- **Course Title:** Engineering Cost Analysis & Economy (ENGR 222)
- **Session:** Fall 2024
- **Instructor:** Sudipta Chowdhury (chowdhurys@marshall.edu)
- **Class Time: TR 9.30 AM-10.15 AM**
- **Office hours: TR 1.00 PM-2.30 PM**

Independent Projects with Budget Limitation

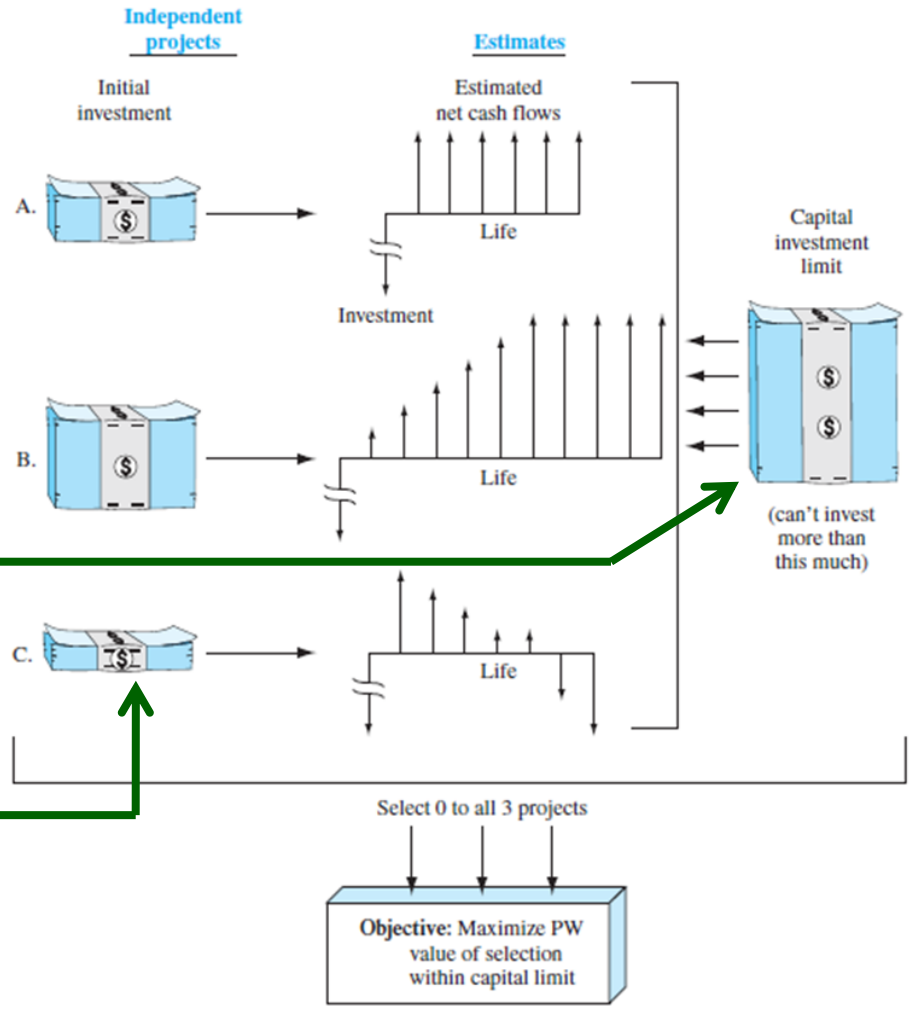
Overview of Capital Rationing

Capital is a scarce resource; never enough to fund all projects

Each project is independent of others; select one, two, or more projects; don't exceed budget limit *b*

'Bundle' is a collection of independent projects that are mutually exclusive (ME)

For 3 projects, there are $2^3 = 8$ ME bundles, e.g., A, B, C, AB, AC, BC, ABC, Do nothing (DN)



Capital Budgeting Problem

Each project selected entirely or not selected at all

Budget limit restricts total investment allowed

Projects usually quite different from each other and have different lives

Objective of Capital Budgeting

Maximize return on project investments using a specific measure of worth, usually PW

