American University of Armenia
IE 340 – Engineering Economics
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Chapter 10 – Dealing with Uncertainty

Risk and Uncertainty

- **Risk and uncertainty are similar in that they both present the problem of not knowing what future conditions will be**
- **Risk offers estimates of probabilities for possible outcomes**
- **Uncertainty does not provide estimates of probabilities for possible outcomes**
- **This book treats them as interchangeable**

Four major Sources of Uncertainty

1. Possible inaccuracy of cash-flow estimates used in the study

2. Type of business relative to the future health of the economy

3. Type of physical plant and equipment involved

4. Length of study period

Possible Inaccuracy of Cash-flow estimates

- **How much source information is available**

- **How dependable is the source information**

- **Uncertainty in capital investment requirements is often reflected as a *contingency* above actual cost of plant and equipment**

Type of Business Involved Relative to Health of Economy

Some businesses will typically be more at risk of declining with when there is a general decline in the economy -- when the economy has gone into recession

Type of Physical Plant and Equipment Involved

- Some types of structures and equipment have definite economic lives and market values – they may be used in a multitude of settings

- Other dwellings and equipment, being made for very specific and singular functions, may have little or no resale value

Length of Study Period

The longer the study period, the greater the level of uncertainty of a capital investment

Sensitivity Analysis

- **Sensitivity** – The degree to which a measure of merit (i.e., PW, IRR, etc…) will change as a result of changes in one or more of the study factor values.

Sensitivity Analysis Techniques

1. Breakeven Analysis
2. Sensitivity Graph (spider-plot)
3. Combination of factors

Breakeven Analysis

- Technique commonly used when an uncertain single factor (EG: capacity utilization) determines the selection of an alternative or acceptability of an engineering project

- For given alternative, if best estimate of actual outcome of common factor is higher or lower than the breakeven point, and assumed certain, the best alternative becomes apparent

Breakeven Analysis

Indifference between alternatives

$(EW_A = f_1(y); EW_B = f_2(y)$

$EW_A = EW_{B;}$ $f_1(y) = f_2(y)$: Solve for y

Economic acceptability of engineering project

$EW_p = f(z) = 0$

The value of 'z' is the value at which we would be indifferent between accepting or rejecting the project

Breakeven Problem Involving Two Alternatives

Most easily approached mathematically by equating an equivalent worth of the two alternatives expressed as a function of the factor of interest

Breakeven Analysis for Economic Acceptability of an Engineering Project

Most easily approached by equating an equivalent worth of the project to zero as a function of the factor of concern

Because of the potential difference in project lives, care should be taken to determine whether the co-terminated or the repeatability assumption best fits the situation

Example applications of Breakeven Analysis

- Annual revenue and expenses
- Rate of return
- Market (or salvage) value
- Equipment Life
- Capacity utilization

Example

- Two electric motors are being considered to power an industrial hoist. Each is capable of providing 90 hp. Pertinent data for each motor are presented bellow.

- If the expected usage of the hoist is 500 hr per year, what would the cost of electrical energy have to be (in cents per kilowatt-hour) before the D-R motor is favored over the Westhouse motor? The MARR is 12% per year. [*Note: 1hp = 0.746KW*]

Example

	Motor	
	D-R	Westhouse
Capital investment	$2,500	$3,200
Electrical efficiency	0.74	0.89
Maintenance per year	$40	$60
Useful life	10 yr	10 yr

Example: Solution

- Let X = electrical energy cost in $/kW-hr. Equate the equivalent uniform annual worth of both motors:
-
- $AW_{D\text{-}R}(12\%) = AW_{WH}(12\%)$
-
- -$2,500(A/P,12%,10) - $40 - (90 hp/0.74)(0.746 kW/hp)(500 hrs)(X / kW-hr)
- = -$3,200(A/P,12%,10) - $60 - (90 hp/0.89)(0.746 kW/hp)(500 hrs)(X / kW-hr)
-
- $482.5 + ($45,364.87)(X) = $626.4 + ($37,719.10)(X)
-
- X = $143.90 / $7,645.77 = $0.0188 / kW-hr or <u>1.88¢ / kW-hr</u>

Sensitivity Grapfh (Spider-plot)

An analysis tool applicable when the breakeven analysis does not fit the project situation

Makes explicit the impact of uncertainty in the estimates of each factor of concern on the economic measure of merit

EXAMPLE 10-4

- The best cash-flow estimates for a machine being considered for installation:
- Capital Investment (I) = $11,500
- Revenues/yr (A) = $5,000
- Expenses (A) = $2,000
- Market Value (MV) = $1,000
- Useful Life (N) = 6 years

EXAMPLE 10-4

Investigate PW over a range of $\pm$ 40% changes in estimates for

a. Capital investment

b. Annual net cash flow

c. Market value

d. Useful Life

$$PW(10\%) = -\$11,500 + \$3,000\ (P / A, 10\%, 6) + \$1,000\ (P / F, 10\%, 6) = \$2,130$$

EXAMPLE 10-4

- **(a) Capital investment varies by + - p**

PW(10%) = -(1+_ p%/100)*$11,500 + $3,000(P/A, 10%, 6) + $1,000(P/F, 10%, 6)

- **(b) Annual cash flow varies by + - a**

PW(10%) = - $11,500 +
(1+_ a%/100)*$3,000(P/A, 10%, 6) + $1,000(P/F, 10%, 6)

