رویکردی جامع برای ارزیابی اقتصادی در پروژه
همراه با آموزش مدلسازی در اکسل (Excel)

بخش نهم:

ارزیابی اقتصادی: ارزیابی اقتصادی پروژه های دولتی

ارائه دهندگان:

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What we will learn?

- Purposes of this session
- Public sector projects
  - Definition
  - Size of investment
  - Life estimate
  - Annual cash flow estimate
  - Funding
  - Interest rate
  - Alternative selection criteria
  - Environment of the evaluation
- Public private partnership (PPP)
  - Definition
  - Traditional model
  - Modern model

What we will learn?

- Benefit/Cost analysis
- Water Treatment Facility #3 Case
- Economic analysis of a single project
  - Definition
  - Ratio 1
  - Ratio 2
  - Ratio 3
  - How to select?
- Economic analysis of mutually exclusive projects
  - How to select?
  - Example 1
  - Example 2
  - Example 3

Modern Public-Private Partnership (PPP)

- The **amount of funding** committed to the project **may not cover** the **actual build cost** because it is considerably **higher than estimated**.
- A **reasonable profit** may **not** be **realized** by the **private corporation** due to **low usage** of the **facility** during the **operate phase**.

HOW TO SOLVE?

- To **prevent** such **problems**, the **original contract** may provide for **special subsidies** and **loans guaranteed** by the **government unit**.
  - The **subsidy** may **cover costs plus** (**contractually agreed-to**) **profit** if **usage** is **lower** than a **specified level**.
  - The **level used** may be the **breakeven point** with the **agreed-to profit margin** considered.

Benefit / Cost analysis

- To **perform** a **benefit/cost economic analysis** of **public alternatives**:
  1. Costs (initial and annual)
  2. Benefits
  3. Disbenefits (if considered)

  Sometimes there may be **income** that needs to be modeled.

  must be estimated as accurately as possible in ***monetary units***.

Costs—estimated expenditures *to the government entity* for construction, operation, and maintenance of the project, less any expected salvage value.

Benefits—advantages to be experienced *by the owners, the public.*

Disbenefits—expected undesirable or negative consequences *to the owners* if the alternative is implemented. Disbenefits may be indirect economic disadvantages of the alternative.

Benefit / Cost analysis

- It is **difficult** to **estimate** and **agree** upon the **economic impact** of **benefits** and **disbenefits** for a **public sector alternative**.

*For example, assume a **short bypass** around a **congested area** in **town** is recommended.*

***How much** will it benefit a driver in **dollars per driving minute** to be able to **bypass** **five traffic lights** while **averaging 35 miles per hour**, as compared to **currently driving** through the lights **averaging 20 miles per hour** and **stopping** at an average of **five lights** for an **average** of **45 seconds each**?*

Benefit / Cost analysis

- The **bases** and **standards** for **benefits** estimation are always **difficult** to **establish** and **verify**.

- Relative to **revenue** **cash flow estimates** in the **private sector**, **benefit estimates** are **much harder** to make, and **vary more widely** around **uncertain averages**.

- The **disbenefit** itself **may not be known** at the **time** the **evaluation** is **performed**.

Benefit / Cost analysis

The **viewpoint of the public sector analysis** must be determined before cost, benefit, and dis-benefit estimates are made and before the evaluation is formulated and performed. There are several viewpoints for any situation, and the different perspectives may alter how a cash flow estimate is classified.

- In general, the **viewpoint** of the analysis should be as **broadly defined** as those who will **bear** the **costs** of the project and **obtain its benefits**.

- **Once established**, the **viewpoint** assists in **categorizing** the **costs**, **benefits**, and **disbenefits** of **each alternative**.

Water Treatment Facility #3 Case

PE

Water Treatment Facility #3 Case: Allen Water Utilities has planned for the last 25 years to construct a new drinking water treatment facility that will supply the rapidly growing north and northwest areas of the city. An expectation of over 100,000 new residents in the next several years and 500,000 by 2040 prompted the development of the plant starting in 2012. The supply is from a large surface lake currently used to provide water to all of Allen and the surrounding communities. The project is termed WTF3, and its initial capital investment is $540 million for the treatment plant and two large steel-pipe transmission mains (84- and 48-inch) that will be installed via tunneling approximately 100 to 120 feet under suburban areas of the city to reach current reservoirs.

Tunneling was selected after geotechnical borings indicated that open trenching was not supportable by the soil and based upon a large public outcry against trenching in the living areas along the selected transmission routes. Besides the treatment plant construction on the 95-acre site, there must be at least three large vertical shafts (25 to 50 feet in diameter) bored along each transmission main to gain underground access for equipment and debris removal during the tunneling operations.

The stated criteria used to make decisions for WTF3 and the transmission mains were economics, environment, community impact, and constructability.

There are major long-term benefits for the new facility. These are some mentioned by city engineers:

- It will meet projected water needs of the city for the next 50 years.
- The new treatment plant is at a higher elevation than the current two plants, allowing gravity flow to replenish reservoirs, thereby using little or no electric pumping.
- There will be an increase in the diversity and reliability of supply as other plants age.
- It will provide a water quality that is more consistent due to the location of the raw water intakes.
- The facility uses water supplies already purchased; therefore, there is no need to negotiate additional allowances.

The disbenefits are mostly short-term during the construction of WTF3 and transmission mains. Some of these are mentioned by citizen groups and one retired city engineer:

- There will be disruption of habitat for some endangered species of birds, lizards, and trees not

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Water Treatment Facility #3 Case

found in any other parts of the country.

- Large amounts of dust and smoke will enter the atmosphere in a residential area during the 3½ years of construction, tunneling, and transmission main completion.
- Noise pollution and traffic congestion will result during an estimated 26,000 truck trips to remove debris from the plant site and tunnel shafts, in addition to the problems from regular construction traffic.
- Natural landscape in plant and tunnel shaft sites will be destroyed.
- Safety will be compromised for children in a school where large trucks will pass about every 5 minutes for approximately 12 hours per day, 6 days per week for 2½ years.
- There may be delays in fire and ambulance services in emergencies, since many neighborhood streets are country-road width and offer only single ingress/egress streets for neighborhoods along the indicated routes.
- The need for the facility has not been proved, as the water will be sold to developers outside the city limits, not provided to residences within Allen.
- Newly generated revenues will be used to pay off the capital funding bonds approved for the plant's construction.

Last year, the city engineers did a benefit/cost analysis for this massive public sector project; none of the results were publicized. Public and elected official intervention has now caused some of the conclusions using the criteria mentioned above to be questioned by the general manager of Allen Water Utilities.

Water Treatment Facility #3 Case

Example 1: The situation with the location and construction of the **new WTF3** and associated transmission mains described has **reached a serious level.**

- **Before** going public to the city council with the **analysis performed last year**, the **director** of **Allen Water Utilities** has asked an **engineering management consultant** to **review** it and **determine** if it was an **acceptable analysis** and **correct economic decision**, then and now.

- The lead consultant, **Joel Whiterson** assigned for the analysis. Within the **first hour** of checking background notes, Joel **found several initial estimates** (**shown in next slide**) from **last year** for **expected consequences if** WTF3 **were built**.

- He realized that **no viewpoint of the study** was defined, and, in fact, the **estimates were never classified** as costs, benefits, or disbenefits.

- He did determine that **disbenefits** were **considered** at **some point** in the analysis, though the estimates for them are very **sketchy**.

Water Treatment Facility #3 Case

Example 1: **Joel** defined **two viewpoints**: a ***citizen*** **of Allen** and the **Allen Water Utilities** ***budget***. He wants to identify each of the estimates as a **cost**, **benefit**, or **disbenefit** from each viewpoint.

Economic Dimension	Monetary Estimate
1. Cost of water: 10% annual increase to Allen households	Average of $29.7 million (years 1–5, steady thereafter)
2. Bonds: Annual debt service at 3% per year on $540 million	$16.2 million (years 1–19); $516.2 million (year 20)
3. Use of land: Payment to Parks and Recreation for shaft sites and construction areas	$300,000 (years 1–4)
4. Property values: Loss in value, sales price, and property taxes	$4 million (years 1–5)
5. Water sales: Increases in sales to surrounding communities	$5 million (year 4) plus 5% per year (years 5–20)
6. M&O: Annual maintenance and operations costs	$300,000 plus 4% per year increase (years 1–20)
7. Peak load purchases: Savings in purchases of treated water from secondary sources	$500,000 (years 5–20)

Water Treatment Facility #3 Case

Solution: How this classification is done will vary depending upon who does the analysis.

Viewpoint 1: ***Citizen of the city of Allen***.

Goal: Maximize the quality of life and wellness of citizens with family and neighborhood

Costs: 1, 2, 4, 6 **Benefits:** 5, 7 **Disbenefits:** 3

Economic Dimension	Monetary Estimate
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Water Treatment Facility #3 Case

Solution: How this classification is done will vary depending upon who does the analysis.

Viewpoint 2: ***Allen Water Utilities budget.***

Goal: Ensure the budget is balanced and of sufficient size to fund rapidly growing city service demands.

Costs: 2, 3, 6 **Benefits:** 1, 5, 7 **Disbenefits:** 4

Economic Dimension	Monetary Estimate
1. Cost of water: 10% annual increase to Allen households	Average of $29.7 million (years 1–5, steady thereafter)
2. Bonds: Annual debt service at 3% per year on $540 million	$16.2 million (years 1–19); $516.2 million (year 20)
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Water Treatment Facility #3 Case

Notice:

- The inclusion of **disbenefits** can easily **change** the **economic decision**.
  - However, **agreement** on the **disbenefits** and their **monetary estimates** is **difficult (to impossible)** to develop, **often** resulting in the **exclusion** of any **disbenefits** from the **economic analysis**.
    - This problem **usually** transfers the consideration of **disbenefits** to the **noneconomic** (**i.e., political**) realm of public project decision making.

Economic analysis of a single project

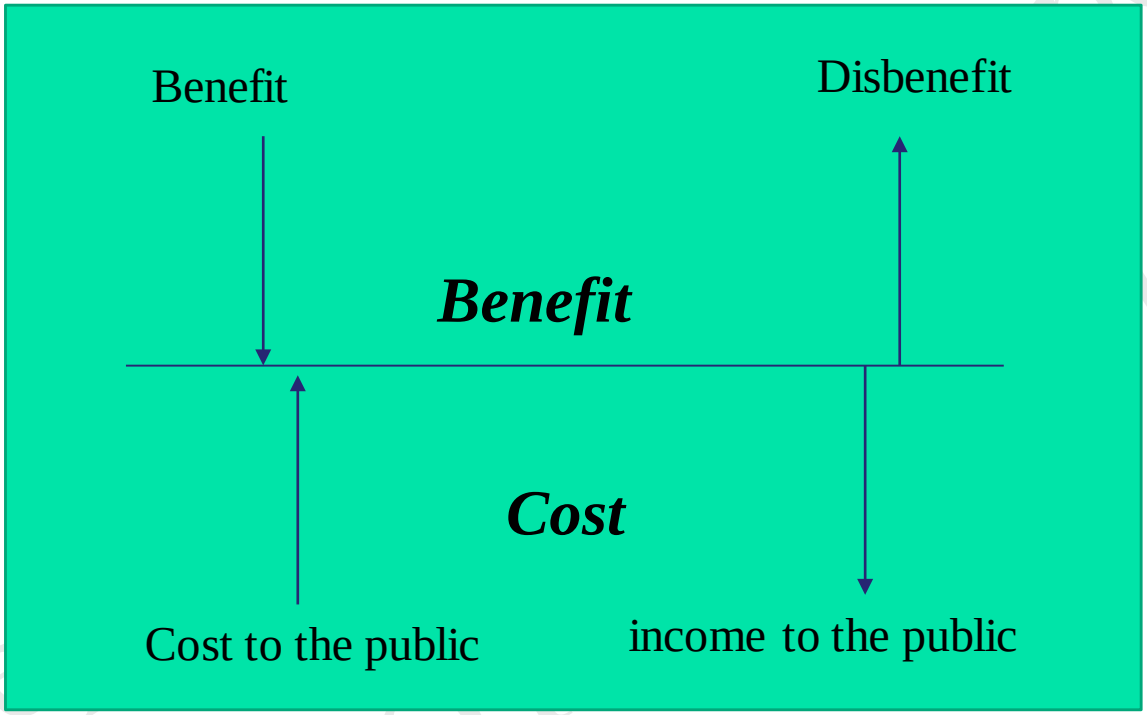
- **Several variations** of the **B/C ratio**; however, the **fundamental** approach is the **same**.
- **All cost** and **benefit** estimates must be **converted** to a common **equivalent monetary** unit (**PW, AW, or FW**) at the **discount rate** (**interest rate**).
- The **B/C ratio** is **then** calculated using one of these relations:

$$B/C = \frac{\text{PW of benefits}}{\text{PW of costs}} = \frac{\text{AW of benefits}}{\text{AW of costs}} = \frac{\text{FW of benefits}}{\text{FW of costs}}$$

$$B/C = \frac{\text{benefits} - \text{disbenefits}}{\text{costs}} = \frac{B - D}{C}$$

$$\text{Modified } B/C = \frac{\text{benefits} - \text{disbenefits} - \text{M\&O costs}}{\text{initial investment}}$$

Benefit / Cost analysis



Economic analysis of a single project – Ratio 1

$$B/C = \frac{\text{PW of benefits}}{\text{PW of costs}} = \frac{\text{AW of benefits}}{\text{AW of costs}} = \frac{\text{FW of benefits}}{\text{FW of costs}}$$

- PW and AW are preferred
- Costs are + sign
- **Salvage values** and **additional revenues** to the government **subtracted** from **costs** in the **dominator**
- **Disbenefits** are considered in **different ways**, but **most commonly**, are **subtracted** from the **benefits** in the **numerator**.

مثال (جاده) :

منافع برای عموم: کاهش هزینه بهره برداری وسیله نقلیه از جمله سوخت، کاهش زمان مسافرت، افزایش ایمنی، تسهیل رانندگی، افزایش ارزش زمین

زیانها برای عموم: زمینهای کشاورزی که از بین میروند، افزایش آلودگی هوا، کاهش تحرک دامها در عرض بزرگراه

هزینه ها برای کشور: هزینه های ساخت، هزینه های نگهداری، هزینه های اداری

درآمدها برای کشور: عوارض، افزایش مالیاتها ناشی از افزایش قیمت زمین و فعالیت تجاری

Economic analysis of a single project – Ratio 2

$$B/C = \frac{\text{benefits} - \text{disbenefits}}{\text{costs}} = \frac{B - D}{C}$$

- This is conventional B/C ration, probably the most widely used.
- Costs are + sign
- **Salvage values** and **additional revenues** to the government **subtracted** from **costs** in the **dominator.**
- **Disbenefits** are **subtracted** from the **benefits** in the **numerator**.

Economic analysis of a single project – Ratio 3

$$\text{Modified B/C} = \frac{\text{benefits} - \text{disbenefits} - \text{M\&O costs}}{\text{initial investment}}$$

- The ***modified B/C ratio*** includes all the estimates associated with the project, **once operational**.
- **Maintenance and operation (M&O)** costs are placed in the **numerator** .
- **Salvage values** and **additional revenues** to the government **subtracted** from **initial investment** in the **dominator.**
- The ***modified B/C ratio*** will obviously **yield** a **different value** than the **conventional B/C method**.
  - However, the **modified procedure** can change the **magnitude** of the ratio **but not** the **decision** to **accept** or **reject** the project.

