

Course Title
Engineering Economic Analysis

Chapter 6
Risk Analysis

Lecture 10 (Week 10)

**Project risk, Sources of risk and uncertainty,
Methods of describing project risk (Break
even analysis)**

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Learning Objective

From studying this chapter the students will be able to understand on the topics:

- Concept of Risk, Certainty and Uncertainty
- Sources of risk and uncertainty
- Methods of describing project risk (Break even analysis)

6.1 Concept of risk and uncertainty

In previous lectures, economic analysis of an investment project was based on the assumption that a complete information about the cash flow over the life a project was available. It means that there was no uncertainty connected with the cash flow and same cash flow will occur over the life of a project, i.e. *certainty*. But this type of situation is very rare in the economic analysis of project. The estimate of cash flows are connected with some degree of uncertainty due to uncontrollable factors. These uncontrollable factors might be:

- (a) Total market for the product (the market share that the firm can attain and the growth in the market)
- (b) The cost of producing the product, including labor and materials
- (c) The selling price of a product
- (d) The life of the project
- (e) The cost and life of the equipment needed and
- (f) The effective tax rates.

A common approach is to make single- number “best estimates” for each of the uncertain factors and then to calculate measures of profitability, such as NPW or rate of return for the project. [1] This approach has two drawbacks:

- (a) No guarantees can ever ensure that the “best estimates” will ever match actual values.
- (b) Managers have no way of determining either the probability that a project will lose money or the probability that it will generate profit.

In this type of situation, the best can the business firm can estimate the range of possible future cost and benefits and the relative chance of achieving a reasonable return on investment. [1] Hence we use the term *risk* to describe investment project whose cash flow is not known in advance with the absolute certainty. Risk refers to a lack of predictability about economic environment and about outcomes and choices that are available in a decision situation. [2]

Project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective. A risk has a cause and if it occurs, a consequences. Simply risk means uncertainty and the result of uncertainty. Risk assessment enables corporations, governments, and investors to assess the probability that an adverse event might negatively impact a business, economy, project, or investment. [3] Risk analysis is the process of identifying and analyzing potential issues that could negatively impact key business initiatives or projects. This process is done in order to help organizations avoid or mitigate those risks. Quantitative statements about risk are given as numerical probabilities or as values for likelihood of occurrence. Probabilities are given as decimal fractions in the interval 0.0 to 1.0. An event or outcome that is certain to occur has a probability of 1.0. As the probability of an event approaches 0, the event becomes increasingly less likely to occur. The assignment of probabilities of the various outcomes of an investment project is generally called risk analysis. [1]

Types of Decision

Decision making Under Certainty

Deterministic estimates are made and entered into measure of worth relations-PW, FW, AW, ROR, B/C –and decision making is based on the results. The values estimated can be considered the most likely to occur with all chance placed on the single value estimate.

Decision making Under Risk

Decision situation where several states are possible and probabilities of their occurrence are explicitly stated.

Decision under Uncertainty

Decision making under uncertainty means there are two or more values observable, but the chance of their occurring cannot be estimated. Risk and uncertainty are different, though complementary concept. Risk refers to a situation where a project has a number of possible alternative outcomes, but the probability of each occurring is known. Uncertainty refers to a situation in which these probabilities are not known.

Difference between risk and uncertainty

In practice, the terms are often used interchangeably. However there is difference between these two terms.

Comparison Basis	Risk	Uncertainty
Definition	An event, if occurs, can affect any project objective.	There is no information about the future event, or impact.
Key Feature	Risk can be measure	Uncertainty cannot be measured.
Control	As the outcomes are known, risk can be controlled.	As the outcomes are unknown, uncertainty cannot be controlled.
Probability	Risks have the probability of occurring.	Probabilities of uncertainties cannot be guessed.

Table Source: [4]

6.2 Sources of Risk and Uncertainty

1. Inaccurate cash flow estimate.

The first source is the possible inaccuracy of the cash flow estimate used in the study. The accuracy of cash inflow estimate is difficult to determine. If they are based on past experience, a fair degree of reliance may be placed on estimates. Otherwise the, the estimate would become more uncertain.

