ITM515 STRATEGIC TECHNOLOGY MANAGEMENT

Chapter 7

Choosing Innovation Projects

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Contents

Overview

- Firms have to make difficult choices about which projects are worth the investment
  - Capital rationing: The allocation of a finite quantity of resources over different possible uses

- Methods of choosing innovation projects range
  - from informal to highly structured
  - from entirely qualitative to strictly quantitative

Methods for Choosing Projects

- Qualitative methods
  - Screening questions: Evaluation criteria on market, technology, environment, capability ….
  - Portfolio mapping

- Quantitative methods
  - Discounted cash flow methods: NPV, B/C ratio, IRR
  - Multiple criteria decision making methods: **AHP, DEA**

Analytic Hierarchy Process (AHP)

- Introduction to AHP
- AHP procedure
  1. Decomposition
  2. Pairwise comparison
  3. Local priority computation
  4. Consistency check
  5. Global priority computation

Introduction to AHP

- Basic concept (Saaty, 1980)
  - One of the most widely used multi-criteria decision making (MCDM) method
  - Modeling a problem as a hierarchy and conducting pairwise comparisons
  - Mirroring both qualitative and quantitative perspectives
- Procedure

1. Decomposition

↓

2. Pairwise comparison

↓

3. Priority computation

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4. Consistency check

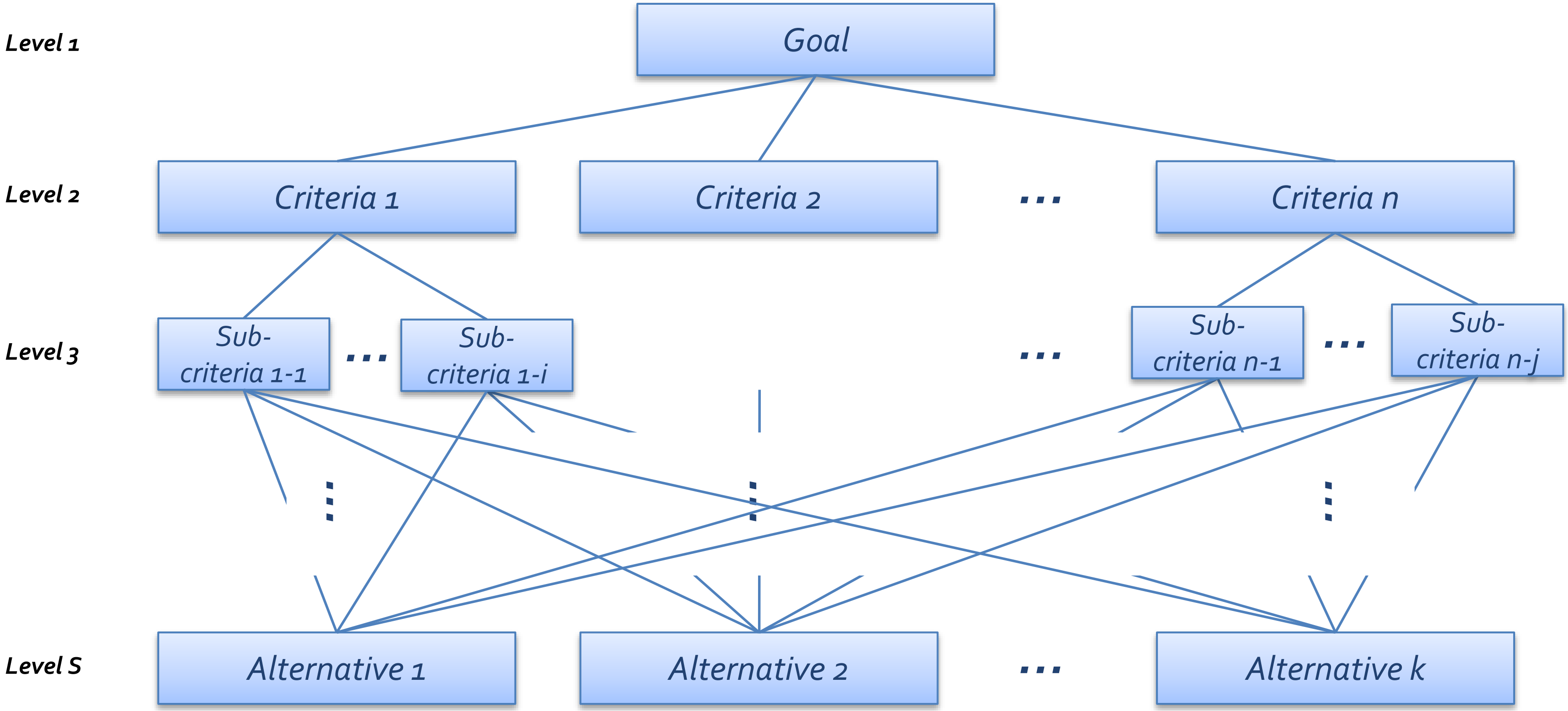
↓

5. Synthesis of priorities

1. Decomposition (1/2)

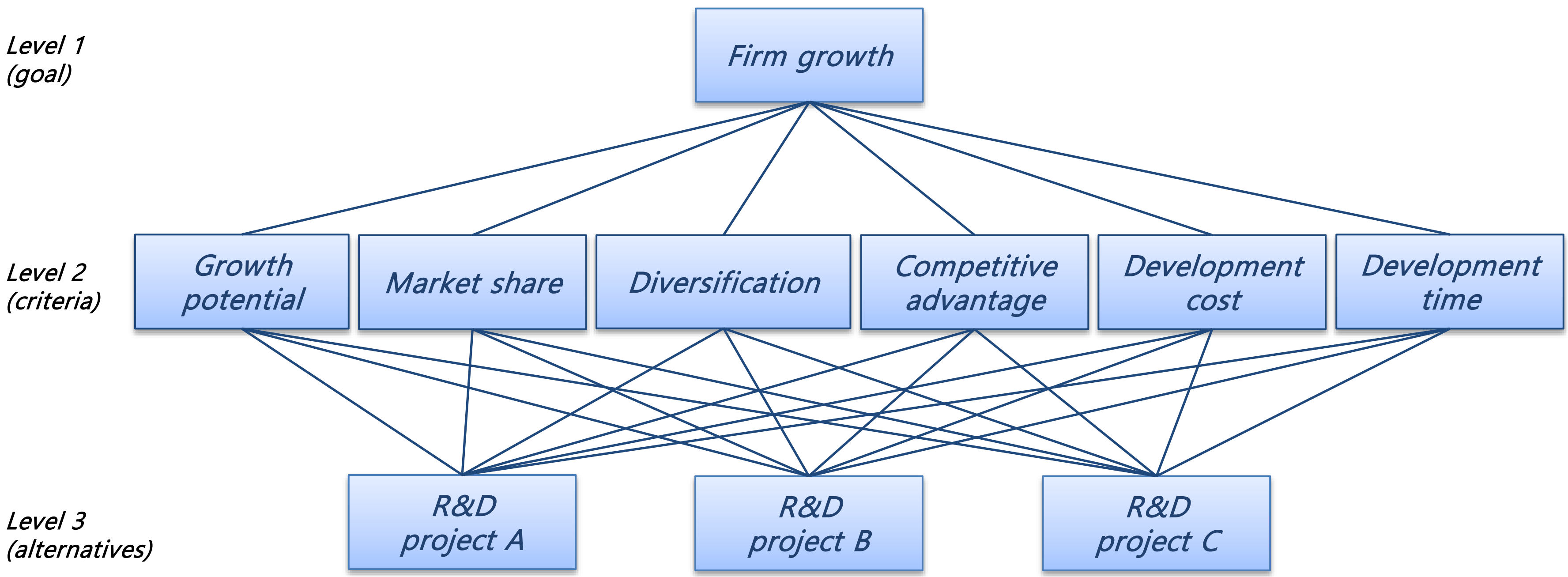
➢ AHP Hierarchy

- Decompose the problem into hierarchy



1. Decomposition (2/2)

- Example: choose the best R&D project!



