

School of Civil and Environmental
Engineering

Engineering Economics (CEng 5211)

Chapter 3: Economic Evaluation

Contents

Economic Evaluation

- Present worth analysis
- Future worth analysis
- Payback period
- Internal rate of return

3.1 Present Worth Analysis

General

- ❑ The decision making process involves the identification of the **best alternative** from among different alternatives.
- ❑ There may initially be many alternatives, nevertheless **only a few will be feasible and actually evaluated**.
- ❑ Therefore, each alternative is a stand-alone option that involves description and best estimates of parameters such as first cost (purchase prices, development, installation), estimated annual incomes and expenses, salvage value, interest rate, etc.
- ❑ To select an alternative among different ones, the measure-of-worth values are compared. This is simply the result of engineering economy analysis.
- ❑ Making a choice on the **base of economic worth**.

3.1 Present Worth Analysis

General

- Three estimates are needed in performing an engineering economic analysis:
 - Planning horizon
 - Minimum attractive rate of return (MARR)
 - Cash flow

A. Planning Horizon (Study Period):

- defines the period of time over which the comparison of investment alternatives is to occur,
- It is the width of the window through which you look to assess the economic performance of the alternatives.
- We could have different cases:
 - Planning horizon=Useful life of alternative
 - $PH >$ one or more of the alternatives
 - $PH <$ longest lived alternative

- *Compare investment alternatives over a common period of time.*

3.1 Present Worth Analysis

General

B. MARR

- ❑ We have repeatedly emphasized that money has a time value. In our previous discussions, we have examined investment opportunities using an interest rate to compound (move forward in time) or discount (move backward in time) cash flows.
- ❑ Since any investment will consume some portion of an organization's scarce resource, it is important for the investment to **earn more than it costs** to obtain the investment capital (we call an organization's cost of obtaining capital "*cost of capital*").
- ❑ MARR is generally a policy emanating from the top-level management of an organization. The lowest return that the company would be willing to accept.
- ❑ It should at least be as large as the weighted average cost of capital:
 - with an allowance for risk: high expected risk → increase MARR
 - and consideration of opportunity cost: depends on the number of projects.

3.1 Present Worth Analysis

General

B. MARR

- Comparing WACC—RR: WACC should never be greater than Rate of return
- You should always get more from your investments than what you are paying to borrow the money.
- **ROR ≥ MARR > WACC**

$$\text{WACC} = \% \text{ Debt} * i + \% \text{ Equity} * r$$

Where:

i = Average interest rate for debt

r = Average return for stock (usually the inverse of the ratio of price to earnings)

- Example: $\text{WACC} = 50\%(0.8) + 50\% (0.14) = 0.11$
- If you decide to use present worth analysis to compare alternatives then you have indicated a preference for the use of a single sum of money at a time called “the present ” as the base for comparison : Chosen as criterion of the maximization of present worth.

