458.401 Process & Product Design

09

Profitability Analysis

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Quantitative Measure of Profitability

Economic Evaluation Procedure

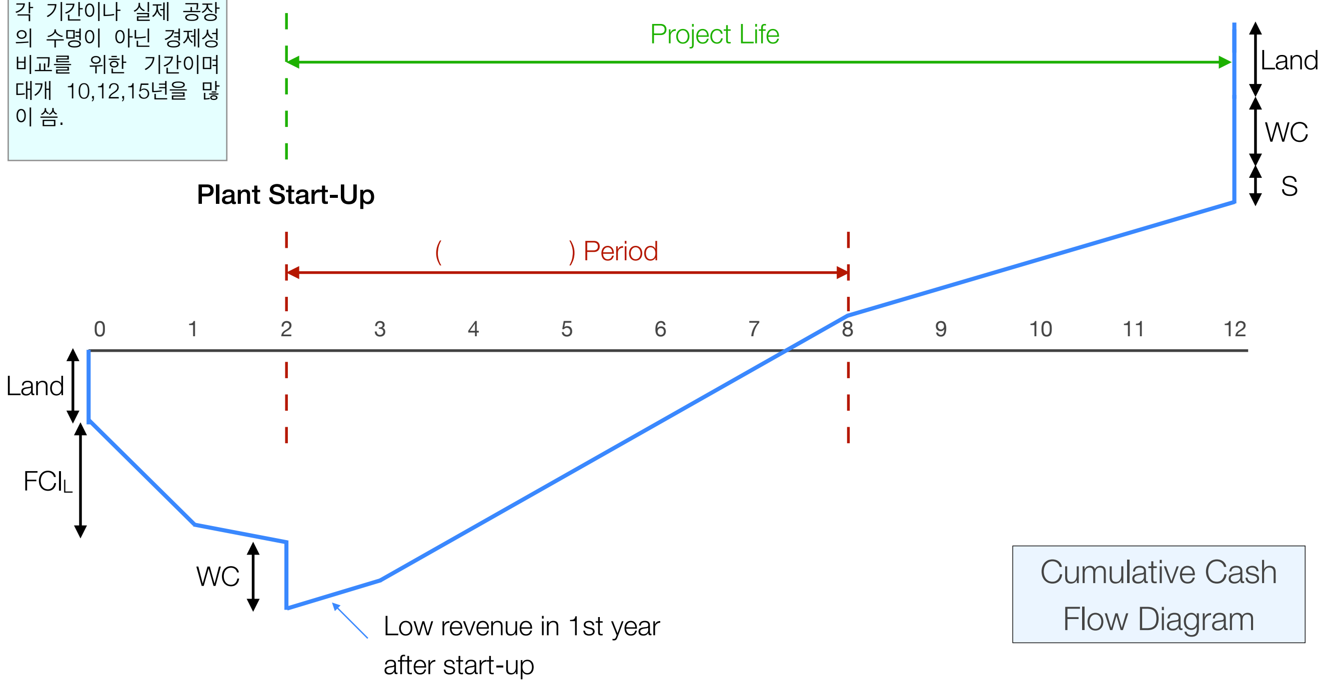
1. PFD preparation
2. Material and heat balance calculation
3. Major equipment sizing
4. Capital cost estimate
5. Production cost calculation (   )
6. Product sales price and sales revenue forecasting
7. Estimate return on investment

Cash Flows for a New Project (Scenario)

1. Purchase land
2. Build plant in 2 years (years typically)
3. Plant start-up: working capital in the first year of plant operation
4. Plant produces product and revenue
   a. Depreciate capital over first 5 year-MACRS
   b. Plant operates for some period of time - time over which profitability analysis is performed
5. At the end of the project working capital, land, and salvage value are recovered

Cash Flows for a New Project

__________는 감가상각 기간이나 실제 공장의 수명이 아닌 경제성 비교를 위한 기간이며 대개 10,12,15년을 많이 씀.



Non-discounted Profitability Criteria

- 3 Bases for Profitability
  - Time
  - Cash
  - Interest Rate
- Non-discounted techniques do not take into account the time value of money, and thus are NOT recommended for evaluating new, large projects.

