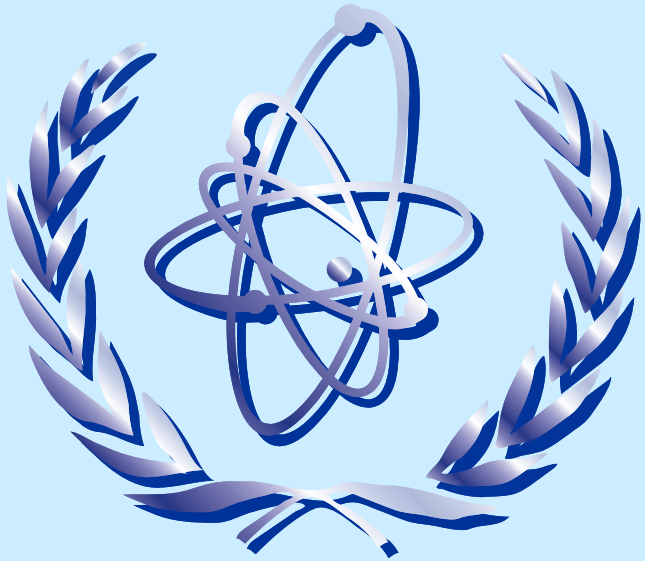
Basic Level 1. PSA course for analysts



Reliability data analysis, specific aspects

Content

- EXPERT ESTIMATION OF VALUES FOR USE IN PSA
- INITIATING EVENT DATA
- ADDITIONAL COMMENTS AND NOTES

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

ESTIMATION EXAMPLE 1

HOW LONG IS THE MISSOURI RIVER?

UNITS

- Length in Kilometres

SUPPORTING INFORMATION

- The Missouri River is located in the central part of the United States.

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 1 GROUP ESTIMATES

Group	Lower Bound	Best Estimate	Upper Bound
1			
2			
3			
4			
5			

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXPERT UNCERTAINTY WEIGHTS

EXPERTS TRAINED IN UNCERTAINTY:

- Lower Bound: 0.1
- Best Estimate: 0.8
- Upper Bound: 0.1

EXPERTS NOT TRAINED IN UNCERTAINTY:

- Lower Bound: 0.2
- Best Estimate: 0.6
- Upper Bound: 0.2

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 1 ESTIMATES

Value	Probability	Cumulative

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
EXAMPLE 1 EXPERT ESTIMATES
UNCERTAINTY DISTRIBUTION

5th Percentile:

Median:

95th Percentile:

Mean:

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

HOW LONG IS THE MISSOURI RIVER?

4,130 Kilometres

Reference:

Concise Columbia Electronic Encyclopaedia, Third Edition, 1994.

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

ESTIMATION EXAMPLE 2

WHAT IS THE FREQUENCY OF FATAL AIRCRAFT CRASHES?

UNITS

- Aircraft crash events per flight

SUPPORTING INFORMATION

- Crashes that result in fatality of one or more passengers or crew
- Flight is defined as a departure (takeoff)
- All U.S. scheduled commercial airlines
- Excludes terrorism, sabotage, and suicide

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 2 GROUP ESTIMATES

Group	Lower Bound	Best Estimate	Upper Bound
1			
2			
3			
4			
5			

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 2 ESTIMATES

Value	Probability	Cumulative

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
EXAMPLE 2 EXPERT ESTIMATES
UNCERTAINTY DISTRIBUTION

5th Percentile:

Median:

95th Percentile:

Mean:

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
WHAT IS THE FREQUENCY OF FATAL AIRCRAFT CRASHES?

4.64E-07 Fatal Crash per Flight

Reference:

United States Federal Aviation Agency, National Transportation Safety Board, Data from 1982 - 1998.

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

FATAL AIRCRAFT CRASH DATA BY YEAR

Fatal Airline Accidents U.S. Scheduled Service Airlines, 1982-1998 Source: U.S. Federal Aviation Agency, National Transportation Safety Board			
Year	**Fatal Accidents**	**Flight Departures**	**Accident Rate**
1982	4	5,162,346	7.75E-07
1983	4	5,235,262	7.64E-07
1984	1	5,666,076	1.76E-07
1985	4	6,068,893	6.59E-07
1986	2	6,928,103	2.89E-07
1987	4	7,293,025	5.48E-07
1988	3	7,347,575	4.08E-07
1989	8	7,267,341	1.10E-06
1990	6	7,795,761	7.70E-07
1991	4	7,503,873	5.33E-07
1992	4	7,515,373	5.32E-07
1993	1	7,721,870	1.30E-07
1994	4	7,824,802	5.11E-07
1995	2	8,105,570	2.47E-07
1996	3	7,851,298	3.82E-07
1997	3	9,908,048	3.03E-07
1998	1	9,921,000	1.01E-07
Total	58	125,116,216	4.64E-07