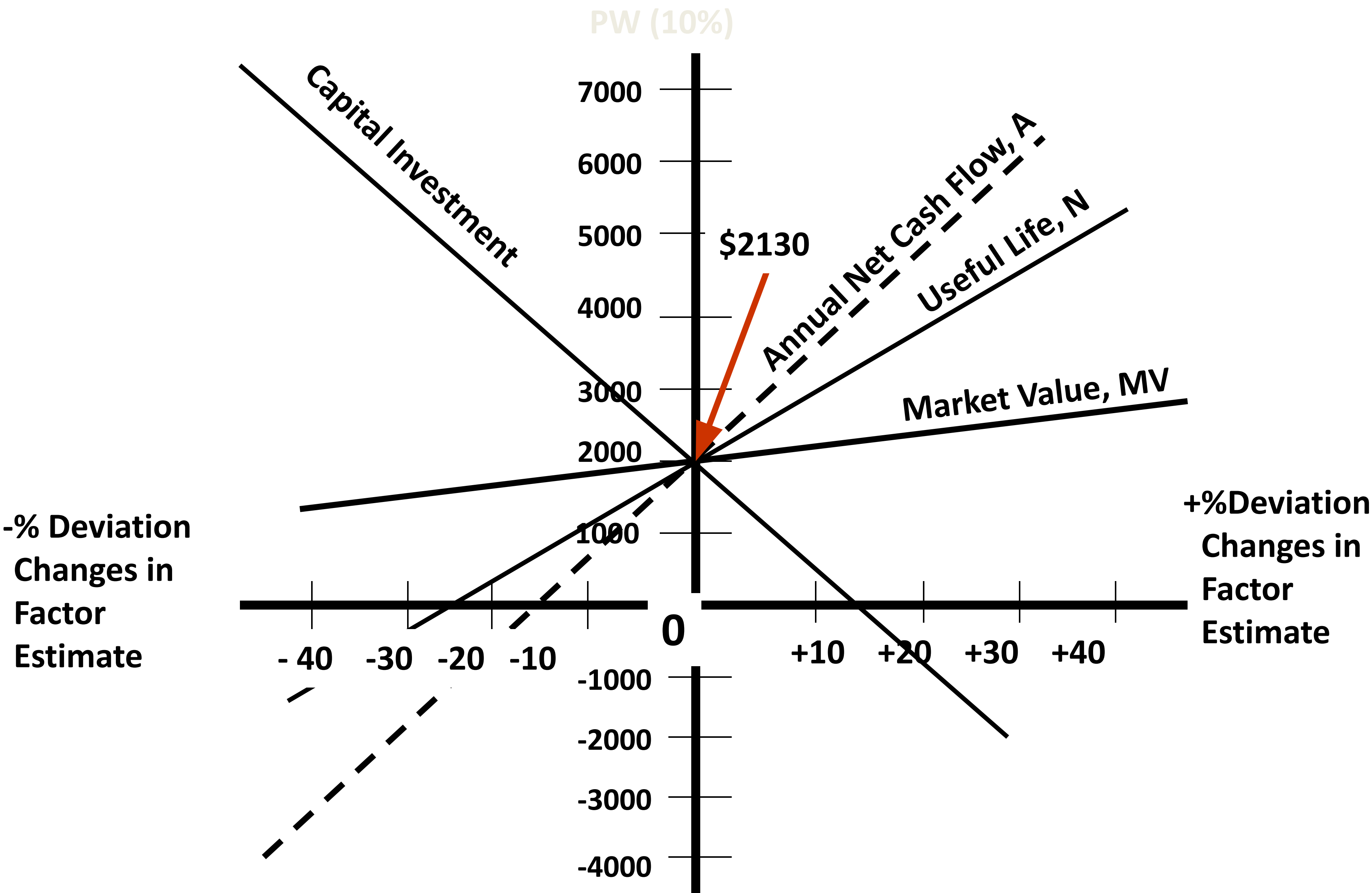
- **(c) Market Value varies by + - s**

PW(10%) = - $11,500 +
$3,000(P/A, 10%, 6) + (1+_ s%/100)*$1,000(P/F, 10%, 6)

- **(d) Useful life varies by + - n**

PW(10%) = - $11,500 +
$3,000(P/A, 10%, (6+_n%/100)) + $1,000(P/F, 10%, (6+_n%/100))

Sensitivity Graph (Spider-plot) for Four Factors



Revelations of Spider-plot

- **Shows the sensitivity of the present worth to percent deviation changes in each factor's best estimate**

- **Other factors are assumed to remain at their best estimate values**

- **The relative degree of sensitivity of the present worth to each factor is indicated by the slope of the curves (the "steeper" the slope of a curve the more sensitive the present worth is to the factor)**

- **The intersection of each curve with the abscissa shows the percent change in each factor's best estimate at which the present worth is zero**

Revelations of spider-plot

In this example

- Present worth is insensitive to MV
- Present worth is sensitive to I, A, and N

Measuring Sensitivity by a Combination of Factors

1. Develop a sensitivity graph for the project

   a. For most sensitive factors, improve estimates and reduce range of uncertainty

2. Use sensitivity graph to select most sensitive project factors. Analyze combined effects of these factors on project's economic measure of merit by:

   a. Additional graphical technique for two most sensitive factors

   b. Determine the impact of selected combinations of three or more factors -- **scenarios**

Pitfalls of Risk Adjusted MARR

- **A widely used industrial practice for including some consideration of uncertainty is to increase the MARR**

- **Even though intent of risk-adjusted MARR is to make more uncertain projects appear less economically attractive, opposite may appear to be true**

- **Cost-only projects are made to appear more desirable as the interest rate is adjusted upward to account for uncertainty**

Reduction of Useful Life

- By dropping from consideration those revenues (savings) and expenses that may occur after a reduced study period, heavy emphasis is placed on rapid recovery of capital in early years of a project’s life

- This method is closely related to the discounted payback technique and suffers from most of the same deficiencies