Non-discounted Profitability Criteria

Time Criterion

Payback Period = PBP

PBP = time required after start-up to recover the FCI_L for the project

also known by payout period, payoff period, and cash recovery period

The shorter the PBP, the more profitable the project.

Non-discounted Profitability Criteria

Cash Criterion

Cumulative Cash Position = CCP

CCP = worth of the project at the end of the project life

Because CCP depends on the size of project, it is better to use the cumulative cash ratio, CCR

$$CCR = \frac{\text{Sum of all positive cash flows}}{\text{Sum of all negative cash flows}} = 1 + \frac{CCP}{\text{Land} + WC + FCI_L}$$

( ) implies the project is potentially profitable.

Non-discounted Profitability Criteria

Interest Rate Criterion

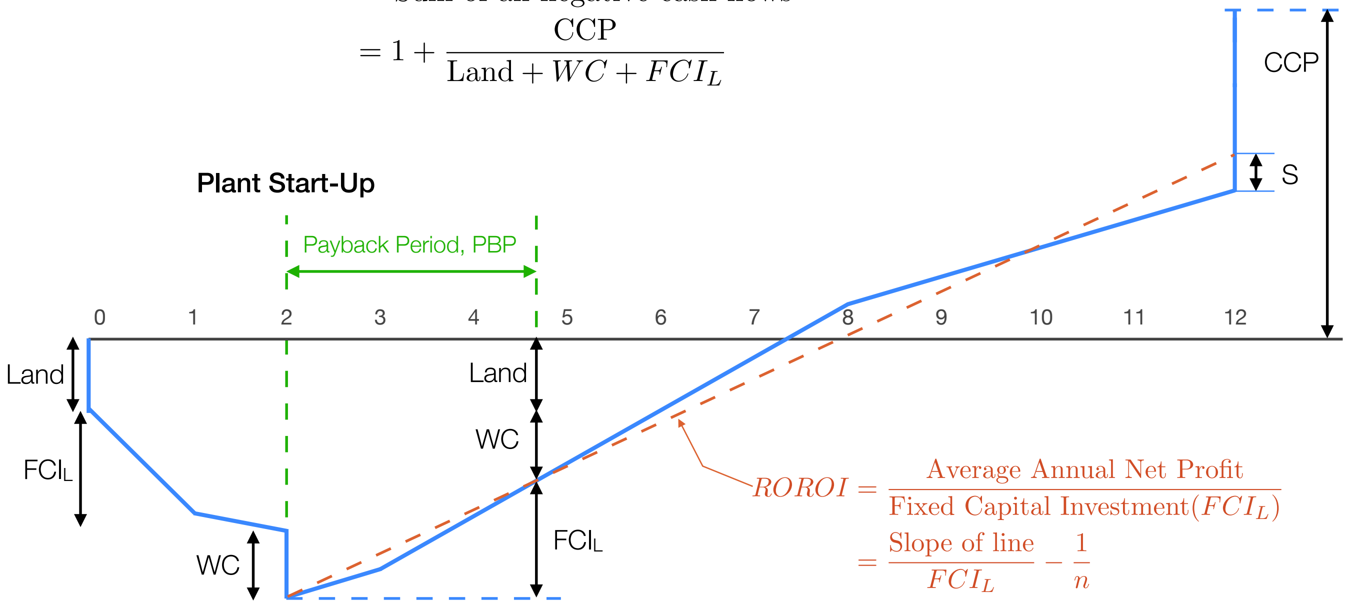
Rate of Return on Investment = ROROI

$$ROROI = \frac{\text{Average Annual Net Profit}^{*}}{\text{Fixed Capital Investment } (FCI_L)}$$

* An average over the life of the plant after start-up

Non-discounted Profitability Criteria

$$CCR = \frac{\text{Sum of all positive cash flows}}{\text{Sum of all negative cash flows}}$$
$$= 1 + \frac{\text{CCP}}{\text{Land} + WC + FCI_L}$$



$$ROROI = \frac{\text{Average Annual Net Profit}}{\text{Fixed Capital Investment}(FCI_L)}$$
$$= \frac{\text{Slope of line}}{FCI_L} - \frac{1}{n}$$

