

# Sensitivity and Uncertainty

## Understanding the Input and Output Variability of a System Model

### Highlights

#### Why is Uncertainty Analysis Important?

- Provides decision makers with an assessment of overall model accuracy
- Documents the variability in each input value
- Enables “rolling up” of uncertainty in input values into uncertainty in output measures

#### Why is Sensitivity Analysis Important?

- Investigates the robustness of the model
- Allows the modeler to assess the impact of modeling assumptions
- Determines which of the modeling input uncertainties have the greatest effect on model output measure uncertainty
- Provides insight into how the system behaves in response to changes in input values
- Gives analysts understanding of the interaction of multiple input factors

#### What are the Research Areas?

- Screening of variables to reduce model dimensionality
- Working with sparse data sets when little information is available
- Analyzing complex systems for improved resiliency



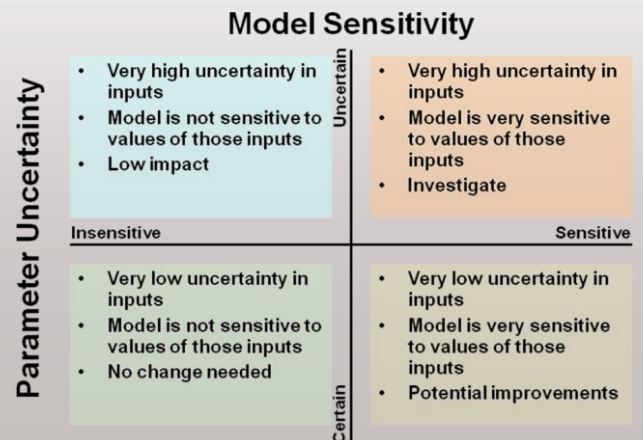
### Sensitivity and Uncertainty Overview

Sensitivity and uncertainty analysis is often thought of as one activity, relating to the study of variability in a system model. It actually represents two distinct concepts, each with their own purpose, that are frequently explored simultaneously.

Uncertainty analysis attempts to quantify the uncertainty in the outputs of a model that result from model assumptions and uncertainty in model input values. It reflects the uncertainty in the conclusions of the study.

Sensitivity analysis tries to identify how variation in input values relates to variation in output measures. It is performed by changing an input variable or combinations of input variables and observing the effect on output measures. It is performed on inputs that are estimates as well as those that are known with great accuracy. This type of analysis is useful for identifying potential modifications to a system to improve performance.

The two types of analyses are complementary. Sensitivity analysis determines which input uncertainties matter most.

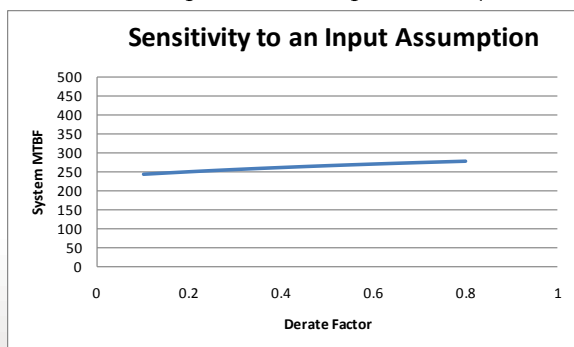


# Sensitivity and Uncertainty

## Sensitivity Example

A newly designed system will be installed in a helicopter. A reliability model was constructed to predict system level mean time between failures (MTBF) based on the component level inputs. Some of the component MTBF values were based on previous use in a fixed wing aircraft. To account for the harsher environment of rotary wing flight each of those MTBFs were multiplied by 0.3, which is a typical de-rating factor for that type of environment change. What is the observed performance of the components selected is not typical?

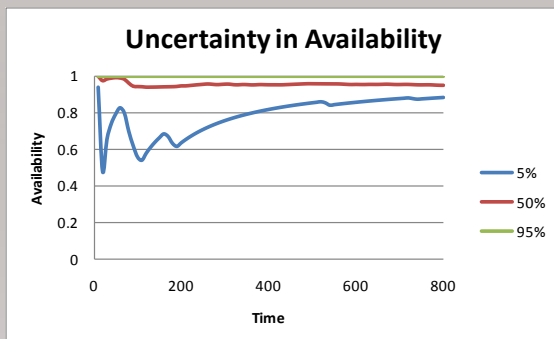
The de-rating factor, which was applied to a subset of the components, was varied across a range of reasonable values and found to not cross significant changes in the system MTBF.



## Uncertainty Example

### Limited Duration Employment

A system comprised of exponentially distributed components is deployed for a short duration mission. The mean time to failure and the mean time to repair of each component are well characterized from years of system use, and the system availability is known to be 0.945. Can the operator expect to observe the known availability during the deployment?



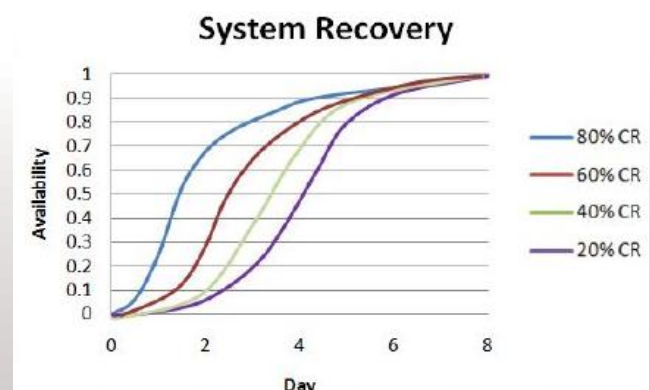
## Uncertainty Example Continued

The reported availability is a steady state value which is realized after extended operations. Because of the exponential nature of the components, there is uncertainty in the expected availability during deployments which varies depending on the length of the mission. This uncertainty is present even if the inputs parameters are known exactly.

## Sensitivity and Uncertainty Example

### System Recovery from a Maintenance Event

A system comprised of exponentially distributed components is deployed for a short duration mission. The mean time to failure and the mean time to repair of each component are well characterized from years of system use, and the system availability is known to be 0.945. Can the operator expect to observe the known availability during the deployment?



The uncertain input parameter was varied over a range of likely values and the resulting graph shows the range in expected availability, thus showing the sensitivity to the uncertainty in the input values.



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