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

FATAL AIRCRAFT CRASH DATA BY RATE

Fatal Airline Accidents U.S. Scheduled Service Airlines, 1982-1998 Source: U.S. Federal Aviation Agency, National Transportation Safety Board			
Year	**Fatal Accidents**	**Flight Departures**	**Accident Rate**
1998	1	9,921,000	1.01E-07
1993	1	7,721,870	1.30E-07
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1992	4	7,515,373	5.32E-07
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1987	4	7,293,025	5.48E-07
1985	4	6,068,893	6.59E-07
1983	4	5,235,262	7.64E-07
1990	6	7,795,761	7.70E-07
1982	4	5,162,346	7.75E-07
1989	8	7,267,341	1.10E-06
Total	58	125,116,216	4.64E-07

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 2 EXAMINATION OF DATA

- LOWEST ACCIDENT RATE: 1.01E-07 (1998)
- HIGHEST ACCIDENT RATE: 1.10E-06 (1989)
- MEDIAN ACCIDENT RATE: 5.11E-07 (1994)

- THE ACCIDENT RATE IS NOT IMPROVING OVER TIME

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

ESTIMATION EXAMPLE 3

WHAT IS THE HUMAN ERROR RATE FOR OPERATOR ACTIONS TO START A RAPID COOLDOWN AND PRESSURE REDUCTION AFTER A STEAM GENERATOR TUBE RUPTURE?

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
WHAT IS THE HUMAN ERROR RATE FOR SGTR COOLDOWN?

UNITS

- Error per event

SUPPORTING INFORMATION

- 10-minute time window to start cooldown
- All actions can be performed in Main Control Room
- Composite error rate for operating crew
- "Average" indications, alarms, procedures, training
- No significant equipment failures

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 3 GROUP ESTIMATES

Group	Lower Bound	Best Estimate	Upper Bound
1			
2			
3			
4			
5			

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 3 ESTIMATES

Value	Probability	Cumulative

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
EXAMPLE 3 EXPERT ESTIMATES
UNCERTAINTY DISTRIBUTION

5th Percentile:

Median:

95th Percentile:

Mean:

EXPERT ESTIMATION OF VALUES FOR USE IN PSA
WHAT IS THE HUMAN ERROR RATE FOR SGTR COOLDOWN?

Median: 1.00E-01 Error per event

EF: 10

Reference:

Accident Sequence Evaluation Program Human Reliability Analysis Procedure, NUREG/CR-4772, 1987, Table 8-2.

EXPERT ESTIMATION OF VALUES FOR USE IN PSA

EXAMPLE 3 EXAMINATION OF REFERENCE

- **SUGGESTED ERROR RATE UNCERTAINTY DISTRIBUTION:**

1st Percentile:	3.83E-03
5th Percentile:	1.00E-02
Median:	1.00E-01
95th Percentile:	1.00
99th Percentile:	2.61
Mean:	2.66E-01

- **THE ASEP REFERENCE ERROR RATE IS NOT CORRECT!**

INITIATING EVENT DATA

ACCOUNTING FOR PLANT-TO-PLANT VARIABILITY

INITIATING EVENT DATA

COMBINED GENERIC EXPERIENCE

- 10 PLANTS
- 10 OPERATING YEARS EACH
- 100 REACTOR TRIP EVENTS

INITIATING EVENT DATA

COMBINED GENERIC EXPERIENCE (cont.)

INITIATING EVENT MEAN FREQUENCY:

- 1 REACTOR TRIP PER YEAR

INITIATING EVENT UNCERTAINTY:

- HIGH CONFIDENCE THAT REACTOR TRIP FREQUENCY IS 1 EVENT PER YEAR

INITIATING EVENT DATA

DETAILED GENERIC EXPERIENCE

- 10 PLANTS
- 10 OPERATING YEARS EACH
- 9 PLANTS HAVE 0 REACTOR TRIP EVENTS
- 1 PLANT HAS 100 REACTOR TRIP EVENTS

INITIATING EVENT DATA

DETAILED GENERIC EXPERIENCE (cont.)

INITIATING EVENT MEAN FREQUENCY:

- 1 REACTOR TRIP PER YEAR

INITIATING EVENT UNCERTAINTY:

- 90% PROBABILITY THAT REACTOR TRIP FREQUENCY IS LESS THAN 0.1 EVENT PER YEAR
- 10% PROBABILITY THAT REACTOR TRIP FREQUENCY IS 10 EVENTS PER YEAR

INITIATING EVENT DATA
PLANT-TO-PLANT VARIABILITY

- SELECT RELEVANT GENERIC PLANT POPULATION
- 2-STAGE BAYESIAN UPDATE
- LIMITED PLANT-SPECIFIC OPERATING EXPERIENCE ELIMINATES CONTRIBUTION FROM "OUTLIERS"