Discounted Profitability Criteria

- For this type of analysis, we discount all the cash flows back to time zero. This puts all the investments and other cash flows on a equal footing
- The resulting discounted cumulative cash flow diagram is then used to evaluate profitability
- Even though simple payback and/or ROI are used in everyday settings, non-discounted criteria are not recommended these days
- DPBP (Discounted Payback Period)
- Discounted Cumulative Cash Position, more commonly known as the net present value (NPV) or net present worth (NPW)
- Discounted cash flow rate of return (DCFROR)
- NPV or DCFROR are recommended, and both criteria require an estimate of N (project life)
- For large capital projects, e.g., new plants or significant additions, discounted criteria are always used

Discounted Profitability Criteria

Example 10.2 (all figures in millions of $)

Land = 10

FCI_L = 150 (year 1 = 90, year 2 = 60)

WC = 30

R = 75

COM_d = 30

t = 45%, *i* = 10% p.a.

S = 10

Depreciation = MACRS over 5 years

Project life, n = 10 years after start-up

> i (internal interest rate) is usually determined by corporate management and represents the minimum rate of return that the company will accept for any new investment.

09 Profitability Analysis

Discounted Profitability Criteria

End of year, *k*	Investment	d_k	$FCI_L - \sum d_k$	R	COM_d	$(R-COM_d-d_k)(1-t)+d_k$	Cash flow	∑CF	Disc CF	∑Disc CF
0	(10)	-	150.00	-	-		(10)	(10)	(10)	(10)
1	(90)	-	150.00	-	-		(90)	(100)	(81.82)	(91.82)
2	(60)+(30)=(90)	-	150.00	-	-		(90)	(190)	(74.38)	(166.20)
3	-	30.00	120.00	75	30	38.25	38.25	(151.75)	28.74	(137.46)
4	-	48.00	72.00	75	30	46.35	46.35	(105.40)	31.66	(103.80)
5	-	28.80	43.20	75	30	37.71	37.71	(67.69)	23.41	(82.39)
6	-	17.28	23.92	75	30	32.53	32.53	(35.16)	18.36	(64.03)
7	-	17.28	8.64	75	30	32.53	32.53	(2.64)	16.69	(47.34)
8	-	8.64	0.00	75	30	28.64	28.64	26.00	13.36	(33.98)
9	-	-	0.00	75	30	24.75	24.75	50.75	10.50	(23.48)
10	-	-	0.00	75	30	24.75	24.75	75.50	9.54	(13.94)
11	-	-	0.00	75	30	24.75	24.75	100.25	8.67	(5.26)
12	10+30=40	-	0.00	85	30	30.25	70.25	170.50	22.38	17.12

Discounted Profitability Criteria

End of year, k	Investment	d_k	$FCI_L - \sum d_k$	R	COM_d	$(R-COM_d-d_k)(1-t)+d_k$	Cash flow	∑CF	Disc CF	∑Disc CF
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10	-	-	0.00	75	30	24.75	24.75	75.50	9.54	(13.94)
11	-	-	0.00	75	30	24.75	24.75	100.25	8.67	(5.26)
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Land

FCI_L

WC

MACRS = % of FCI_L

$R - COM_d$ = 75-30 = 45

Land

WC

R + Salvage

Disc CF = $CF/(1+i)^k$

Discounted Profitability Criteria

- Same basis for criteria as before except we use the discounted cash flows and discounted cumulative cash flow diagram
- Cash Basis
  - CCP ⟶ Net Present Value, NPV
  - CCR ⟶ Present Value Ratio, PVR

NPV = Cumulative discounted cash position at the end of the project

$$PVR = \frac{\text{Present Value of All Positive Cash Flows}}{\text{Present Value of All Negative Cash Flows}}$$

Discounted Profitability Criteria

- Time Basis
  - PBP ⟶ Discounted Payback Period, *DPBP*
- DPBP = Time required, after start-up, to recover the fixed capital investment, FCI_L, required for the project, with all cash flows discounted back to time zero

Discounted Profitability Criteria

- Interest Basis
  - ROROI ⟶ Discounted Cash Flow Rate of Return , *DCFROR*
- The discounted cash flow rate of return (DCFROR) is defined to be the interest rate at which all the cash flows must be discounted in order for the net present value of the project to be equal to zero
- DCFROR = Interest or discount rate for which the NPV of the project is equal to zero

