TS6d Session

Probabilistic Radiological Risk Assessments for Radiation Facilities with Vague Information

The 13th International Congress of
the International Radiation Protection Association
13-18 May 2012, GLASGOW, SCOTLAND

Han-Ki Jang
Radiation Research Division
Korea Radioisotope Association
hkjang@ri.or.kr

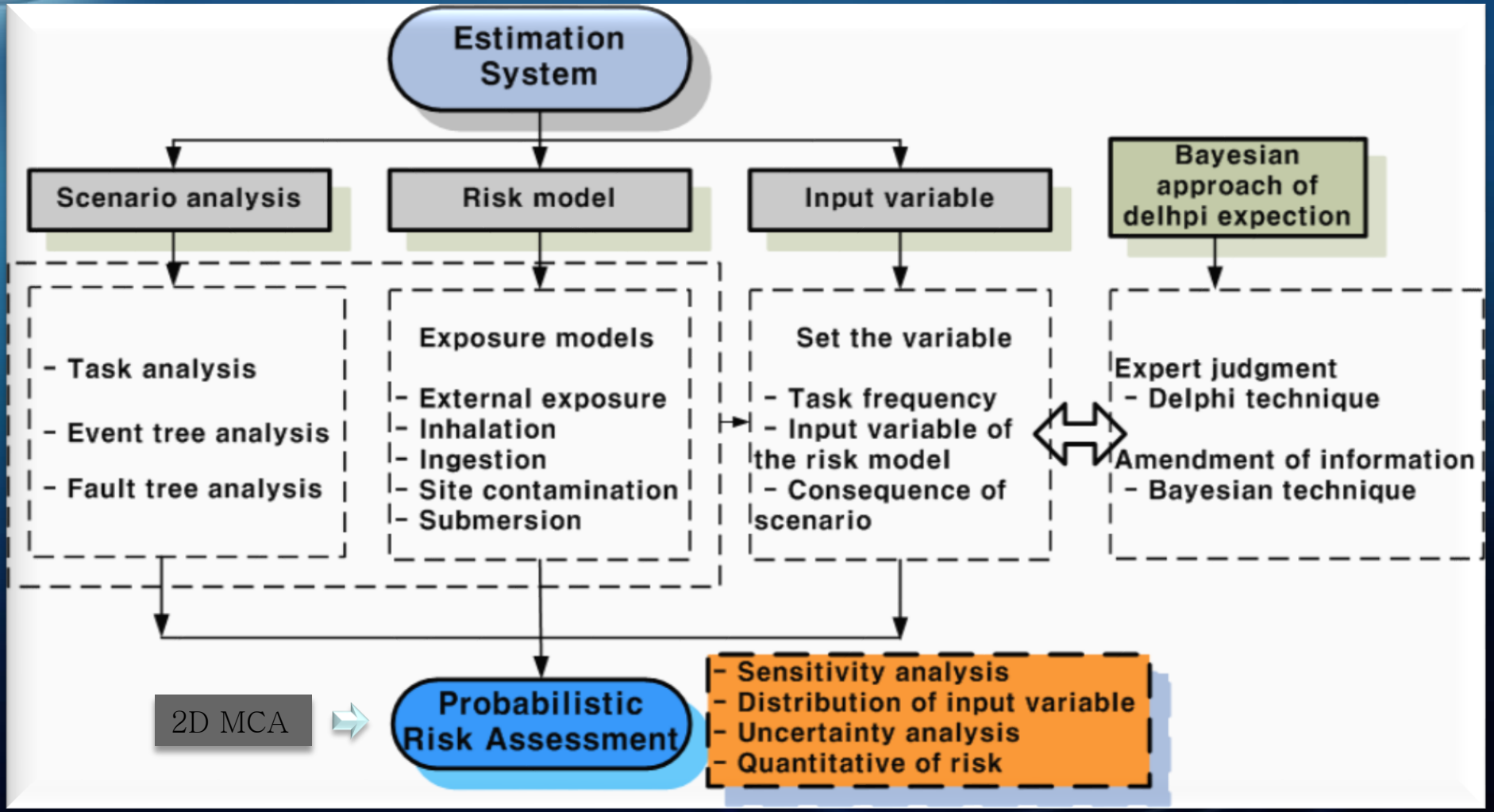
The Objectives of This Work

- To provide streamlined technique for the radiological risk assessment in operation of such radiation facilities
  - Delphi approach
  - Bayesian update
  - two-dimensional Monte Carlo analysis

- To develop procedures for the radiological risk assessment with vague information on risk contributing factors.