3.1 Present Worth Analysis

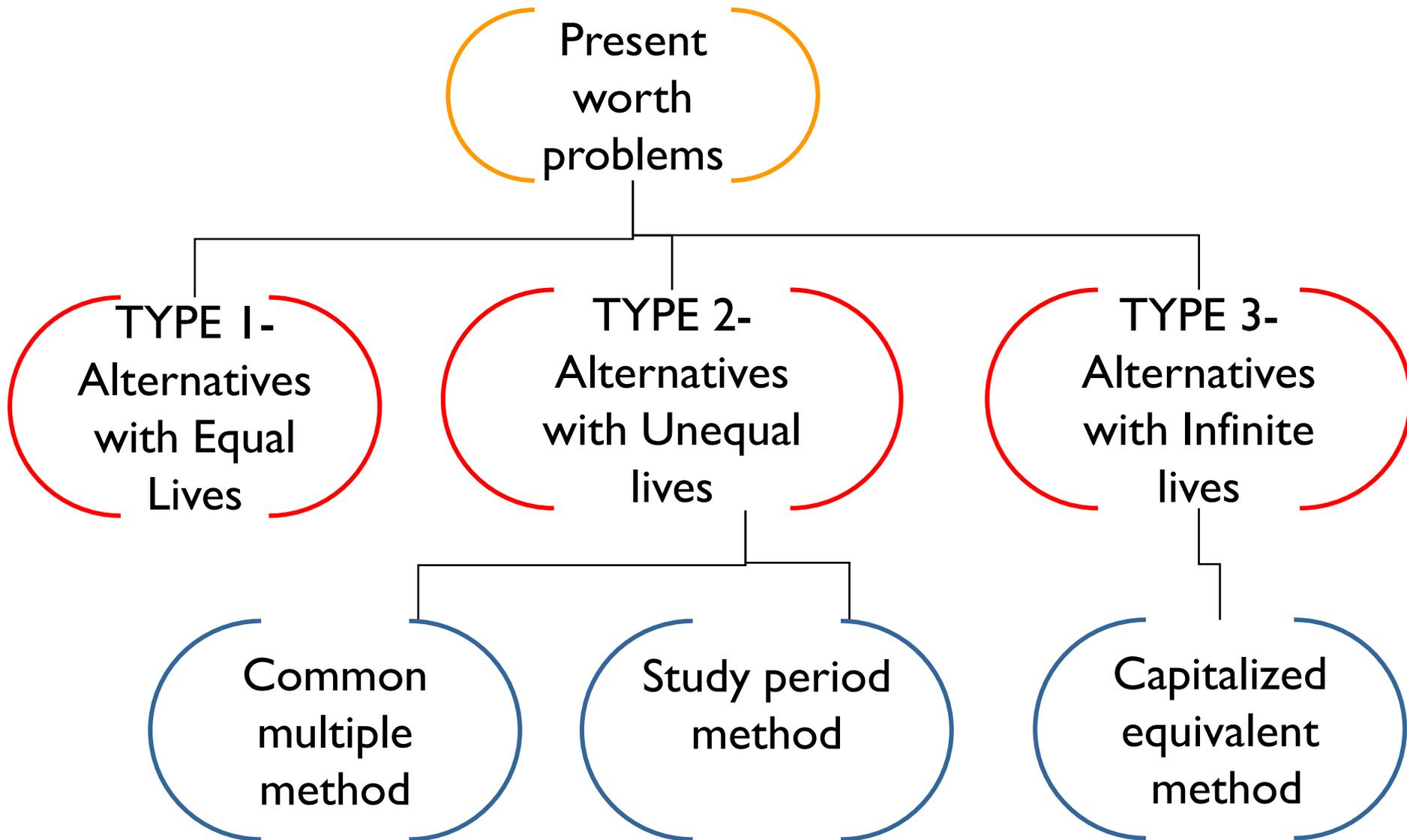
General

- ❑ Once the alternatives are evaluated and compared, the best alternative is selected and implemented. Keep in mind that the alternatives represent projects that are economically and technologically viable

Investment Alternatives

- ❑ There are two categories of investment alternatives while dealing with multiple alternatives.
- ❑ **Independent Investment:** This means that a decision on one investment does not affect the other.
- ❑ **Mutually Exclusive Investment:** In this case acceptance of one automatically eliminates the others.

3.1 Present Worth Analysis



3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

- Planning horizon duration (when alternatives have unequal lives)
 - Set PH equal to the **shortest life** among the alternatives
 - Set PH equal to the **longest life** among the alternatives
 - Set PH equal to the **least common multiple** of lives of various alternatives.
 - Use **standard length** horizon (Example: 10 yrs)
 - PH equal to the period of time that best fit the organization's need for the investment.
- Is also summarized into:
 - Study period
 - LCM

3.1 Present Worth Analysis

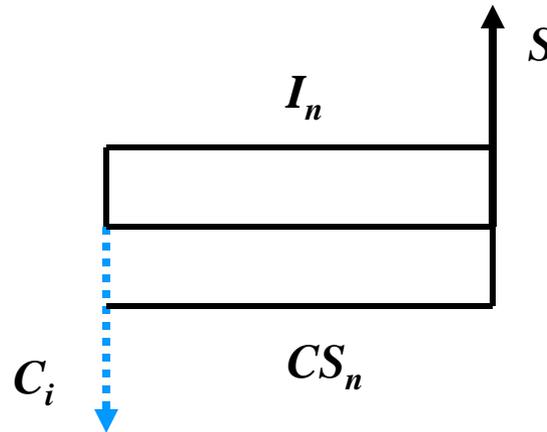
Present Worth (Net Present Value) Method

- ❑ In present worth method all **disbursements** and **receipts** are **brought to their net present worth** and the comparison of their present worth is made.
- ❑ In the present value method, the present time (time zero or start of year 1) **equivalent value** of all the **costs** and **benefits incurred during the life** of the **system** or the **project** is calculated using a specific interest rate.
- ❑ In this method all cash inflows and outflows of a given project (having a given project life) are brought to time 0. If the **difference** between the **inflows minus the outflows** is **positive** then the **project is acceptable**.
- ❑ If it is to **compare** among various **projects**, the one **having more positive value** is **economically the best alternative**.

