

# Eco-Efficiency of Local Development by Local Governments Using LCA and Stated Preference Method

H.Kurishima<sup>1</sup>, H.Setoyama<sup>2</sup>, K.Tahara<sup>1</sup>, Y.Genchi<sup>1</sup>, A.Inaba<sup>1</sup>

*<sup>1</sup>Research Center for Life Cycle Assessment, AIST*

*<sup>2</sup>Tokyu Construction Ltd.*



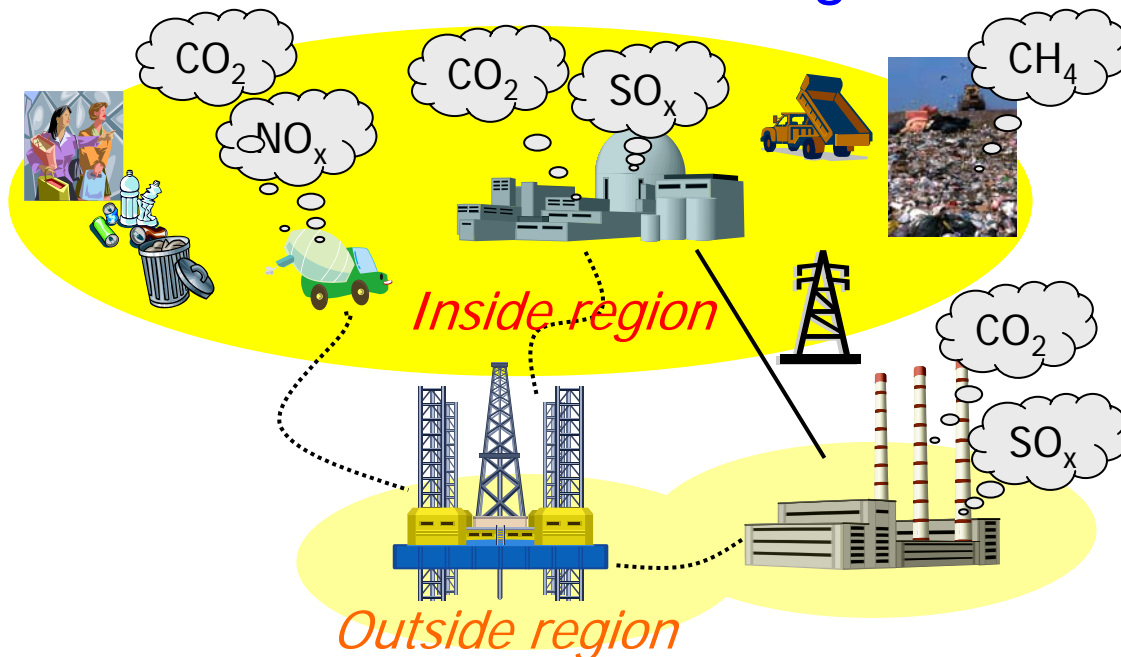
**TOKYU CONSTRUCTION**

# Table of Contents

- Background
- Outline of Case Study
  - Study area and target project
- Methodology
  - Eco-Efficiency
  - LCA
  - Conjoint Analysis
- Results
- Summary and future plans

# Background 1

- Developments by Japanese Local Governments
  - Local needs > Environmental impact
  - Environmental issues → regional and global



**It is necessary to  
apply life cycle thinking to local development**

## Background 2

- Technical issues of policy evaluation using LCA
  - Is ‘not developing’ the best solution?
    - Policy practices are not limited to reducing the environmental impact.
    - We have to think the merit of the development
  - What is the functional unit?
    - Local governments would like to compare development proposals.
    - Functions differ from proposal to proposal.