Economic analysis of a single project – How to select?

The decision guideline is simple:

If B/C ≥ 1.0, accept the project as economically justified for the estimates and discount rate applied.

If B/C < 1.0, the project is not economically acceptable.

- If the **B/C value** is exactly or very **near 1.0**, **noneconomic factors** will help make the decision.

Economic analysis of mutually exclusive projects – How to select?

If we have a few projects and one option should be selected:

1. If **initial funds** are **limited**, select **project** with **least initial investment**

2. If **initial funds** are **not limited**:

   - If **benefits** are to be **maximized** = ignore cost, pick the one with highest *B*.
     - ✓ **Not appropriate** for **construction** projects, **suitable** for **military** actions
   - If **advantage** of **benefit** over **construction** is to be **maximized**
     1. **Ignore magnitude**, pick the one with the **highest *B/C* ratio or (*B-C*)**
        - ✓ **Not recommended**
     2. **Do not ignore magnitude**, pick **incremental *B/C* analysis**.
        - ✓ **Recommended**

DO NOT FORGET TO PERFORM SENSITIVITY ANALYSIS

Economic analysis of mutually exclusive projects – How to select?

Incremental B/C Analysis

Step 1: Put alternatives in ascending order (lowest to the highest) of cost (PW or AE)

Step 2: Remove alternatives with $B/C < 1$

Step 3: Select first alternative on the list as **"current best (*CB*)"** and next one as **"challenge (*CH*)"**

Step 4: calculate $(B(CH) - B(CB)) / (C(CH) - C(CB))$

- If ***B/C >1*** therefore, *CB* is eliminated and *CH* becomes *CB*
- If ***B/C < 1*** therefore, *CB* remains *CB* and *CH* is eliminated

Step 5: continue until list is exhausted

Economic analysis of mutually exclusive projects – Example 1

Example 1: A certain stretch of rural highway is in such bad condition that its resurfacing or relocation is required. The present location is designated as H; two possible new locations that will shorten the distance between the terminal points are designated as J and K. Location K is somewhat shorter than J but involves a considerably higher investment for grading and structures. An economic study comparing the proposals for the three locations is to use a study period of 20 years and a MARR of 7%.

Economic analysis of mutually exclusive projects – Example 1

Example 1: The estimated initial investment to be made by the Highway Department would be $11,000,000 at location H, $70,000,000 at J, and $130,000,000 at K. If location H is abandoned now, it will have zero salvage value. Also, it is assumed to have no residual value at the end of 20 years if this location is kept in service. However, because the estimated useful lives of the works that would be constructed at J or K are longer than the 20-year analysis period, residual values are estimated at the end of 20 years. These are $30,000,000 for J and $55,000,000 for K. Estimated annual maintenance costs, also to be paid by the Highway Department are $3,500,000 for location H, $2,100,000 for J, and $1,700,000 for K.

Economic analysis of mutually exclusive projects – Example 1

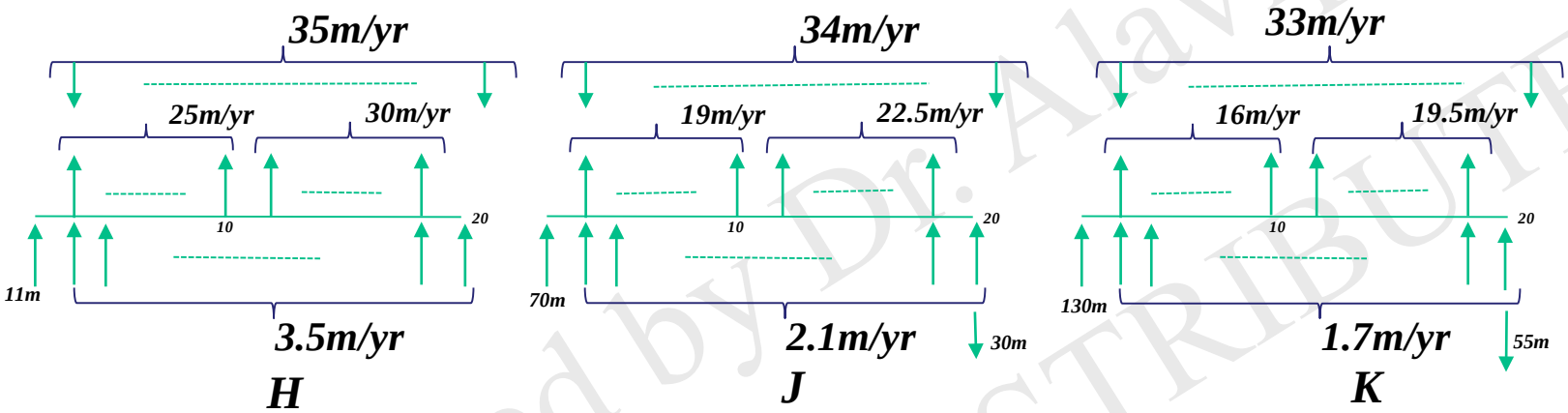
Example 1: For location H, annual road user costs are estimated as $25,000,000 in the first 10 years and $30,000,000 in the second 10 years. For location J which is shorter, the corresponding estimated user costs are $19,000,000 in the first 10 years and $22,500,000 thereafter. For the even shorter location K, the corresponding figures are $16,000,000 and $19,500,000. The ecological benefits to the general public are $35,000,000, $34,000,000, and $33,000,000 per year for alternatives H, J, and K respectively.

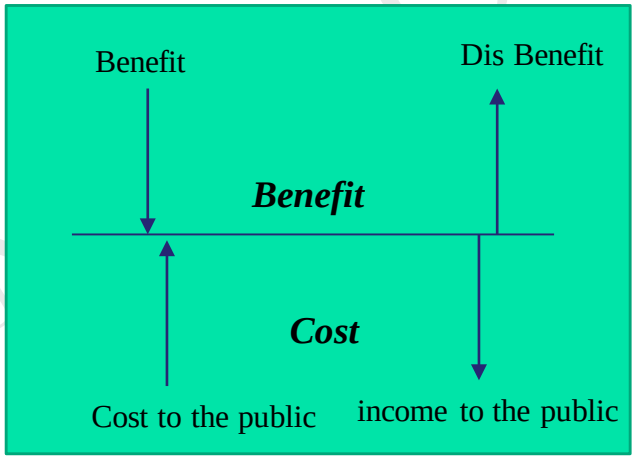
Economic analysis of mutually exclusive projects – Example 1

Solution Example 1

MARR=7%

Salvage value= صرفه جویی های دولت





Economic analysis of mutually exclusive projects – Example 1

$$Pw_H(cost)(7\%) = 11{,}000{,}000 + 3{,}500{,}000\left(\frac{P}{A}, 7, 20\right) = 48{,}079{,}000$$

$$Pw_H(Ben)(7\%) = -25{,}000{,}000\left(\frac{P}{A}, 7, 10\right) - 30{,}000{,}000\left(\frac{P}{A}, 7, 10\right)\left(\frac{P}{F}, 7, 10\right) + 35{,}000{,}000\left(\frac{P}{A}, 7, 20\right) = 88{,}046{,}024$$

$$Pw_J(cost)(7\%) = 70{,}000{,}000 + 2{,}100{,}000\left(\frac{P}{A}, 7, 20\right) - 30{,}000{,}000\left(\frac{P}{F}, 7, 20\right) = 84{,}495{,}400$$

$$Pw_J(Ben)(7\%) = -19{,}000{,}000\left(\frac{P}{A}, 7, 10\right) - 22{,}500{,}000\left(\frac{P}{A}, 7, 10\right)\left(\frac{P}{F}, 7, 10\right) + 34{,}000{,}000\left(\frac{P}{A}, 7, 20\right) = 146{,}374{,}268$$

$$Pw_K(cost)(7\%) = 130{,}000{,}000 + 1{,}700{,}000\left(\frac{P}{A}, 7, 20\right) - 55{,}000{,}000\left(\frac{P}{F}, 7, 20\right) = 133{,}797{,}800$$

$$Pw_K(Ben)(7\%) = -16{,}000{,}000\left(\frac{P}{A}, 7, 10\right) - 19{,}500{,}000\left(\frac{P}{A}, 7, 10\right)\left(\frac{P}{F}, 7, 10\right) + 33{,}000{,}000\left(\frac{P}{A}, 7, 20\right) = 167{,}564{,}166$$

Economic analysis of mutually exclusive projects – Example 1

$$\frac{Pw_H(Ben)}{Pw_H(cost)} = \frac{88{,}046{,}024}{48{,}079{,}000} = 1.83 > 1$$

$$\frac{Pw_J(Ben)}{Pw_J(cost)} = \frac{146{,}372{,}268}{84{,}495{,}400} = 1.73 > 1$$

$$\frac{Pw_K(Ben)}{Pw_K(cost)} = \frac{167{,}564{,}166}{133{,}797{,}800} = 1.25 > 1$$

$Pw_H(cost) < Pw_J(cost) < Pw_K(cost)$

H → J → K

H=CB ,J=CH → $\frac{Pw_J(Ben) - Pw_H(Ben)}{Pw_J(cost) - Pw_H(cost)} = 1.6 > 1$

CB is eliminated

CH → Becomes CB

J=CB ,K=CH → $\frac{Pw_K(Ben) - Pw_J(Ben)}{Pw_K(cost) - Pw_J(cost)} = 0.43 < 1$ → CB → Remains CB

$\therefore Select\ J$

Eliminate k

Economic analysis of mutually exclusive projects – Example 2

Example 2: A river goes through an urban area. Because there have been occasional floods that have caused damage to property in this area, a flood control project has been proposed. Estimates have been made for two alternative designs, one involving channel improvement (CI) and the other involving a dam and reservoir (D&R). Economic analysis is to be based on an estimated 50-year project life, assuming zero terminal salvage value, and using a MARR of 6%.

Economic analysis of mutually exclusive projects – Example 2

Example 2: Flood damages are expected to be $480,000 per year if the present condition of no flood control (NFC) is continued. The alternative (CI) will reduce this figure to $105,000. The alternative (D&R) will reduce it to $55,000.

The (CI) alternative has an estimated first cost of $2,900,000 and annual maintenance costs of $35,000. Both these require disbursements by the Waterways Department.

Economic analysis of mutually exclusive projects – Example 2

Example 2: The (D&R) alternative has an estimated first cost of $5,300,000 and estimated annual maintenance costs of $40,000, both requiring disbursements by the Waterways Department. This alternative also has two types of adverse consequences related to the conservation of natural resources. These negative benefits are the following: The dam will cause damage to the nearby fisheries. This is priced at $28,000 per year. The reservoir will cause loss of land for agricultural purposes. This is priced at $10,000 per year.
Calculate which alternative one should prefer by using benefit-cost analysis.

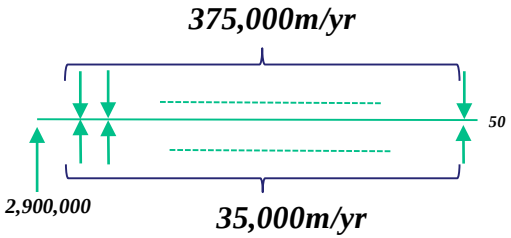
Economic analysis of mutually exclusive projects – Example 2

Solution Example 2

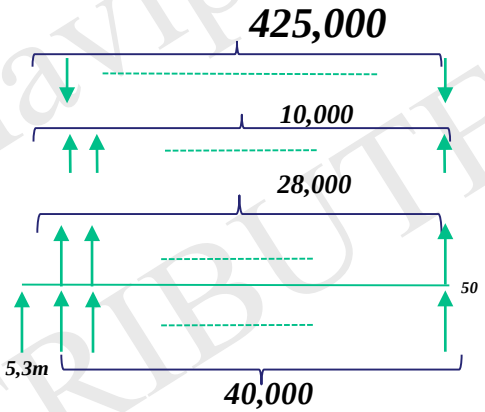
MARR=6%

Benefit for CI 480,000-105,000=375,000 yr

Benefit for *D&R* 480,000-55,000=425,000 yr



CI



D&R

$$AE_{CI}(cost)(6\%) = 35{,}000 + 2{,}900{,}000\left(\frac{A}{P}, 6, 50\right) = 219{,}000 \text{ yr}$$

$$AE_{CI}(Ben)(6\%) = 375{,}000\ yr$$

$$AE_{D\&R}(cost)(6\%) = 40{,}000 + 5{,}300{,}000\left(\frac{A}{P}, 6, 50\right) = 376{,}232 \text{ yr}$$

$$AE_{D\&R}(Ben)(6\%) = 425{,}000 - 28{,}000 - 10{,}000 = 387{,}000 \text{ yr}$$

Economic analysis of mutually exclusive projects – Example 2

$$\frac{AE_{CI}(Ben)}{AE_{CI}(cost)} = \frac{375{,}000}{219{,}000} = 1.7 > 1$$

$$\frac{AE_{D\&R}(Ben)}{AE_{D\&R}(cost)} = \frac{387{,}000}{376{,}232} = 1.03 > 1$$

CI – D&R

CB ***CH***

$$\frac{AE_{D\&R}(Ben) - AE_{CI}(Ben)}{AE_{D\&R}(cost) - AE_{CI}(cost)} = \frac{387{,}000 - 375{,}000}{376{,}232 - 219{,}000} = 0.08 < 1$$

$\therefore$ *Select CI*

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رویکردی جامع برای ارزیابی اقتصادی در پروژه
همراه با آموزش مدلسازی در اکسل (Excel)

بخش دهم:

تحلیل حساسیت، سر به سر، عدم قطعیت و ریسک: تحلیل حساسیت ارزیابی های اقتصادی

ارائه دهندگان:

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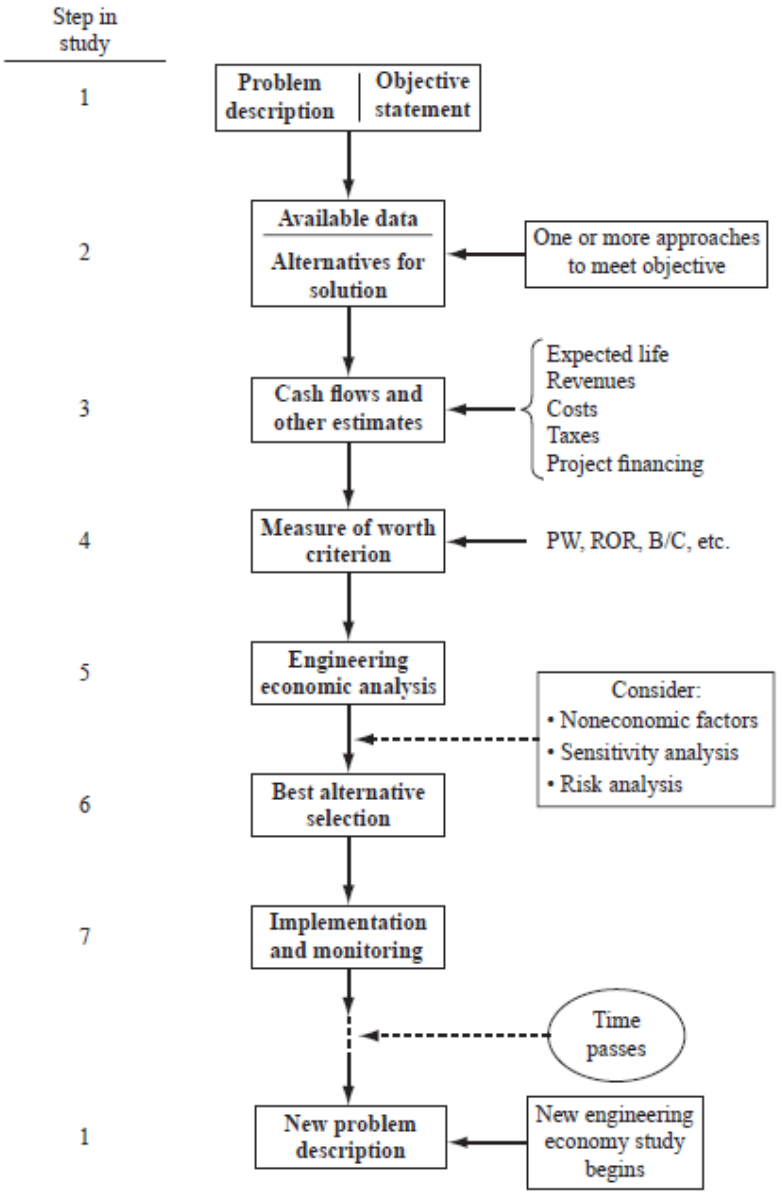
What we will learn?