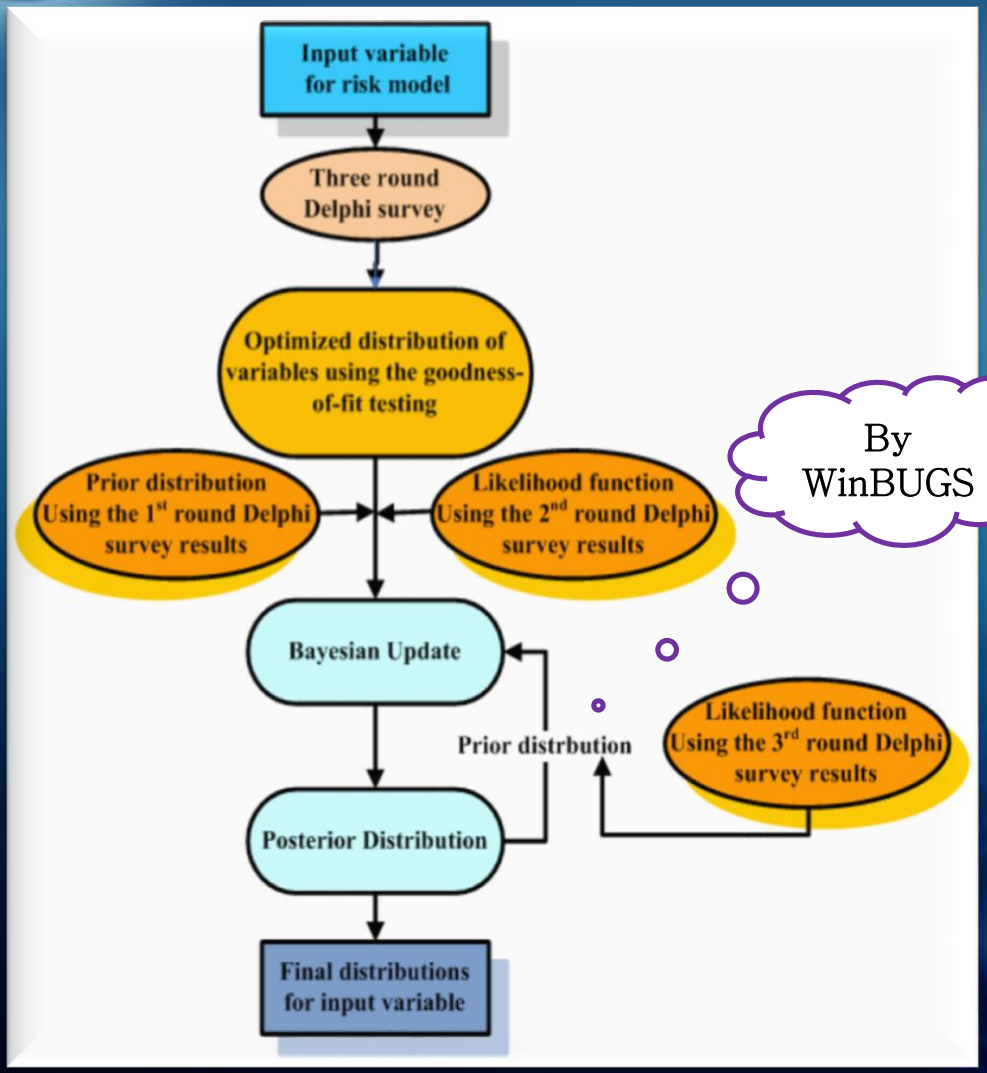
- To provide information through the investigation of factors in risk model which supports risk assessment of radiation facilities with vague information.

Process of Risk Assessment in This Work



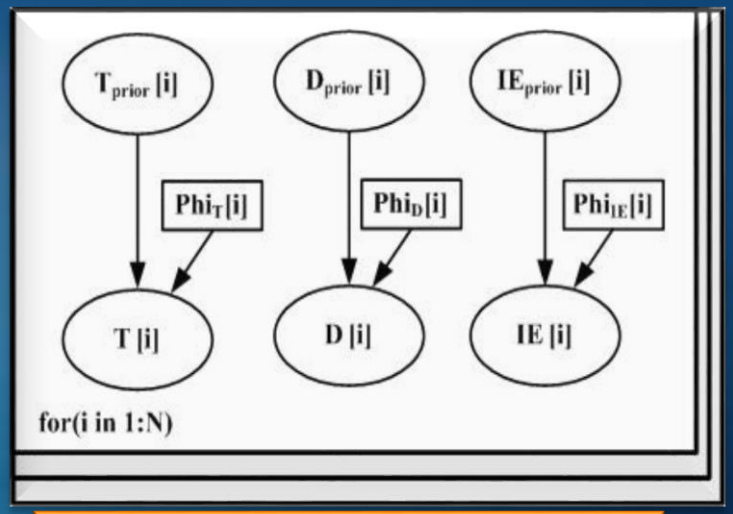
The flow chart of radiological risk assessment