**The concept of eco-efficiency is an effective method**

# Outline of Case Study: Study area

- Taki town, Mie prefecture, Japan
  - Population: 10,769 (Census 2000)
  - Agricultural community with plenty of undeveloped lands
    - Area 50km<sup>2</sup>: Farm land 14km<sup>2</sup>(28%), Forest 21km<sup>2</sup>(42%)
  - Signature Agricultural Products
    - rice, Ise yams, mandarins, persimmons, beef cattle (Matsusaka beef)
  
- Location of an LCD factory from 1995
  - Employees: 2,360
  - Floor space: 344,000 m<sup>2</sup>



**The population growth has increased demands for urban facilities from both the residents and the employees**

# Outline of Case Study: Target Project

The population growth has increased demands for urban facilities from both the residents and the employees



## Project: Development of a commercial district (10ha)

Goal: Establishing facilities to meet the needs of the residents and the employees  
(Shopping mall, Leisure facilities, Medical facilities, Apartments)

Study Scope:

- (1) Stage: Construction stage and operation stage for 20years
- (2) LCI material: environmental burden ( $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ ,  $\text{SO}_x$ ,  $\text{NO}_x$ , PM, sludge, solid waste), resource consumption (coal, crude oil, natural gas, iron, copper, aluminum, limestone)

Table. Proposed facilities

| facilities       |                     | floor space,<br>structure     | facility outlines   |
|------------------|---------------------|-------------------------------|---|
| shopping mall    |                     | 4,000~32,000m <sup>2</sup> ·S |   |
| Leisure          | park                | 2,000m <sup>2</sup> ·S        | restroom, drinking water fountain, lamp   |
|                  | restaurant district | 980m <sup>2</sup> ·S          | restaurant(350m <sup>2</sup> ),fast-foods(260m <sup>2</sup> )x2, buckwheat noodle(50m <sup>2</sup> ),chinese(60m <sup>2</sup> ) |
|                  | karaoke             | 600m <sup>2</sup> ·S          | 33 rooms  |
|                  | bathhouse           | 2,600m <sup>2</sup> ·S        | many baths, sauna   |
|                  | culture school      | 1,200m <sup>2</sup> ·S        | 5 rooms, meeting room, manager office   |
|                  | cinema complex      | 2,500m <sup>2</sup> ·S        | 5 cinemas   |
|                  | gym                 | 1,500m <sup>2</sup> ·S        | no pool   |
| Medical          | clinic              | 200m <sup>2</sup> ·S          | no hospitalization equipment  |
|                  | collective clinics  | 870m <sup>2</sup> ·S          | same as above. internal medicine, surgery, pediatric, otolaryngology(200m <sup>2</sup> x4),dentistry(70m <sup>2</sup> )         |
|                  | general clinic      | 4,000m <sup>2</sup> ·S        | hospitalization equipment (80 beds)   |
| rental apartment |                     | 720~7,200m <sup>2</sup> ·RC   | 10~100 households   |

S: Steel building, RC: Reinforced Concrete building

# Methodology: About Eco-Efficiency

Eco-Efficiency  
 ↑  
 Economic  
 Ecological (Environment)