- Why do we need sensitivity analysis?
- What does sensitivity analysis mean?
- Determining sensitivity to parameter variation
- Cases of sensitivity analysis
  - Sensitivity of one alternative to one parameter
    - ✓ Example 1
    - ✓ Example 2
    - ✓ Example 3
  - Sensitivity one alternative to two parameters
    - ✓ Example 4
  - Sensitivity of several alternatives to one parameter
    - ✓ Example 5
    - ✓ Example 6
- Sensitivity analysis using three estimates
  - Example 7

Steps in engineering economy study

Implementing a structured procedure is the best approach to select the best solution to the problem. The steps in an engineering economy study are as follows:

1. Identify and understand the problem; identify the objective of the project.
2. Collect relevant, available data and define viable solution alternatives.
3. Make realistic cash flow estimates.
4. Identify an economic measure of worth criterion for decision making.
5. **Evaluate each alternative; consider noneconomic factors; use sensitivity analysis as needed.**
6. Select the best alternative.
7. Implement the solution and monitor the results.



Why do we need sensitivity analysis?

- Since the estimates of **cash flow amounts** and **timing** are about the **future**, they will be **somewhat different** than what is actually **observed**, due to c**hanging circumstances** and **unplanned events**.

- The **variation** between an amount or **time estimated now** and that **observed** in the **future** is caused by the **stochastic (random)** nature of all economic events.

- **Sensitivity analysis** is utilized to **determine how a decision might change** according to **varying estimates**, especially those **expected to vary widely**.

What does sensitivity analysis mean?

- The term **parameter represents** any **variable** or **factor** that **may change** the **result**.
  - Annual operating cost (AOC)
  - Salvage value
  - Estimated life (n)
  - Production rate
  - Material cost
  - Etc.

Sensitivity analysis determines how a measure of worth—PW, AW, FW, ROR, B/C, or CER—is altered when one or more parameters vary over a **selected range of values.** Usually one parameter at a time is varied, and independence with other parameters is assumed. Though this approach is an oversimplification in real-world situations, since the dependencies are difficult to accurately model, the end results are usually correct.

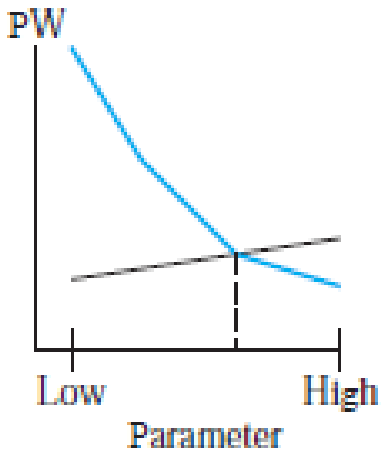
What does sensitivity analysis mean?

- Does variation in a parameter such as **MARR alter the decision**?
  - The variation **will not alter** the **decision** to select an alternative **when all compared alternatives return** considerable **more than the MARR**.
    - ✓ Thus, the decision is relatively **insensitive to the MARR**.
- Does variation in a parameter such as *n* or AOC alter the decision?
  - Yes

Parameters such as MARR and other interest rates (loan rates, inflation rate) are more stable from project to project. If performed, sensitivity analysis on them is for specific values or over a **narrow range of values.** This point is important to remember if simulation is used for decision making under risk

Determining sensitivity to parameter variation

- **Plotting** the sensitivity of **PW, AW, or ROR versus** the **parameter(s) studied** is very helpful.
- **Two alternatives** can be **compared** with respect to **a given parameter** and the **breakeven point**.
  - This is the **value** at which the **two alternatives** are **economically equivalent**.
    - ✓ However, the **breakeven chart commonly** represents **only one parameter** per chart.



Determining sensitivity to parameter variation

- When **several parameters** are studied, sensitivity analysis can become **quite complex**.
- The **computer** facilitates **comparison of multiple parameters** and **multiple measures of worth**, and the **software** can rapidly **plot the results**.

Determining sensitivity to parameter variation

- **General procedure** to follow when **conducting a thorough sensitivity analysis**.

1. **Determine** **which parameter(s)** of interest **might vary** from the **most likely estimated value**.
2. **Select** the **probable range** and **an increment of variation** for **each parameter**.
3. **Select** the **measure of worth**.
4. **Compute** the **results for each parameter**, using the **measure of worth** as a basis.
5. **Display** the **parameter versus** the **measure of worth graphically** to better interpret the sensitivity.

Determining sensitivity to parameter variation

- **When** there are **two or more alternatives**, it is **better** to use the **PW or AW** measure of worth in **Step 3**.

- If **ROR** is **used**, it **requires the extra efforts** of **incremental analysis** between alternatives.

Cases of sensitivity analysis

1. Sensitivity of one alternative to one parameter
2. Sensitivity of one alternative to two parameters
3. Sensitivity of several alternatives to one parameter

Sensitivity of one alternative to one parameter

- When we want to see **how sensitive an alternative** is to **one parameter at a time**
  - MARR
  - Income
  - Expenditures
  - Years of investment
  - Etc.

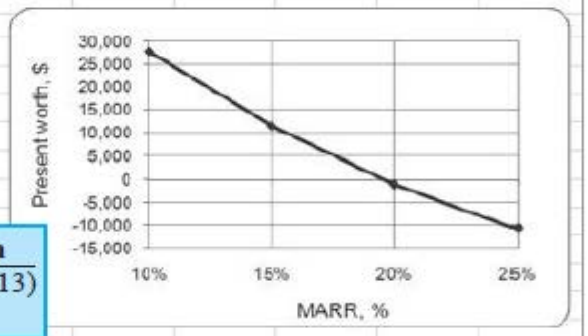
- This is **not very realistic** because we **only change one parameter at a time** and other parameters **remain fixed**, however **in reality many parameters change simultaneously**.
  - For example, when there is **uncertainty** about **both income and expenditure**.

Sensitivity of one alternative to one parameter – Example 1

n is economic life of the machine

	A	B	C	D
1		Cash flow		
2	Year	for n = 10	MARR	PW, $
3	0	-80,000	10%	27,831
4	1	25,000	15%	11,510
5	2	23,000	20%	-962
6	3	21,000	25%	-10,712
7	4	19,000		
8	5	17,000		
9	6	15,000		
10	7	13,000		
11	8	11,000		
12	9	9,000		
13	10	7,000		

PW computation
= NPV(C6,B$4:B$13)
+B$3

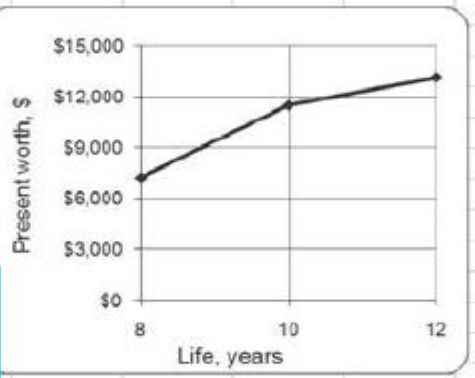


Sensitivity analysis of PW to variation in (*a*) MARR values and (*b*) life estimates,

(*a*)

	A	B	C	D
1		Cash flow		
2	Year	for n = 12		
3	0	-80,000	Life, n	PW, $
4	1	25,000	8	7,222
5	2	23,000	10	11,510
6	3	21,000	12	13,146
7	4	19,000		
8	5	17,000		
9	6	15,000		
10	7	13,000		
11	8	11,000		
12	9	9,000		
13	10	7,000		
14	11	5,000		
15	12	3,000		

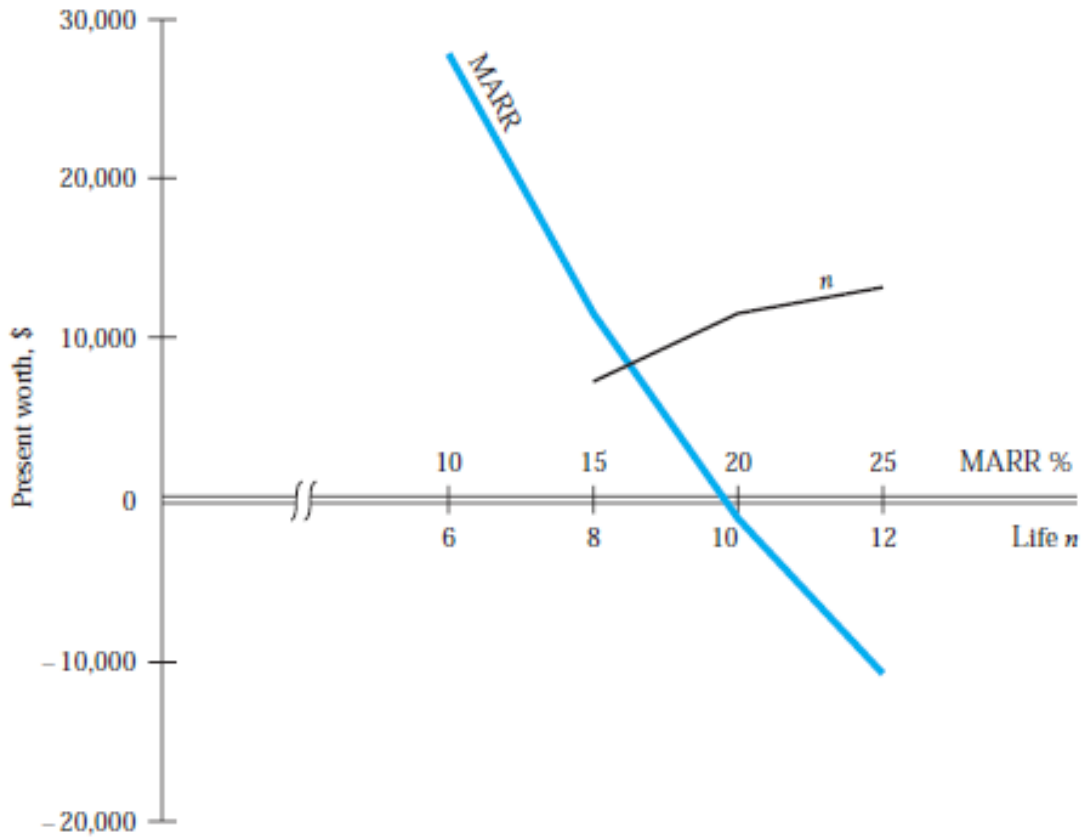
PW computation
= NPV(15%,B$4:B$15)
+B$3



(*b*)

Sensitivity of one alternative to one parameter – Example 1

- The PW curve levels out above *n=10*
- PW is sensitive to changes in MARR values, but not very sensitive to variations in *n*



Plot of PW versus MARR and *n* for sensitivity analysis.

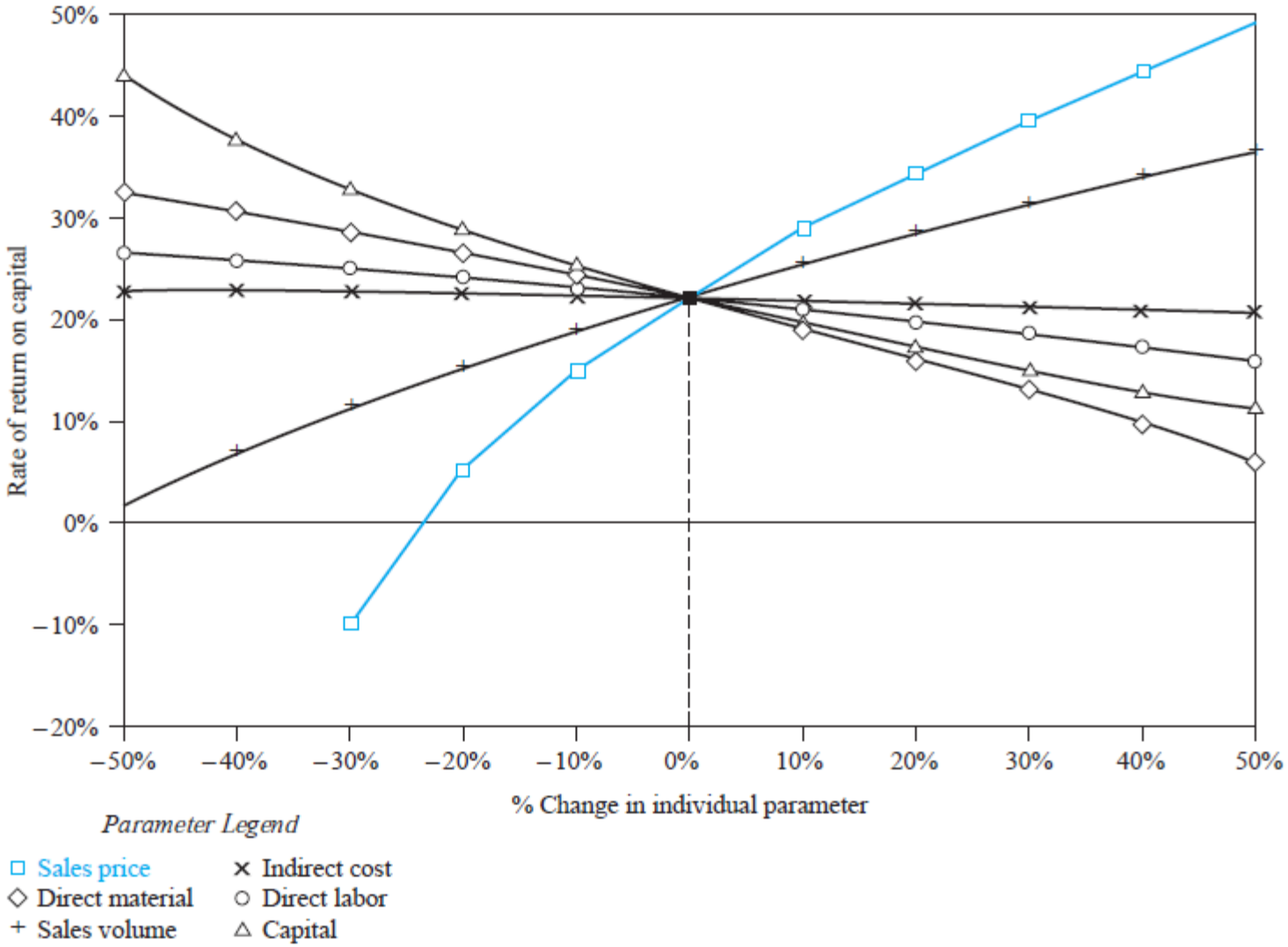
Sensitivity of one alternative to one parameter – Spider graph

- When the sensitivity of ***several parameters*** is considered for ***one alternative*** using a ***single measure of worth***,

  it is helpful to **graph percentage change** for each parameter versus the measure of worth. This is sometimes called a **spider graph.**

Sensitivity of one alternative to one parameter – Example 2

Sensitivity analysis graph of percent variation from the most likely estimate.