2. Pairwise comparison (1/2)

➢ Importance scale

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or moderated importance
9	Extreme importance
2, 4, 6, 8	For compromise between the above values

"Growth potential" is strongly more important than "Market share".

➢ Pairwise comparison for criteria w.r.t. the goal

- Assign the relative importance to each pair of criteria w.r.t. the goal

	Growth potential	Market share	Diversification	Competitive advantage	Development cost	Development time
Growth potential	1	5	7	6	1/3	1/4
Market share	1/5	1	5	3	1/5	1/7
Diversification	1/7	1/5	1	1/3	1/7	1/8
Competitive advantage	1/6	1/3	3	1	1/5	1/6
Development cost	3	5	7	5	1	1/2
Development time	4	7	8	6	2	1

2. Pairwise comparison (2/2)

➢ Pairwise comparison for alternatives w.r.t. each criterion

- Assign the relative importance to each pair of alternatives w.r.t. each criterion

Growth potential	A	B	C
A	1	6	4
B	1/6	1	1/3
C	1/4	3	1

Competitive advantage	A	B	C
A	1	1/2	1
B	2	1	2
C	1	1/2	1

Diversification	A	B	C
A	1	1	1
B	1	1	1
C	1	1	1

Market share	A	B	C
A	1	1/3	1/2
B	3	1	3
C	2	1/3	1

Development cost	A	B	C
A	1	9	7
B	1/9	1	1/5
C	1/7	5	1

Development time	A	B	C
A	1	5	1
B	1/5	1	1/5
C	1	5	1

3. Local priority computation

➢ Normalization

- Sum the values in each column and divide each element by column total

Growth potential	A	B	C	A	B	C
A	1	6	4	0.706	0.6	0.750
B	1/6	1	1/3	0.118	0.1	0.063
C	1/4	3	1	0.176	0.3	0.188
Total	1.416	10	5.333			

➢ Priority computation using average

- Compute priorities by averaging each row

Growth potential	A	B	C	A	B	C	Average (Priority)
A	1	6	4	0.706	0.6	0.750	0.685
B	1/6	1	1/3	0.118	0.1	0.0625	0.094
C	1/4	3	1	0.176	0.3	0.1875	0.221
Total	1.416	10	5.333	1	1	1	1

4. Consistency check (1/2)

- CI (Consistency Index)
  - Compute CI

$$CI = \frac{\Lambda_{\max} - n}{n-1} = \frac{3.055-3}{3-1} = 0.028$$

Growth potential	A	B	C	Priority	Sum product	Sum product / Priority
A	1	6	4	0.685	2.133	3.114
B	1/6	1	1/3	0.094	0.282	3.000
C	1/4	3	1	0.221	0.674	3.050
					Average($\Lambda_{\max}$)	3.055

$$\begin{bmatrix} 1 & 6 & 4 \\ 1/6 & 1 & 1/3 \\ 1/4 & 3 & 1 \end{bmatrix} \begin{bmatrix} 0.685 \\ 0.094 \\ 0.221 \end{bmatrix} = \begin{bmatrix} 2.133 \\ 0.282 \\ 0.674 \end{bmatrix}$$

4. Consistency check (2/2)

➢ CR (Consistency Ratio)

- Compute CR

$$CR = \frac{CI}{RI} = \frac{0.028}{0.58} = 0.048$$

※ RI (Random Index): CI obtained from simulations with large samples of purely random judgments

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

- Check consistency
  - ✓ if CR < 0.1, considered acceptable
  - ✓ if CR > 0.1, revision required

5. Global priority computation

➢ Synthesis of local priorities

- Linearly combine priorities of criteria with those of alternatives for each criterion