Quantity of goods or services produced or provided to customers  
 Net sales

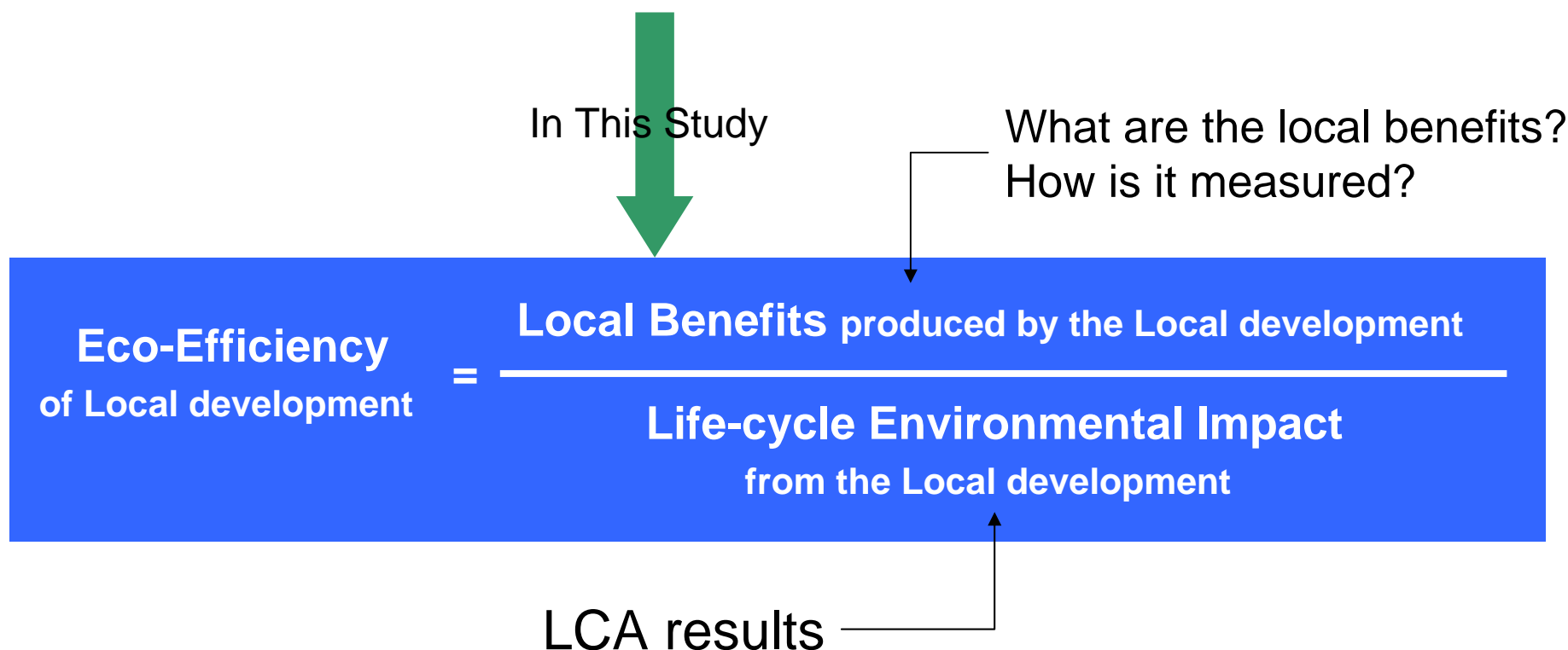
$$\text{Eco-Efficiency} = \frac{\text{Product or Service value}}{\text{Environmental influence}}$$

Energy consumption  
 Materials consumption  
 Water consumption  
 Greenhouse gas emissions (CO<sub>2</sub>...)  
 Ozone depletion substance emissions  
 .....

WBSCD(1994)

# Methodology: Eco-Efficiency in this study

$$\text{Eco-Efficiency} = \frac{\text{Product or Service value}}{\text{Environmental influence}}$$



# Methodology: LCA

- Inventory Analysis
  - Construction stage: IO table analysis (AIJ 2003 etc)
  - Operation stage: Bottom up Approach (AIST, JLCA etc)
  
- Life-Cycle Impact Assessment
  - LIME: **L**ife-cycle **I**mpact assessment **M**ethod based on **E**ndpoint modeling (It is an endpoint-type LCIA methodology for Japan)
  - The results of weighing can be described as monetary values and will have practical applications in the fields of eco-efficiency, life cycle costing and environmental accounting.