Development of Probability Distributions

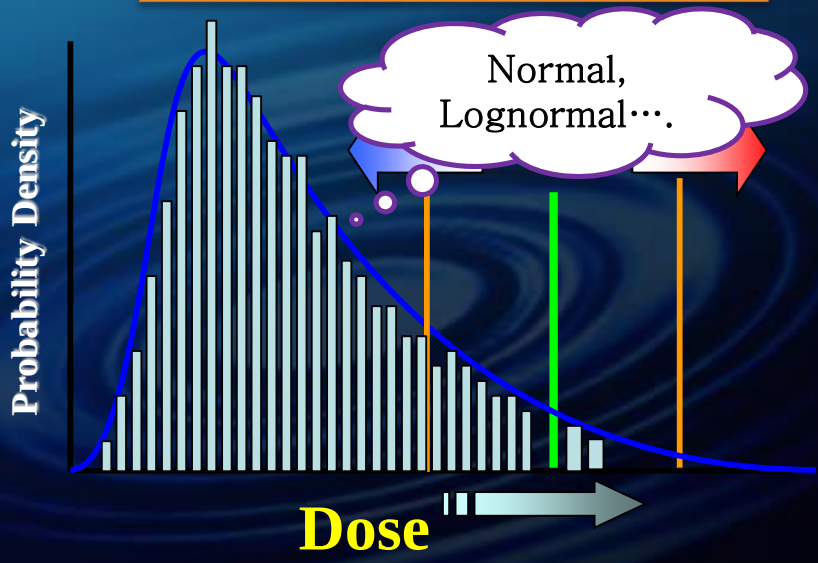


Bayesian update flow chart

By WinBUGS



WinBUGS model for input variables

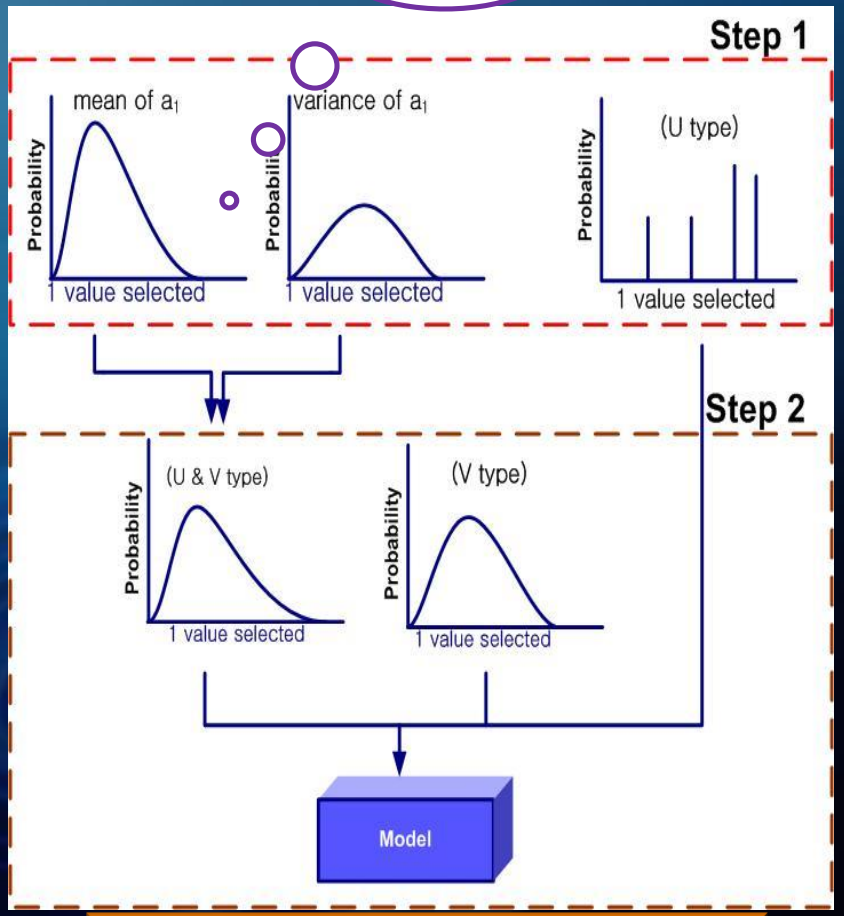


Two-Dimensional Simulations

General Approach for Simulation of Variability and Uncertainty

- A two-dimensional approach to Monte Carlo Simulation can be employed to properly disaggregate and evaluate the consequences of variability and uncertainty.
- To simulate their interactions such **as for variability with uncertain parameters, second order uncertainty and generalized case for interactions between variability and uncertainty when both variability and uncertainty are important**.
- The two-dimensional approach is referred to by some as “nesting” or “double looping”
- The sample size for the two-dimensional simulation is $m \times n = m^2 = n^2$

Classification of variability and uncertainty

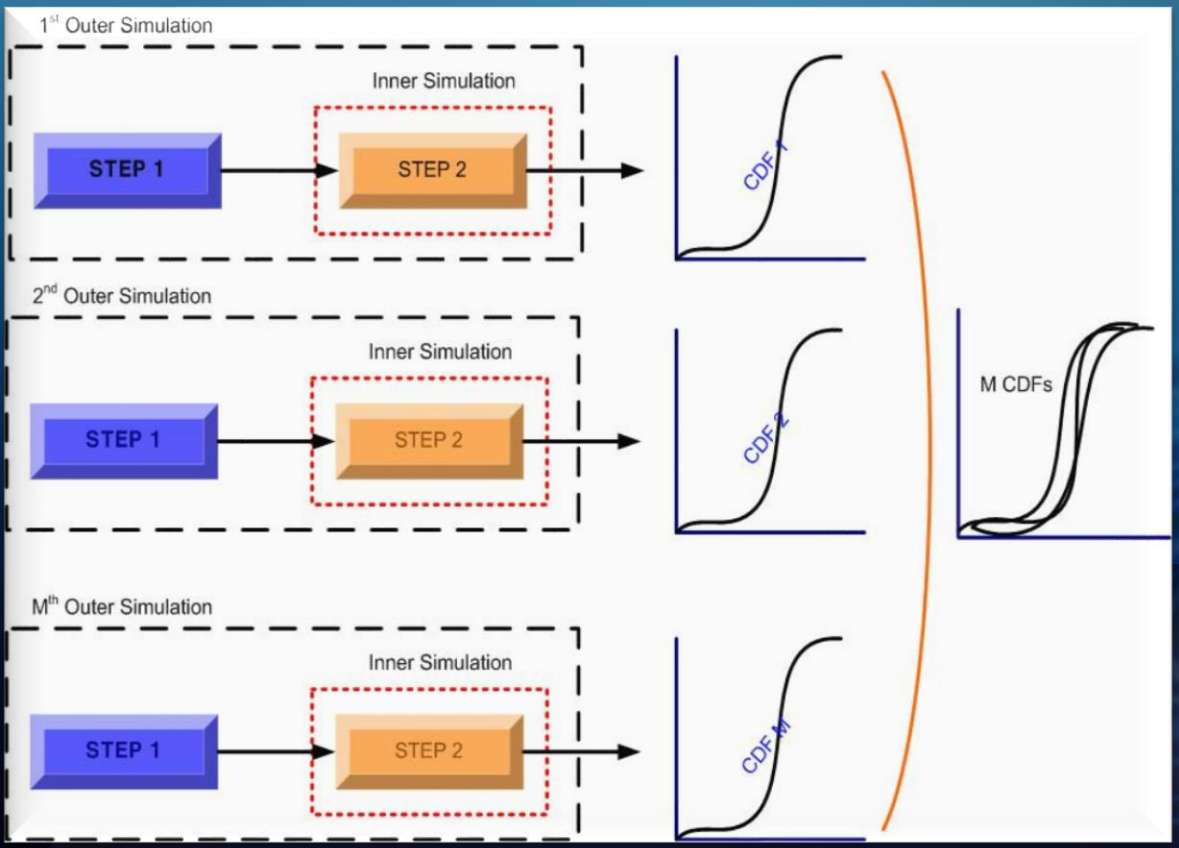


Step procedure for 2D MCA

Two-Dimensional Simulations

Simulation Logic for Two-Dimensional Monte Carlo Analysis

- Diagram showing of 2D Monte Carlo model in which the variability and uncertainty dimensions are computed in nested loops.