Discounted Profitability Criteria

End of year, k	Investment	d_k	FCI_L-$\sum d_k$	R	COM_d	$(R-COM_d-d_k)(1-t)+d_k$	Cash flow	∑CF	Disc CF	∑Disc CF
0	(10)	-	150.00	-	-		(10)	(10)	(10)	(10)
1	(90)	-	150.00	-	-		(90)	(100)	(81.82)	(91.82)
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11	-	-	0.00	75	30	24.75	24.75	100.25	8.67	(5.26)
12	10+30=40	-	0.00	85	30	30.25	70.25	170.50	22.38	17.12

Discounted Profitability Criteria

Interest Rate	NPV ($million)
0%	170.50
10%	17.12
12%	0.77
13%	-6.32
15%	-18.66
20%	-41.22

$$\frac{(\text{DCFROR} - 12\%)}{13\% - 12\%} = \frac{(0 - 0.77)}{(-6.32 - 0.77)} = 0.109$$

DCFROR = (   )%

Project Evaluation

- MARR, Minimum Acceptable (Compound) Rate of Return

Description	Level of Risk	Typical MARR (%)
Very low risk, hold capital short-term	Safe	4 - 8
New production capacity where company has established position in market	Low	8-16
New product or process technology, company has established market position	Medium	16-24
New process or product in new market	High	24-32
High R&D and marketing development	Very High	32-48

Comparing Several Large Projects

When comparing projects with large capital investments, the question becomes what criterion should we use to discriminate between alternatives?

Consider the following example (figures are in $millions)

	Initial Investment	NPV	DCFROR
Project A	$ 60	11.9	14.3%
Project B	$120	15.2	12.9%
Project C	$100	15.9	13.3%

The capital limit for this year is $120 million so we may only choose A or B or C. Which is best?

Comparing Several Large Projects

When comparing projects with large capital investments, the question becomes what criterion should we use to discriminate between alternatives?

Consider the following example using a hurdle rate *i* = 10% (figures are in $millions)

	After tax cash $i = 1$	Flow in year i $i = 2$ - 10	Initial Investment	NPV	DCFROR
Project A	10	12	$ 60	11.9	14.3%
Project B	22	22	$120	15.2	12.9%
Project C	12	20	$100	15.9	13.3%

The capital limit for this year is $120 million so we may only choose A or B or C. Which is best?

Solve for DCFROR?

NPV = -$60 + ($10)(P/F, i, 1) + ($12)(P/A, i, 9)(P/F, i,1) = 0

$$-60 + 10 \times \frac{1}{1+i} + 12 \times \frac{(1+i)^9 - 1}{i(1+i)^9} \times \frac{1}{1+i} = 0$$

```
>> dcfror = @(x) -60+10/(1+x) + 12*((1+x)^9 -1)/(x*(1+x)^9)/(1+x)

dcfror =

  다음 값을 갖는 function_handle:

    @(x)-60+10/(1+x)+12*((1+x)^9-1)/(x*(1+x)^9)/(1+x)

>> x = fzero(dcfror, 0.5)

x =

    0.1435
```

Comparing Several Large Projects

Start with lowest capital investment - Project A - NPV is positive so this is a viable investment.

Compare incremental investment in going from Project A to Project C (the next largest investment case)

Δ investment = \$100 - \$60 = \$40

Δ cash flow = \$12 - \$10 = \$2 for year 1

= \$20 - \$12 = \$8 for years 2 - 10

Δ NPV = -40 + 2(P/F, 0.1, 1) + 8(P/A, 0.1, 9)(P/F, 0.1, 1) = \$3.7

Δ DCFROR = 11.9%

Because the incremental investment has a positive ΔNPV - Project C is better than Project A

Comparing Several Large Projects

Basically what we have just compared is the following:

Case 1 - Invest \$60 in Project A and \$40 at a rate of 10%

Case 2 - Invest \$100 in Project C

Since C is better than A, we now compare C with the next largest investment - Project B