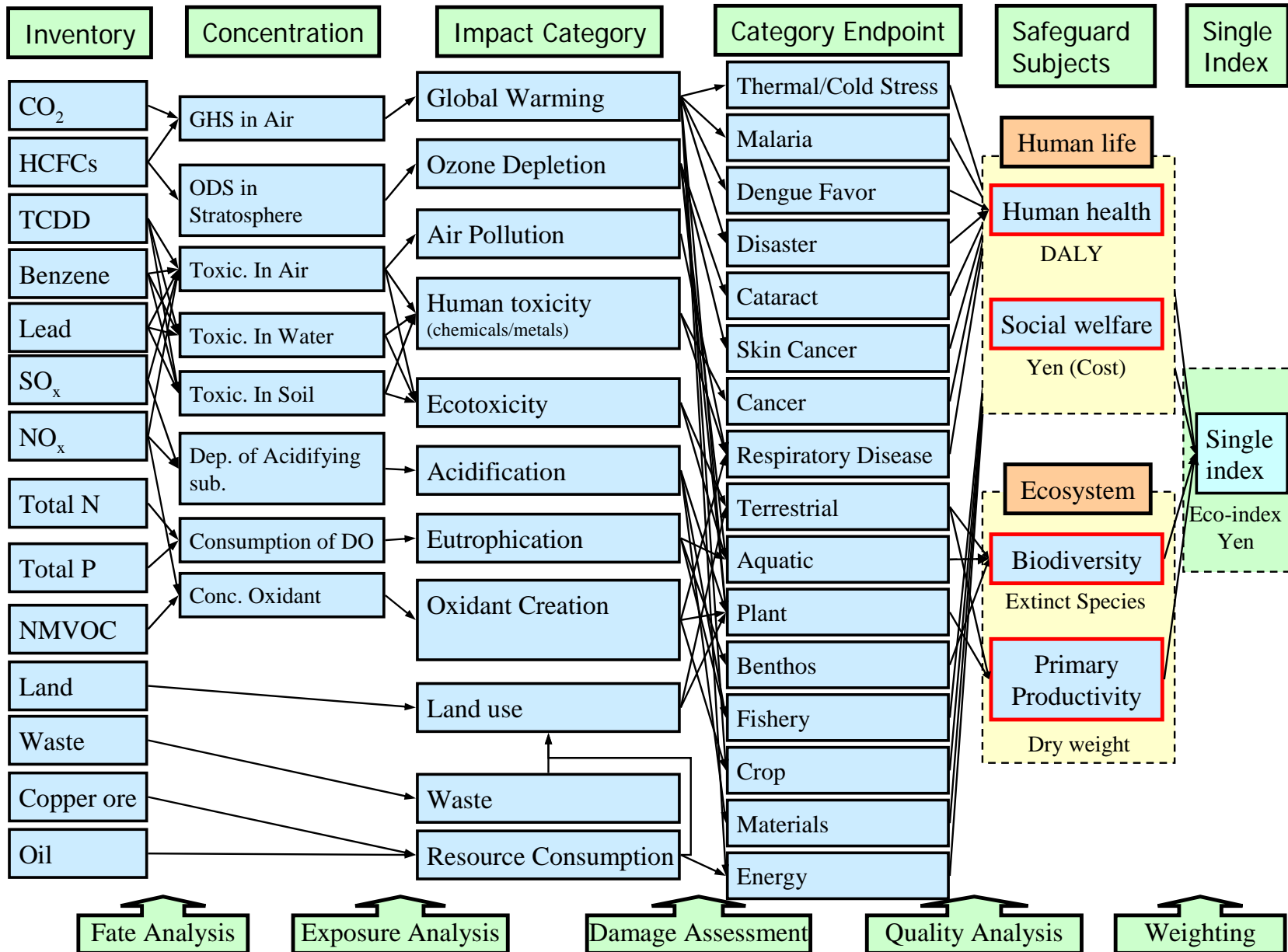


Fig. Conceptual Figure of LIME

# What are the local benefits?

## How is it measured?

- Depends on the goal of the local development
- In this project ...
  - Project goal : Introduction of facilities to meet the needs of residents and employees
  - ⇒ The local benefits are defined as the needs of both the residents and employees needs
- Needs are based on their subjective preferences
  - Stated Preference(SP) method
    - ex. CVM, Conjoint Analysis

**We estimated it using the Conjoint Analysis**

# Methodology: About Conjoint Analysis

- It originated in mathematical psychology in the 1970s.
- It is used in the social sciences, marketing and product management.
- It assumes that the utility (value) for a product can be expressed as a sum of utilities for its attributes (“part-worths”).

$$U = u(a_1) + u(a_2) + \dots = \sum_{\text{attributes}} \text{utilities}$$

- It can quantify the utility of the products.
- If it examines attributes including the payment attribute, it can estimate the utility of product as monetary value.