ADDITIONAL COMMENTS AND NOTES

PLANT-SPECIFIC VS. GENERIC DATA

- AVOID ARBITRARY DECISIONS TO USE ONLY PLANT-SPECIFIC DATA OR ONLY GENERIC DATA
- NO LOGICAL JUSTIFICATION FOR "CLASSICAL STATISTICS" ASSUMED 1/3 FAILURE (OR 1/2 FAILURE)
- "MATURE" ESTIMATES DO NOT USUALLY CHANGE DRAMATICALLY AS MORE DATA ARE COLLECTED
  - TRANSITION FROM GENERIC TO PLANT-SPECIFIC
  - TRANSITION FROM NO FAILURES TO ONE FAILURE
- BAYESIAN ANALYSIS

ADDITIONAL COMMENTS AND NOTES

PROPERTIES OF BAYESIAN UPDATING

- WITH "WEAK" EVIDENCE, THE PRIOR DOMINATES THE RESULTS
- WITH "STRONG" EVIDENCE, THE RESULTS ARE NOT SENSITIVE TO THE PRIOR (DOMINATED BY THE EVIDENCE)
- SUCCESSIVE UPDATES PROVIDE CONSISTENT TREATMENT OF NEW COLLECTED EVIDENCE

ADDITIONAL COMMENTS AND NOTES

PRECAUTIONS

- BEWARE OF DATA IN PSA REPORTS BEFORE ~1987
- BEWARE OF U.S. NRC AND IAEA DATA BEFORE ~1992
- BEWARE OF IEEE-500 (AVOID IT)
- BEWARE OF HUMAN ERROR RATE "DATA"
- BEWARE OF SUPPORT SYSTEM INITIATING EVENT DATA

ADDITIONAL COMMENTS AND NOTES

RECENT U.S. REFERENCES

- INITIATING EVENT FREQUENCIES
  - NUREG/CR-5750, FEBRUARY 1999
- LOSS OF OFFSITE POWER
  - NUREG/CR-5496, NOVEMBER 1998
- COMMON CAUSE FAILURES
  - NUREG/CR-5485, NOVEMBER 1998
  - NUREG/CR-5497, OCTOBER 1998
- SPECIFIC SYSTEMS (RPS, AFW, OTHERS)
  - NUREG/CR-5500, CONTINUING

ADDITIONAL COMMENTS AND NOTES

PSA DATA SELECTION

- PLANT CHARACTERISTICS
  - PLANT TYPE (MAY NOT BE VERY IMPORTANT)
  - OPERATING HISTORY (NEW, STARTUP, MATURE)
- EQUIPMENT CHARACTERISTICS - CONSISTENT WITH PSA MODELS
  - LEVEL OF DETAIL
  - COMPONENT BOUNDARIES
  - DEFINITION OF FAILURE
- "NATIONAL PRIDE"

ADDITIONAL COMMENTS AND NOTES

PSA DATA SELECTION (cont.)

- PROFESSIONALLY DEVELOPED, INDEPENDENTLY REVIEWED PSA DATABASES ARE NOW MATURE
- NO SINGLE "PERFECT" DATABASE
- REVIEW AND COMPARE DATA FROM SEVERAL MODERN SOURCES
- IF YOU TRY TO COLLECT ONLY "PERFECT" DATA THAT APPLY ONLY TO YOUR PLANT AND YOUR EQUIPMENT, YOU WILL....
  - SPEND TOO MUCH TIME (MONEY) ON DATA ANALYSIS
  - NOT SPEND ENOUGH TIME (MONEY) ON OTHER ISSUES THAT ARE MORE IMPORTANT TO RISK
  - NEVER FINISH (OR START) YOUR PSA

ADDITIONAL COMMENTS AND NOTES

PERSPECTIVE ON FAILURE RATES

FAILURE RATE, λ	1 FAILURE EVERY – OF OPERATION	
10^{-1} FAILURE / HOUR	10	HOURS
10^{-2}	4	DAYS
10^{-3}	1.3	MONTHS
10^{-4}	14	MONTHS
10^{-5}	11.4	YEARS
10^{-6}	114	YEARS
10^{-7}	1,140	YEARS
10^{-8}	11,400	YEARS
10^{-9}	114,000	YEARS

ADDITIONAL COMMENTS AND NOTES

PERSPECTIVE ON UNAVAILABILITY

UNAVAILABILITY	OUT OF SERVICE	
10^{-1}	17	HOURS / WEEK
10^{-2}	7	HOURS / MONTH
10^{-3}	9	HOURS / YEAR
10^{-4}	1	HOUR / YEAR
10^{-5}	5	MINUTES / YEAR
10^{-6}	32	SECONDS / YEAR
10^{-7}	1	HOUR / 1,140 YEARS
10^{-8}	1	HOUR / 11,400 YEARS
10^{-9}	1	HOUR / 114,000 YEARS