Sensitivity of one alternative to one parameter – Example 3

Example 3: Consider a cash flow where the initial cost is $10,000 and the annual income is estimated as $3,000 over a five-year period. The minimum attractive rate of return is 12%. Calculate the sensitivity of the outcome of economic analysis to errors ranging between -40% to +40% in the following parameters:

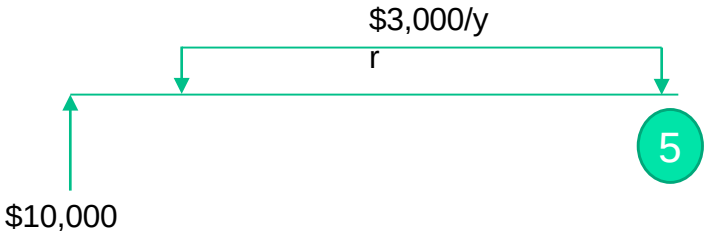
a) Annual receipts

b) Initial investment

c) Minimum attractive rate of return

d) Planning horizon

Sensitivity of one alternative to one parameter – Example 3



$$AE(\%12) = -10000\left(\frac{A}{P},12,5\right) + 3000 = \$226/yr$$

$$a)\ AE(\%12) = -10{,}000\left(\frac{A}{P},12,5\right) + 3000(1+x) \Longrightarrow when\ AE = 0 \Longrightarrow x = \%-7.47$$

$$\Longrightarrow Income = \$2{,}776$$

$$b)AE(\%12) = -10{,}000\left(\frac{A}{P},12,5\right)(1+x) + 3000 \Longrightarrow when\ AE = 0 \Longrightarrow x = \%8.14$$

$$\Longrightarrow \text{Initial investment} = \$10{,}814$$

$$c)AE(?) = -10{,}000\left(\frac{A}{P},12(1+x),5\right) + 3000 \Longrightarrow when\ AE = 0 \Longrightarrow x = \%27$$

$$\Longrightarrow MARR = \%15.24$$

$$d)AE(\%12) = -10{,}000\left(\frac{A}{P},12,5(1+x)\right) + 3000 \Longrightarrow when\ AE = 0 \Longrightarrow x = \%-10$$

$$\Longrightarrow n = 4.5\ year$$

Sensitivity of one alternative to one parameter – Example 3

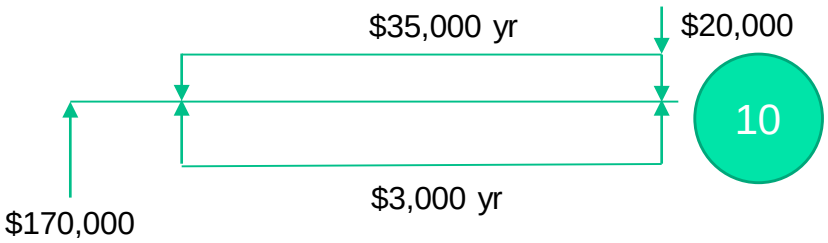
Sensitivity of one alternative to two parameters

- It is very similar to **Case 1** with the **exception** that **two parameters** are considered **simultaneously**.
  - For example, the **uncertainty about both income and expenditure**

Sensitivity of one alternative to two parameters – Example 4

Example 4: Consider a cash flow where the initial cost is $170,000 and the salvage value at the end of a life of 10 years is $20,000. The yearly incomes and disbursements are $35,000 and $3,000, respectively. The analyst is unsure about the magnitude of incomes and disbursements and wants to conduct sensitivity analysis to see the effects of changes in these two parameters. Plot the percentage of error in incomes against the percentage of error in disbursements. Identify the indifference line. Take MARR=13%.

Sensitivity of one alternative to two parameters – Example 4



$$a)\ AE(\%13) = -170000\left(\frac{A}{P},13,10\right) + 3500(1+x) - 3000(1+y) + 20000\left(\frac{A}{F},13,10\right)$$

$$\Longrightarrow AE(\%13) = 0 \Longrightarrow 1757 + 35000x - 3000y = 0$$

$$\Longrightarrow y = 11.67x + 0.5857$$

$$x = 0 \Longrightarrow y = \%58.57, Expenditures = \$4,757$$

$$y = 0 \Longrightarrow x = \% - 5.02 \Longrightarrow Income = \$33,243/yr$$

Sensitivity of one alternative to two parameters – Example 4

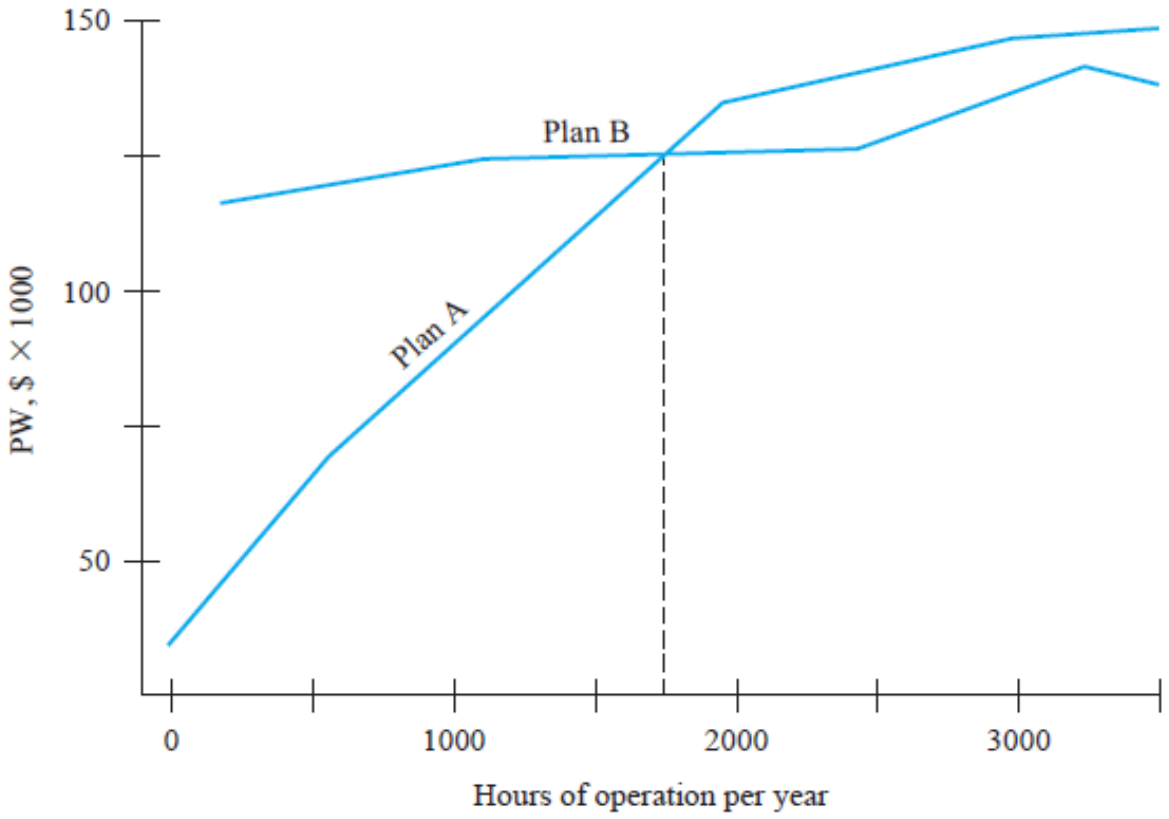
Sensitivity of several alternatives to one parameter

- When there are **more than one alternative** and only there is an **uncertainty** about **one parameter**.
  - For example, we are **unsure** about the **years of investment**. The investor will see how **alternatives change** according to **different years of investment** and select what **he/she thinks that is best** to go with.
  - If ***two alternatives*** are compared and the **sensitivity to *one parameter* is so**ught, the graph may show **quite nonlinear results**.

Sensitivity of several alternatives to one parameter – Example 5

- ***Example 5***: Plan A is very sensitive in the range of 0 to 2000 hours, but it is comparatively insensitive above 2000 hours. Plan B is more attractive due to its relative insensitivity. The breakeven point is at about 1750 hours per year.

Sample PW sensitivity to hours of operation for two alternatives.



Sensitivity of several alternatives to one parameter – Example 6

Example 6: Conduct a sensitivity analysis by considering the variation in the annual equivalent amount for three investment alternatives to changes in the following parameters:

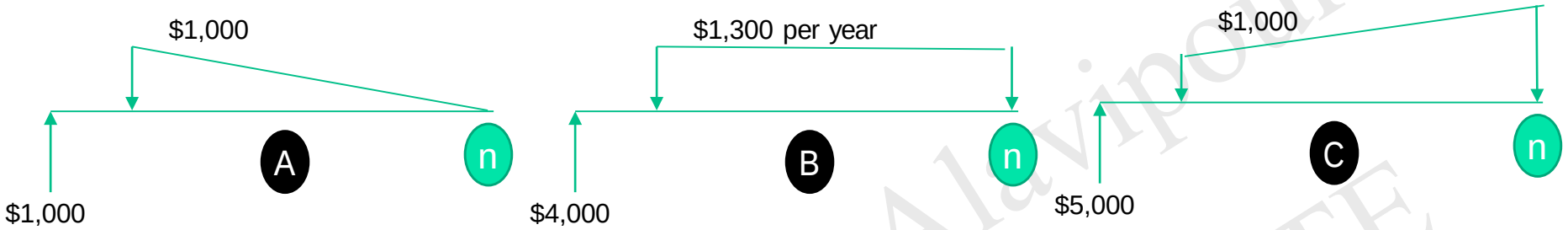
a) Changes in the gradient (G) between \$0-200 per year. Assume the planning horizon (n) is 10 years and MARR is 15%.

b) Changes in MARR between 0-30%. Assume the planning horizon (n) is 10 years and the gradient (G) is \$100 per year.

c) Changes in the planning horizon (n) between 0-20 years. Assume MARR is 15% and the gradient (G) is \$100 per year.

	ALT A	ALT B	ALT C
Initial cost	\$1,000	\$4,000	\$5,000
Revenue in first year	\$1,000	\$1,300	\$1,000
Revenue in following years	Decreasing gradient G	\$1,300	Increasing gradient G
Minimum attractive rate of return	MARR	MARR	MARR
Planning horizon	n	n	n

Sensitivity of several alternatives to one parameter – Example 6



$a)$

$$AE_A(15\%) = -1000\left(\frac{A}{P},15,10\right) + 1000 - G\left(\frac{A}{G},15,10\right) = 800.7 - 3.3832G$$

$$AE_B(15\%) = -4000\left(\frac{A}{P},15,10\right) + 1300 = \$502.8\ per\ year$$

$$AE_C(15\%) = -500\left(\frac{A}{P},15,10\right) + 1000 + G\left(\frac{A}{G},15,10\right) = 3.5 + 3.3882G$$

Sensitivity of several alternatives to one parameter – Example 6

Sensitivity of several alternatives to one parameter – Example 6

Sensitivity of several alternatives to one parameter – Example 6

Sensitivity analysis using three estimates

- We can thoroughly **examine** the **economic advantages** and **disadvantages** among **two or more alternatives** by making **three estimates for each parameter**:

1. **Pessimistic estimate**
2. **Most likely estimate**
3. **Optimistic estimate**

- This is **usually used** when the **market changes** and we **want to see** what **result** will be achieved in the **worst**, **most likely**, and **best situations**.

Sensitivity analysis using three estimates

- Usually the **most likely estimate is used**. However, **four situations** can be occurred:

1. **If pessimistic, most likely, and optimistic estimates are positive**
   - Do invest
2. **If most likely and optimistic estimates are positive, but pessimistic estimate is negative**
   - There is a risk, but check other parameters to make decision
3. **When only optimistic estimate is positive and others are negative**
   - There is a higher risk, investment not recommended
4. **When all estimates are negative**
   - Do not invest

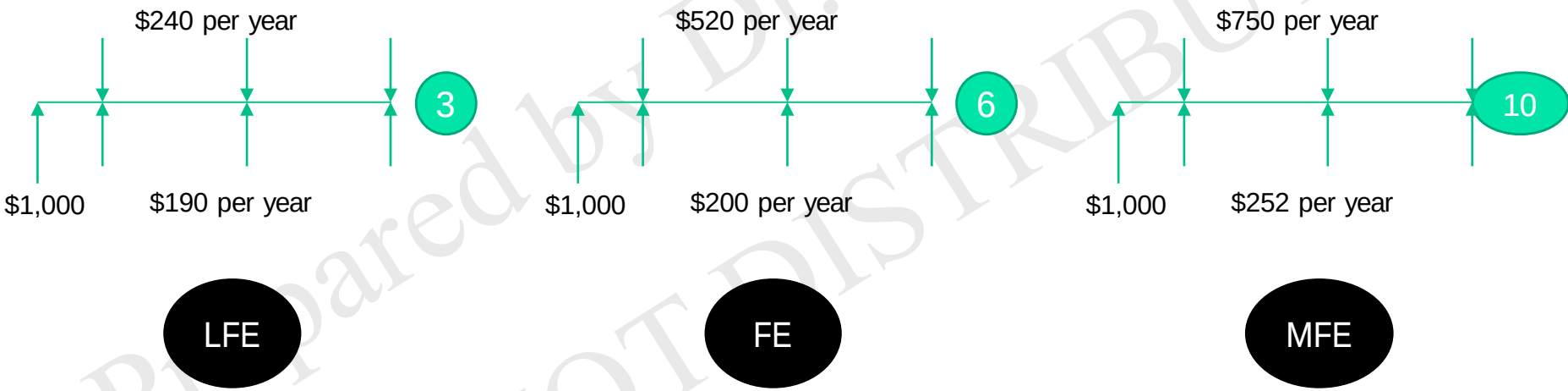
Sensitivity analysis using three estimates – Example 7

Example 7: The initial value of a machine is $1,000. The minimum attractive rate of return for the company is estimated as 5%. The machine produces four items, A, B, C, and D that may have different operation costs, production quantities, selling prices over different periods of annual income. The most favorable, the least favorable, and the fair estimates for this operation are presented below. **Is this operation economically feasible?**

ITEMS ESTIMATED	LEAST FAVORABLE ESTIMATE	FAIR ESTIMATE	MOST FAVORABLE ESTIMATE
Annual number of units produced	300	500	652
Income per unit	$0.80	$1.04	$1.15
Period of annual income	3 yrs	6 yrs	10 yrs
Operating Cost:			
Item A	$60/yr	$90/yr	$120/yr
Item B	60	60	70
Item C	50	40	60
Item D	20	10	2

Sensitivity analysis using three estimates – Example 7

	LFE	FE	MFE
Annual cost	$190 per year	$200 per year	$252 per year



Sensitivity analysis using three estimates – Example 7

	LFE	FE	MFE
Annual cost	$190 per year	$200 per year	$252 per year

$$a)\ AE_{LFE}(5\%) = 240 - 190 - 1,000\left(\frac{A}{P}, 5, 3\right) = -\$317\ per\ year$$

$$AE_{FE}(5\%) = 520 - 200 - 1,000\left(\frac{A}{P}, 5, 6\right) = \$123\ per\ year$$

$$AE_{MFE}(5\%) = 750 - 252 - 1,000\left(\frac{A}{P}, 5, 10\right) = \&368\ per\ year$$

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همراه با آموزش مدلسازی در اکسل (Excel)

بخش یازدهم:

تحلیل حساسیت، سر به سر، عدم قطعیت و ریسک: تجزیه و تحلیل سر به سر

ارائه دهندگان:

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(M.Sc., PMP)

What we will learn?