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2. Nature of business

The second source is the nature of business involved in the economy. All the business are not same nature because some types of business operations are less stable than the others. Whenever capital is to be invested in an engineering project, the nature of the business as well as expectations of future economic conditions (i.e. interest rate) should be considered in deciding what risk is present.

3. Physical plant and equipment

The third source of risk and uncertainty is the type of physical plant and equipment involved in the project. The cost (ownership as well as operating) cost for same type of plant and equipment may differ as well as the physical life and economic life of a plant might be different. The value of the plant will depend upon the specific task that it can perform.

4. Study period

The fourth important source of risk and uncertainty is the length of the study period. Study period or planning horizon is always the perspective of investor. The cash flow is generated over the life of the study period to expect the satisfactory economic return of an investment. If the planning horizon is long, the chances of occurring uncertainty of a capital investment increases and vice versa.

6.3 Method of describing project risk

There are several potential sources contributing to project risk. These risks should be analyzed using the different methods:

1. Break Even Analysis
2. Sensitivity Analysis
3. Scenario Analysis (optimistic – pessimistic – most likely estimation)
4. Risk adjusted MARR
5. Decision Tree
6. Reduction in useful life

6.3.1 Break Even Analysis

One of the most common tools used in evaluating the economic feasibility of a new enterprise or product is the break-even analysis. The main objective of Break-Even Analysis is to find out the condition of no loss and no gain. When one of the engineering economy symbols – P, F, A, i, or n – is not known or not estimated, a break-even quantity can be determined by setting an equivalence relation for PW or AW equal to zero. [5]

It is also known as the cost – volume – profit analysis, is widely used for financial studies because it is simple and extracts useful insights from modest amount of data. [2] A break-even analysis reveals when your investment is returned dollar for dollar, no more and no less, so that you have neither gained nor lost money on the venture. [6]

Break – Even Analysis for a Single Project

The break-even point is the point at which revenue is exactly equal to costs. At the breakeven point, no profit is being made, nor will any losses incurred. Break-even analysis is based on two types of costs: Fixed costs and Variable costs.

Fixed Cost

Fixed cost are those that remain the same (constant) for the firm regardless of how many goods are produced. All start- up cost such as land, building, rent, insurance, equipment etc. are considered as fixed cost since you have to make these outlays before you sell your first item. Fixed cost are reduced through improved equipment, information systems and workforce utilization. [5]

Variable costs

Variable costs are those cost which vary with the number of item produced. These are recurring costs that you absorb with each unit produce or sell. It includes cost of wages, raw materials, electric, fuel, advertisement etc. It is usually possible to decrease variable costs through improvements in design, efficiency, materials, quality, safety and sales volume. [5]

Let,

s be the selling price per unit.

v be the variable cost per unit.

FC be the fixed cost per period.

Q be the quantity of production.

- Total sales (S) = s*Q(1)

- Total cost of Firm (TC) = Variable cost + Fixed cost

$$(TC) = v*Q + FC..... (2)$$

Linear plot of these two equations is given in the figure 6.1 below. The intersection point of the total sales revenues and the total cost line is called the breakeven point. At the intersection point the total cost is equal to total revenue and is the condition of no loss or no gain.