	Growth potential (0.182)	Market share (0.083)	Diversification (0.028)	Competitive advantage (0.052)	Development cost (0.262)	Development time (0.393)	Global Priority
A	0.685	0.151	0.333	0.250	0.718	0.455	0.526
B	0.094	0.575	0.333	0.500	0.100	0.091	0.162
C	0.221	0.274	0.333	0.250	0.182	0.455	0.312

$$\begin{bmatrix} 0.685 & 0.151 & 0.333 & 0.250 & 0.718 & 0.455 \\ 0.094 & 0.575 & 0.333 & 0.500 & 0.100 & 0.091 \\ 0.221 & 0.274 & 0.333 & 0.250 & 0.182 & 0.455 \end{bmatrix} \begin{bmatrix} 0.182 \\ 0.083 \\ 0.028 \\ 0.052 \\ 0.262 \\ 0.393 \end{bmatrix} = \begin{bmatrix} 0.526 \\ 0.162 \\ 0.312 \end{bmatrix}$$

- Make the final decision: *Select R&D project A!!*

Data Envelopment Analysis (DEA)

- Introduction to DEA
- Basic DEA model
- Example
- R&D project selection with DEA

Introduction to DEA

- Purpose
  - Performance measurement & benchmarking
    - ✓ Providing efficiency scores as an overall measure of performance
    - ✓ Providing the way to improve efficiency
  - MCDM(multiple criteria decision making)

- Features
  - Non-parametric approach
  - Relative comparisons among DMUs
    - ✓ DMU(Decision Making Unit): Homogeneous groups who have the same objective and conduct similar activities
  - Linear programming model

Introduction to DEA

- **Advantages**
  - Capable of providing the way of benchmarking
  - Capable of handling multiple inputs and outputs
  - Not require prescribed functional forms of production
  - Not require prescribed weights to be attached each input and output

- **Application areas**
  - Service industry
    - ✓ Branch-based business where branches are homogeneous
    - ✓ Hospitals, fast food restaurants, banks, schools, etc.
  - R&D project selection

Basic DEA model

- Variables

Variables	Description
E_k	The efficiency ratio of DMU k *k=1,2,…,K where K is the total number of DMUs being evaluated*
u_j	A coefficient for output j – A measure of the relative decrease in efficiency with each unit reduction of output value *j=1,2,…,M where M is the total number of output types being considered*
v_i	A coefficient for input i – A measure of the relative increase in efficiency with each unit reduction of input value *i=1,2,…,N where N is the total number of input types being considered*
O_{jk}	The number of observed units of output j generated by DMU k during one time period
I_{jk}	The number of actual units of input i used by DMU k during one time period

Basic DEA model

Objective function

- Objective: Give the DMU being evaluated the highest possible efficiency
- Formula:

$$\max \ E_e = \frac{u_1 O_{1e} + u_2 O_{2e} + \cdots + u_M O_{Me}}{v_1 I_{1e} + v_2 I_{2e} + \cdots + v_N I_{Ne}}$$

Where e is the index of the DMU being evaluated

Constraints

- Constraint: No DMU will exceed a ratio of 1.0
- Formula:

$$\frac{u_1 O_{1k} + u_2 O_{2k} + \cdots + u_M O_{Mk}}{v_1 I_{1k} + v_2 I_{2k} + \cdots + v_N I_{Nk}} \leq 1$$

$$k = 1,2, \cdots, K$$

Basic DEA model

- Linear programming form

$$\max \; E_e = u_1 O_{1e} + u_2 O_{2e} + \cdots + u_M O_{Me}$$

$$\text{s.t.} \; u_1 O_{11} + u_2 O_{21} + \cdots + u_M O_{M1} - (v_1 I_{11} + v_2 I_{21} + \cdots + v_N I_{N1}) \leq 0$$

$$\vdots \qquad\qquad \vdots$$

$$u_1 O_{1K} + u_2 O_{2K} + \cdots + u_M O_{MK} - (v_1 I_{1K} + v_2 I_{2K} + \cdots + v_N I_{NK}) \leq 0$$