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

- In order to evaluate projects one need to use **discounted cash flow techniques** (DCF). One of these is the method of **net present worth** (NPW) or **net present value** (NPV).



$$PW_{\text{costs}} = C_i + CS_n(P/A, i, n)$$

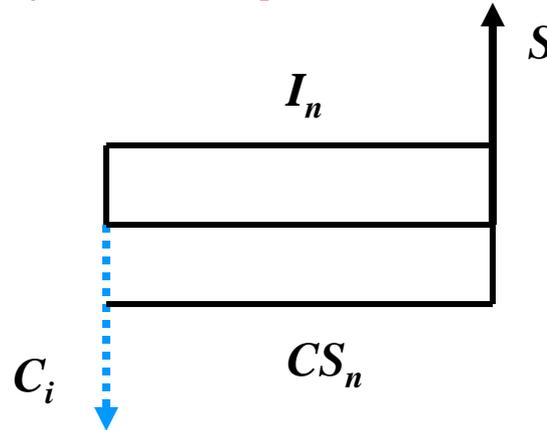
$$PW_{\text{incomes}} = I_n(P/A, i, n) + S(P/F, i, n)$$

$$NPW(NPV) = PW_{\text{incomes}} - PW_{\text{costs}}$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

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$$NPW(NPV) = PW_{\text{incomes}} - PW_{\text{costs}}$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Example

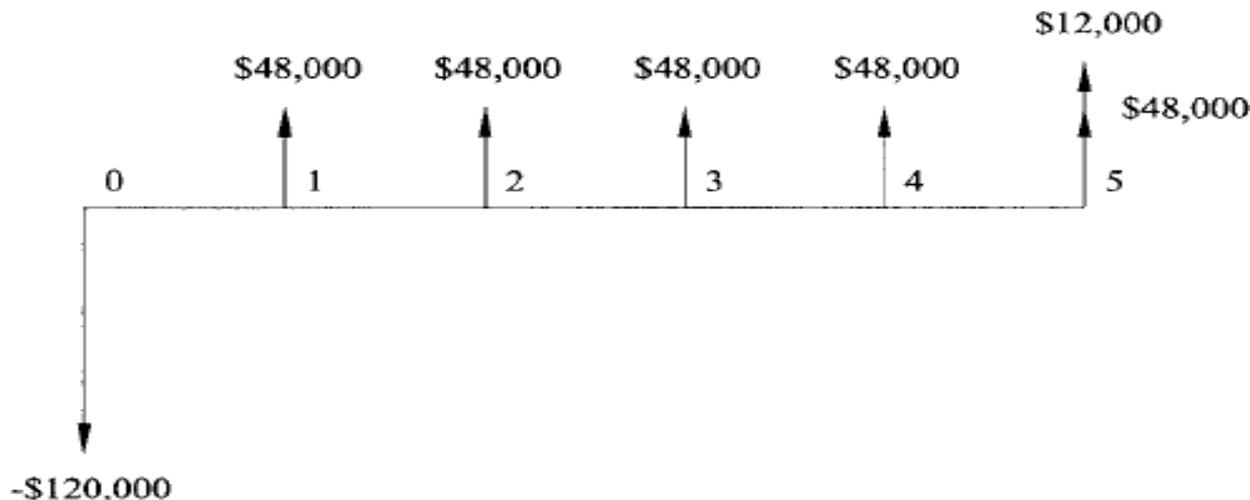
Your company is looking at purchasing a front-end loader at a cost of **\$120,000**. The loader would have a useful life of **five** years with a salvage value of **\$12,000** at the end of the **fifth** year. The loader can be billed out at **\$95.00** per hour. It costs **\$30.00** per hour to operate the front-end loader and **\$25.00** per hour for the operator. Using **1,200** billable hours per year determine the net present value for the purchase of the loader using a MARR of 20%. **Should your company purchase the loader?**

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:

- ❖ The **hourly profit [HP]** on the loader equals the billing rate less the operation cost and the cost of the operator.
- ❖ $HP = \$95.00 - [\$30.00 + \$25.00] = \40.00 per hr
- ❖ Annual Profit = $\$40.00/\text{hr} \times [1,200 \text{ hr/yr}] = \$48,000/\text{yr}$



**Cash Flow
Diagram**

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:

- ❖ The present value of the annual profits [P_{AP}] by using USPWF:
- ❖ $P_{AP} = \$48,000[(1+0.20)^5-1] / [0.20(1+0.20)^5] = \$143,549$
- ❖ The P_{AP} is positive because it is a cash receipt.
- ❖ The present value of the salvage value [P_{SV}] by using SPPWF
- ❖ $P_{SV} = \$12,000/(1+0.20)^5 = \$4,823$
- ❖ The P_{SV} is positive because it is a cash receipt.
- ❖ The present value purchase price [P_{PP}] of the loader = purchase price. Because the net present value is measured at the time of the initial investment.
- ❖ The P_{PP} is negative because it is a cash disbursement.

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:

- $NPV = P_{AP} + P_{SV} + P_{PP}$
- ❖ Because the NPV is **greater** than **zero**, the purchase of the front-end loader will produce a return greater than the MARR and your company should invest in the front-end loader.
- ❖ When comparing two alternatives with positive net present values, the alternative with the **largest net present value** produces the most profit in excess of the MARR.