- What is break-even analysis?
- When break-even analysis is suitable?
- How to use break-even analysis for projects?
  - Break-even analysis for a single project
    - ✓ Example 1
    - ✓ Example 2
  - Break-even analysis between two alternatives or projects
    - ✓ Example 3
    - ✓ Example 4

What is break-even analysis?

- **Breakeven analysis** is performed to **determine** the **value of a variable** or **parameter** of **a project** or **alternative** that makes **two elements equal**.
  - For example, the **sales volume** that **will equate revenues** and **costs**.

- **A breakeven study** is performed for **two alternatives** to **determine** when **either alternative is equally acceptable**.

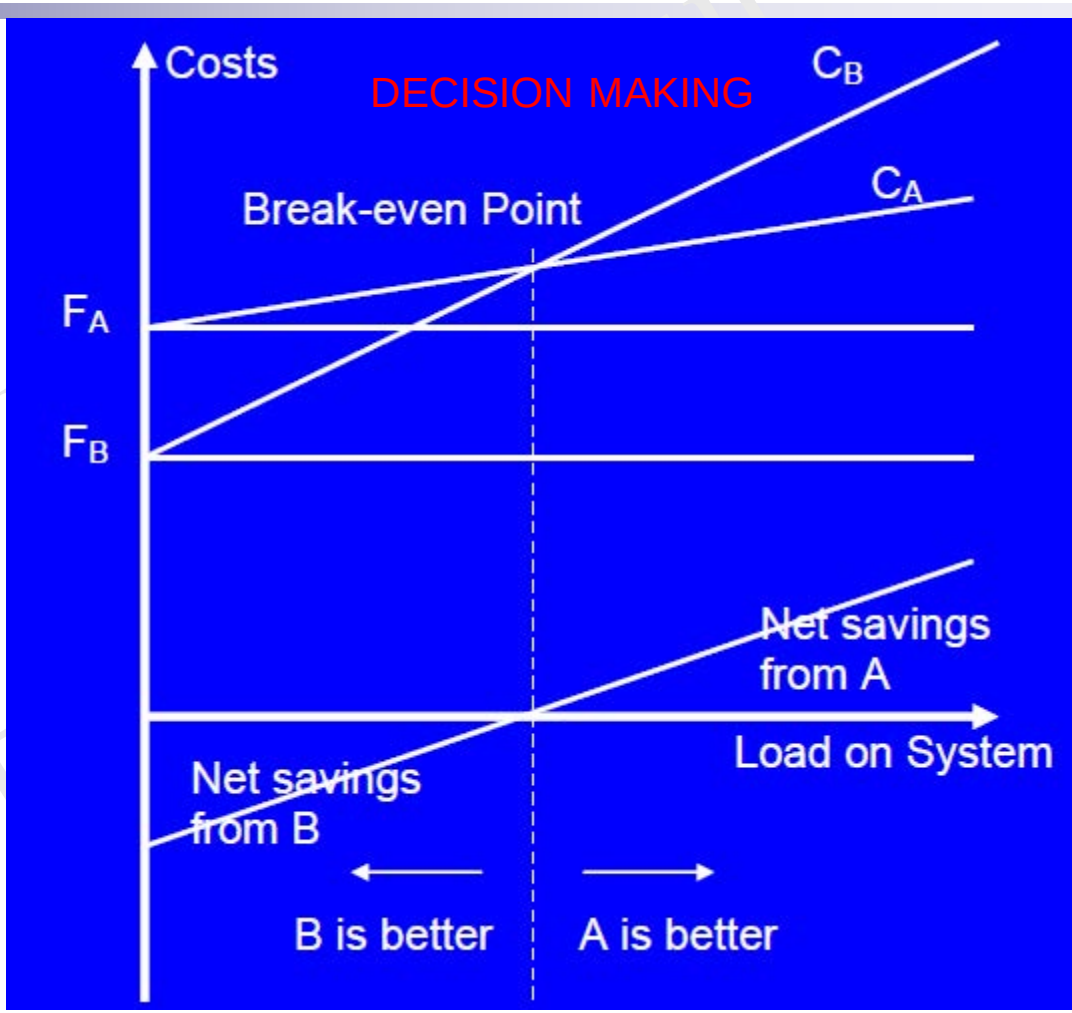
- **Breakeven analysis** is commonly **applied** in **make-or-buy decisions** when a **decision is needed** about the source for **manufactured components**, **services**, etc.

When is break-even analysis suitable?

1. **Break-even analysis** is **suitable** when the **costs** or **benefits** of a system **consist** of **fixed** and **variable components**, such as:
   - ❖ Owning and operating costs for construction equipment

and the **decision** wants to be made for **selecting** between **two or more alternatives**.

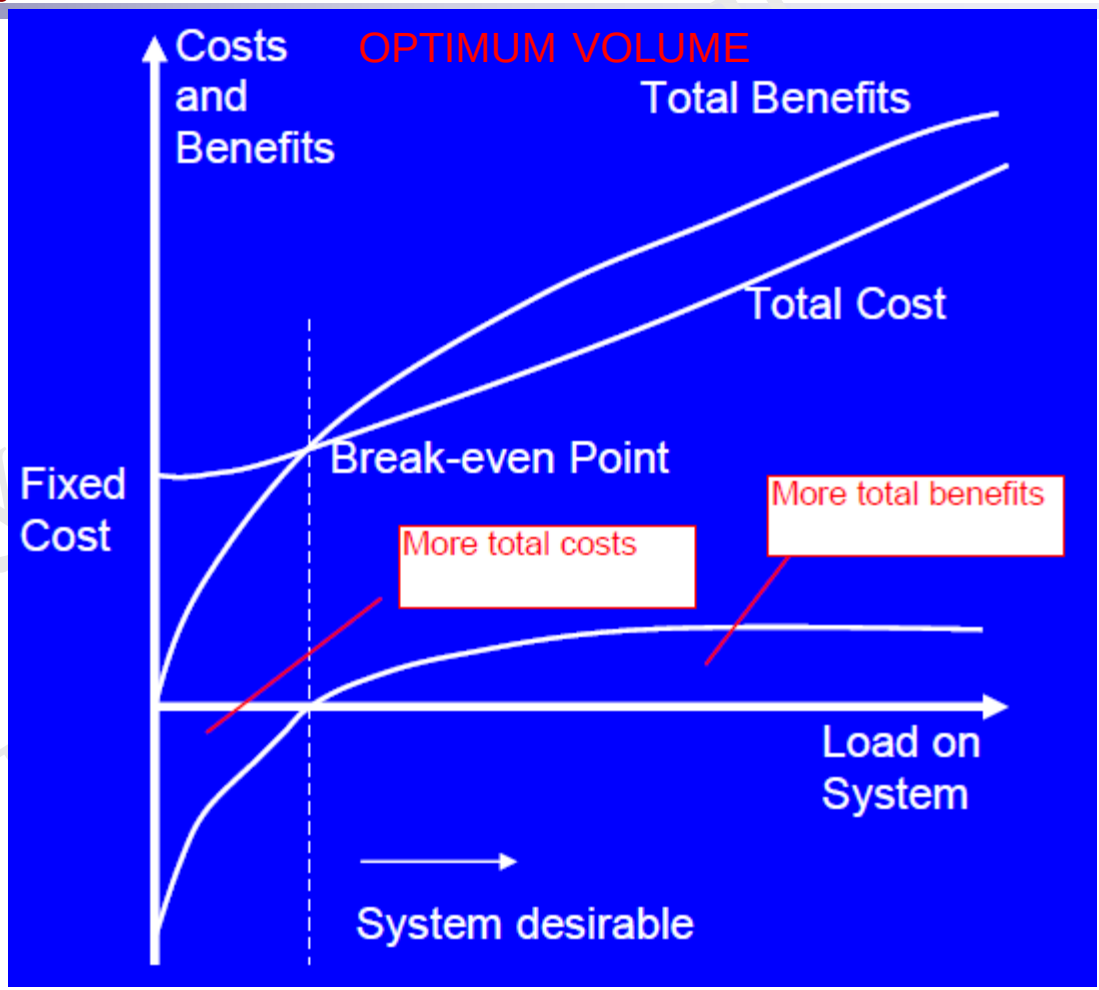
- ❑ ***F*** is a **fixed** and ***C*** is a **total cost**
- ❑ **Load on system** can be the **production rate for an equipment**



When is break-even analysis suitable?

2. It is **also suitable** when a **firm** wants to **evaluate** **income** and **costs** in terms of **volume**.
   - ❖ It is possible to use this analysis to **compare two systems**.

- ❑ The **bottom curve** shows **how much** the **benefits** and **costs** would be based on **load** on system.



How to use break-even analysis for a project?

1. Break-even analysis for a single project **(OPTIMUM VOLUME)**
2. Break-even analysis between two alternatives or projects **(DECISION MAKING)**

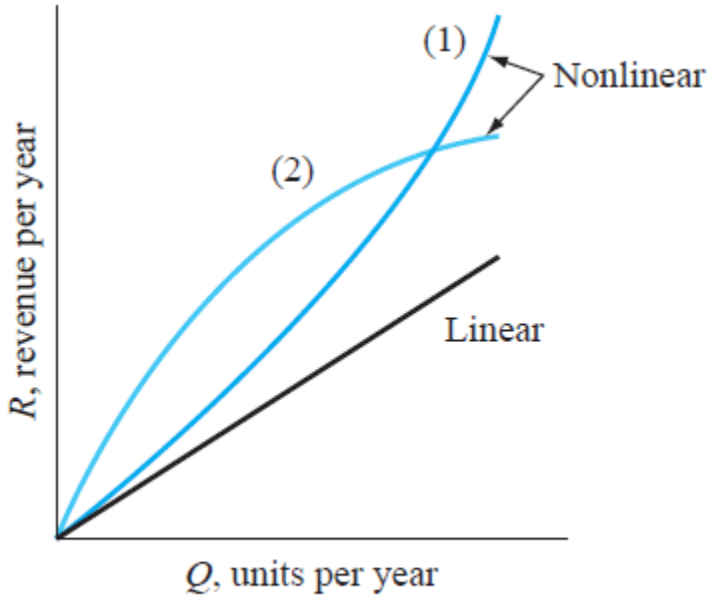
Break-even analysis for a single project

- **First** we need to **divide** the **components of the costs** into **two categories**:

1. **Fixed costs**
   - If the **volume** of the parameters **change**, these costs still **remain fixed**.
     1. For example, if the **production rate changes**, the **material cost** remains **fixed** and in this case the **material cost is a fixed cost**.
     2. However, if the **quantity** of the **work changes**, the **material cost** changes as well and in this case the **material cost is a variable cost**.
2. **Variable costs**
   - If the **volume** of the parameters **change**, these costs **change** as well.
     - ✓ For example, the **labor cost** changes if the **volume** of the work changes in the work, however the **salary of the secretary** in an office **remains fixed**.

Break-even analysis for a single project – Revenue relations

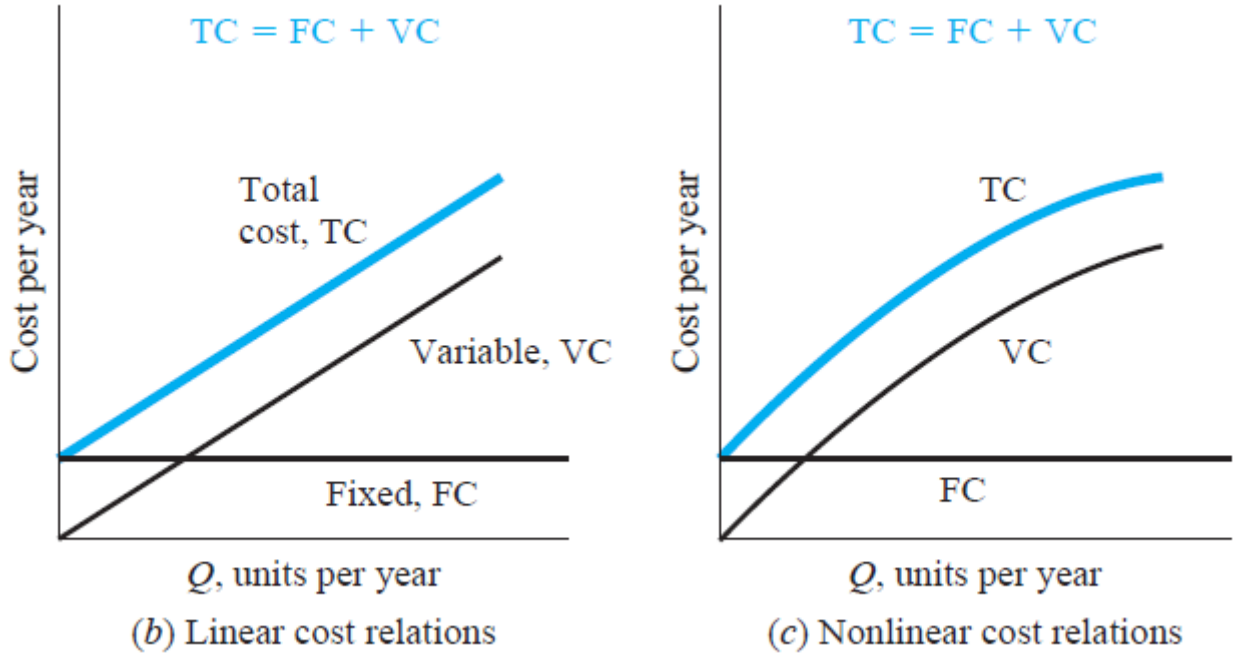
- **Linear and non-linear revenue relations**