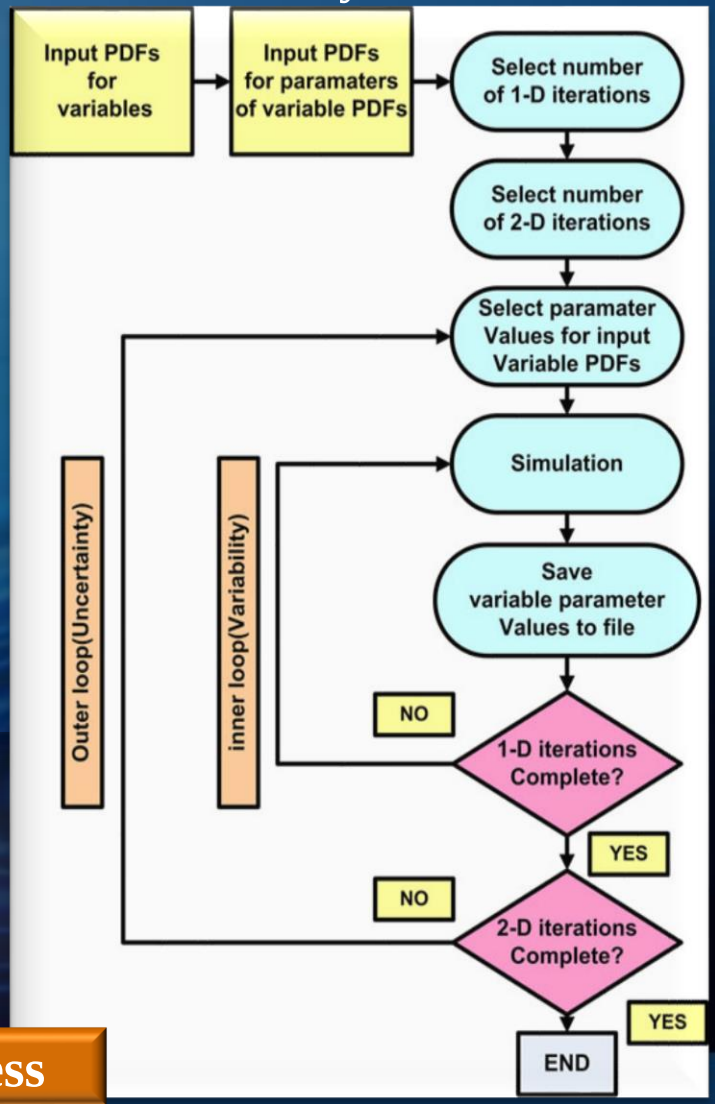
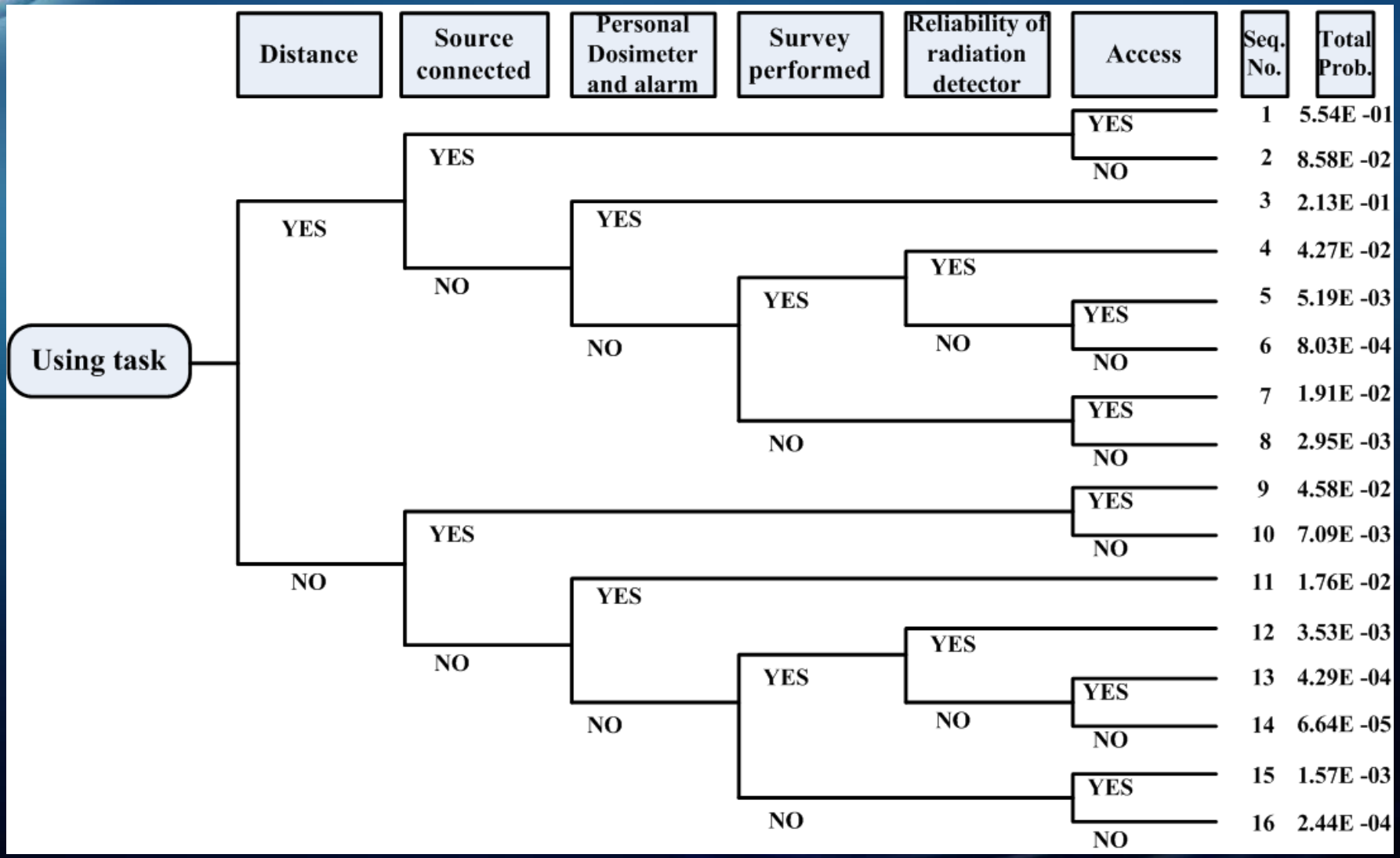


