# Lesson 06

## New Toys

E213 – Engineering Cost Decisions

Interactive Seminar

SCHOOL OF
ENGINEERING

REPUBLIC POLYTECHNIC

# Module Coverage: Topic Tree

## E213 – Engineering Cost Decisions

- Cost Allocation and Estimation
  - Activity Based Costing method
  - Cost Estimation techniques
- Concept of Equivalence
  - Single payment
  - Uniform series and uniform gradient
- Project Evaluation
  - Single Project Evaluation
    - MARR & EW Method
    - IRR& ERR
  - Multiple Projects Comparison
    - Project life = study period
      - Payback method
    - Project life ! = study period
      - Repeatability/Co-terminated Assumption
    - Public Project Evaluation
      - B/C Ratio Approach
- Depreciation and Tax
  - depreciation
  - Tax
- Replacement Analysis
- Sensitivity Analysis

# Scenario

In last week's problem, UShoot, a leading toy manufacturer in USA producing toy guns for children and adults had set up its new factory in China after it concluded its feasibility study. The new factory is doing well and would like to expand its operations by setting up a new manufacturing line to produce a new range of toy guns to meet the growing market needs.


Daniel, a cost analyst of UShoot, has been tasked by management to find out whether this new product development project is economically feasible. He estimated that an initial investment of $620,000 is needed for the product design and setup of a new manufacturing line. He has also estimated the annual revenue and cost that will be incurred to the project over the next 7 years.

Based on market projections, at the end of year 7, the company needs to decommission the manufacturing line and equipment at a cost of $60,000 to make way for other business needs.

In UShoot, the management adopts a MARR of 18% per year for evaluation of new product development projects. Meanwhile, the management also stipulates a reinvestment rate of 16% per year for project evaluations as the rate could be sustainable over a long term.

Daniel understands that he needs to use internal rate of return and external rate of return methods to evaluate the economic feasibility of a project. However, he is not sure which method is more appropriate for this new product development project. Help Daniel on the analysis and decision making. Justify your recommendation.

# Recall: Rate of Return (ROR)

*"Rate of return (ROR) is the rate paid on the unpaid balance of borrowed money, or the rate earned on the unrecovered balance of an investment so that the final payment or receipt brings the balance to exactly zero with interest considered." – Engineering Economy, Leland Blank, Anthony Tarquin, McGraw-Hill*

***Note:***

- ***Pay attention to "balance to ZERO" & "interest considered"***
- ***Recall what you learned before, already have a clue to solve such type of problems?***

# ROR Methods

- Higher ROR indicates higher return

- Two methods are used to determine the rate of return:
  - **Internal Rate of Return (IRR)**
  - **External Rate of Return (ERR)**

# Internal Rate of Return (IRR)

- IRR is the interest rate that equates the equivalent worth of an alternative's cash inflows (receipts or savings) to the equivalent worth of cash outflows (expenditures)
- $PW_{\text{cash inflows}} = PW_{\text{cash outflows}}$
- Mathematically, IRR is the value of i'% at which:

$$\sum_{k=0}^{N} R_k \, (P/F, i'\%, k) = \sum_{k=0}^{N} E_k \, (P/F, i'\%, k)$$

Where $R_k$ = Net revenue or saving for the $k^{th}$ year

$E_k$ = Net expenditure, including any investment cost, for the $k^{th}$ year

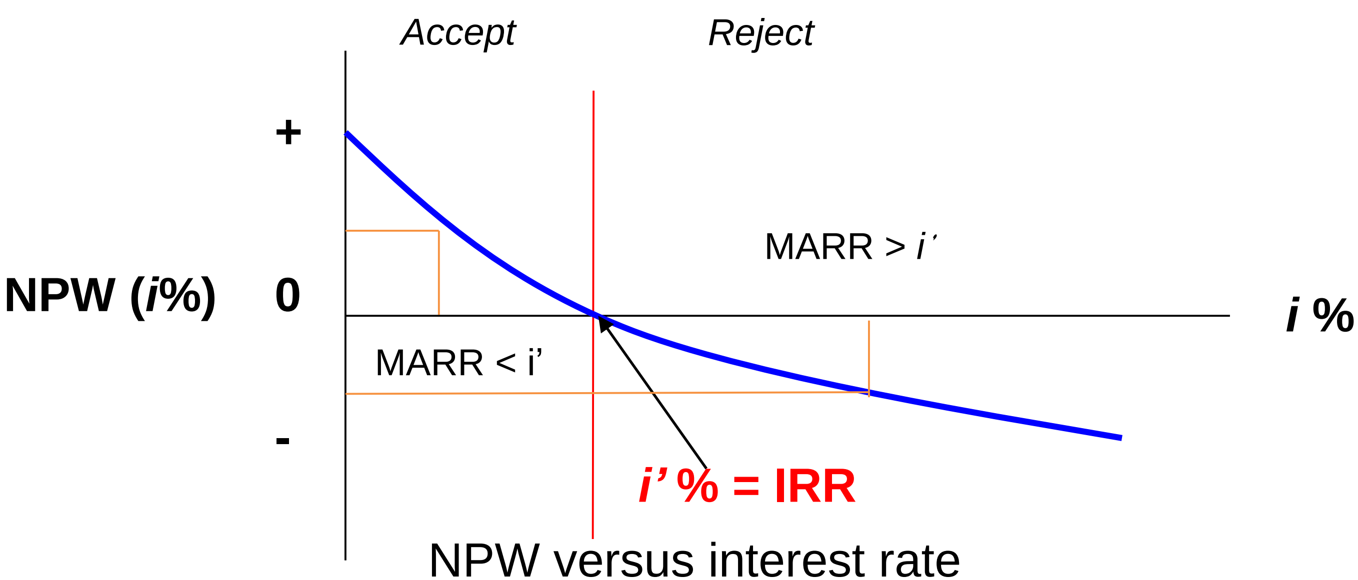
N = Project life

# IRR

**Net Present Worth (NPW(i'%)) = PW(i'%)cash inflows - PW(i'%)cash outflows**

**To compute IRR for an alternative, set *NPW = 0***

$$NPW = \sum_{k=0}^{N} R_k\,(P/F, i'\%, k) - \sum_{k=0}^{N} E_k\,(P/F, i'\%, k) = 0$$




NPW versus interest rate

**IRR = *i'*%**

**If *i´* > MARR, the alternative is acceptable**

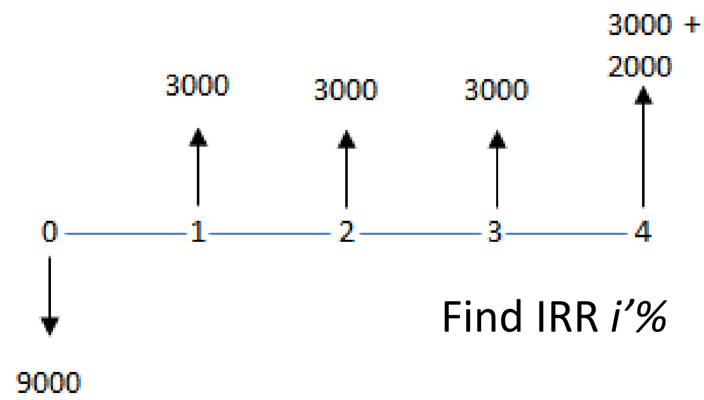
**If *i´* = MARR, Indifference towards the alternative**

**If *i´*< MARR, the alternative is not acceptable**

# IRR - Linear Interpolation

MARR = 15%

| | Cash Flows (\$) |
|---|---|
| Investment Cost | 9,000 |
| Expected Life | 4 Years |
| Salvage Value | 2000 |
| Annual Receipts | 8000 |
| Annual Expenses | 5000 |




Find IRR *i'%*

NPW(*i'%*) = -9,000 + 3000 (P/A, *i'%*, 4) + 2000 (P/F, *i'%*, 4)

***By Excel:***

NPW(18%) = -9,000 + 3000 (P/A, *18%*, 4) + 2000 (P/F, *18%*, 4) = 101.76

IRR between 18% and 19%

NPW(19%) = -9,000 + 3000 (P/A, *19%*, 4) + 2000 (P/F, *19%*, 4) = -86.91

| | A | B |
|---|---|---|
| 1 | **Year** | **Cash Flow** |
| 2 | **0** | **-9000** |
| 3 | **1** | **3000** |
| 4 | **2** | **3000** |
| 5 | **3** | **3000** |
| 6 | **4** | **5000** |
| 7 | **IRR** | **18.54%** |

fx =IRR(B2:B6)

