

# Course Title

## Engineering Economic Analysis

### Lecture 8 (week 8)

**Comparing mutually exclusive, contingent and independent projects in combination.**

### **Chapter 5: Replacement Analysis (Basic Concepts and Terminologies)**

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#### **Learning Objective**

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

- Definition of mutually exclusive alternatives in terms of combination of project.
- Concept of independent, contingent and mutually exclusive alternatives.
- Introduction to replacement analysis and its concept.
- Reasons for replacement analysis and basic terminologies.

## 4.9 Definition of Mutually Exclusive Investment Alternatives in terms of Combination of Projects

Until now we have learned about comparing two or more mutually exclusive alternatives. In this section, we will examine the process of deciding whether projects should be included in the capital budget. In particular, we will consider decision procedures that should be applied when we have to evaluate a set of multiple investments alternatives for which we have a limited capital budget. We distinguish a project from investment alternatives, which is a decision option. For a single project, we have two investment alternatives: to accept or reject the project. [1] For two independent projects, we can have four investment alternatives: (a) to accept both projects, (b) to reject both projects (c) to accept only the first project and (d) to accept only the second project. [1]

To perform a proper capital budgeting analysis a firm must group all projects under consideration into decision alternatives. We should try to make the combination of the alternatives in order to maximize its present worth as long as the budget limitation does not exceed. Such combinations of projects will then be mutually exclusive. [2] Each combination of project is mutually exclusive because each is unique and the acceptance of one combination of investment projects precludes the acceptance of any of the other combination. [3]

Before the analysis or evaluation of any alternative (project), we have to categorize the projects. Projects can be categorized as

1. Independent Project and
2. Dependent Project
  - (a) Contingent Project and
  - (b) Mutually exclusive project

### 1. Independent Project

Two or more proposals or projects are independent when the acceptance or rejection of any of them does not entail the acceptance or rejection of any other. [4]Independent projects are usually designed to accomplish different purposes thus the probability of selecting any number of projects. [5]These alternatives do not compete with each other, each project is evaluated separately. For example, proposal for installing air conditioner and proposal for advertisement can be two independent project in an office. Only projects that are economically independent of one another can be evaluated separately.

### 2. Dependent Project

In many decision problems, several investment projects are related to one another such that the acceptance or rejection of one project influences the acceptance or rejection of others. [1]Two types of dependencies can be observed:

Contingent and  
Mutually Exclusive

**Contingent Project**

A project may be contingent upon some other project, in the sense that the acceptance or rejection of one may result in the corresponding acceptance and rejection of the other. [4] In other words, if the acceptance of one requires the acceptance of another. For example, the purchase of computer printer requires the purchase of the computer initially. It means printer is contingent on computer.

**Mutually Exclusive Alternatives**

A set of projects are mutually exclusive if at most one of them may be accepted. It is thus a question of picking the single economically best project (or of rejecting them all) [4]. Mutually exclusive alternatives compete with each other in the evaluation. For example buying versus leasing a equipment for construction work. If one is selected other is rejected. If no alternative is economically justifiable, Do Nothing (DN) option is the default option.

**Do Nothing (DN) Option**

Do nothing is always a option to continue with the current system or facilities. It means that among the different alternatives developed, we are not selecting any one of them and continuing with the already existing options. If it is absolutely required that one of the defined alternatives be selected, do nothing is not considered as an option. [5]

**Formulation of Mutually Exclusive Combination of Projects**

1. Considering alternative A, B and C as an independent project then the possible combination of alternatives can be:

<b>Mutually exclusive Combination</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>Remark</b>
1	X	X	X	Do nothing
2	√	X	X	Select A
3	X	√	X	Select B
4	X	X	√	Select C
5	√	√	X	Select A & B
6	√	X	√	Select A & C
7	X	√	√	Select B & C
8	√	√	√	Select All

2. If A , B, C are the mutually exclusive alternatives then we can make following combination

Mutually exclusive combination	A	B	C	Remarks
1	X	X	X	Do nothing
2	√	X	X	Accept A
3	X	√	X	Accept B
4	X	X	√	Accept C

3. If A, B, C are three alternatives where C is contingent on B and B is contingent on A, we can make following combination.