Illustration of the 2D MCA process

Constructing Event Tree[i.e. field radiography



Consideration expected incidence factors of potential exposure

Modeling uncertainty on each variable

Correlation and deterministic value of safety factors in NDT

Tasks	Safety factors					
Storage	SF1	SF2	SF3	SF4	SF5	SF6
SF1	1.00	0.71	0.60	0.75	0.66	-
SF2	0.71	1.00	0.31	0.69	0.45	-
SF3	0.60	0.31	1.00	0.68	0.72	-
SF4	0.75	0.69	0.68	1.00	0.80	-
SF5	0.66	0.45	0.72	0.80	1.00	-
Transport						
SF1	1.00	0.55	0.14	0.61	-	-
SF2	0.55	1.00	0.36	0.53	-	-
SF3	0.14	0.36	1.00	0.31	-	-
SF4	0.61	0.53	0.31	1.00	-	-
Using						
SF1	1.00	0.46	0.27	0.12	0.43	0.35
SF2	0.46	1.00	0.58	0.49	0.49	0.72
SF3	0.27	0.58	1.00	0.71	0.83	0.68
SF4	0.12	0.49	0.71	1.00	0.59	0.39
SF5	0.43	0.49	0.83	0.59	1.00	0.64
SF6	0.35	0.72	0.68	0.39	0.64	1.00
Exchange						
SF1	1.00	0.39	0.55	0.24	-	-
SF2	0.39	1.00	0.59	0.70	-	-
SF3	0.55	0.59	1.00	0.66	-	-
SF4	0.24	0.70	0.66	1.00	-	-
…	…	…	…	…	…	…

NDT	Task					
Seq. No.	Special	Exchange	Management	Storage	Transport	Using
1	5.40E-01	9.00E-01	9.00E-01	6.30E-01	6.88E-01	5.63E-01
2	1.66E-01	7.23E-02	5.61E-02	1.80E-01	1.65E-01	6.44E-02
3	2.99E-02	9.56E-03	1.75E-02	3.55E-02	5.78E-03	2.37E-01
4	4.08E-03	3.19E-03	1.77E-04	6.76E-03	1.10E-03	4.45E-02
5	1.58E-01	1.28E-02	1.60E-02	9.62E-02	1.08E-01	5.40E-03
6	2.84E-02	1.69E-03	1.62E-04	1.83E-02	3.76E-03	6.17E-04
7	3.87E-03	5.63E-04	6.23E-03	1.78E-02	7.17E-04	1.84E-02
8	5.83E-02		1.95E-03	3.51E-03	2.69E-02	2.11E-03
9	1.05E-02		1.97E-05	6.68E-04	9.41E-04	3.90E-02
10	1.43E-03		1.78E-03	9.51E-03	1.79E-04	4.45E-03
11			1.80E-05	1.81E-03		1.64E-02
12						3.08E-03
13						3.74E-04
14						4.27E-05
15						1.28E-03
16						1.46E-04
Total	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

Reference Risk in this study: 1×10^{-2} per year

Modeling uncertainty on each variable

- **Delphi survey results and input variables [NDT; Using task]**

  - field radiography: 110 input data, Variables of using task from three-stage Delphi survey

Input Variable	NDT group			KINS group			Whole panel		
	Mean	SD	95%	Mean	SD	95%	Mean	SD	95%
1st round Delphi									
Freq.[week^{-1}]	212	141	299	493	352	738	337	287	470
T. [min]	4.30	4.64	7.18	5.28	7.78	10.4	4.76	6.16	7.53
Dist.[m]	11.4	4.65	14.3	11.7	13.7	20.1	11.5	9.95	15.9
2nd round Delphi									
Freq.[week^{-1}]	317	154	417	390	267	555	360	213	453
T. [min]	9.5	14.4	18.4	7.40	8.36	12.6	8.45	11.5	13.5
Dist.[m]	11.8	3.29	13.8	10.9	6.98	15.2	11.3	5.34	13.7
3rd round Delphi									
Freq.[week^{-1}]	307	135	391	389	238	536	348	193	433
T. [min]	15.1	18.6	26.6	11.4	21.4	24.6	13.2	19.6	21.8
Dist.[m]	10.6	3.5	12.8	9.9	7.3	14.5	10.3	5.6	12.7