# Methodology: Conjoint Analysis in this study

- Utility for facility introduction and location for 20 years

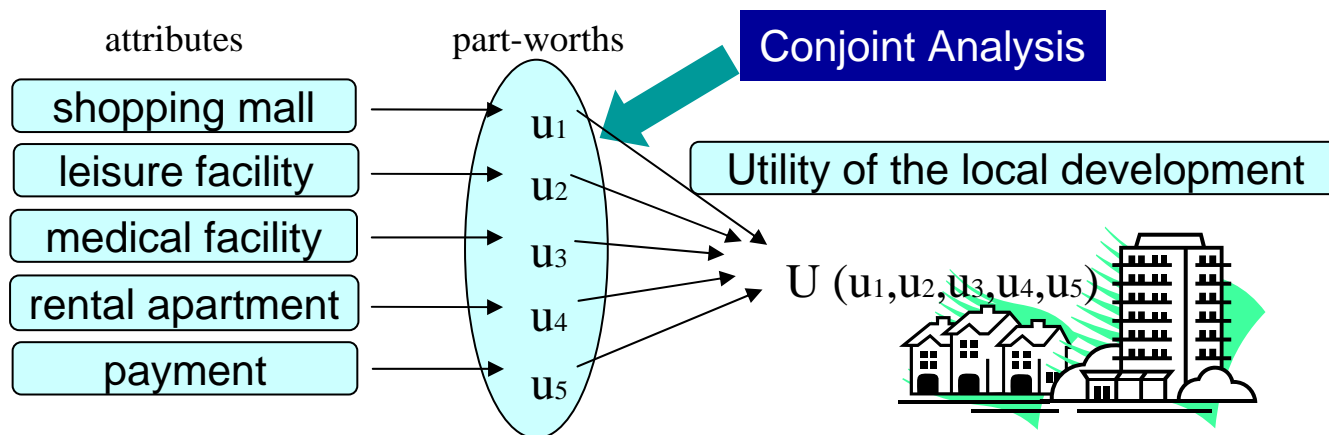


Table. Attributes and level of conjoint in this study

|   | attribute 1                 | attribute 2                             | attribute 3                 | attribute 4                 | attribute 5                     |
|---|-----------------------------|---|-----------------------------|-----------------------------|---------------------------------|
|   | Area of commercial facility | Households of rental apartment building | version of medical facility | version of leisure facility | amount of payment per household |
| 1 | 4,000 m2                    | No development                          | No development              | No development              | 10,000 yen                      |
| 2 | 8,000 m2                    | 10                                      | Clinic                      | Park                        | 20,000 yen                      |
| 3 | 16,000 m2                   | 50                                      | Collective clinics          | restaurant                  | 50,000 yen                      |
| 4 | 32,000 m2                   | 100                                     | General clinic              | Karaoke                     | 100,000 yen                     |
| 5 | —                           | —                                       | —                           | Bathhouse                   | —                               |
| 6 | —                           | —                                       | —                           | Culture school              | —                               |
| 7 | —                           | —                                       | —                           | Cinema complex              | —                               |
| 8 | —                           | —                                       | —                           | Gym                         | —                               |

# Methodology: Conjoint Analysis in this study

- Questionnaire method: Choice Based Conjoint (CBC)
  - “Please choose the best plan for you.”