$$v_1 I_{1e} + v_2 I_{2e} + \cdots + v_N I_{Ne} = 1$$

$$u_j \geq 0, \qquad j = 1,2,\cdots,M$$

$$v_i \geq 0, \qquad i = 1,2,\cdots,N$$

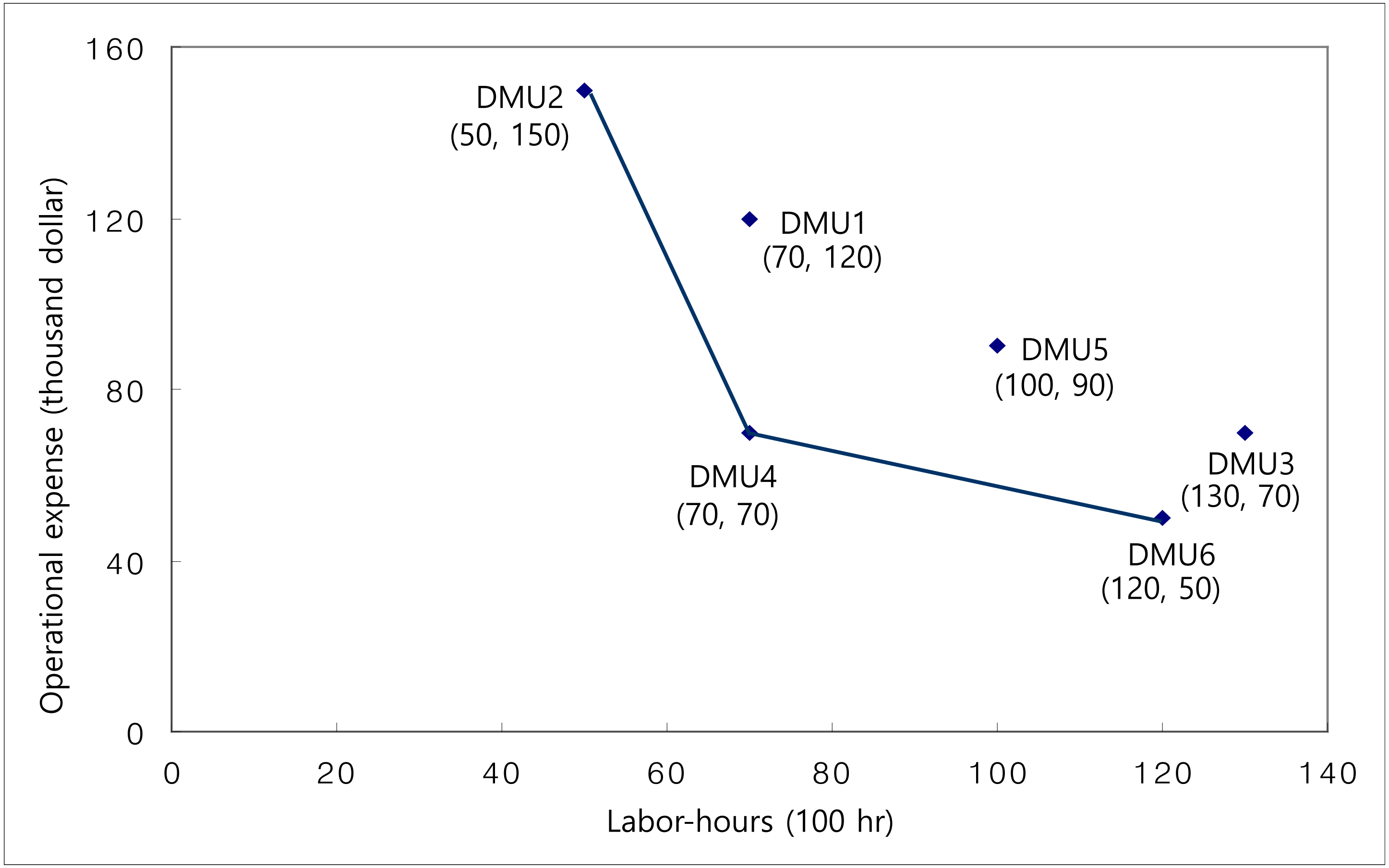
Example

- Data: Tourist hotel

DMUs	Output	Input	
	Number of guests	Labor-hours (100 hr)	Operational cost (thousand dollar)
DMU1	500	70	120
DMU2	500	50	150
DMU3	500	130	70
DMU4	500	70	70
DMU5	500	100	90
DMU6	500	120	50

Example

- Efficient frontier



Example

➢ LP formulation

DMU 1)
$$\begin{aligned} \max\ E_1 &= 500u_1 \\ s.t.\quad 500u_1 - 70v_1 - 120v_2 &\le 0 \\ 500u_1 - 50v_1 - 150v_2 &\le 0 \\ 500u_1 - 130v_1 - 70v_2 &\le 0 \\ 500u_1 - 70v_1 - 70v_2 &\le 0 \\ 500u_1 - 100v_1 - 90v_2 &\le 0 \\ 500u_1 - 120v_1 - 50v_2 &\le 0 \\ 70v_1 + 120v_2 &= 1 \\ u_1, v_1, v_2 &\ge 0 \end{aligned}$$

DMU 2)

⋮

DMU 6)

Example

Results

DMU	Efficiency (E)	Efficiency Reference Set	u_1	v_1	v_2
DMU1	0.8750	DMU2 (0.4375) DMU4 (0.5625)	0.0018	0.0100	0.0025
DMU2	1	---	0.0020	0.0114	0.0029
DMU3	0.8033	DMU4 (0.3115) DMU6 (0.6885)	0.0016	0.0033	0.0082
DMU4	1	---	0.0020	0.0114	0.0029
DMU5	0.7539	DMU4 (0.8923) DMU6 (0.1077)	0.0015	0.0031	0.0077
DMU6	1	---	0.0020	0.0041	0.0102

DMUs corresponding to the binding constraints (shadow price)