Modeling uncertainty on each variable

- **Bayesian update results for safety factors in Delphi survey**
  - Using the WinBUGS program

Safety factors	Percentiles of NDT safety factors						
	2.5%	5%	Mean	Median	95%	97.5%	MC error [%]
Storage							
SF1	0.04	0.07	0.54	0.51	0.96	1.00	6.83E-04
SF2	0.01	0.02	0.17	0.15	0.38	0.43	1.93E-04
SF3	0.03	0.06	0.49	0.45	0.95	1.00	6.13E-04
SF4	0.02	0.04	0.36	0.33	0.82	0.92	4.33E-04
SF5	0.01	0.03	0.26	0.23	0.60	0.67	2.80E-04
Transport							
SF1	0.02	0.03	0.28	0.25	0.60	0.67	4.10E-04
SF2	0.02	0.04	0.35	0.32	0.76	0.85	4.52E-04
SF3	0.00	0.01	0.08	0.07	0.18	0.20	9.50E-05
SF4	0.02	0.04	0.31	0.28	0.67	0.75	4.43E-04
SF5	0.03	0.05	0.47	0.43	0.96	1.00	5.97E-04
Using							
SF1	0.01	0.02	0.17	0.15	0.38	0.43	2.00E-04
SF2	0.03	0.06	0.48	0.44	0.96	1.00	6.18E-04
SF3	0.02	0.05	0.40	0.37	0.88	0.98	5.05E-04
SF4	0.03	0.05	0.47	0.43	0.97	1.00	5.57E-04
SF5	0.01	0.02	0.20	0.18	0.45	0.51	2.19E-04
SF6	0.01	0.02	0.22	0.20	0.49	0.55	2.79E-04
Exchange							
…	…	…	…	…	…	…	…	…

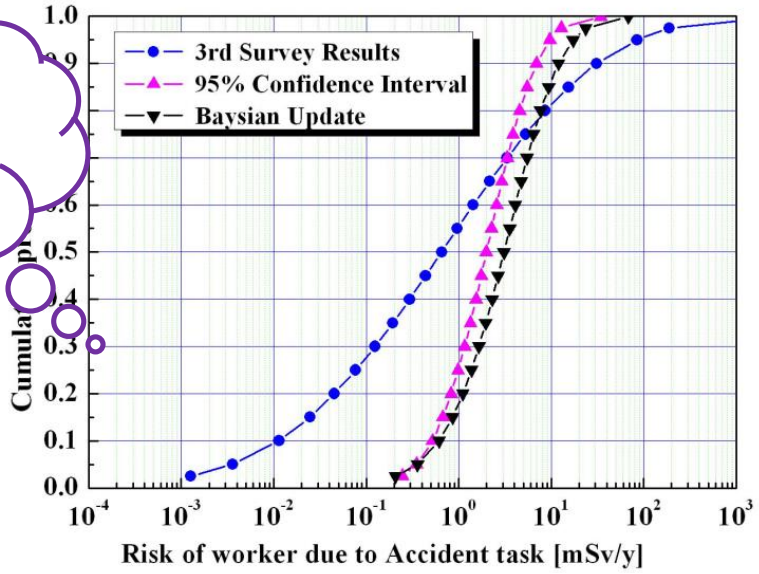
1D MCA Results of Modified input Variables

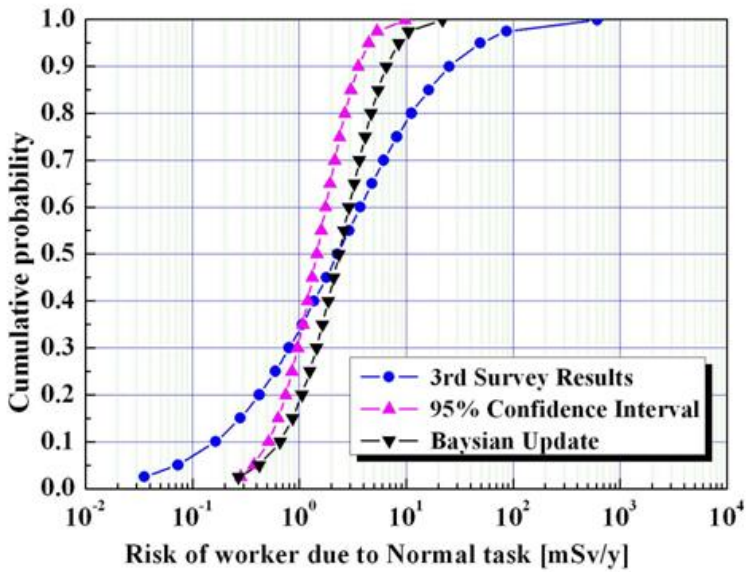
Risk of three types

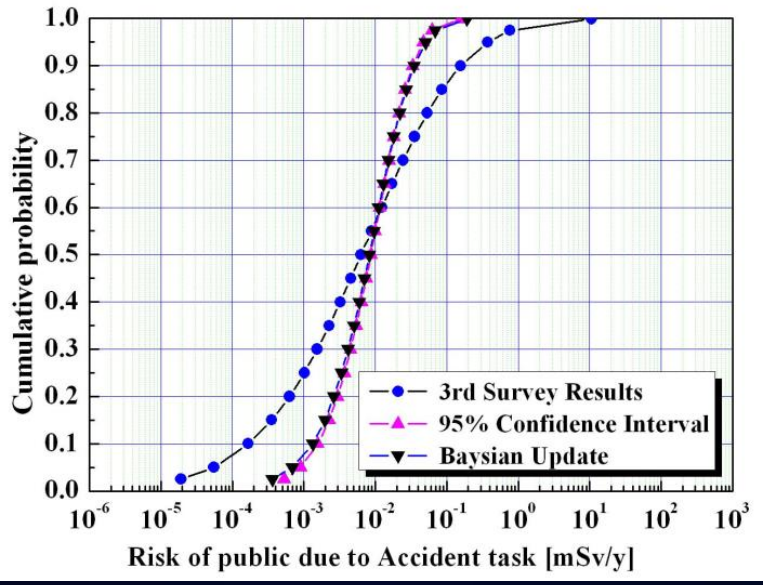
(Using task)