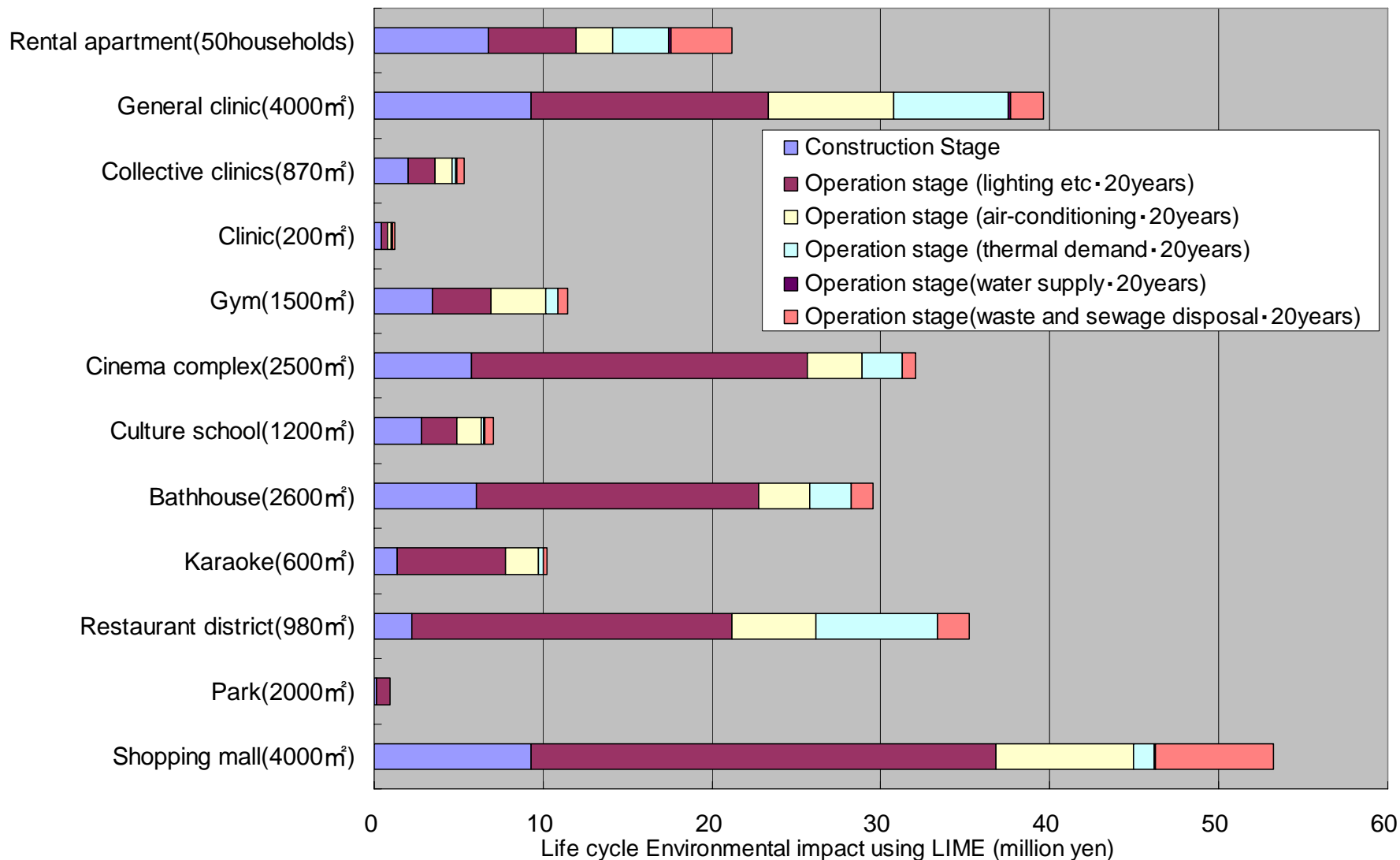
|                       | Plan no.1                       | Plan no.2                              | Plan no.3                        | Plan no.4                        | Plan no.5     |
|-----------------------|---------------------------------|--|----------------------------------|----------------------------------|---------------|
| Shopping mall         | Small<br>(4,000m <sup>2</sup> ) | Extra large<br>(32,000m <sup>2</sup> ) | Middle<br>(8,000m <sup>2</sup> ) | Large<br>(16,000m <sup>2</sup> ) | No developing |
| Leisure facility      | -                               | Bathhouse                              | Gym                              | Cinema complex                   |               |
| Medical facility      | -                               | Collective clinics                     | -                                | Clinic                           |               |
| Rental Apartment      | -                               | -                                      | 50 households                    | 10 households                    |               |
| Payment per household | 10,000 JPY                      | 20,000 JPY                             | 20,000 JPY                       | 100,000 JPY                      |               |
|                       | ↓                               | ↓                                      | ↓                                | ↓                                | ↓             |
| answer                | 1                               | 2                                      | 3                                | 4                                | 5             |

Such a question was repeated eight times per man.