(*a*) Revenue relations—(1) increasing and (2) decreasing revenue per unit

Break-even analysis for a single project – Cost relations

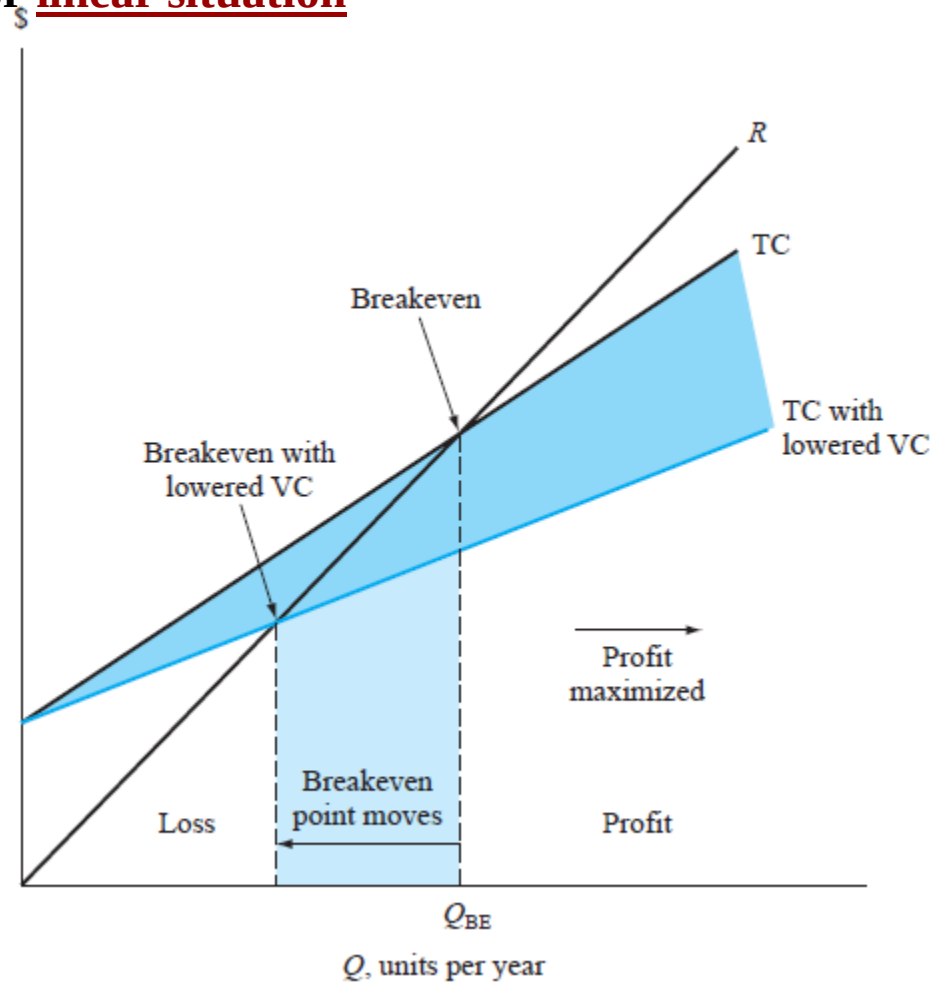
- **Linear and non-linear cost relations**



(b) Linear cost relations (c) Nonlinear cost relations

Break-even analysis for a single project – Revenue and cost relations

- **Revenue** and **total cost** relations for **linear situation**

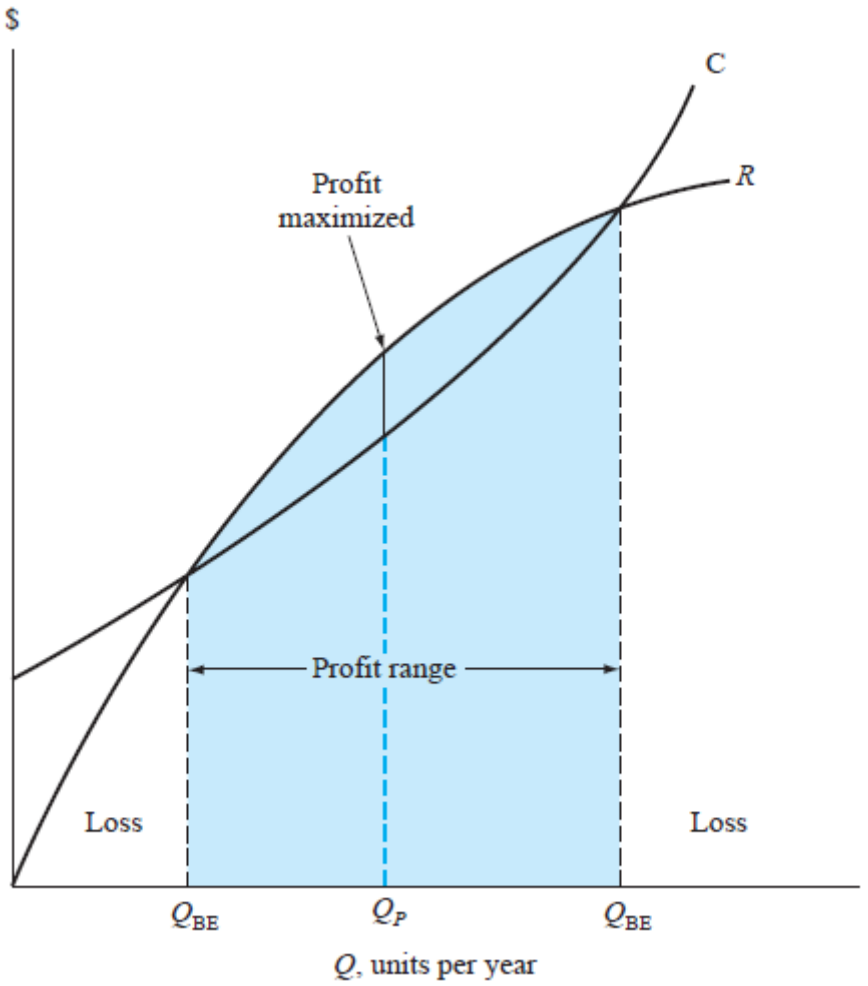


$$\text{Profit} = \text{revenue} - \text{total cost}$$
$$= R - \quad C$$
$$= R - (FC + VC)$$

Break-even analysis for a single project – Revenue and cost relations

- **Revenue and total cost relations for non-linear situation**

$$\begin{aligned}\text{Profit} &= \text{revenue} - \text{total cost} \\ &= R - \text{C} \\ &= R - (\text{FC} + \text{VC})\end{aligned}$$



Break-even analysis for a single project – Example 1

Example 1: An excavation contractor intends to purchase either large trucks or smaller trucks to transport material from borrow pits to fills. The revenues will be 20 cents per ton-mile and the annual costs will either be $20,000 and 5 cents per ton-mile for the large trucks; or $6,000 and 8 cents per ton-mile for the smaller trucks.

What is the break-even volume for the trucks?

Break-even analysis for a single project – Example 1

- The break-even point for **each individual type** of truck is found at the **intersection of total cost and total revenue**.

  - For large trucks:
    - ✓ Ycost = 20,000 + 0.05x
    - ✓ Yrev = 0.20x

      When cost = revenue

      20,000 + 0.05x = 0.20x

      X = 133,000 Ton-miles

  - For small trucks:
    - ✓ Ycost = 6,000 + 0.08x
    - ✓ Yrev = 0.20x

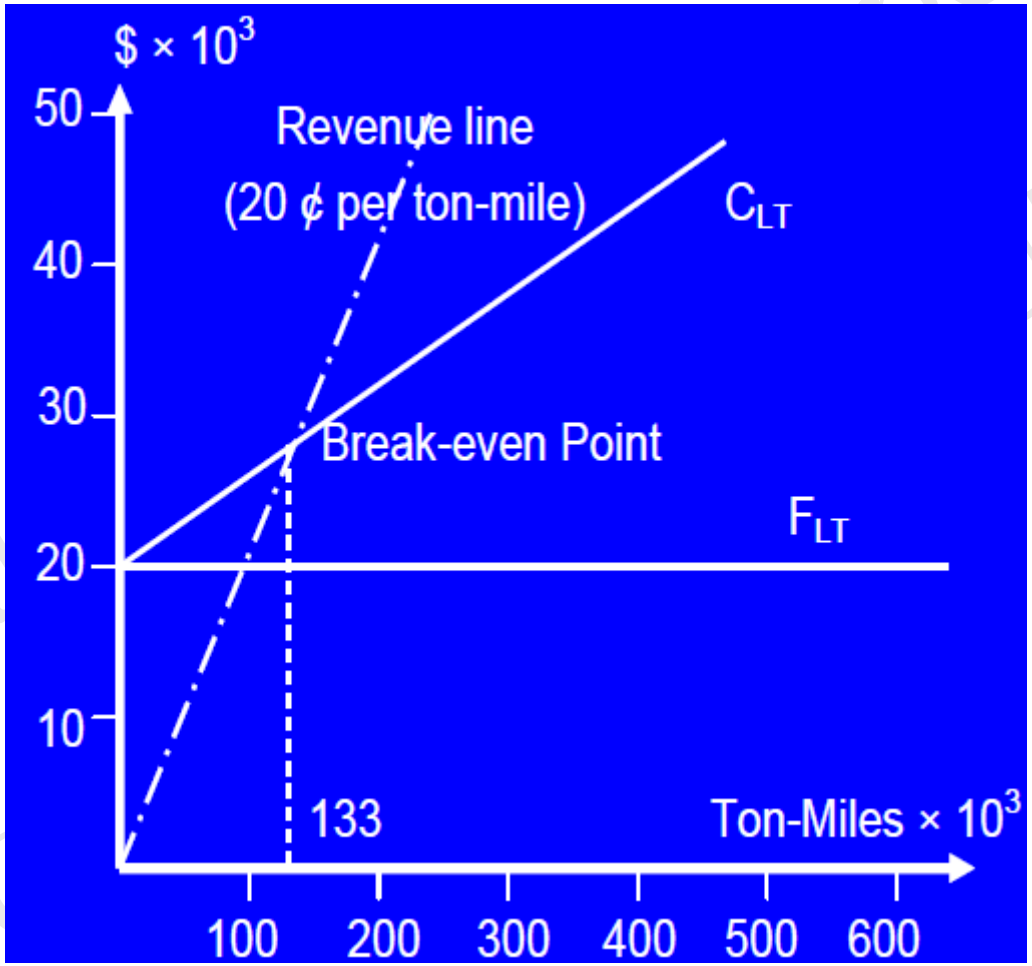
      When cost = revenue

      6,000 + 0.08x = 0.20x

      X = 50,000 Ton-miles

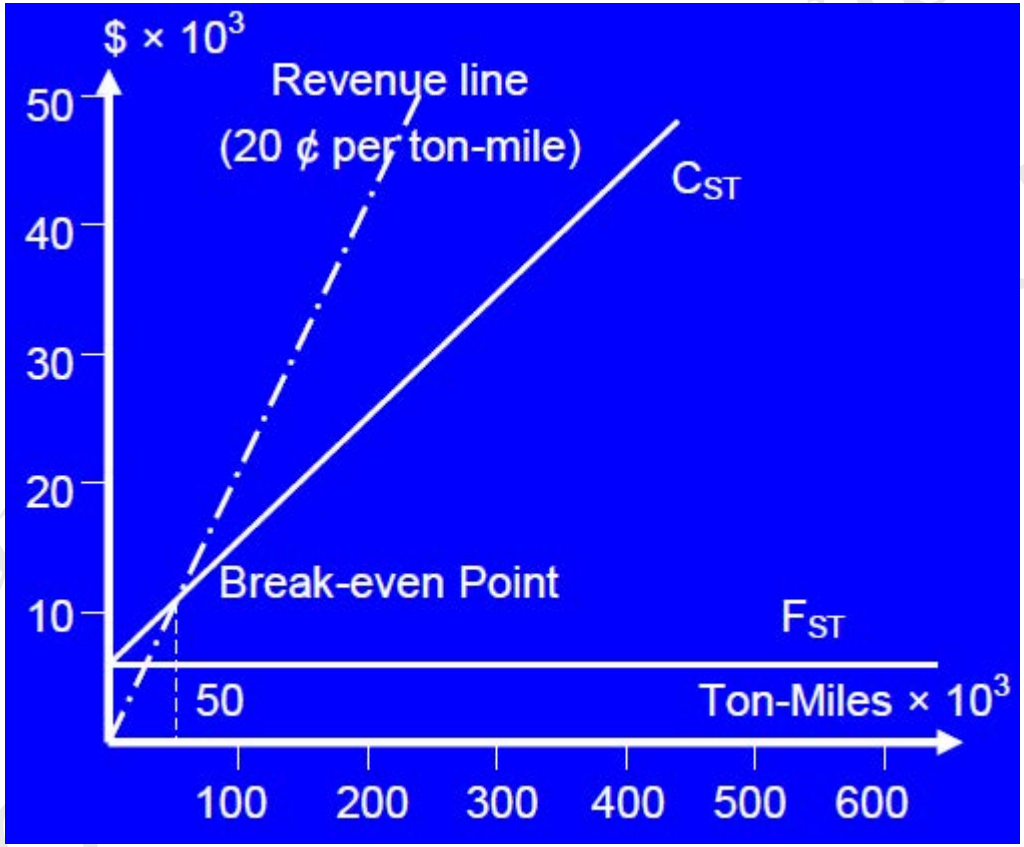
Break-even analysis for a single project – Example 1

- X = 133,000 Ton-miles for large trucks



Break-even analysis for a single project – Example 1

- X = 50,000 Ton-miles for small trucks



Break-even analysis for a single project – Example 2

Example 2: A contracting company buys manual concrete vibrators for $800 per unit. Fixed costs of the operation are $14,000.

The vibrators are shipped to the sites and charged at their individual accounts. The shipment costs 40% of the price charged to each site.

What price should each site be charged to allow the central office to break even on a shipment of 500 vibrators?

Break-even analysis for a single project – Example 2

Set:

P = unit price charged to sites ($/unit)

Total cost of operation:

= $14,000 + (500 units × $800/unit) + (500 units × $0.40P/unit)
= 14,000 + 400,000 + 200p
= 414,000 + 200p

Total charged to sites:

= 500p

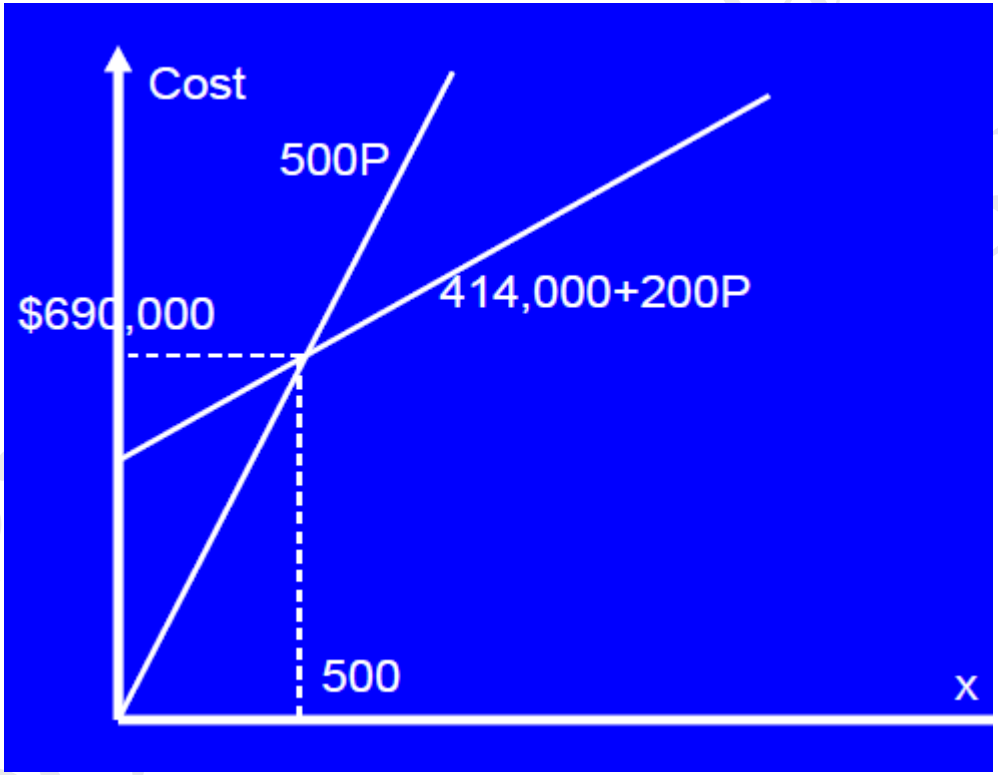
When cost is equated to charge:

414,000 + 200p = 500p

P = $1,380 per unit

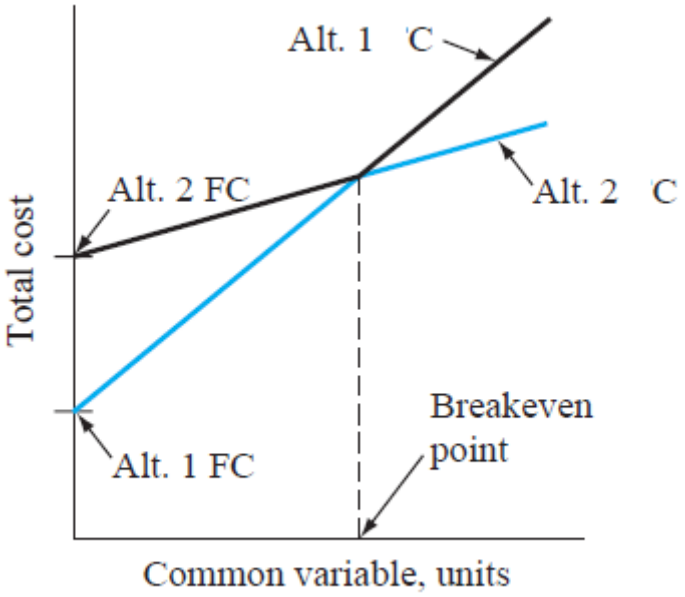
Break-even analysis for a single project – Example 2

P = $1,380 per unit, then the cost is equal to $690,000



Break-even analysis between two alternatives or projects

- The parameter can be the **interest rate**, **first cost**, **annual operating cost**, **MARR**
- This is the **linear relation**



Break-even analysis between two alternatives or projects – Example 3

Example 3: An excavation contractor intends to purchase either large trucks or smaller trucks to transport material from borrow pits to fills.