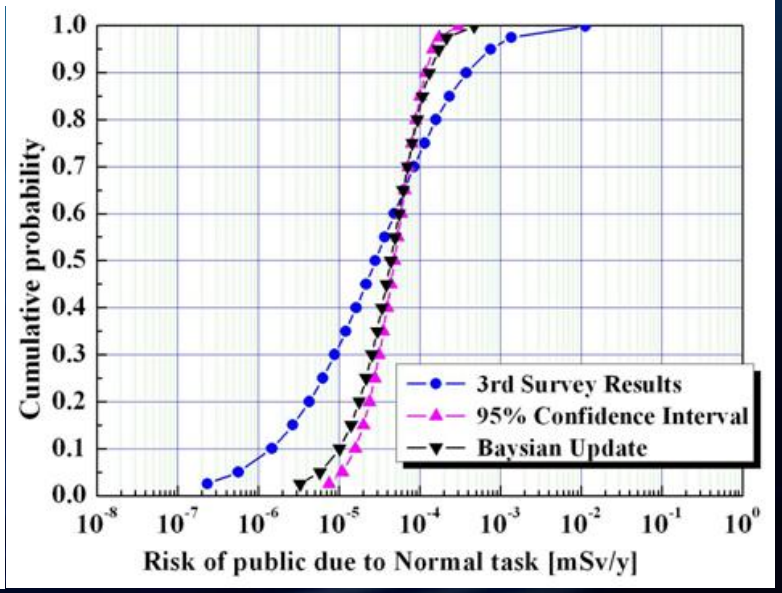
(a) worker

(b) public









Risk from different characterizing methods of input variable [(a) worker (b) public due to normal task and accident]

Modeling uncertainty on each variable

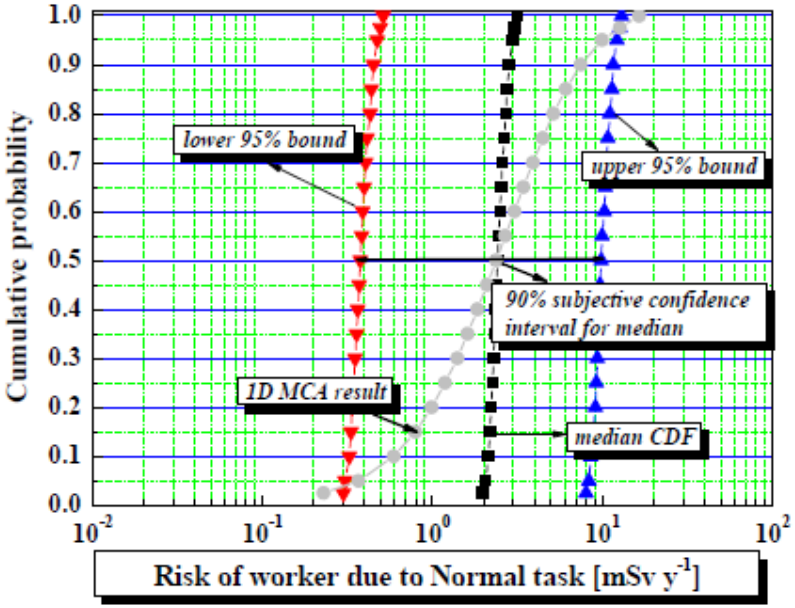
Model Variable, Distribution Parameter for Using task in NDT

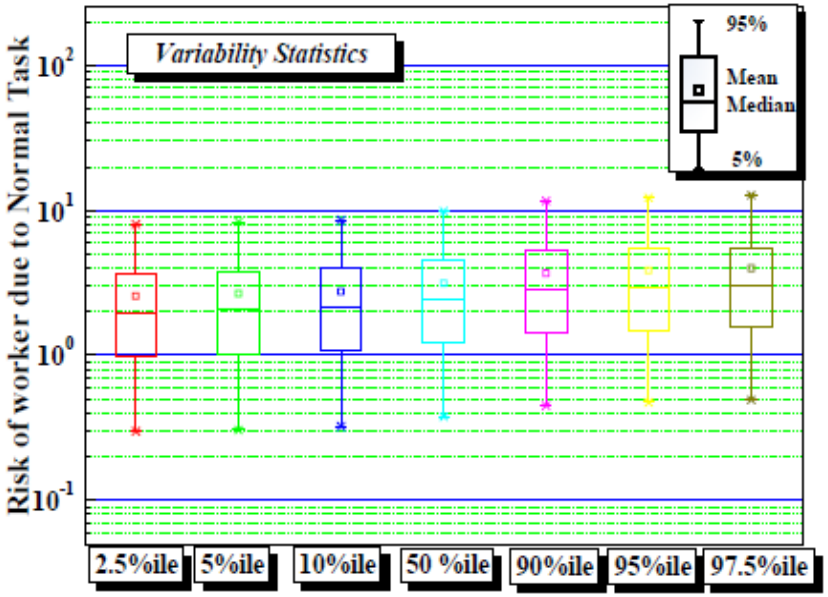
- information about the variability and uncertainty of model variables for 2D MCA