# Results: Inventory analysis

| version of facilities           |                             | Shopping mall          | Park                   | Restaurant district  | Karaoke              | Bathhouse              | Culture school         | Cinema complex         | Gym                    | Clinic               | Collective clinics   | General clinic         | Rental apartment |
|---------------------------------|-----------------------------|------------------------|------------------------|----------------------|----------------------|------------------------|------------------------|------------------------|------------------------|----------------------|----------------------|------------------------|------------------|
| size of facilities              |                             | 4,000(m <sup>2</sup> ) | 2,000(m <sup>2</sup> ) | 980(m <sup>2</sup> ) | 600(m <sup>2</sup> ) | 2,600(m <sup>2</sup> ) | 1,200(m <sup>2</sup> ) | 2,500(m <sup>2</sup> ) | 1,500(m <sup>2</sup> ) | 200(m <sup>2</sup> ) | 870(m <sup>2</sup> ) | 4,000(m <sup>2</sup> ) | 10(household)    |
| resource and energy consumption | coal                        | 2.33E+06               | 5.75E+04               | 1.57E+06             | 5.87E+05             | 1.40E+06               | 1.90E+05               | 1.63E+06               | 3.02E+05               | 4.02E+04             | 1.82E+05             | 1.25E+06               | 1.07E+05         |
|                                 | natural gas                 | 2.79E+06               | 6.91E+04               | 1.88E+06             | 6.98E+05             | 1.67E+06               | 2.31E+05               | 1.94E+06               | 3.70E+05               | 4.83E+04             | 2.18E+05             | 1.52E+06               | 1.29E+05         |
|                                 | crude oil                   | 1.30E+06               | 2.36E+04               | 1.57E+06             | 1.84E+05             | 7.54E+05               | 2.19E+05               | 7.71E+05               | 5.88E+05               | 3.19E+04             | 1.40E+05             | 1.96E+06               | 1.66E+05         |
|                                 | iron                        | 3.53E+05               | 1.14E+04               | 8.64E+04             | 5.29E+04             | 2.29E+05               | 1.06E+05               | 2.20E+05               | 1.32E+05               | 1.76E+04             | 7.67E+04             | 3.53E+05               | 4.89E+04         |
|                                 | copper                      | 1.94E+03               | 8.82E+01               | 4.75E+02             | 2.91E+02             | 1.26E+03               | 5.77E+02               | 1.20E+03               | 7.22E+02               | 9.74E+01             | 4.24E+02             | 1.95E+03               | 2.59E+02         |
|                                 | aluminium                   | 2.04E+04               | 2.50E+01               | 5.38E+03             | 6.04E+02             | 3.58E+03               | 1.57E+03               | 2.38E+03               | 1.48E+03               | 3.04E+02             | 1.32E+03             | 6.07E+03               | 2.06E+03         |
|                                 | limestone                   | 5.47E+05               | 6.02E+04               | 1.34E+05             | 8.18E+04             | 3.54E+05               | 1.64E+05               | 3.41E+05               | 2.04E+05               | 2.73E+04             | 1.19E+05             | 5.45E+05               | 9.27E+04         |
| environmental burden            | CO <sub>2</sub>             | 1.95E+07               | 3.47E+05               | 1.40E+07             | 3.95E+06             | 1.09E+07               | 2.20E+06               | 1.21E+07               | 4.03E+06               | 4.00E+05             | 1.78E+06             | 1.46E+07               | 1.43E+06         |
|                                 | CH <sub>4</sub>             | 4.88E+02               | 6.74E+00               | 2.40E+02             | 9.25E+01             | 2.57E+02               | 5.36E+01               | 2.00E+02               | 7.66E+01               | 1.50E+01             | 6.61E+01             | 3.53E+02               | 6.61E+01         |
|                                 | PM(point)                   | 7.61E+02               | 2.46E+01               | 2.90E+02             | 5.35E+01             | 2.21E+02               | 8.12E+01               | 1.96E+02               | 1.13E+02               | 1.42E+01             | 6.21E+01             | 4.38E+02               | 8.13E+01         |
|                                 | PM(non-point)               | 6.84E+00               | 1.69E-01               | 4.63E+00             | 1.73E+00             | 4.10E+00               | 5.47E-01               | 4.78E+00               | 8.74E-01               | 1.15E-01             | 5.23E-01             | 3.63E+00               | 3.00E-01         |
|                                 | N <sub>2</sub> O            | 1.03E+03               | 2.24E+01               | 7.02E+02             | 2.37E+02             | 5.89E+02               | 8.84E+01               | 6.60E+02               | 1.50E+02               | 1.87E+01             | 8.40E+01             | 6.13E+02               | 6.06E+01         |
|                                 | NO <sub>x</sub> (point)     | 1.67E+04               | 1.63E+02               | 7.88E+03             | 2.46E+03             | 8.38E+03               | 2.71E+03               | 8.50E+03               | 3.76E+03               | 4.74E+02             | 2.08E+03             | 1.16E+04               | 1.69E+03         |
|                                 | NO <sub>x</sub> (non-point) | 8.56E+01               | 2.12E+00               | 5.79E+01             | 2.16E+01             | 5.13E+01               | 6.85E+00               | 5.99E+01               | 1.09E+01               | 1.44E+00             | 6.54E+00             | 4.55E+01               | 3.75E+00         |
|                                 | SO <sub>x</sub>             | 5.82E+03               | 5.94E+01               | 2.31E+03             | 9.89E+02             | 3.36E+03               | 1.16E+03               | 3.41E+03               | 1.50E+03               | 2.04E+02             | 8.92E+02             | 4.49E+03               | 5.78E+02         |
|                                 | sewage sludge               | 1.12E+02               | 0.00E+00               | 2.88E+01             | 1.76E+01             | 6.54E+01               | 2.11E+01               | 0.00E+00               | 2.97E+01               | 7.59E+00             | 3.30E+01             | 1.52E+02               | 3.79E+01         |
|                                 | water supply sludge         | 2.15E+03               | 3.59E+02               | 5.55E+02             | 3.40E+02             | 1.26E+03               | 4.07E+02               | 5.96E+02               | 5.72E+02               | 1.46E+02             | 6.36E+02             | 2.93E+03               | 7.30E+02         |
|                                 | other waste                 | 3.19E+05               | 9.07E+03               | 8.14E+04             | 2.74E+04             | 1.27E+05               | 5.81E+04               | 1.14E+05               | 6.86E+04               | 9.97E+03             | 4.34E+04             | 1.99E+05               | 2.50E+04         |
| slag                            | 2.63E+04                    | 1.16E-02               | 1.55E+04               | 2.80E+03             | 9.96E+03             | 2.88E+03               | 1.16E+04               | 6.99E+03               | 2.82E+03               | 1.23E+04             | 5.64E+04             | 1.14E+04               |                  |
| fly ash                         | 2.11E+04                    | 0.00E+00               | 5.57E+03               | 5.90E+02             | 3.60E+03             | 1.59E+03               | 2.46E+03               | 1.47E+03               | 3.00E+02               | 1.30E+03             | 6.00E+03             | 0.00E+00               |                  |