Example

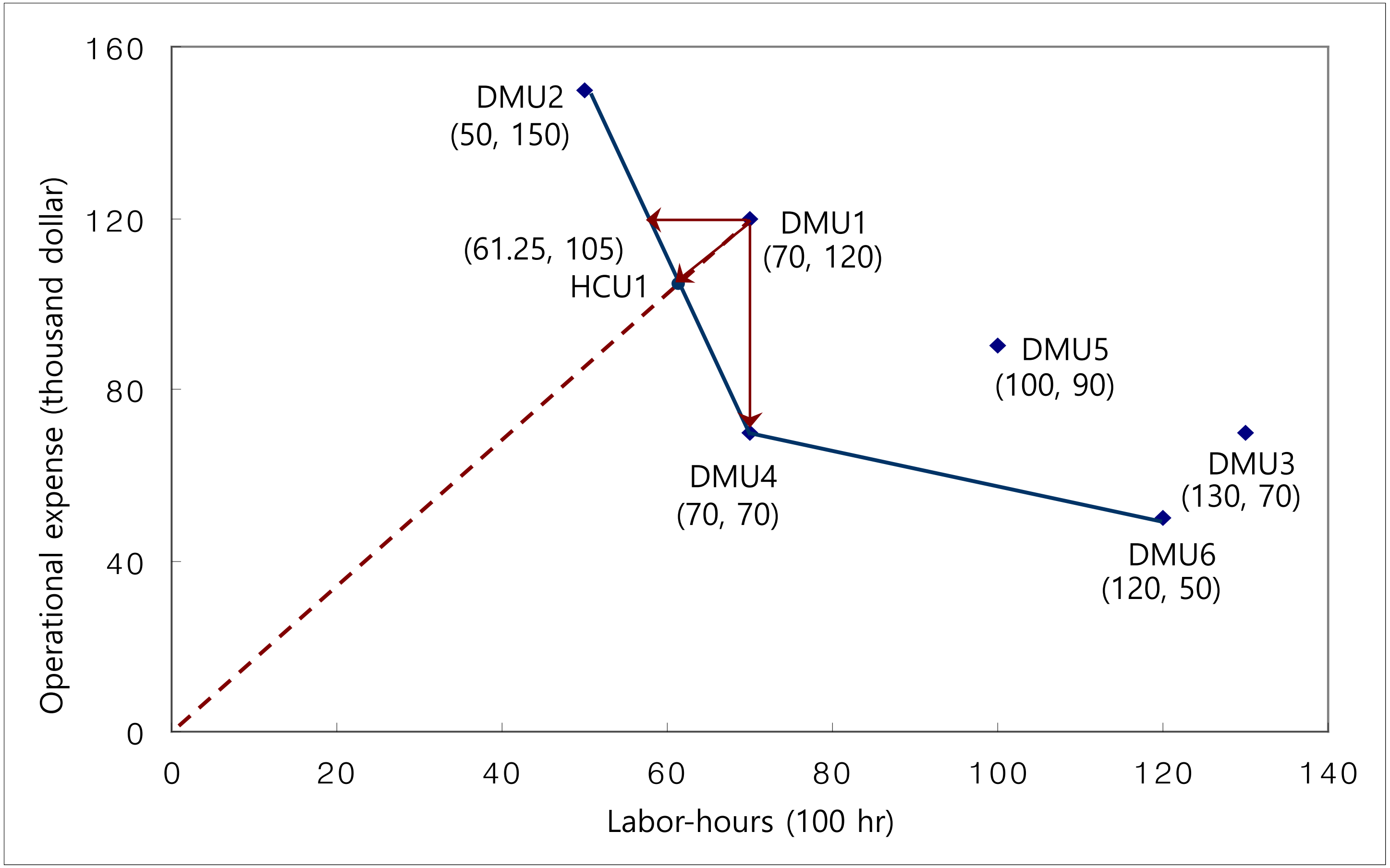
- Improvement - How to make DMU1 efficient (1/2)
  - Arithmetic calculation
    - ✓ Benchmark any efficient DMU
    - ✓ Reduce each input → increase efficiency ratings by 0.125
      - Reduce labor-hours by 12.5(=0.125÷0.01)
      - Reduce operational cost by 50(=0.125÷0.0025)
    - ✓ Benchmark HCU(Hypothetical Composite Unit)1

	Reference Set		**HCU1**	**DMU1**	**Excess Inputs Used**
	DMU2 (0.4375)	**DMU4 (0.5625)**			
Labor-hours	0.4375×50 +	0.5625×70 =	61.25	70	8.75 (=70-61.25 =70×0.125)
Operational cost	0.4375×150 +	0.5625×70 =	105	120	15 (=120-105 =120×0.125)

Example

➢ Improvement - How to make DMU1 efficient (2/2)

- Graphical representation



R&D project selection with DEA

- Example: DEA ranking of projects of the Advanced Technologies Group of Bell Laboratories

Rank (PHI)	Investment	Cash flow – most likely	Cash flow – optimistic	Cash flow – pessimistic
1 (1)	4,322	1,296,700	1,353,924	1,184,192
2 (1)	850	525,844	551,538	493,912
3 (1)	1	4	4	3
4 (1)	478	545,594	822,164	411,082
5 (1)	1	15	15	11
6 (1)	65	89,144	178,289	0
7 (1)	1,068	685,116	1,027,386	342,558
8 (1)	4	3,766	4,707	2,824
9 (1)	20	4,800	4,800	−96
10 (1.08)	2	23	27	18
50 (2.85)	9	116	139	93
100 (4.06)	15	60	72	48
150 (4.85)	40	5,531	13,829	2,766
200 (11.85)	38	90	135	45