# IRR – Linear Interpolation cont'

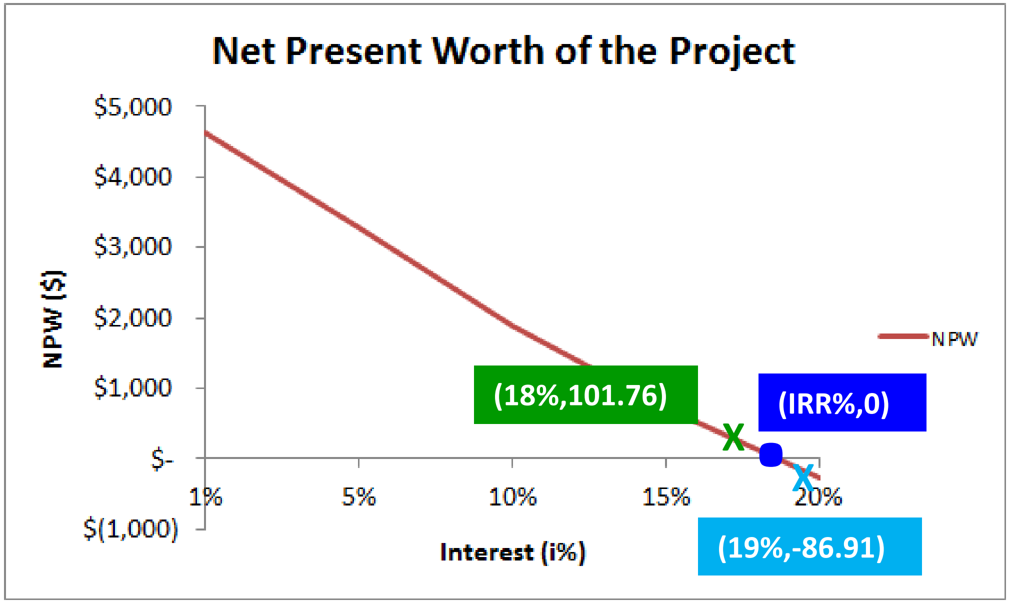
NPW(18%) = 101.76
NPW(19%) = -86.91

Gradient: $\frac{Y_1 - Y_2}{X_1 - X_2} = \frac{Y_2 - Y_3}{X_2 - X_3}$

$$\frac{0 - 101.76}{IRR\% - 18\%} = \frac{101.76 - (-86.91)}{18\% - 19\%}$$

$$\frac{(-1\%)(-101.76)}{188.67} = IRR\% - 18\%$$

$$IRR\% = 18\% + 0.54\%$$
$$IRR\% = \mathbf{18.54\%}$$




| i% | NPW |
|---|---|
| 1% | $ 4,627.86 |
| 5% | $ 3,283.26 |
| 10% | $ 1,875.62 |
| 15% | 708.44 |
| 20% | (269.29) |

***By Linear Interpolation:***

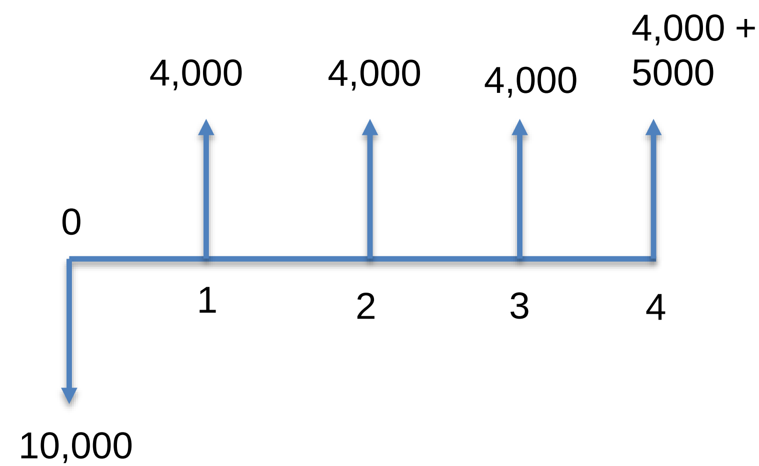
| *i* | *NPW* |
|---|---|
| *18%* | *101.76* |
| *IRR(i'%)* | *0* |
| *19%* | *-86.91* |

**Invest in this project since IRR of 18.54% > MARR of 15%**

# Test Yourself !

Given the below information. What is the IRR and is the project economically feasible? MARR = 20%

| | Cash Flows ($) |
|---|---|
| Investment cost | 10,000 |
| Expected life | **4** years |
| Salvage value | 5000 |
| Annual receipts | 6000 |
| Annual expenses | 2000 |




NPW(*i'%*) = -10,000 + 4000 (P/A, *i'%*, 4) + 5000 (P/F, *i'%*, 4)

NPW(32%) = -10,000 + 4000 (P/A, 32%, 4) + 5000 (P/F, 32%, 4) = 29.60

NPW(33%) = -10,000 + 4000 (P/A, *33%*, 4) + 5000 (P/F, *33%*, 4) = -154.66

IRR between 32% and 33%

***By Excel:***

| | A | B |
|---|---|---|
| 1 | Year | Cash Flow |
| 2 | 0 | -10000 |
| 3 | 1 | 4000 |
| 4 | 2 | 4000 |
| 5 | 3 | 4000 |
| 6 | 4 | 9000 |
| 7 | IRR | 32.16% |

fx =IRR(B2:B6)

# IRR – Linear Interpolation cont’

NPW(32%) = 29.60

NPW(33%) = -154.66

***By Linear Interpolation:***

| *i* | *NPW* |
|---|---|
| *32%* | *29.60.76* |
| *IRR(i’%)* | *0* |
| *33%* | *-154.66* |