The revenues will be 20 cents per ton-mile and the annual costs will either be $20,000 and 5 cents per ton-mile for the large trucks; or $6,000 and 8 cents per ton-mile for the smaller trucks.

What truck is preferable?

Break-even analysis between two alternatives or projects – Example 3

- The break-even point **between large and small trucks** is found at the **intersection of the two cost lines**.

  - For large trucks:
    - ✓ Ycost = 20,000 + 0.05x
    - ✓ Yrev = 0.20x

      When cost = revenue

      20,000 + 0.05x = 0.20x

      X = 133,000 Ton-miles
  - For small trucks:
    - ✓ Ycost = 6,000 + 0.08x
    - ✓ Yrev = 0.20x

      When cost = revenue

      6,000 + 0.08x = 0.20x

      X = 50,000 Ton-miles

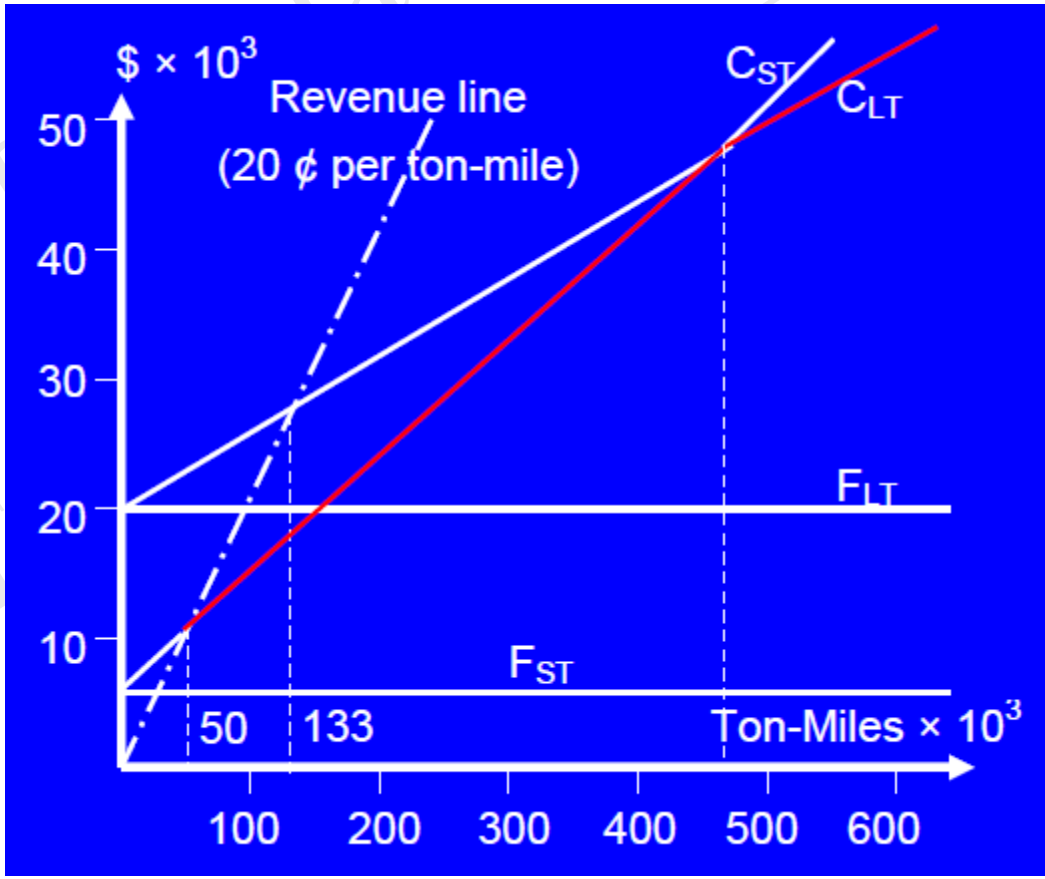
20,000 + 0.05X = 6,000 + 0.08X

X = 466,667 Ton-miles

Break-even analysis between two alternatives or projects – Example 3

- If x > 466,667 Ton-miles, prefer large trucks
- If 50,000 < x < 466,667 Ton-miles, prefer small trucks
- If x < 50,000 Ton-miles, both large and small trucks make a loss

WHAT IF REVENUE LINE ALSO CHANGED FOR EACH?



Break-even analysis between two alternatives or projects – Example 4

Example 4: An excavation contractor intends to purchase either large trucks or smaller trucks to transport material from borrow pits to fills. The revenues will be 20 cents per ton-mile and the annual costs will either be $20,000 and 5 cents per ton-mile for the large trucks; or $6,000 and 8 cents per ton-mile for the smaller trucks.

What should the ton-mile operating cost of the large trucks be, if they are to be preferable to smaller trucks for traffic that is greater than 300,000 ton-miles per year?

Break-even analysis between two alternatives or projects – Example 4

$$20{,}000 + 300{,}000k \leq 6{,}000 + (0.08 \times 300{,}000)$$

$$K = \$0.0333 \text{ per ton-mile}$$

Break-even analysis between two alternatives or projects – Example 5

Example 5: A contractor can produce doors for use in one of her large building construction sites at an annual estimated fixed cost of $90,000 and variable cost of $375 per door.

She can also buy the complete set at a price of $600 per door for the first 500 and $315 for all doors purchased beyond the 500-door limit.

For what quantities should she prefer which alternative?

Break-even analysis between two alternatives or projects – Example 5

- Set X = number of doors used
- The cost of manufacturing doors on site: Ca = 90,000 + 375x
- The cost of purchasing up to 500 doors: Cb1 = 600x,
  When $x \leq 500$ doors

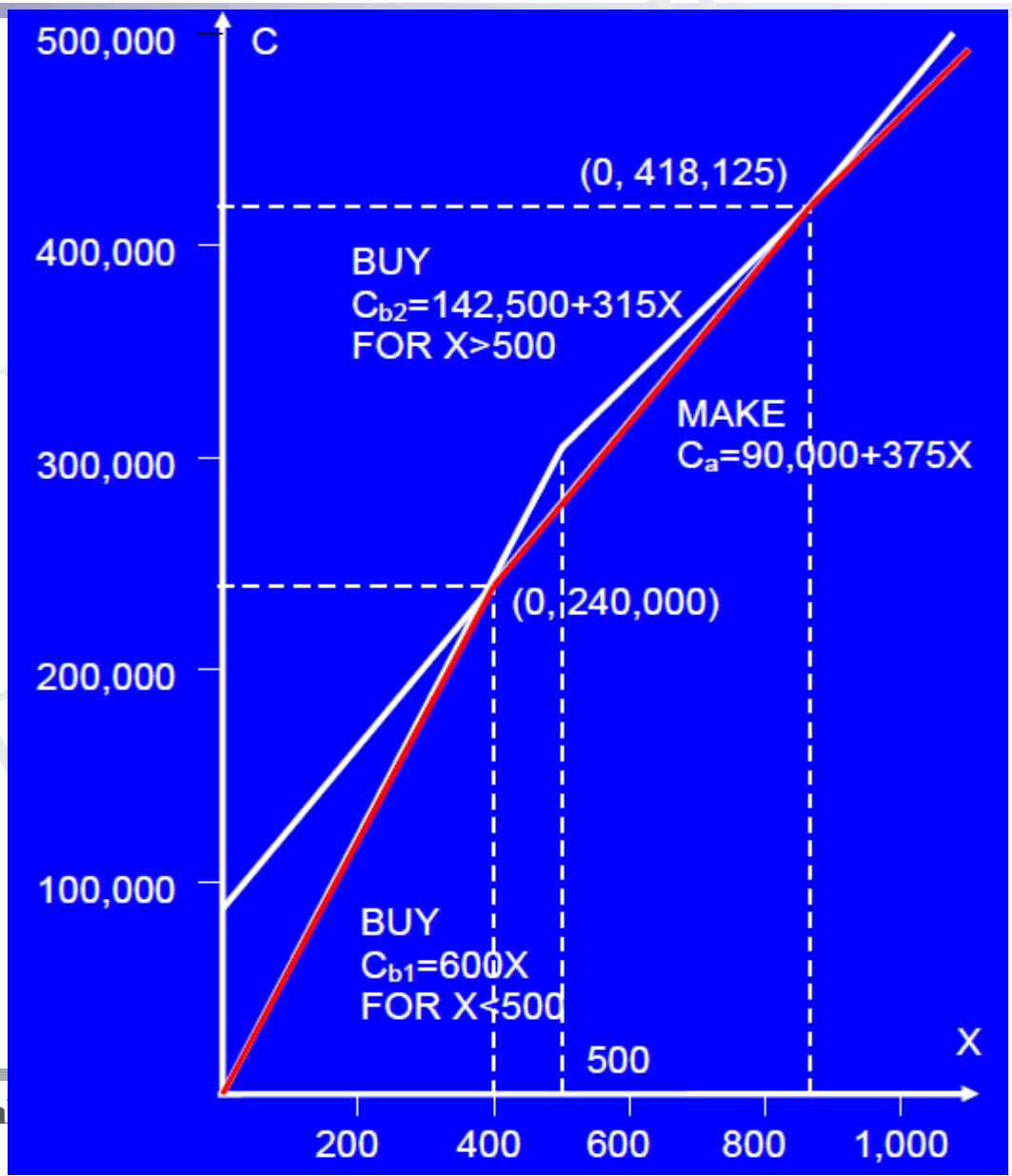
- The cost of purchasing doors beyond the 500-door limit: Cb2 = (600 × 500) + 315(x - 500)
  = 300,000 + 315x – 157,500
  = 142,500 + 315x
  When x > 500 doors

The intersection point between (a) and (b1) is: 90,000 + 375x = 600x
X = 400 doors, When $x \leq 500$ doors

The intersection point between (a) and (b2) is: 90,000 + 375x = 142,500 + 315x
X = 875 doors, When x > 500 doors

Break-even analysis between two alternatives or projects – Example 5

- If she needs 400 < x < 875 doors, she should manufacture the doors on site.
- If she needs x < 400 doors or x > 875 doors, then she should purchase them.



موسسه مهندسی و مدیریت ساخت علوی پور

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رویکردی جامع برای ارزیابی اقتصادی در پروژه
همراه با آموزش مدلسازی در اکسل (Excel)

بخش دوازدهم:

تحلیل حساسیت، سر به سر، عدم قطعیت و ریسک: تصمیم گیری در شرایط عدم قطعیت

ارائه دهندگان:

سید محمدرضا علوی‌پور

(PhD, PMP, CMIT)

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(M.Sc., PMP)

What we will learn?

- Interpretation of certainty, risk, and uncertainty
- Types of circumstances for decision-making
  - Decision making under certainty
  - Decision making under risk
  - Decision making under uncertainty
    - ✓ The Laplace principle
    - ✓ The Maximin rule for profit (Example 1)
    - ✓ The Maximax rule for profit (Example 2)
    - ✓ The Hurwicz rule (Example 3)
    - ✓ The Minimax regret rule (Example 4)
    - ✓ Example 5

What we will learn?

- Types of circumstances for decision-making
  - Decision making under uncertainty
    - ✓ Do you think we should always follow the rules?
      - Example 6
      - Example 7
      - Example 8
    - ✓ Do these rules have problem?
      - Example 9
      - Example 10
      - Example 11
    - ✓ Conclusion

Interpretation of certainty, risk, and uncertainty

- We are **guaranteed** that variation will **occur** in **engineering economy** due to its emphasis on **decision making** for the **future**.

- **Except** for the use of **breakeven analysis**, **sensitivity analysis**, and **expected values**, virtually **all our estimates** have been **certain; that is, no variation** in the amount has entered into the computations of PW, AW, ROR, or any relations used.

- To **allow a parameter** of an **engineering economy** study to **vary** implies that ***risk***, and possibly ***uncertainty***, is introduced.

Interpretation of certainty, risk, and uncertainty

❑ Risk

When there may be two or more observable values for a parameter *and* it is possible to estimate the chance that each value may occur, **risk** is present. Virtually all decision making is performed *under risk.*

❖ Decision making under risk when an **annual cash flow** estimate has a **50-50 chance** of being **either -$1,000 or +$500**.

❑ Uncertainty

Decision making under **uncertainty** means there are two or more values observable, but the chances of their occurring cannot be estimated or no one is willing to assign the chances. The observable values in uncertainty analysis are often referred to as *states of nature.*

❖ **National inflation** in a particular country during the **next 2 to 4 years**: remain low, **increase 2% to 6$% annually**, or **increase 6% to 8% annually**. If there is **no indication** that which of **these three values are likely to happen**, this is a statement that **indicates decision making under uncertainty**.

Types of circumstances for decision-making

- So, decisions can be made under **three circumstances**:

1. **Decision-making under certainty**
   - ✓ Has been taught in all previous sessions. All sessions assumed that the parameters were deterministic.
2. **Decision-making under risk**
   - ✓ Will be taught in next section.
3. **Decision-making under uncertainty**
   - ✓ Will be taught in this section.

Decision making under certainty

- This is what **we have done in most analyses thus far**.
- **Deterministic estimates** are made and **entered into measure of worth relations**—PW, AW, FW, ROR—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**.
  - A **typical example** is an asset's **first cost estimate** made with **certainty**, say, *P* = $50,000.
- The term ***deterministic,*** in lieu of ***certainty***, is often used when **single-value** or **single point estimates** are used exclusively.