Mutually exclusive combination	A	B	C	Remarks
1	X	X	X	Do nothing
2	√	X	X	Accept A
3	√	√	X	Accept A and B
4	√	√	√	Accept all

#### Example 4.6

Engineering projects B1, B2, C1, C2 and D are being considered with cash flows estimated over four years are as shown in table below. Using the PW method and MARR = 10% per year, determine what combination of projects is best if the capital to be invested is (a) unlimited and (b) limited to \$ 48000. [3]

Cash Flows for End of Year (\$)					
Project	0	1	2	3	4
B1	-50000	20000	20000	20000	20000
B2	-30000	12000	12000	12000	12000
C1	-14000	4000	4000	4000	4000
C2	-15000	5000	5000	5000	5000
D	-10000	6000	6000	6000	6000

The combination of project is

- Project B1 and Project B2 (mutually exclusive and independent of C set)
- Project C1 and Project C2 (mutually exclusive and contingent on the acceptance of B2)
- Project D (contingent on the acceptance of C1)

#### Step 1

Calculate the PW of all alternatives

$$PW_{B1} = -50,000 + 20,000 (P/A, 10\%, 4) = \$ 13,400$$

$$PW_{B2} = -30,000 + 12,000 (P/A, 10\%, 4) = \$ 8,038$$

$PW_{C1} = -14,000 + 4,000 (P/A, 10\%, 4) = -\$1,320$  (not been eliminated from consideration because project D and B2 is contingent on it)

$$PW_{C2} = -15,000 + 5,000 (P/A, 10\%, 4) = \$ 849$$

$$PW_D = -10,000 + 6,000 (P/A, 10\%, 4) = \$ 9,019$$

### Step 2

Develop the mutually exclusive combinations of projects and cash flow according to combinations.

Mutually exclusive combination	Project					Invested capital (\$)	PW (10%) (\$)
	B1	B2	C1	C2	D		
1	X	X	X	X			
2	√	X	X	X			
3	X	√	X	X			
4	X	√	√	X			
5	X	√	X	√			
6	X	√	√	X			
Mutually exclusive combination	Cash Flows for End of Year (\$)				Invested capital (\$)	PW (10%) (\$)	
	1	2	3	4			
1	0	0	0	0	0	0	
2	20,000	20,000	20,000	20,000	-50,000	13,400	
3	12,000	12,000	12,000	12,000	-30,000	8,038	
4	16,000	16,000	16,000	16,000	-44,000	6,738	
5	17,000	17,000	17,000	17,000	-45,000	8,887	
6	22,000	22,000	22,000	22,000	-54,000	15,757	

### Step 3

#### Decision

1. Mutually exclusive combination 6 is the best combination which PW is \$ 15,700 when the capital is unlimited.
2. Mutually exclusive combination 6, 2 are not feasible if capital is limited to \$ 48,000, of the remaining combinations, combination 5 has the highest present worth of \$ 8,900.

## CHAPTER 5 REPLACEMENT ANALYSIS

### 5.1 Introduction

- When should the new machine replace the existing machine?
- When should a process be redesigned?
- When should a product be redesigned?

The most common question asked in the industry or organization is when should the existing be replaced?

As time passes, a previously implemented business asset (equipment) tends to lose its ability to produce a desired output. Aging equipment often has a higher risk of breakdowns, and to avoid such expenses we should plan for scheduled replacements. When we conduct an engineering economic analysis to compare our available asset against the best available replacement asset, this process is known as *replacement analysis*.

A decision situation often encountered in business firms and government organizations, as well as by individuals, is whether an existing asset should be retired from use, continued in service, or replaced with a new asset. [3] Replacement refers to a broad concept embracing the selection of similar but new assets to replace existing assets and the evaluation of entirely different ways to perform an asset's function. [6] Replacement study in engineering economics provides the information for sound decisions that improve the operating efficiency and the competitive position of enterprise.

In another way we can say the replacement analysis is an economic analysis to compare existing and new facilities. Engineer's objective is to keep the present plant operating economically. Should the existing equipment be retained or replaced? This is the major objective or decision that the organization or firm have to make for running the business successfully. The existing equipment is known as the *defender* and the best available replacement equipment (new equipment) is known as the challenger. Replacement Analysis is the domain of comparing the existing defender and the *challenger* replacement.

***Replacement is never a question of “if we replace” but rather a question of “when we replace”?***

***The key question is: “Shall we replace the defender now, or keep it for one or more years before replacing it?”***

### 5.2 Why we need replacement analysis?

The reasons for considering replacement are numerous. Firstly, the current asset (defender) may have number of deficiencies including high set-up cost; excessive maintenance, declining

production efficiency energy consumption, and physical impairment. For example, when you are confronted with a car that is expensive to operate and maintain, and a major overhaul, you consider replacing the car.