3.1 Present Worth Analysis

Present Worth Analysis of Alternatives with Different-life Span

- ❑ When the present worth method is used to compare mutually exclusive alternatives that have different lives, then the PW of the alternatives must be compared **over the same number of years and end at the same time.**
- ❑ A fair comparison can be made only when the PW values represent costs (and receipts) associated with equal periods (if not shorter lived alternatives will be favored though they may not be economically favorable).
- ❑ The equal-period requirement can be satisfied by comparing the alternatives over a period of time equal to the least common multiple (LCM) of their lives.
- ❑ The **LCM** approach automatically makes the cash flows for all alternatives extend to the same time period.
- ❑ For example, alternatives with expected lives of **2** and **3** years are compared over a **6**-year time period. And alternatives with expected lives of **2, 4** and **5** years are compared over a **20**-year time period

3.1 Present Worth Analysis

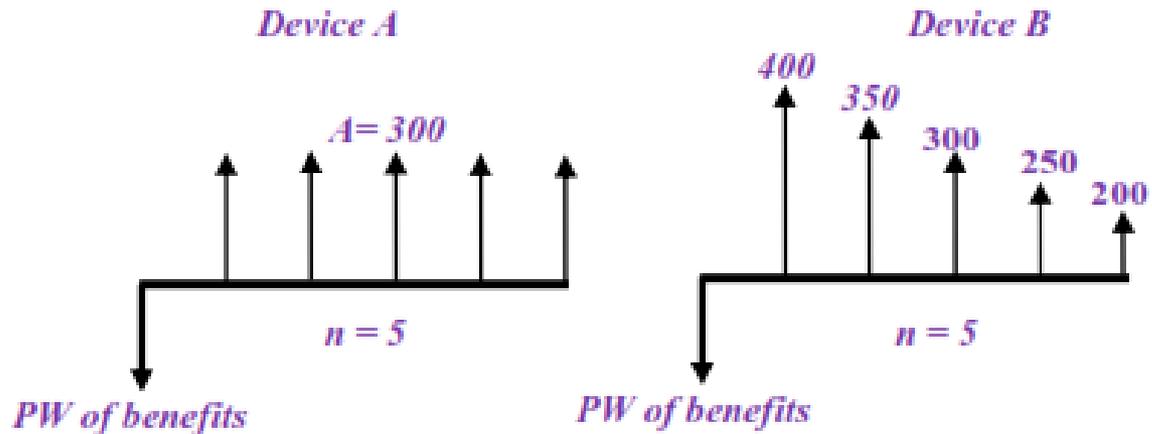
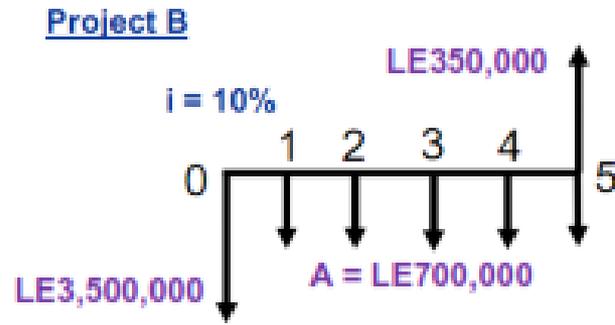
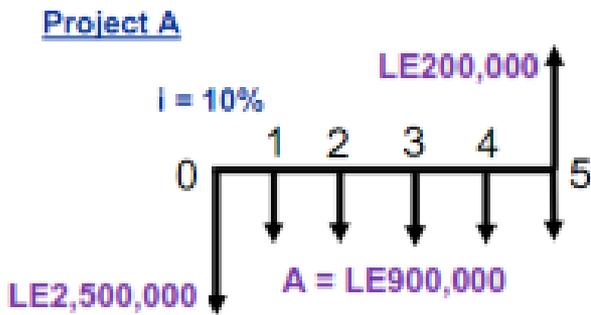
Present Worth Analysis of Alternatives with Different-life Span

- ❑ Such a procedure requires that some assumptions be made about subsequent life cycles of the alternatives
- ❑ The assumptions of a PW analysis of different-life alternatives for the LCM method are as follows:
 - ✓ The service provided by the alternatives will be needed for at least the LCM of years
 - ✓ The selected alternative will be repeated over each life cycle of the LCM in exactly the same manner
 - ✓ The cash flow estimates will be the same in every life cycle

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Example: Alternatives with Equal Lives



3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Example: I-Alternatives with Unequal Lives

Your company needs to purchase a dump truck and has narrowed the selection down to two alternatives. The first alternative is to purchase a new dump truck for **\$65,000**. At the end of the seventh year the salvage value of the new dump truck is estimated to be **\$15,000**. The second alternative is to purchase a used dump truck for **\$50,000**. At the end of the fourth year the salvage value of the used dump truck is estimated to be **\$5,000**. The annual profits, revenues less operation costs, are **\$17,000** per year for either truck. Using a MARR of **18%** calculate the net present value for each of the dump trucks. Which truck should your company purchase?