Capital Budgeting for Equal-Life Projects

Procedure

Develop $\leq 2^m$ ME bundles that do not exceed budget *b*

Determine NCF for projects in each viable bundle

Calculate PW of each bundle j at MARR (i)

$$\text{PW}_j = \text{PW of bundle net cash flows} - \text{initial investment}$$

$$= \sum_{t=1}^{t=n_j} \text{NCF}_{jt}(P/F, i, t) - NCF_{j0}$$

Note: Discard any bundle with PW < 0; it does not return at least MARR

Select bundle with maximum PW (numerically largest)

Select projects to maximize PW at i = 15% and b = $70,000

Project	Initial investment, $	Annual NCF, $	Life, years	Salvage value, $
A	−25,000	+6,000	4	+4,000
B	−20,000	+9,000	4	0
C	−50,000	+15,000	4	+20,000

Solution: Five bundles meet budget restriction. Calculate NCF and PW values

Bundle, j	Projects	NCF_{j0}, $	NCF_{jt}, $	SV, $	PW_j, $
1	A	−25,000	+6,000	+4,000	−5,583
2	B	−20,000	+9,000	0	+5,695
3	C	−50,000	+15,000	+20,000	+4,261
4	A, B	-45,000	+15,000	+4,000	+112
5	**B, C**	**-70,000**	**+24,000**	**+20,000**	**+9,956**
6	DN	0	0	0	0

Conclusion:
Select projects B and C with max PW value

LCM is not necessary **in capital budgeting; use PW over respective lives to select independent projects**

Same procedure **as that for equal lives**

Example: If MARR is 15% and $b = \$20{,}000$ select projects

Project	Initial Investment, $	Annual Net Cash Flow, $	Project Life, Years
A	−8,000	3870	6
B	−15,000	2930	9
C	−8,000	2680	5
D	−8,000	2540	4

Capital Budgeting Using LP Formulation

Why use linear programming (LP) approach? --

Manual approach not good for large number of projects as 2^m ME bundles grows too rapidly

Apply 0-1 integer LP (ILP) model to:

- **Objective:** Maximize Sum of PW of NCF at MARR for projects
- **Constraints:** Sum of investments $\leq$ investment capital limit
  Each project selected ($x_k = 1$) or not selected ($x_k = 0$)

LP formulation strives to maximize Z

$$\text{Maximize:} \quad \sum_{k=1}^{k=m} PW_k X_k = Z$$

$$\text{Constraints:} \quad \sum_{k=1}^{k=m} \text{NCF}_{k0} X_k \leq b$$

$$x_k = 0 \text{ or } 1 \qquad \text{for } k = 1,\ 2,\ \ldots,\ m$$

Example: LP Solution of Capital Budgeting Problem

MARR is 15%; limit is $20,000; select projects using LP

Project	Initial Investment, $	Annual Net Cash Flow, $	Project Life, Years	PW @ 15%, $
A	−8,000	3870	6	6646
B	−15,000	2930	9	−1019
C	−8,000	2680	5	984
D	−8,000	2540	4	−748

LP formulation for projects A, B, C, D labeled k = 1, 2, 3, 4 and b = $20,000 is:

Maximize: $6646x_1 - 1019x_2 + 984x3 - 748x4$

Constraints: $8000x_1 + 15,000x2 + 8000x3 + 8000x4 \leq 20,000$

$x_1, x2, x3, \text{and } x4 = 0 \text{ or } 1$

Let's Practice

The independent project estimates below have been developed by the engineering and finance managers. The corporate MARR is 8% per year, and the capital investment limit is $4 million. Use linear programming and spreadsheet to solve it.

Project	Project Cost, $ M	Life, Years	NCF,$ per Year
1	-1.5	8	360,000
2	-3	10	600,000
3	-1.8	5	520,000
4	-2	4	820,000

QUESTIONS?