$$\frac{0 - 29.60}{IRR - 32\%} = \frac{29.60 - (-154.66)}{32\% - 33\%}$$

IRR = 32.16%

**Accept this project since IRR of 32.16% > MARR of 20%**

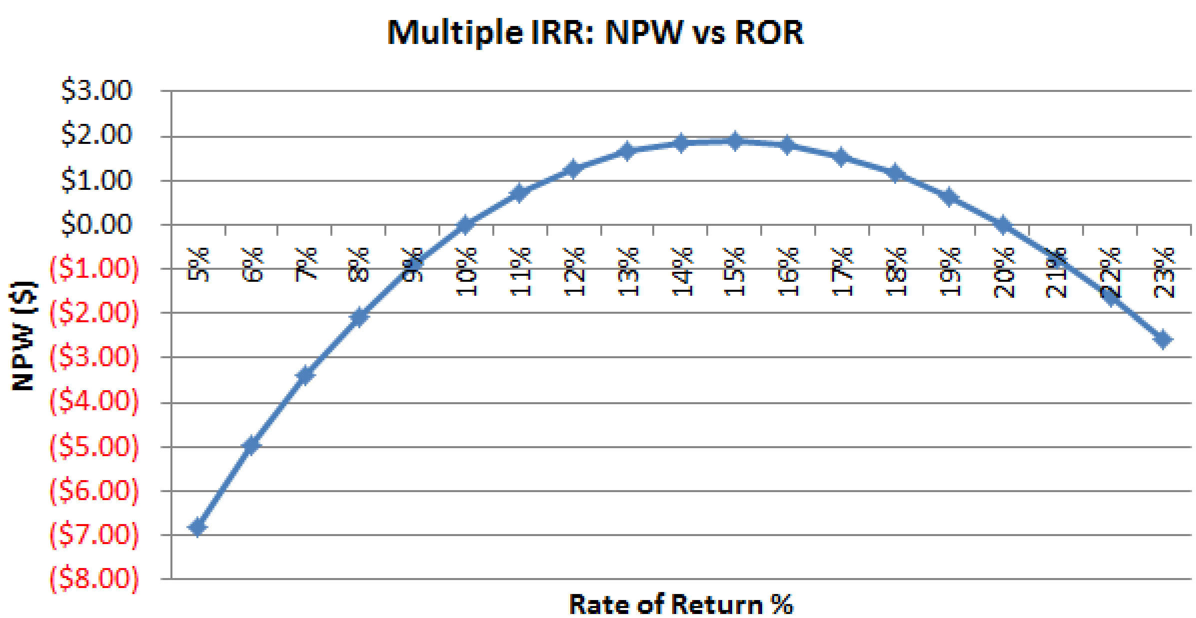
# Multiple IRR

- A possibility of multiple IRR when change of sign happens at net cash flow (-, + , -).

| Period (N) | Cash Flow |
|---|---|
| *0* | *-$1000* |
| *1* | *$2300* |
| *2* | *-$1320* |

IRR at 10% and 20% when PW = 0

| i % | NPW |
|---|---|
| 5% | ($6.80) |
| 6% | ($4.98) |
| 7% | ($3.41) |
| 8% | ($2.06) |
| 9% | ($0.93) |
| 10% | $0.00 |
| 11% | $0.73 |
| 12% | $1.28 |
| 13% | $1.64 |
| 14% | $1.85 |
| 15% | $1.89 |
| 16% | $1.78 |
| 17% | $1.53 |
| 18% | $1.15 |
| 19% | $0.64 |
| 20% | $0.00 |
| 21% | ($0.75) |
| 22% | ($1.61) |
| 23% | ($2.58) |




IRR may not be suitable to evaluate the project because there are more than one IRR.

# Limitations of IRR method

- Computing IRR is a tedious process (involves trial and error calculations in order that i'% converges or can be interpolated)

- Possibility of getting multiple IRR

- IRR assumes reinvestment at i'% rate. If i'% is substantially larger than MARR, it is an unrealistic assumption. Thus, an alternative way is to use the external rate of return (ERR) which can analyze the investment more realistically by fixing an external re-investment rate.

# External Rate of Return (ERR) Method

- **External Rate of Return (ERR) Method**
  - It takes into account the interest rate external to a project.
    - The net cash flows generated by the project over the project life are reinvested (or borrowed) at the external reinvestment rate (ε%)
    - IF this external reinvestment rate happens to equal the project's IRR, then the ERR method produces results identical to those of the IRR method
  - It is also known as the "modified internal rate of return (MIRR)" method