$$\text{Total Cost} = \text{Total Sales}$$

$$\text{Variable cost} + \text{fixed cost} = s*Q$$

$$\text{Or, } v*Q + FC = s*Q$$

$$\text{Or, } FC = s*Q - v*Q$$

$$\text{Or, } Q_{\text{BEP}} = FC / (s - v) \text{ (units)}$$

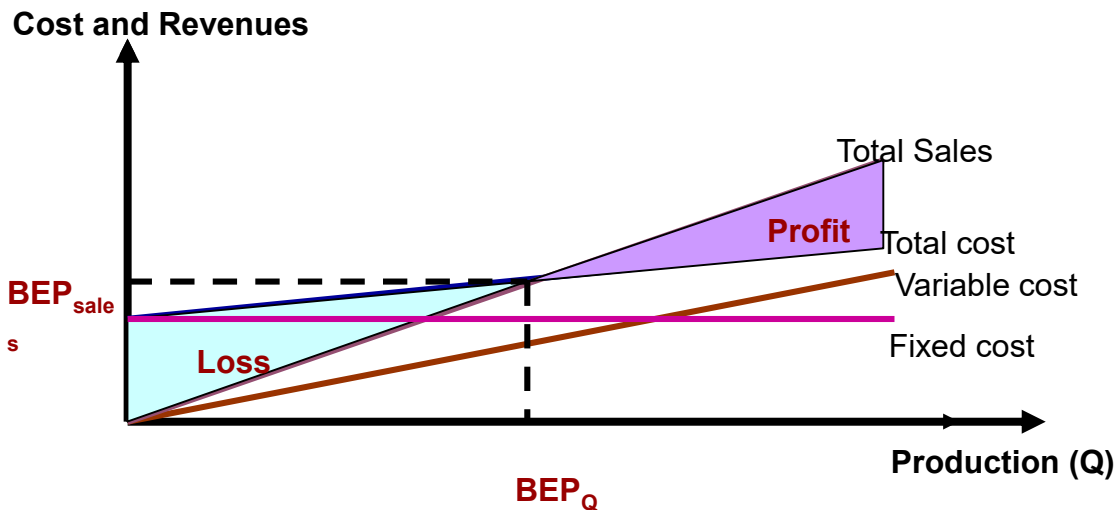


Fig6.1: Break even analysis

Example 6.1

A company produces a product whose fixed cost and the total cost is \$ 40,000 and \$ 85,000 respectively. The total sales is \$ 105,000 and sales volume is 15000. For this situation,

- Find break-even point in terms of number of units.
- What should be the output if the profit desired is \$ 50,000?

Given, Fixed cost (FC) = \$ 40,000

Total cost (TC) = \$ 85,000

Total sales (S) = \$ 105,000

Sales volume = 15,000

Break-even point (Q_{BEP}) = ?

Break-even point (Q_{BEP}) = ? (If profit = \$50,000)

- Finding the Break-even point in terms of number of units

We know,

$$Q_{\text{BEP}} = FC / (s - v) \text{ (units)}$$

$$Q_{\text{BEP}} = \$40,000 / (s - v) \text{ (units)}$$

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Total Cost (TC) = Fixed cost (FC) + Variable Cost (VC)

$$VC = \$85,000 - \$40,000$$

$$VC = \$ 45,000$$

Variable cost per unit (v) = $\$45,000/15,000 = \3 per unit

Selling cost per unit (s) = $\$ 105,000/15,000 = \$ 7$ per unit

$$Q_{\text{BEP}} = 40,000 / (7 - 3) \text{ (units)}$$

$$Q_{\text{BEP}} = \mathbf{10,000 \text{ (units)}}$$

(b) If the profit desired is \$ 50,000

Profit = Total Sales – Total Cost

$$50,000 = s*Q - FC + VC$$

$$50,000 = s*Q - (40,000 + v *Q)$$

$$90,000 = (7-3)*Q$$

$$22,500 = Q$$

Break even units for the profit to be \$ 50,000 is **22,500 units**.

Break – Even Analysis between Two Alternatives

When the selection between two engineering project alternatives is heavily dependent upon a single factor, we can solve for the value of that factor. That value is known as the breakeven point, i.e. the value at which we are indifferent between the two alternatives. This break even value calculation is similar to that used to calculate incremental rate of return.

In mathematical terms,

$$EW_A = f_1(y) \text{ and } EW_B = f_2(y)$$

Where,

EW_A = Equivalent worth calculation for the net cash flow of Alternative A

EW_B = Equivalent worth calculation for the net cash flow of Alternative B

y = a common factor affecting the equivalent worth values of Alternative A and Alternative B

The breakeven point between Alternative A and Alternative B is the value of factor y for which the two equivalents worth values are equal.

That is, $EW_A = EW_B$,

$f_1(y) = f_2(y)$, which may be solved for y .