Decision making under certainty

Sensitivity analysis performed under certainty or uncertainty?

In fact, ***sensitivity analysis*** *using different values of an estimate is* ***simply another form of analysis with certainty****,* ***except that*** *the analysis is* ***repeated with different values****,* ***each estimated with certainty****.*

Decision making under risk

- Now the **element of chance** is formally **taken into account**.

- In an engineering economy study, **observed parameter values** will **vary** from the **value estimated** at the time of the study.

  However, **when performing the risk analysis**, **not all parameters** should be considered as **probabilistic (or at risk).**

  Those that are **estimable with a relatively high degree of certainty** should be **fixed for the study**.

Decision making under risk

- **Fundamentally**, there are **two ways** to consider **risk in an analysis**:

1. **Expected value analysis**
2. **Simulation analysis** **(Risk Management Course)**

Decision making under risk – Expected value analysis

- Use the **chance** and **parameter** **estimates** to calculate **expected values *E* (parameter)** via formulas.
- Analysis results in ***E* (cash flow)**, ***E* (AOC)**; and the final result is the expected value for a measure of worth, such as ***E* (PW)**, ***E* (AW)**, ***E* (ROR)**, ***E* (BC)**. To select the alternative, **choose the most favorable expected value** of the measure of worth.

The **expected value** can be interpreted as a long-run average observable if the project is repeated many times. Since a particular alternative is evaluated or implemented only once, the expected value results in a **point estimate.** However, even for a single occurrence, the expected value is a meaningful number.

The expected value $E(X)$ is computed using the relation

$$E(X) = \sum_{i=1}^{i=m} X_i P(X_i)$$

where X_i = value of the variable X for i from 1 to m different values
$P(X_i)$ = probability that a specific value of X will occur

Decision making under risk – Simulation analysis

- Use the **chance** and **parameter** estimates to **generate repeated computations** of the **measure of worth** relation **by randomly sampling** from a **plot for each varying parameter**.

- When a **representative** and **random sample** is complete, **an alternative** is selected **utilizing a table** or **plot of the results**.

- Usually, **graphics** are an **important part** of decision making via **simulation analysis**.

Decision making under uncertainty

- When **chances** are **not known** for the identified states of nature (or values) of the uncertain parameters,

  use of expected value–based decision making under risk is ***not an option*** and

  decision making under uncertainty should be adopted.

Decision making under uncertainty – Types of methods

- These are common methods that can be used for decision-making under uncertainty:

1. **The Laplace principle**
2. **The Maximin rule for profit**
3. **The Maximax rule for profit**
4. **The Hurwicz rule**
5. **The Minimax regret rule**

The Laplace principle

- **Laplace criterion** is based on the **principle** of **insufficient reason**.
- The **equally likely decision criterion** finds that alternative with the **highest average outcome**.

- **How to do that?**

1. The decision maker first calculates the average outcome for every alternative.
2. Then select the maximum average outcome.

- When to choose this principle?

When all alternatives occur equally for each alternative!

The Maximin rule for profit

- The **Maximin decision rule** is used by a **pessimistic decision maker** who wants to make a **conservative decision**.
- Basically, the **decision rule** is to consider the **worst consequence** of **each possible course of action** and chooses the one that has the **least worst consequence**.

- **How to do that? Select the best of worst option.**

1. Choose the worst option in each alternative.
2. Choose the alternative with the best result.

- **When to choose this principle?**

When you want to make a conservative decision!

The Maximin rule for profit – Example 1

Choices	Profit		
	Strong market	Fair market	Poor market
Invest $8000	$800	$200	-$400
Invest $4000	$400	$100	-$200
Invest $2000	$200	$50	-$100
Invest $1000	$100	$25	-$50

The Maximax rule for profit

- **Whereas Minimax** is the rule for the **pessimist**, **Maximax** is the rule for the **optimist**.
- A **slogan** for Maximax might be **"best of the best"** - a **decision maker** considers the **best possible outcome** for each course of action, and **chooses the course of action** that corresponds to the **best of the best possible outcomes**.

- **How to do that? Select the best of best option.**

1. Choose the best option in each alternative.
2. Choose the alternative with the best result.

- **When to choose this principle?**

When you want to make an optimistic decision!

The Maximax rule for profit – Example 2

Choices	Profit		
	Strong market	Fair market	Poor market
Invest $8000	$800	$200	-$400
Invest $4000	$400	$100	-$200
Invest $2000	$200	$50	-$100
Invest $1000	$100	$25	-$50

The Hurwicz rule

- The Criterion of **Realism decision rule** is an attempt to make a **tradeoff between complete risk indifference**, and **total risk aversion**.
- With this procedure, the **decision maker** will decide **how much emphasis** to put **on each extreme.**

How to do that?

1. One must choose a Coefficient of Realism, called alpha (**α**), which is a decimal number between 0 and 1. This number provides the emphasis on the **optimistic view**.
2. The number (1-**α**), then, is the amount of emphasis that is placed on the most **pessimistic outcome**.

$$(best-possible-outcome)\times\alpha+(worst-possible-outcome)\times(1-\alpha)$$

3. Choose the **maximum** between alternatives

When to choose this principle?

When you have clue about optimistic and pessimistic coefficients!

The Hurwicz rule – Example 3

Alternative	State of Nature		Criterion of Realism or Weighted Average (α = 0.8) ($)
	Favorable Market ($)	Unfavorable Market ($)	
Construct a large plant	200,000	-180,000	124,000
Construct a small plant	100,000	-20,000	76,000
Do nothing	0	0	0

The Minimax regret rule

- This rule is for **minimizing regrets**.
- Regret here is understood as **proportional** to the **difference** between **what we actually get**, and the **better position that we could have achieved if** a different course of action **had been chosen**.
- **Regret** is sometimes also called **"opportunity loss"**.

- **How to do that? Worst of the best**

1. Select the best alternative for each scenario (e.g., the best alternative for strong market and best alternative for fair market).
2. Subtract each scenario in each alternative from the best alternative for that scenario.
3. Use Minmax to select the final result

- **When to choose this principle?**

When you want to minimize your opportunity loss!

The Minimax regret rule – Example 4

Choices	Profit		
	Strong market	**Fair market**	**Poor market**
Invest $8000	$800	$200	-$400
Invest $4000	$400	$100	-$200
Invest $2000	$200	$50	-$100
Invest $1000	$100	$25	-$50

Choices	Regret		
	Strong market	**Fair market**	**Poor market**
Invest $8000	0	0	350
Invest $4000	400	100	150
Invest $2000	600	150	50
Invest $1000	700	175	0

Example 5

Example 5: The following payoff matrix is given. First check for dominance. Which alternative is most desirable? Use the following principles **(this problem is for profit)**:

a) The Laplace principle

b) The maximin rule

c) The maximax rule

d) The Hurwicz rule

e) The minimax-regret rule

	STATES OF NATURE		
ALTERNATIVES	**S1**	**S2**	**S3**
A1	$ 8,000	$7,000	$4,000
A2	$10,000	$ 0	$4,000
A3	$ 1,000	$9,000	$5,000
A4	$ 5,000	$6,000	$7,000
A5	$ 4,000	$6,000	$5,000

Example 5

چون تمامی حالت های A_5 از A_4 کمتر یا مساوی هستند حذف می شود اما مابقی گزینه ها باید بررسی گردد.

	S1	S2	S2
A1	8000	7000	4000
A2	10000	0	4000
A3	1000	9000	5000
A4	5000	6000	7000

زمانی از لاپلاس استفاده می شود که همه شرایط از لحاظ ما یکسان باشند.

a) Laplace

$$A_1 \rightarrow \frac{(8000 + 7000 + 4000)}{3} = 6333$$

$$A_2 \rightarrow \frac{(10000 + 0 + 4000)}{3} = 4667$$

$$A_3 \rightarrow \frac{(1000 + 9000 + 5000)}{3} = 5000$$

$$A_4 \rightarrow \frac{(5000 + 6000 + 7000)}{3} = 6000$$

Example 5

b) Maximin

	S1	S2	S2
A1	8000	7000	4000
A2	10000	0	4000
A3	1000	9000	5000
A4	5000	6000	7000

$\Longrightarrow A_4$

c) *Maximax*

	S1	S2	S2
A1	8000	7000	4000
A2	10000	0	4000
A3	1000	9000	5000
A4	5000	6000	7000

$\Longrightarrow A_2$

Example 5

d) *Huwice rule*

$\alpha = \%15 \Rightarrow index\ of\ optimism$

$For\ profit = (best\ possible\ outcome) * \alpha + (worst) * (1 - \alpha)$

$A_1 \longrightarrow (8000 * 0.15) + (4000 * 0.85) = 4600$

$A_2 \longrightarrow (1000 * 0.15) + (0 * 0.85) = 1500$

$A_3 \longrightarrow (9000 * 0.15) + (1000 * 0.85) = 2200$

$A_4 \longrightarrow (7000 * 0.15) + (5000 * 0.85) = 5400$

Example 5

e) *Minimax regret rule*

	S1	S2	S2
A1	8000	7000	4000
A2	10000	0	4000
A3	1000	9000	5000
A4	5000	6000	7000
Max	10000	9000	7000

	S1	S2	S2	Max
A1	2000	2000	3000	3000
A2	0	9000	3000	9000
A3	9000	0	2000	9000
A4	5000	3000	0	5000
Max	10000	9000	7000	

Example 5

Laplace = A1

Maximin = A4

Maximax = A2

Hurwicz = A4

Minimax = A1

Which one is better? Let's see the problems with these methods first!

Do you think we should always follow the rules? – Example 6

Example 6: Use the maximin rule to decide which of the two alternatives given in the following payoff matrix is more desirable.

	STATES OF NATURE	
ALTERNATIVES	**N1**	**N2**
A	$0.01	$0.01
B	$ 0	$100

Do you think we should always follow the rules? – Example 6

If you choose A, you will achieve nothing. First you need to take a look at data.

	N1	N2	Min
A	0.01	0.01	0.01
B	0	100	0

قبل از انتخاب کورکورانه باید به ماتریس نگاه کنیم.

Do you think we should always follow the rules? – Example 7

Example 7: Use the maximax rule to decide which of the two alternatives given in the following payoff matrix is more desirable.

	STATES OF NATURE	
ALTERNATIVES	**N1**	**N2**
A	$99	$99
B	$ 0	$100

Do you think we should always follow the rules? – Example 7

Are you sure you want to select B? It does not make sense at all!

	N1	N2	Max
A	99	99	99
B	0	100	100

Do you think we should always follow the rules? – Example 8

Example 8: Use the Hurwicz rule with an index of optimism of α = 40% to decide which of the two alternatives given in the following payoff matrix is more desirable.

	STATES OF NATURE					
ALTERNATIVES	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**
A	$100	$100	$100	$100	$100	$ 0
B	$ 0	$ 0	$ 0	$ 0	$ 0	$100

Do you think we should always follow the rules? – Example 8

You should not look at alpha in this example!

	N1	N2	N3	N4	N5	
A	100	100	100	100	0	100*0.4+0*0.6=40
B	0	0	0	0	100	100*0.4+0*0.6=40

Do these rules have problem? – Example 9

Example 9: a) Use the maximin rule to decide which one of the two alternatives given in the following payoff matrix is more desirable:

STATES OF NATURE		
ALTERNATIVES	N1	N2
A	$ 0	$100
B	$ 50	$ 50

b) The analyst remembered that a bonus of $100 is available in state of nature N1. Revise the payoff matrix to reflect the additional bonus and use the maximin rule again to decide which one of the two alternatives is more desirable.

c) Use the maximax and the Hurwicz (α=40%) rules to do (a) and (b). Do you experience the same problem?

Do these rules have problem? – Example 9

B is selected!

a) *Maximin*

	N1	N2	Min
A	0	100	0
B	50	50	50

$$\Longrightarrow \boldsymbol{Max, B\ is\ selected}$$

Do these rules have problem? – Example 9

- ***We added the fix amount to A and B and the result changed, however it should not!***

b) *Maximin*

	N1	N2	Min
A	100	100	100
B	150	50	50

$\Longrightarrow \boldsymbol{Max, A\ is\ selected}$

- ***Maximin rule lacks column linearity!***
  - ***This is also true for Maximax and Hurwicz rules!***

Do these rules have problem? – Example 10

Example 10: a) Use the minimax regret rule to decide which one of the two alternatives given in the following payoff matrix is more desirable:

	STATES OF NATURE		
ALTERNATIVES	N1	N2	N2
A	$100	$125	$ 25
B	$ 25	$125	$ 75

Do these rules have problem? – Example 10

A is selected!

	N1	N2	N3
A	100	125	25
B	25	125	75
Max	100	125	75

			Max
0	0	50	50
75	0	0	75

$$\Rightarrow Min, A\ is\ selected$$

Do these rules have problem? – Example 10

Example 10: b) The analyst realized that a third alternative was overlooked. The new payoff matrix is now as follows. Use the minimax regret rule again to decide which one of the three alternatives is more desirable.

	STATES OF NATURE		
ALTERNATIVES	N1	N2	N2
A	$100	$125	$ 25
B	$ 25	$125	$ 75
C	$ 25	$ 25	$125

Do these rules have problem? – Example 10

This time B is selected! Weird right?

	N1	N2	N3
A	100	125	25
B	25	125	75
C	25	25	125
MAX	100	125	125

			Max
0	0	100	100
75	0	50	75
75	100	0	100

$$\Rightarrow Min, B\ is\ selected$$

Do these rules have problem? – Example 11

Example 11: a) A construction company is bidding a contract. They can manufacture special low-operating-cost equipment which will be ready if they get the contract; or they can purchase higher-operating-cost equipment after they know they have won the contract. The payoffs, in thousands of dollars are shown in the following matrix.

Use the Laplace principle to decide which of the two alternatives is more desirable.

STATES OF NATURE		
ALTERNATIVES	No Contract	Win Contract
Manufacture	- $ 50	$125
Purchase	$ 0	$100

Do these rules have problem? – Example 11

Purchase is selected and it makes sense, because it is true that we may achieve lower profit, but at least we are safe.

	No contract	Win	
A	-50	125	75/2=32.5
B	0	100	100/2=50

Do these rules have problem? – Example 11

Example 11: b) The construction company bids two additional contracts that may have the same payoffs of the first one if they win them. The new payoff matrix is given below. Use the Laplace principle again to decide which of the two alternatives is more desirable.

STATES OF NATURE				
ALTERNATIVES	No Contract	Win Contract 1	Win Contract 2	Win Contract 3
Manufacture	- $ 50	$125	$125	$125
Purchase	$ 0	$100	$100	$100

Do these rules have problem? – Example 11

This time manufacture is selected and it makes sense, because the possibility of the occurrence of No contract is less in this new example!

$$Man \rightarrow \frac{-50 + 3 * 125}{4} = 81.25$$

$$Pur \rightarrow \frac{0 + 3 * 100}{4} = 75$$

Conclusion

- **Maximin**, **Maximax**, and **Hurwicz** all have **lacks of column linearity**.
- **Minmax regret matrix** also has the problem when **new alternative is added**.
- **Laplace is very safe**, **no column linearity**! But it is **very sensitive** to the **numbers**.

Solution:

After you use the methods:

1. *You should always try to **make decision** **based on your thought**.*
2. ***Then**, **select a method** that works well **with your goal**.*
3. ***Finally**, check the **shortcomings** that **each method** may **encounter after the method is used**.*

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