# General 3 Steps of calculating ERR

$$ERR \overset{?}{=} i'\%$$

Step 3


$$\sum_{k=0}^{N} R_k (F/P, \varepsilon\%, N-k)$$

Step 2

Step 1

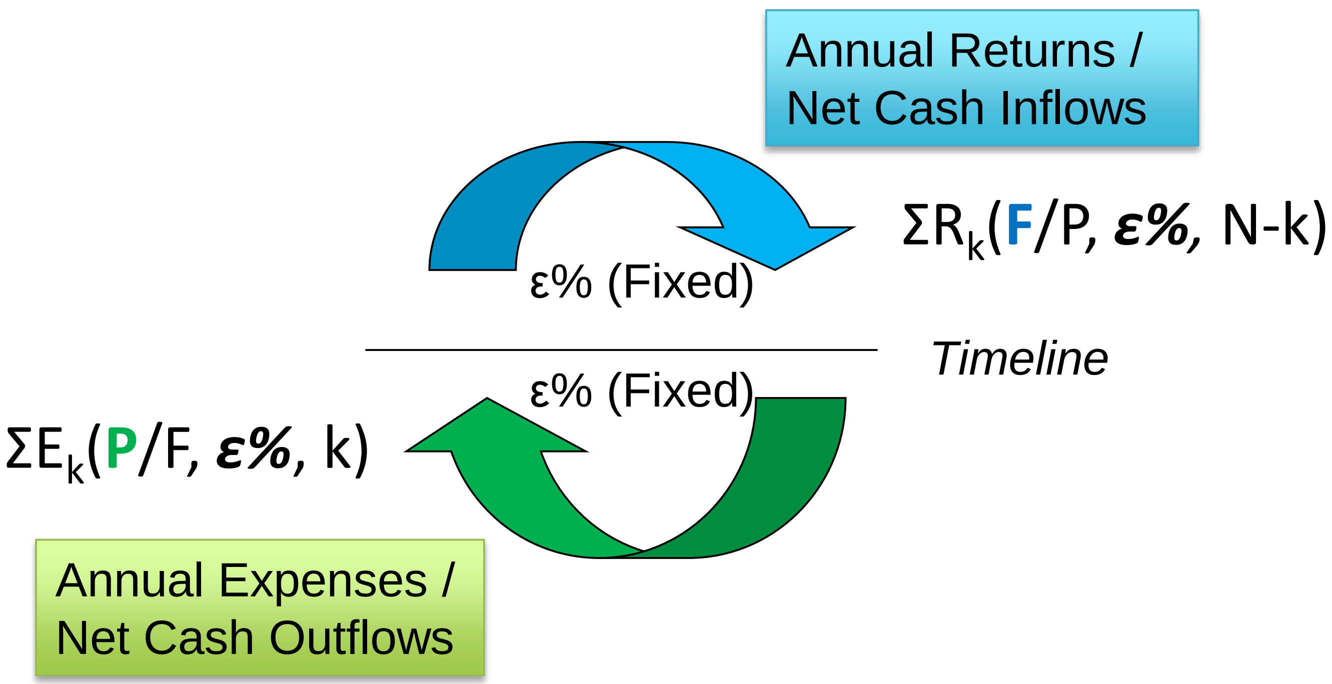
$$\sum_{k=0}^{N} E_k (P/F, \varepsilon\%, k)$$

1. All **Net** Cash Outflows are discounted to period 0 at ε% per compounding period;
2. All **Net** Cash Inflows are compounded to period N at ε% per compounding period;
3. External Rate of Return, ERR is the interest rate that establishes the equivalence of (1) & (2)

# External Rate of Return (ERR) Method

- Fix the re-investment rate at **$\varepsilon\%$**.
  - Re-investment rate is the interest rate external to a project at which funds recovered/generated from the project over its life can be reinvested.

- Find the equivalent present/future worth.



# External Rate of Return (ERR)

- Mathematically, ERR is the value of ***i' %*** at which:

$$\sum_{k=0}^{N} E_k (P/F, \varepsilon\%, k)(F/P, i'\%, N) = \sum_{k=0}^{N} R_k (F/P, \varepsilon\%, N-k)$$

where

$R_k$ = **Net Revenue** or net cash inflow in period k

$E_k$ = **Net Expenditure** or net cash outflow in period k

N = Project Life

ε% = Re-investment rate

- **Decision: A project is acceptable if *i'* % ≥MARR.**

# Why ERR method is preferred

- ✓ It can usually be solved for directly rather than by trial and error;
- ✓ It is not subject to the possibility of multiple rates of return.
- ✓ It takes into account company's re-investment rate, at ε%, which will be more realistic compared to some unusually high IRR calculated.

# External Rate of Return Example

**Question:** Determine the ERR of the engineering project where the reinvestment rate is 13% annually and the MARR is 15% per year. Is the project acceptable?

| Period (N) | Cash Flow |
|---|---|
| 0 | ($1,000) |
| 1 | $2,500 |
| 2 | ($1,320) |

$$\sum_{k=0}^{N} E_k(P/F, \varepsilon\%, k) = 1000+1320(P/F,13\%,2)$$
$$= 2033.75$$

$$\sum_{k=0}^{N} R_k(F/P, \varepsilon\%, N-k) = 2500(F/P,13\%,1)$$
$$= 2825$$

2033.75(F/P, *i'*%, 2) = 2825

2033.75 $(1+i')^2$ = 2825

*Therefore,* $i'$ = 0.1786

= 17.86%

**ERR = 17.86% > MARR (15%), It is economically feasible to invest**

# Test Yourself !

Determine the ERR of the engineering project where the reinvestment rate is 13% annually and the MARR is 15% per year. Is the project acceptable?

| Period (N) | Cash Flow |
|---|---|
| 0 | ($500) |
| 1 | $2,500 |
| 2 | ($2,000) |

