


X1
X2
...
Xn
Input
Output, Y
White box


X1
X2
...
Xn
Input
?
Output, Y
Black box
Y = f(X1,X2, ...)


X1
X2
...
Xn
Input
±
Output, Y
Grey box


X1
X2
...
Xn
Input
±
Output, Y
Grey box