Δ investment = \$120 - \$100 = \$20

Δ cash flow = \$22 - \$12 = \$10 for year 1

= \$22 - \$20 = \$2 for years 2 - 10

Δ NPV = -20 + 10(P/F, 0.1, 1) + 2(P/A, 0.1, 9)(P/F, 0.1, 1) = -\$0.4 DDCFROR = 9.4%

Because the incremental investment has a negative ΔNPV - Project C is better than Project B

Therefore, Project C is the best

Comparing Several Large Projects

When comparing large, mutually exclusive projects, the appropriate criterion is choosing the project with the highest NPV

Evaluation of Equipment Alternatives

- Here we consider equipment alternatives for a vital service - this means that one of the alternatives must be purchased and operated. However, alternatives are always available. The usual trade-offs are a higher capital investment for a piece of equipment that will either last longer (longer equipment life - better corrosion resistance) or that is cheaper to operate.
- When comparing equipment with equal lives, a simple NPV comparison is appropriate.

Evaluation of Equipment Alternatives

Equal Equipment Lives

Example

The following equipment alternatives are suggested for an overhead condenser. The service lives for the two alternatives are expected to be the same (12 years) and the internal rate of return for such comparisons is set at 10% p.a.

Alternative	Initial Investment	Yearly Operating Cost
A - Air-Cooled Condenser	$23,000	$1,500
B- Water-Cooled Condenser	$12,000	$3,000

Evaluation of Equipment Alternatives

Alternative	Initial Investment	Yearly Operating Cost
A - Air-Cooled Condenser	$23,000	$1,500
B- Water-Cooled Condenser	$12,000	$3,000

Alternative A

NPV = -23,000 - 1,500(P/A, 0.10, 12) = -$33,200

Alternative B

NPV = -12,000 - 3,000(P/A, 0.10, 12) = -$32,400 ✓

Evaluation of Equipment Alternatives

Unequal Equipment Lives

When the service lives for alternative equipment choices are different then NPV cannot be used.
There are three methods to evaluate alternative equipment with unequal lives:

- Capitalized Cost Method
- Common Denominator Method
- Equivalent Annual Operating Cost Method (EAOC)

The ranking of alternatives does not depend on which method is chosen. So just choose one of them - EAOC

Evaluation of Equipment Alternatives

Unequal Equipment Lives

- EAOC = (Capital Investment)(A/P, i, n_{eq}) + Yearly Operating Cost

$$(A/P, i, n) = \frac{i(1+i)^n}{(1+i)^n - 1}$$

The EAOC will be positive because it is a cost. Therefore, choose the alternative with the smallest EAOC

Evaluation of Equipment Alternatives

Unequal Equipment Lives

Example

Two pumps are considered for a corrosive service. The yearly operating costs include utility and maintenance costs. Which alternative is best if the internal hurdle rate for these types of projects is 8% p.a.?

Alternative	Capital Investment	Yearly Operating Cost	Equipment life, years
A - Carbon Steel	$8,000	$1,800	4
B- Stainless Steel (SUS)	$16,000	$1,600	7

Evaluation of Equipment Alternatives

Unequal Equipment Lives

Example

Alternative	Capital Investment	Yearly Operating Cost	Equipment life, years
A - Carbon Steel	$8,000	$1,800	4
B- Stainless Steel	$16,000	$1,600	7

$$EAOC_A = 8,000\frac{0.08(1.08)^4}{1.08^4 - 1} + 1,800 = \$4,220 \text{ per year}$$

$$EAOC_B = 16,000\frac{0.08(1.08)^7}{1.08^7 - 1} + 1,600 = \$4,670 \text{ per year}$$

Retrofitting Operations - Incremental Analysis (non-discounted)

Non-discounted methods

- Rate of Return on Incremental Investment (ROROII)

$$\text{ROROII} = \frac{\text{Incremental Yearly Savings}}{\text{Incremental Investment}}$$

- Incremental Payback Period (IPBP)

$$\text{IPBP} = \frac{\text{Incremental Investment}}{\text{Incremental Yearly Savings}}$$

Retrofitting Operations - Incremental Analysis (non-discounted)

Example

The following insulations are being considered for the heating loop to an endothermic reactor. If a non-discounted rate of return of 15% (equivalent to a IPBP = 1/0.15 = 6.67 yrs) is set as the hurdle rate for improvement projects such as this, which alternative is best? Note that alternative 1 is the do-nothing option - compare all the others to this one (base case)