Examples of common factors [7]

- **Annual revenues:** solve for the annual revenues to equal (break-even) with annual expenses.
- **Rate of return:** solve for the rate of return on the increment of invested capital at which two given alternatives are equally desirable.
- **Market (salvage) value:** solve for the future resale value that would result in indifference as to preference for an alternative.
- **Equipment life:** solve for the useful life required for alternative to be economically justified.
- **Capacity utilization:** solve for the hours of utilization per year.

Steps to determine breakeven point of common variable

- Define the common variable and its dimensional units.
- Use PW or AW analysis to express the total cost of each alternative as a function of the common variable.
- Equate the two relations and solve for the breakeven value of the variable.
- If the anticipated level is below breakeven value, select alternative with the higher variable cost (larger slope). If the anticipated level is above the break even value select the alternative with lower variable cost (smaller slope). (Figure 6.2)

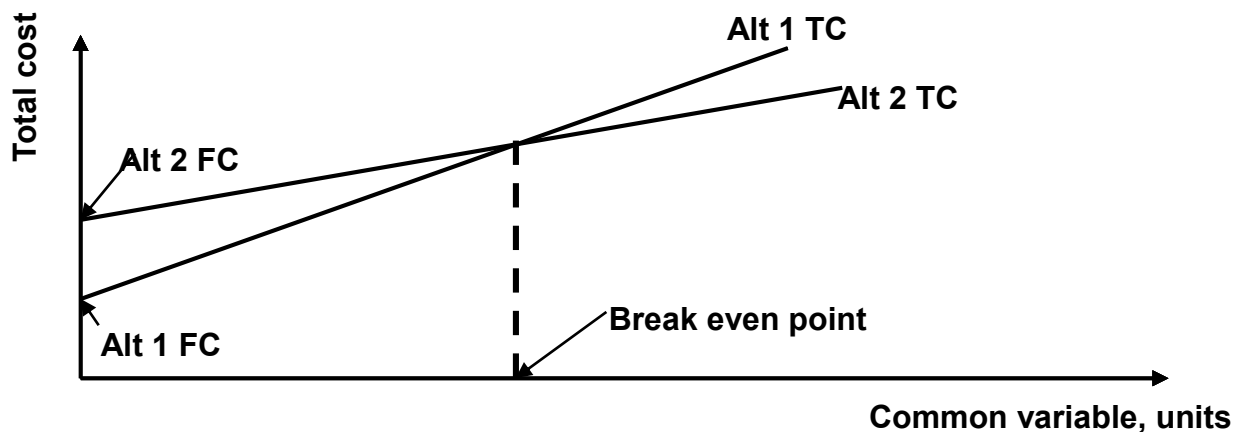


Fig 6.2: Break even analysis of two alternatives [5]

Example 6.2

Suppose that there are two alternative electric motors that provide 100-hp output.

Item	Alpha motor	Beta motor
Purchase cost	\$ 12,500	\$ 16,000
Efficiency	74%	92%
Maintenance Cost	\$500 per year	\$250 per year
Life	10 years	10 years
Annual tax& insurance	1.5% of the investment	
MARR	15%	

- (a) How many hours per year would the motors have to be operated at full load for the annual cost to be equal? Electricity cost = \$0.05 per KW hour.
- (b) If annual operation hour is 600 hrs. Which motor should be selected?

(a)

Alpha Motor

Calculating the Annual equivalent cost.

- 1. Capital Recovery (CR)
 - = \$12,500 (A/P, 15%, 10) – 0
 - = \$ 2,490 per year
- 2. Maintenance Cost
 - = \$ 500 per year
- 3. Tax and insurance
 - = 1.5% of initial investment
 - = 1.5% of \$12,500 = \$187 per year

Beta Motor

Calculating the Annual equivalent cost.