Secondly, potential replacement assets (challengers) may take advantage of new technology and be easily set up, maintained at low cost, high in output, energy efficient and possessing increased capabilities, perhaps at a vastly reduced cost. For example, some new generation computer-controlled manufacturing equipment has rendered many old machines economically obsolete. Also, we can relate to the phenomenal accomplishments with which calculators and personal computers have resulted in increased capabilities, vastly lower prices, and economic obsolescence for equipment only a few years old.

### **5.3 Reasons for Replacement Analysis**

Replacement of an existing asset should be considered in case of following reasons:

#### **1. Deterioration (Physical Impairment)**

The existing equipment is completely or partially worn out and will no longer function satisfactorily without expensive repairs. The changes in the physical condition of an asset can be considered as the deterioration. It is the decline in performance due to wear and tear or misalignment indicated by: [7]

- (i) Increase in maintenance costs.
- (ii) Reduction in product quality and rate of production.
- (iii) Increase in labor costs, and
- (iv) Loss of operating time due to breakdowns.

Deterioration is manifested through excessive operating costs, increased maintenance cost, higher rejection rates or a combination of added equipment cost. [6]

#### **2. Obsolescence**

Obsolescence occurs when the technology of an asset is surpassed by newer and or different technologies. Each new development or refinement of an older asset makes the previous way of accomplishing an objective less appealing. [6] The equipment gets obsolete due to advancement in technology and the unwarranted manufacturing costs arising from such obsolete equipment will

- (i) Reduce profits
- (ii) Impair competition
- (iii) Cause loss in value of machinery. [7]

#### **3. Inadequacy**

When the existing equipment becomes inadequate to meet the demand or it is not able to increase the production rate to desired level, the question of replacement arises.

#### **4. Working Conditions:**

It may be thought of replacing the old equipment and machinery which creates unpleasantness i.e. give rise to unsafe conditions for workers and leads to accidents, making the environment noisy and smoky etc. [7]

#### **5. Financing**

Financial factor involve economic opportunity changes external to the physical operation or use of assets and may involve income tax consideration. [3] Leasing of equipment might be more economic than buying and taking ownership. The existing assets/equipment might have reached their useful life and it is not economical to continue with them.

#### **5.4 Advantages of Replacement Analysis**

- (a) Maintenance costs would be reduced.
- (b) Production costs would be reduced and would keep the company competitive.
- (c) Losses, scraps, rework would be reduced.
- (d) Modernization would be introduced which will help to take-off productivity and returns,
- (e) Delays of down-time costs would be reduced.
- (f) Enthusiasm and morale of workers would be increased resulting into increased human efficiency, better human relations.

#### **5.5 Terminologies in Replacement study**

##### **1. Defender and Challenger**

These are the names of two mutually exclusive alternatives. The defender is the currently installed asset and the challenger is the potential replacement asset.

##### **2. AW Values**

AW values are used as the primary measure of comparison between the defender and challenger.

##### **3. Defender first cost**

It is the initial investment amount  $P$  used for the defender. The current market value (MV) is the correct estimate to use for  $P$  for the defender in a replacement study.

##### **5. Challenger first cost**

It is the amount of cost that must be recovered when replacing a defender with challenger. This amount is almost always equal to  $I$  (investment), the first cost of challenger

## 6. Useful Life

It is an estimate of how long an asset is expected to be used in a trade or business to produce income [3]

## 7. Physical Life & economic life

Physical life is an arbitrary limit on how long we're prepared to keep an obsolete asset in service. Economic life is the time after which we save money by replacing the asset. [8]

## 5.6 Factors to be considered in replacement analysis

### 1. Sunk Cost

All past investment and expenses connected with the asset are sunk cost which does not enter in the replacement analysis. Only current and future cost and investment are relevant. [4]

### 2. Recognition and acceptance of past errors

Any estimation errors made in a previous study related to defender are not relevant (unless income tax) [3]

### 3. Existing asset value need not be considered

### 4. Economic life of the proposed replacement asset (challenger)

### 5. Remaining (economic) life of the old asset (defender)

## References

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

[2] *A Textbook of Engineering Economics*: Damodar Adhikari, First Edition, Dreamland Publication Pvt. Ltd. Kathmandu, Nepal, 2019.

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

[4] *Engineering Economics*: Jose A. Sepulveda, William E. Souder and Byron S. Gottfried, Tata McGraw – Hill Publishing Company Limited, New Delhi, India, 2005.

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

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

[7] <https://www.yourarticlelibrary.com/industries/replacement-of-equipments-reasons-factors-and-problems/90640> (Viewed October 2022)

[8] <http://www.sfu.ca/~jones/ENSC201/Unit09/lecture9.html> (Viewed October 2022)