Alternative	Type of Insulation	Project Cost (PC)	Yearly Savings (YS)
1	None	0	0
2	B - 1″ thick	$3,000	$1,400
3	B - 2″ thick	$5,000	$1,900
4	A - 1″ thick	$6,000	$2,000
5	A - 2″ thick	$9,700	$2,400

Retrofitting Operations - Incremental Analysis (non-discounted)

Example (cont'd)

Option #-Option 1	ROROII	IPBP (years)
2-1	\$1,400/\$3,000 = 0.47 (47%)	\$3,000/\$1,400 = 2.1
3-1	\$1,900/\$5,000 = 0.38 (38%)	\$5,000/\$1,900 = 2.6
4-1	\$2,000/\$6,000 = 0.33 (33%)	\$6,000/\$2,000 = 3.0
5-1	\$2,400/\$9,700 = 0.25 (25%)	\$9,700/\$2,400 = 4.0

Choose the option with the lowest cost that meets the profitability criterion - Option 2. Then compare the option with the next highest capital investment using this as the base case.

Retrofitting Operations - Incremental Analysis (non-discounted)

Example (cont'd)

Option #-Option 2	ROROII	IPBP (years)
3-2	(1,900-1,400)/(5,000-3,000) = 0.25 (25%)	\$2,000/\$500 = 4

Since by moving from Option 2 to Project 3, the profitability criterion is met, make Option 3 the new base case. Then compare other options with the new base case.

Retrofitting Operations - Incremental Analysis (non-discounted)

Example (cont'd)

Option #-Option 3	ROROII	IPBP (years)
4-3	(2,000-1,900)/(6,000-5,000) = 0.1 (10%)	\$1,000/\$100 = 10
5-3	(2,400-1,900)/(9,700-5,000) = 0.106 (10.6%)	\$4,700/\$500 = 9.4

Since neither of the incremental investments in going from Option 3 to Option 4 or 5 meet the profitability criterion - Option 3 is the best.

Note that decisions may be made using either 15% or 6.67 years as the profitability criterion

Retrofitting Operations - Incremental Analysis (discounted)

Discounted methods

- Determine the incremental NPV or EAOC for each option (compared to the do-nothing alternative) and choose the alternative with the highest NPV or lowest EAOC (highest negative value)

  incremental NPV = INPV

Retrofitting Operations - Incremental Analysis (discounted)

Example

Revisit the same example using a project life of 5 years and a discounted hurdle rate of 10% p.a.

Option #-Option 1	INPV = -PC + (P/A, i, n)YS
2-1	-3,000 + {$(1.1)^5$ - 1}/{(0.1)$(1.1)^5$}(1,400) = $2,307
3-1	-5,000 + (3.79)(1,900) = $2,201
4-1	-6,000 + (3.79)(2,000) = $1,580
5-1	-9,700 + (3.79)(2,400) = -$604

Because Option 2 has the highest NPV with respect to the do-nothing Option 1, Option 2 is the best.

09 Profitability Analysis

Retrofitting Operations - Incremental Analysis (discounted)

Example

Revisit the same example using a project life of 5 years and a discounted hurdle rate of 10% p.a.

Option #-Option 1	EAOC = PC(A/P, i, n) - YS
2-1	(3,000){(0.1)$(1.1)^5$}/{$(1.1)^5$ - 1} - 1,400 = -$ 609
3-1	(5,000)(0.2638) - 1,900 = -$ 581
4-1	(6,000)(0.2638) - 2,000 = -$ 417
5-1	(9,700)(0.2638) - 2,400 = $ 158

Because Option 2 has the most negative EAOC with respect to the do-nothing Option 1, Option 2 is best. This result is exactly the same as obtained with the INPV analysis.

Using CAPCOST for Profitability Calculations

Go to COM summary worksheet

Rework Example 10.1 using CAPCOST

- Land = 10
- FCI_L = 150 (year 1 = 90 and year 2 = 60)
- WC = 30
- R = 75
- COM_d = 30
- t = 45%
- S = 10
- Depreciation = MACRS over 5 years
- Project life, n = 10 years after start-up