$$\sum_{k=0}^{N} E_k(P/F, \varepsilon\%, k) = 500+2000(P/F,13\%,2) = 2066.2$$

$$\sum_{k=0}^{N} R_k(F/P, \varepsilon\%, N-k) = 2500(F/P,13\%,1) = 2825$$

2066.2(F/P, *i'%*, 2) = 2825

$2066.2(1+i')^2 = 2825$

*Therefore,* *i'* = 0.1693

= 16.93%

**ERR = 16.93% > MARR (15%), It is economically feasible to invest**

# Suggested Answer for Scenario

# Scenario

In last week's problem, UShoot, a leading toy manufacturer in USA producing toy guns for children and adults had set up its new factory in China after it concluded its feasibility study. The new factory is doing well and would like to expand its operations by setting up a new manufacturing line to produce a new range of toy guns to meet the growing market needs.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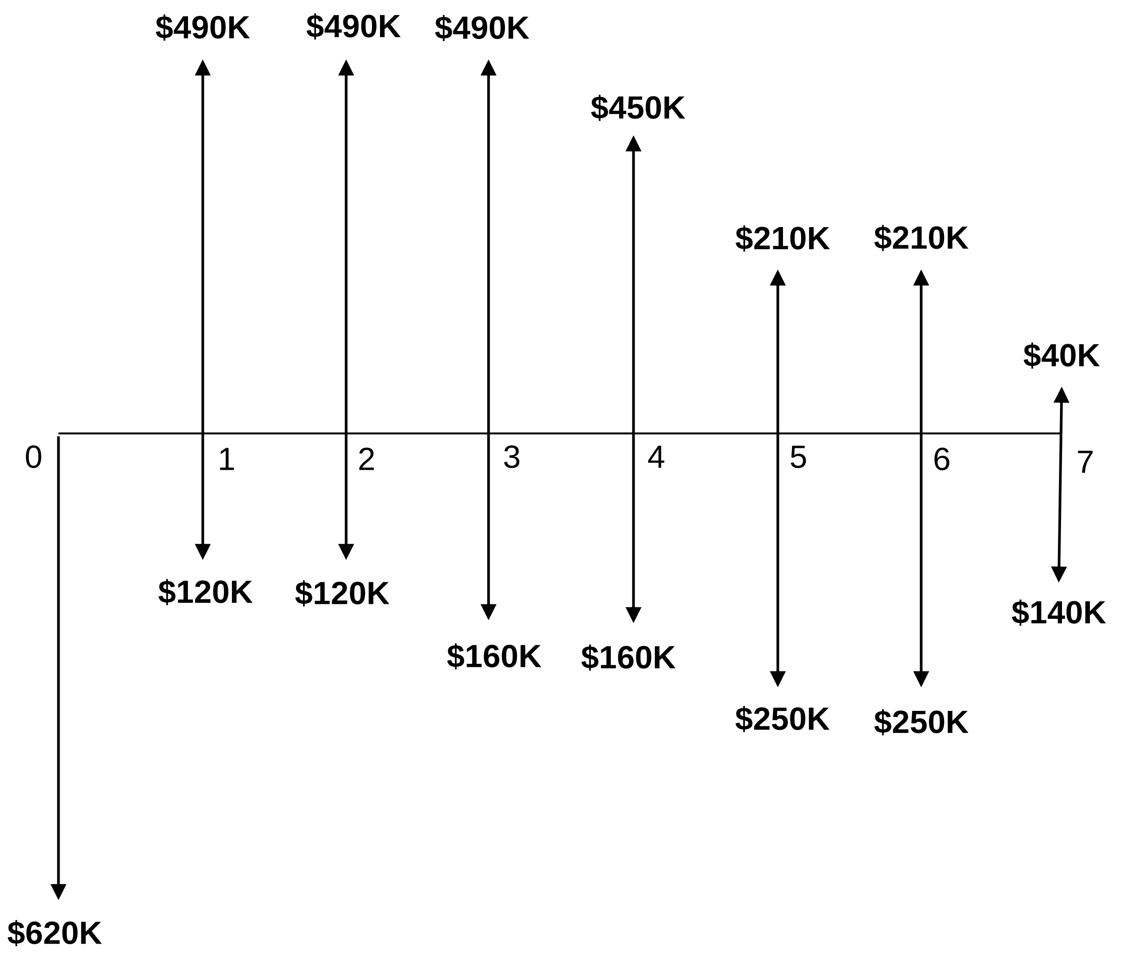
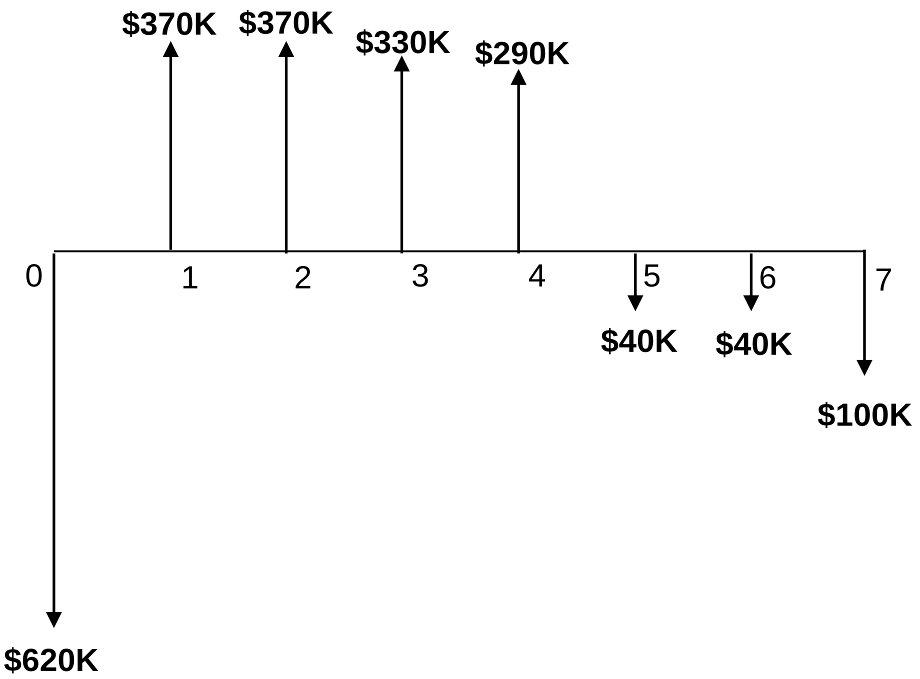
# Problem Statement: Cash Flow