- Capital Recovery (CR)
 - = \$16,000 (A/P, 15%, 10) – 0
 - = \$ 3,190 per year
- Maintenance Cost = \$250 per year
- 3. Tax and insurance
 - = 1.5% of initial investment
 - = 1.5% of \$16,000 = \$240 per year

- 4. Operating expenses for power (electricity cost)
 - Let ‘X’ be the number of hours of operation per year
 - = $\frac{(0.05) * (100) * 0.746 * X}{0.74}$
 - = \$ 5.04 X per year
- Total annual equivalent cost of Alpha motor
 - = \$ 2,490 + \$ 500 + \$187 + \$ 5.04 X
 - = \$3177 + 5.04 X (1)

- 4. Operating expenses for power (electricity cost)
 - Let ‘X’ be the number of hours of operation per year
 - = $\frac{(0.05) * (100) * 0.746 * X}{0.92}$
 - = \$ 4.05 X per year
- Total annual equivalent cost of Beta motor
 - = \$ 3,190 + \$ 250 + \$240 + \$ 4.05 X
 - = \$3680 + 4.05 X (2)

At the Breakeven point,

$$AW_{\text{alpha}} = AW_{\text{beta}}$$

Or, $\$3177 + \$5.04 X = \$3680 + \$4.05X$

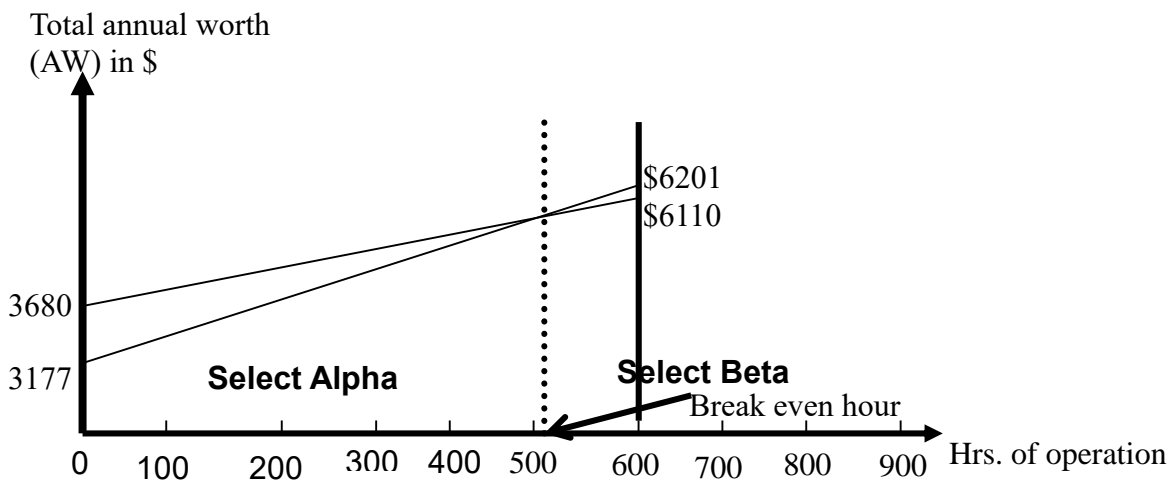
Or, $\$5.04 X - 4.05 X = \$3680 - \$3177$

Or, $X = \$503/0.99 = 508 \text{ hours/year}$

(b) If the operation hours is 600 hrs. Per year,

$$AW_{\text{alpha}} = \$3177 + \$5.04 * 600 = \$6201$$

$$AW_{\text{beta}} = \$3680 + \$4.05 * 600 = \$6110$$



Cost of Beta motor is less than Alpha motor. Hence Select Beta Motor

References:

[1] *Contemporary Engineering Economics*, Chan S. Park Second Edition, Addison-Wesley Publishing Company, 1997.

[2] *Engineering Economics*: James L. Riggs, David D. Bedworth and Sabah U. Randhawa, Fourth Edition, Tata McGraw Hill Education Private Limited, New Delhi, India, 2004.

[3] <https://www.investopedia.com/terms/r/risk-analysis.asp> (Viewed October 2022)

[4] <https://pmstudycircle.com/risk-vs-uncertainty/> (Viewed October 2022)

[5] *Basics of Engineering Economy*: Leland Blank and Anthony Tarquin, Indian Edition, Tata McGraw Hill Education Private Limited, New Delhi, India, 2013.

[6] <https://www.netsuite.com/portal/resource/articles/financial-management/break-even-analysis.shtml> (Viewed October 2022)

[7] *Engineering Economy*: William G. Sullivan, James A. Bontadelli & Elin M. Wicks, Eleventh Edition, Pearson Educations, Inc. 2000.

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