

## IE2111 ISE Principles & Practice II

### Tutorial #4 (Uncertainty & Risk Analysis)

#### Question 1 (based on Sullivan *et al* 2020, P11-26)

Suppose that, for an engineering project, the optimistic (best), most likely (base), and pessimistic (worst) estimates are as shown in the table below:

	Pessimistic	Most likely	Optimistic
Capital Investment	\$ 120,000	\$ 100,000	\$ 90,000
Useful Life	6 years	10 years	12 years
Market Value at EoL	\$ 0	\$ 20,000	\$ 30,000
Net annual cash flow	\$ 20,000	\$ 30,000	\$ 35,000

$MARR = 10\%$ . Assume repeatability.

- (a) Determine the  $AW$  of the project under the following conditions:
  - i. When all the factors are at their most likely values.
  - ii. When all the factors are at their optimistic values.
  - iii. When all the factors are at their pessimistic values.
- (b) Perform one-way range sensitivity analysis of these factors on the  $AW$  of the project and plot a tornado diagram and spider diagram.
- (c) Identify from the tornado and spider diagrams, the sensitive and insensitive factors.

#### Question 2 (based on Sullivan *et al* 2014, P11-3)

The Universal Postal Service is considering the possibility of fixing wind deflectors on the tops of 500 of their long-haul tractors. Three types of deflectors, with the following characteristics, are being considered ( $MARR = 10\%$  per year).

	Winshear	Blowby	Air-vantage
Capital Investment	\$1,000	\$400	\$1,200
Drag reduction	20%	10%	25%
Maintenance per year	\$10	\$5	\$5
Useful life	10 years	10 years	5 years

A 5% in drag reduction means 2% in fuel saving per mile. Fuel cost is expected to be \$4.00 per gallon, and average fuel consumption is 5 miles per gallon without the deflectors.

Let  $X$  denotes the number of miles driven per year by a tractor.

- (a) Assuming repeatability and a study period of 10 years, determine the Equivalent Uniform Annual Cost ( $EUAC$ ) for each of the alternatives in terms of  $X$ . Plot a rainbow diagram for  $EUAC$  vs  $X$ .
- (b) Determine the range of values of  $X$  for which each alternative is the optimal choice.

**Question 3** (based Sullivan *et al* 2014, P11-5)

Consider two alternatives with base-case scenario values as follows:

	Alternative 1	Alternative 2
Capital Investment	\$ 4,500	\$ 6,000
Annual revenues	\$ 1,600	\$ 1,850
Annual expenses	\$ 400	\$ 500
Estimated market value	\$ 800	\$ 1,200
Useful life	8 years	10 years

- (a) Assume repeatability and  $MARR = 15\%$ , determine which alternative should be chosen under the base case scenario values?
- (b) By how much would the capital investment for Alternative 2 have to vary so that the base case value decision would be reversed?
- (c) By how much would the useful life of Alternative 1 have to vary so that the base case value decision would be reversed?

**Question 4** (based Sullivan *et al* 2020, P12-11)

The purchase of a new piece of electronic measuring equipment for use in a continuous metal forming process is being considered. If this equipment were purchased, the capital cost would be \$418,000, and the estimated saving are \$148,000 per year. The useful life of the equipment in this application is uncertain. The estimated probabilities of different useful lives occurring are shown in the following table:

Useful Life, Years ( $N$ )	$p(N)$
3	0.1
4	0.1
5	0.2
6	0.3
7	0.2
8	0.1

Assume that the  $MARR = 15\%$  per year before taxes, and the market value at the end of its useful life is equal to zero. Based on a before- tax analysis.

- (a) What are the  $E[PW]$ ,  $Var[PW]$ , and  $SD[PW]$  associated with the purchase of the equipment?
- (b) Plot a risk profile for the  $PW$  of the project.
- (c) Determine the followings from the risk profile:
- Downside risk of the project, i.e., probability that  $PW \leq 0$ ?
  - Chance of achieving an upside potential of  $PW \geq \$150,000$ ?
  - Present Equivalent Value-at-Risk (95% confidence)?

**Question 5** (based on Sullivan *et al* 2020, P12-19)

Two investment alternatives are being considered. The data below have been estimated by a committee of experts. *MARR* is 15 % per year and project life is not uncertain.

	Alternative <i>A</i>		Alternative <i>B</i>	
EoY	Expected Cash Flow (\$)	Standard Deviation of Cash Flow (\$)	Expected Cash Flow (\$)	Standard Deviation of Cash Flow (\$)
0	-8,000	0	-12,000	500
1	4,000	600	4,500	300
2	6,000	600	4,500	300
3	4,000	800	4,500	300
4	6,000	800	4,500	300

- (a) If all the cash flows are mutually independent, determine the expected value and standard deviation of the *PW* of alternatives *A* and *B*. It is possible to determine which is the preferred alternative?
- (b) If all the cash flows are mutually independent, determine the expected value and standard deviation of the *PW* of the incremental investment from *B* to *A*, i.e.,  $PW(A - B)$ .
- (c) If the cash flows for investment alternative *A* are not mutually independent and the relevant correlation coefficients are  $\rho_{12} = 0.1$ ,  $\rho_{23} = 0.2$ , and  $\rho_{34} = 0.3$ , determine the expected value and standard deviation of its *PW*.