## Cash Flow Diagram:



# Problem Statement: Cash Flow

## Net Cash Flow:




**Solution:**

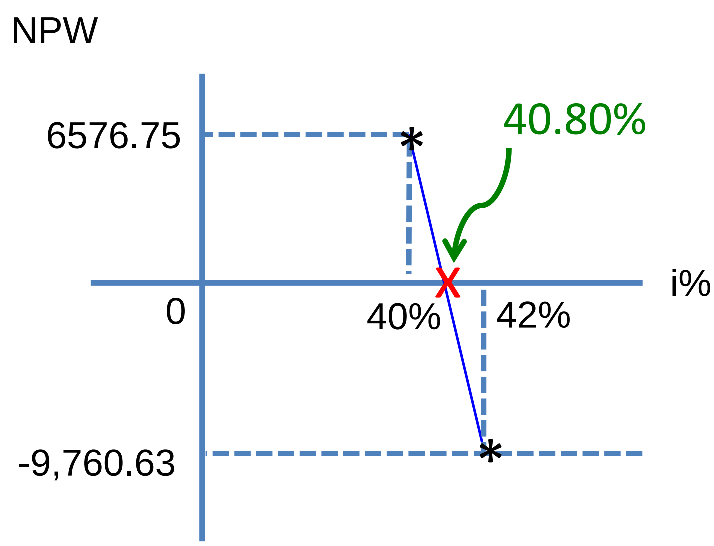
NPW (i'%)
= 370,000(P/F,i'%,1) + 370,000(P/F,i'%,2) + 330,000(P/F,i'%,3) + 290,000(P/F,i'%,4) - 40,000(P/F,i'%,5) - 40,000(P/F,i'%,6) - 100,000(P/F,i'%,7) - 620,000

# Linear Interpolation (IRR)

- Find IRR ($i'\%$) such that NPW($i'\%$) = 0

370,000(P/F,i'%,1) + 370,000(P/F,i'%,2) + 330,000(P/F,i'%,3) + 290,000(P/F,i'%,4) - 40,000(P/F,i'%,5) - 40,000(P/F,i'%,6) - 100,000(P/F,i'%,7) - 620,000 = 0

- Try $i'$ = 40%: NPW(40%) = 6576.75 > 0
- Try $i'$ = 42%: NPW(42%) = -9,760.63 < 0
- Hence 40% < i' < 42%




| | **Linear Interpolation** |
|---|---|
| **NPW(*i%*)** | ***i'%*** |
| **6576.75** | **40%** |
| **0** | **40.80%** |
| -9,760.63 | **42%** |

- By linear interpolation:

$$i' \approx 40 + (40-42)[(0-6576.75) / (-9760.63 - 6576.75)]$$

$$\approx \underline{\mathbf{40.80\%}}$$

# MS Excel (IRR)

| | A | B | C | D |
|---|---|---|---|---|
| 1 | End of Year | Revenue ($) | Operational Cost ($) | Net Cash Flow ($) |
| 2 | 0 | - | 620,000 | -620,000 |
| 3 | 1 | 490,000 | 120,000 | 370,000 |
| 4 | 2 | 490,000 | 120,000 | 370,000 |
| 5 | 3 | 490,000 | 160,000 | 330,000 |
| 6 | 4 | 450,000 | 160,000 | 290,000 |
| 7 | 5 | 210,000 | 250,000 | -40,000 |
| 8 | 6 | 210,000 | 250,000 | -40,000 |
| 9 | 7 | 40,000 | 80,000 | -100,000 |
| 10 | | | IRR | 40.79% |

*fx* =IRR(E2:E9)

- Since *i'* (≈40.79%) > MARR (18%), the project is economically feasible.
- However, IRR method assumes reinvestment at IRR calculated (40.79%) which is substantially larger than MARR, is it a realistic assumption? It seems not!!! We will need to use ERR method to evaluate the feasibility of the project!