3.1 Present Worth Analysis

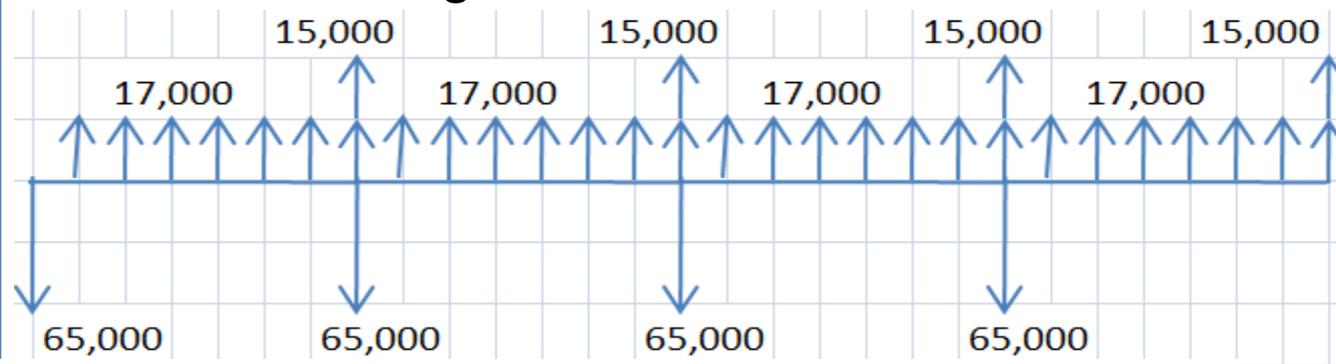
Present Worth (Net Present Value) Method

Solution:

- ❖ The present value of the annual profits for either truck is determined by using USPWF:

$$P_{AP} = \$17,000 [(1+0.18)^{28}-1]/0.18[1+0.18]^{28}] = 17,000*5.502$$
$$= \$93,527$$

Alternative I [New]: The PSV for the new dump truck is determined by summing the PSVs occurring in years 7, 14, 21, and 28. The present value for each salvage value is calculated using SPPWF as follows:



$$P_{SV7} = \$15,000/(1 + 0.18)^7 = \$4,709$$

$$P_{SV14} = \$15,000/(1 + 0.18)^{14} = \$1,478$$

$$P_{SV21} = \$15,000/(1 + 0.18)^{21} = \$464$$

$$P_{SV28} = \$15,000/(1 + 0.18)^{28} = \$146$$

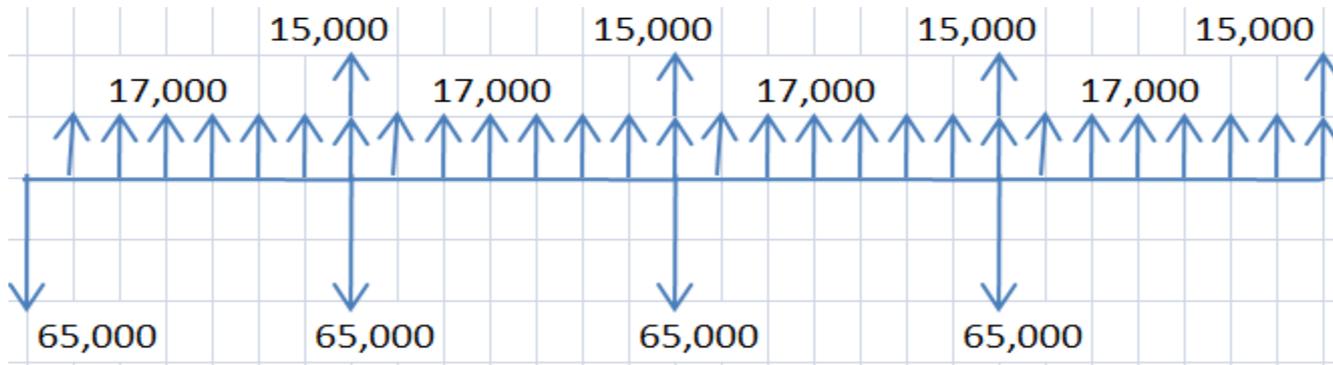
$$P_{SV} = \$4,709 + \$1,478 + \$464 + \$146 = \$6,797$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:

- ❖ The P_{PP} for the new dump truck is determined by summing the present value of purchase prices occurring in years 0, 7, 14, and 21. The present value for each purchase price is calculated using SPPWF as follows:



$$\begin{aligned}P_{PP0} &= -\$65,000/(1 + 0.18)^0 = -\$65,000 \\P_{PP7} &= -\$65,000/(1 + 0.18)^7 = -\$20,405 \\P_{PP14} &= -\$65,000/(1 + 0.18)^{14} = -\$6,406 \\P_{PP21} &= -\$65,000/(1 + 0.18)^{21} = -\$2,011 \\P_{PP} &= -\$65,000 + (-\$20,405) + (-\$6,406) + (-\$2,011) \\P_{PP} &= -\$93,822\end{aligned}$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:

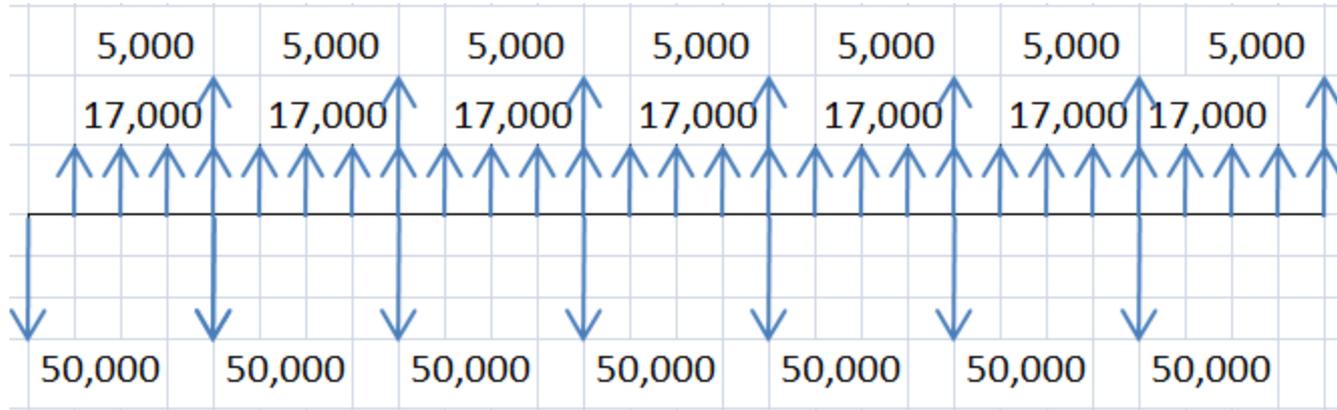
- ❖ The NPV for the purchase of the new dump truck is calculated as follows:
- ❖ $NPV [\text{New}] = \$93,527 + \$6,797 + [-\$93,822] = +\$6,502$

Alternative 2[Used]: The PSVs for the used dump truck is determined by summing the present value of salvage values occurring in years 4, 8, 12, 16, 20, 24, and 28. The present value for each salvage value is calculated using SPPWF as follows:

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:



$$P_{SV4} = \$5,000 / (1 + 0.18)^4 = \$2,579$$

$$P_{SV8} = \$5,000 / (1 + 0.18)^8 = \$1,330$$

$$P_{SV12} = \$5,000 / (1 + 0.18)^{12} = \$686$$

$$P_{SV16} = \$5,000 / (1 + 0.18)^{16} = \$354$$

$$P_{SV20} = \$5,000 / (1 + 0.18)^{20} = \$183$$

$$P_{SV24} = \$5,000 / (1 + 0.18)^{24} = \$94$$

$$P_{SV28} = \$5,000 / (1 + 0.18)^{28} = \$49$$

$$P_{SV} = \$2,579 + \$1,330 + \$686 + \$354 + \$183 + \$94 + \$49$$

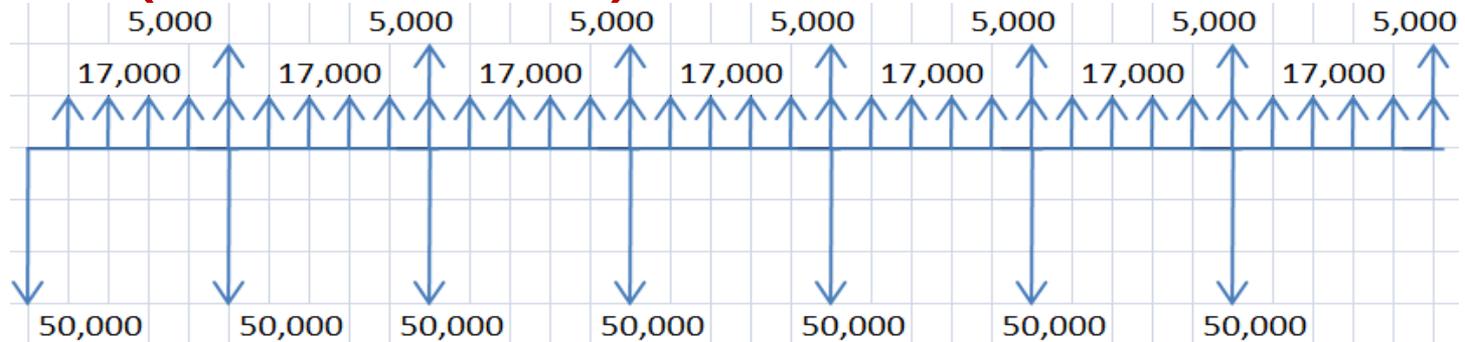
$$P_{SV} = \$5,275$$

- ❖ The PPPs for the used dump truck is determined by summing the present value of purchase prices occurring in years 0, 4, 8, 12, 16, 20, and 24. The present value for each purchase price is calculated using SPPWF as follows:

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution:



$$P_{PP0} = -\$50,000 / (1 + 0.18)^0 = -\$50,000$$

$$P_{PP4} = -\$50,000 / (1 + 0.18)^4 = -\$25,789$$

$$P_{PP8} = -\$50,000 / (1 + 0.18)^8 = -\$13,302$$

$$P_{PP12} = -\$50,000 / (1 + 0.18)^{12} = -\$6,861$$

$$P_{PP16} = -\$50,000 / (1 + 0.18)^{16} = -\$3,539$$

$$P_{PP20} = -\$50,000 / (1 + 0.18)^{20} = -\$1,825$$

$$P_{PP24} = -\$50,000 / (1 + 0.18)^{24} = -\$941$$

$$P_{PP} = -\$50,000 + (-\$25,789) + (-\$13,302) + (-\$6,861) \\ + (-\$3,539) + (-\$1,825) + (-\$941)$$

$$P_{PP} = -\$102,257$$

- ❖ The net present value [NPV] for the purchase of the used dump truck is calculated as follows:
 - $NPV = \$93,527 + \$5,275 + [-\$102,257] = -\$3,455$
- ❖ **The new truck has the highest NPV; therefore, your company should purchase the new truck.**

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Assignment 2

to be submitted Nov 7

1. A construction engineer has been asked to recommend an excavator for acquisition. Three alternatives have been identified, having the characteristics shown on table below. If MARR is 12% which alternative would you recommend?

Excavator alternative	Useful life (Years)	Initial investment (\$)	Annual operating cost (\$)	Salvage value
A	4	15,500	8,750	2,500
B	5	20,250	5,850	3,000
C	6	30,750	3,175	3,250

2. What is MARR, how it is determined, what is considered in trying to determine the MARR?

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Alternatives with Infinite lives: Capitalized equivalence method

- In the present worth analysis, sometimes an infinite analysis period ($n = \infty$) is encountered. Alternatives such as roads, dams, bridges or whatever is sometimes considered **permanent**. In these situations a PW analysis would have an **infinite analysis period**. This analysis is called *capitalized equivalence method*. A *capitalized cost* is the present sum of money that would need to be set aside now, at some interest rate, to yield the funds required to provide the service indefinitely.
- Capitalized equivalent (CE) is the present (at time zero) worth of cash inflows and outflows. CE analysis is very useful to compare long-term projects.
- In other words, CE is a **single amount determined at time zero**, which at a given rate of interest, will be equivalent to the net difference of receipts and disbursements if the given cash flow pattern is repeated in perpetuity (in perpetuity the period assumed is infinite).

$$\begin{aligned}\text{Mathematically, } \mathbf{CE} &= \mathbf{A \times (P/A, i, n=\infty)} \\ &= \mathbf{A \times [((1+i)^\infty - 1) / i(1+i)^\infty]} = \mathbf{A/i}\end{aligned}$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Alternatives with Infinite lives: Capitalized equivalence method

- **Example:**

1. A city plans a pipeline to transport water from a distant watershed area to the city. The pipeline will cost \$8 million and have an expected life of seventy years. The city anticipates it will need to keep the water line in service indefinitely. Compute the capitalized cost assuming 7% interest.

Solution:

- We have the capitalized cost equation $P = A/i$, which is simple to apply when there are end-of-period disbursements A . In this case, the \$8 million repeats every 70 years. We can find A first based on a present \$8 million disbursement.

$$A = P(A/P, i, n) = \$8,000,000(0.0706) = \$565,000$$

Now, the infinite series payment formula could be applied for $n = \infty$:

- Capitalized cost $P = A / i = 565,000 / 0.07 = \$8,071,000$

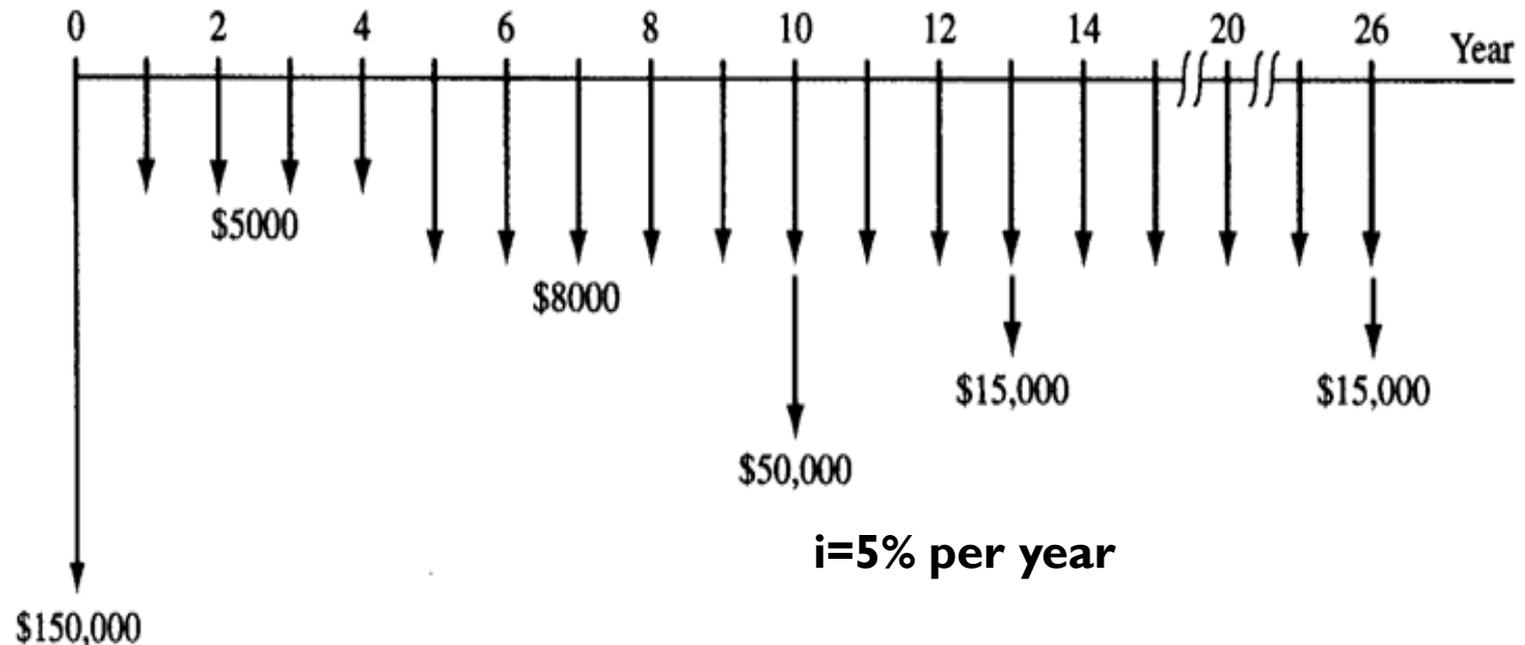
3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Example

2. A new computer system will be used for the indefinite future, find the equivalent value now if the system has an installed cost of \$150,000 and an additional cost of \$50,000 after 10 years. The annual maintenance cost is \$5,000 for the first 4 years and \$8,000 thereafter. In addition, it is expected to be a recurring major upgrade cost of \$15,000 every 13 years. Assume that $i = 5\%$ per year.

Solution:



3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Solution: Draw the cash flow diagram for two cycles.

$$\begin{aligned}\rightarrow CC_1 &= -150,000 - 50,000(P/F, 5\%, 10) - 5,000(P/A, 5\%, 4) - (8,000/0.15)(P/F, 5\%, 4) \\ &= -150,000 - 50,000(0.6139) - 5,000(3.5460) - 160,000(0.8227) = -330,057\end{aligned}$$

- Convert the recurring cost of 15,000 every 13 years into an annual worth A, for the first 13 years.

$$A_1 = -15,000(A/F, 5\%, 13) = -847$$

The same value, $A_1 = -847$, applies to all the other 13 years period as well.

$$\rightarrow CC_2 = \frac{A_1}{i} = \frac{847}{0.05} = -16,940$$

$$\rightarrow CC = (-330,057) + (-16,940) = -346,997$$

3.1 Present Worth Analysis

Present Worth (Net Present Value) Method

Comparing more than two alternatives using Incremental Net Present Value [INPV]

- ❖ **Step 1:** Order the alternatives by increasing initial capital investment.
- ❖ **Step 2:** Find a base alternative [current best alternative]: Cost alternatives: the first alternative in the ordered list [the one with the least capital investment].
- ❖ **Step 3:** Evaluate the difference between the next alternative and the current best alternative. If the incremental cash flow is positive, choose the next alternative as the current best alternative. Otherwise, keep the current best alternative [i.e. **negative**] and drop the next alternative from further consideration.
- ❖ **Step 4:** Repeat Step 3 until the last alternative is considered. Select the current best alternative as the preferred one.

Thank You