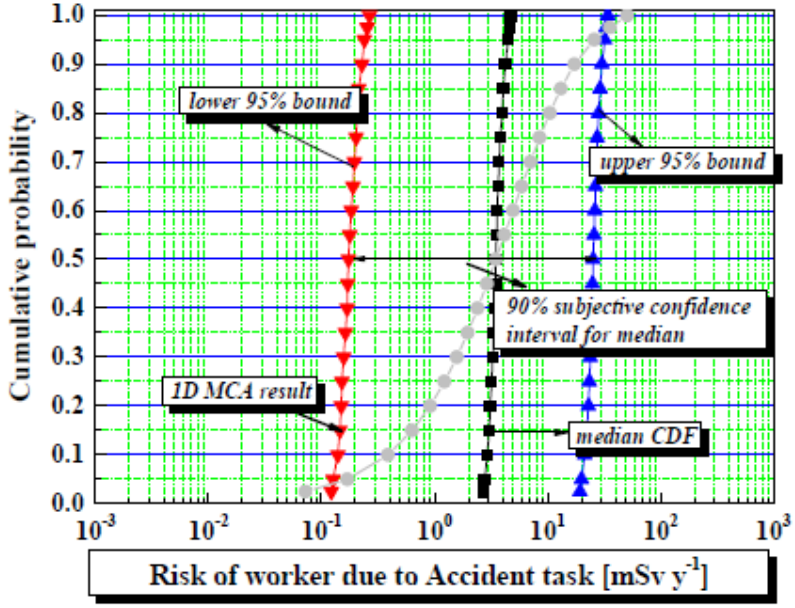
Model Variable		Time		Distance		Frequency		Activity	
Variability (V-Type)	Distribution	Lognormal(M_{Time}, S_{Time})		Lognormal(M_{Dist}, S_{Dist})		Lognormal(M_{Freq}, S_{Freq})		Uniform(Min_{Act}, Max_{Act})	
	Distribution Parameter	M_{Time}	S_{Time}	M_{Dist}	S_{Dist}	M_{Freq}	S_{Freq}	Min_{Act}	Max_{Act}
		0.143	0.07	9.34	1.35	15800	2040	10	56
Uncertainty (U-Type)	Distribution	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle
	Min.	0.129	0.063	8.41	1.21	14200	1830	9	50.4
	Mode	0.143	0.07	9.34	1.35	15800	2040	10	56
	Max.	0.157	0.077	10.3	1.48	17400	2240	11	61.6

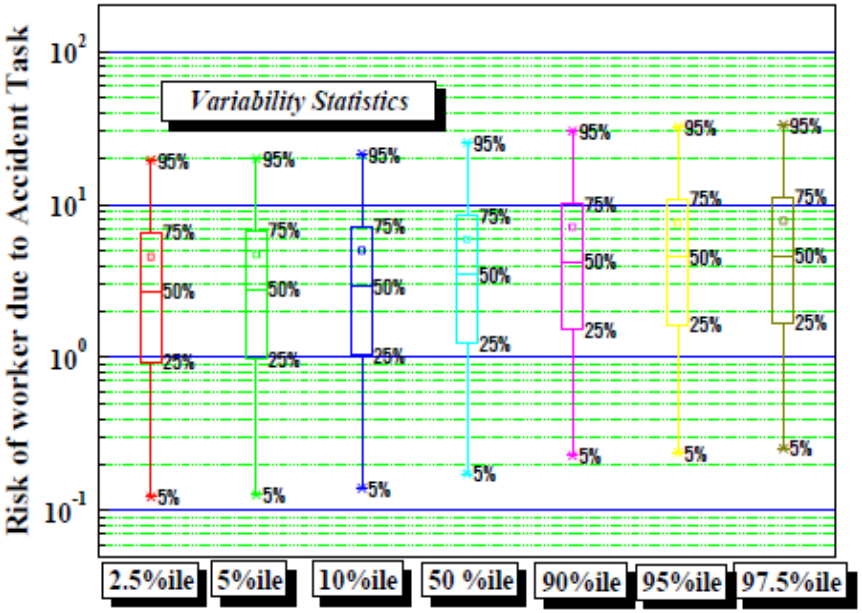
Model Variable		SF1		SF2		SF3		SF4		SF5		SF6	
Variability (V-Type)	Distribution	Lognormal (M_{SF1}, S_{SF1})		Lognormal (M_{SF2}, S_{SF2})		Lognormal (M_{SF3}, S_{SF3})		Lognormal (M_{SF4}, S_{SF4})		Lognormal (M_{SF5}, S_{SF5})		Lognormal (M_{SF6}, S_{SF6})	
	Distribution Parameter	M_{SF1}	S_{SF1}	M_{SF2}	S_{SF2}	M_{SF3}	S_{SF3}	M_{SF4}	S_{SF4}	M_{SF5}	S_{SF5}	M_{SF6}	S_{SF6}
		0.065	0.04	0.33	0.077	0.23	0.09	0.28	0.12	0.12	0.07	0.10	0.047
Uncertainty (U-Type)	Distribution	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle	Triangle
	Min.	0.055	0.035	0.3	0.07	0.21	0.08	0.26	0.11	0.11	0.06	0.09	0.04
	Mode	0.065	0.04	0.33	0.08	0.23	0.09	0.29	0.12	0.12	0.07	0.10	0.05
	Max.	0.07	0.046	0.36	0.087	0.25	0.10	0.32	0.13	0.13	0.08	0.11	0.055

Risk for using task from 2D MCA Results









Conclusions

Risk-informed regulation for Radiation Protection

1. 2D MCA results provide various information about the risk
2. This study can be used as guidance for the decision-making in determining a predicted radiological risk
3. The expert role provides valuable information in case of insufficient data for model variables
4. State of the art for the analysis of risk constraint

THANK YOU FOR YOUR ATTENTION !