# External Rate of Return (ERR) Method

**Equivalent Present Worth** of **<u>All Net Expenditure</u>** or net cash outflow

$$\sum_{k=0}^{N} E_k (P/F, \varepsilon\%, k)$$

$= E_0 + E_5(P/F,16\%,5) + E_6(P/F,16\%,6) + E_7(P/F,16\%,7)$

$= 620{,}000 + 40{,}000(P/F,16\%,5) + 40{,}000(P/F,16\%,6) + 100{,}000(P/F,16\%,7)$

$= 620{,}000 + 40{,}000 * 0.4761 + 40{,}000 * 0.4104 + 100{,}000 * 0.3538$

= $**690,840**

**Equivalent Future Worth** of **<u>All Net Revenue</u>** or net cash inflow

$$\sum_{k=0}^{N} R_k (F/P, \varepsilon\%, N-k)$$

$= R_1(F/P,16\%,6) + R_2(F/P,16\%,5) + R_3(F/P,16\%,4) + R_4(F/P,16\%,3)$

$= 370{,}000(F/P,16\%,6) + 370{,}000(F/P,16\%,5) + 330{,}000(F/P,16\%,4) + 290{,}000(F/P,16\%,3)$

$= 370{,}000 * 2.4364 + 370{,}000 * 2.1003 + 330{,}000 * 1.8106 + 290{,}000 * 1.5609$

= **$2,728,738**

# External Rate of Return (ERR) Method

$$\sum_{k=0}^{N} E_k (P/F, \varepsilon\%, k)(F/P, i'\%, N) = \sum_{k=0}^{N} R_k (F/P, \varepsilon\%, N-k)$$

Recall: $(F/P, i', N) = (1+i')^N$

$690{,}840(F/P,\ i'\%,\ 7) = 2{,}728{,}738$

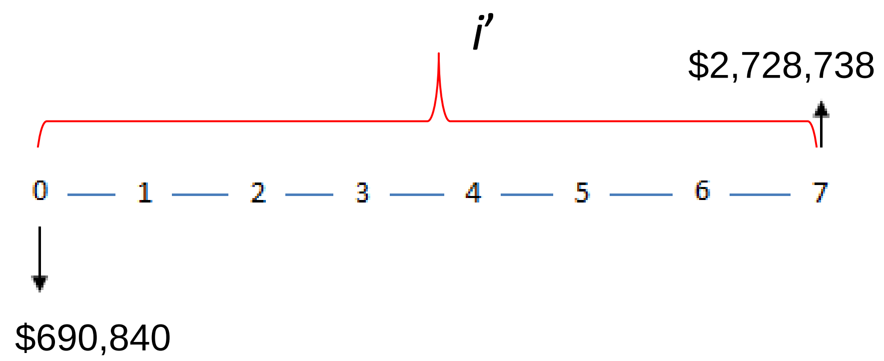
$690{,}840 \cdot (1+i')^7 = 2{,}728{,}738$

$(1+i')^7 = 3.94988$

$1+i' = 1.2168$

$i' = 0.2168$

$= 21.68\%$




Since the rate of return, ERR (21.68%) is more than MARR (18%), the project is economically feasible to invest in.

# Using MS Excel Financial Functions

| | B | C | D | E | F |
|---|---|---|---|---|---|
| 1 | End of Year | Revenue ($) | Operational Cost ($) | Net Cash Flow ($) | Reinvestment |
| 2 | 0 | - | 620,000 | -620,000 | 16% |
| 3 | 1 | 490,000 | 120,000 | 370,000 | |
| 4 | 2 | 490,000 | 120,000 | 370,000 | |
| 5 | 3 | 490,000 | 160,000 | 330,000 | |
| 6 | 4 | 450,000 | 160,000 | 290,000 | |
| 7 | 5 | 210,000 | 250,000 | -40,000 | |
| 8 | 6 | 210,000 | 250,000 | -40,000 | |
| 9 | 7 | 40,000 | 80,000 | -100,000 | |
| 10 | | | ERR | 21.68% | |
| 11 | | | | | |
| 12 | | | IRR | 40.79% | |
| 13 | | | IRR | 40.79% | |

*fx* =MIRR(E2:E9,F2,F2)

Single IRR but significantly higher than re-investment rate.

IRR(values, [guess])

*fx* =IRR(E2:E9,0) = 40.79%

*fx* =IRR(E2:E9,100%) = 40.79%

To find ERR with MSExcel function:
MIRR(values, finance_rate, reinvest_rate)

ERR (21.68%) > MARR (18%) shows that this project is economically feasible.

# Learning Objectives

- ✓ Apply the concept of Rate of Return (ROR)
- ✓ Compute the IRR using Linear Interpolation and MS Excel financial functions
- ✓ Recognize the limitations of Internal Rate of Return (IRR) method
- ✓ Compute the ERR using formula and MS Excel financial functions
- ✓ Evaluate economic feasibility of single project by applying the Internal Rate of Return method (IRR) and External Rate of Return method (ERR).

# E213 Engineering Cost Decisions (Topic Flow)

Today's learning

Application of ABC costing method in cost management

Application of different cost estimating techniques

Comparison of alternatives using the concept of equivalence

Alternatives evaluation using single, uniform series and uniform gradient cash flows

Project evaluation using MARR and Equivalent Worth method

Project evaluation based on Internal Rate of Return and External Rate of Return

Evaluate alternatives of equal life spans using payback method

Evaluate alternatives with different life spans

Evaluate public projects through incremental B/C analysis

Depreciation estimation and consideration in economic analysis

Tax consideration in economic analysis

Replacement analysis application

Risk and uncertainties handling in economic analysis