# Results: LCIA using LIME



# Results: Conjoint Analysis 1

## Utility model for the residents

$$V = \beta_{sm}SM + \beta_{sm^2}SM^2 + \sum_{d=1}^7 \beta_{rec}REC_d + \sum_{d=1}^3 \beta_{medi}MEDI_d + \beta_{resi}RESI + \beta_{cost}COST + \sum_{d=1}^n \beta_{cross}CROS_d$$

$\beta$  : parameters of part-worth  $SM$ : area of Shopping mall (m<sup>2</sup>)  $REC$ : version of Leisure facility (0,1)

$MEDI$ : version of medical facility(0,1)  $RESI$ : households of apartment  $COST$ : payment (JPY)  $CROS$ :cross product (0,1)

|  |                     | $\beta$ | WTP (JPY) | \$      |     |
|--|---------------------|---------|-----------|---------|-----|
| Payment (10,000yen)                                    |                     | -0.201  | -         |         | *** |
| Area of Shopping mall (1,000m <sup>2</sup> )           |                     | 0.047   | 2,300     | 20.00   | *** |
| Square of Area of Shopping mall (1,000m <sup>2</sup> ) |                     | -0.001  | -6        | -0.05   | *** |
| Leisure facilities                                     | Park                | 0.460   | 22,900    | 199.13  | *** |
|  | Restaurant district | 0.458   | 22,800    | 198.26  | *** |
|  | Karaoke             | -0.648  | -32,200   | -280.00 | *** |
|  | Bathhouse           | 0.573   | 28,500    | 247.83  | *** |
|  | Culture school      | -0.130  | -         | -       |     |
|  | Cinema complex      | 0.534   | 26,600    | 231.30  | *** |
|  | Gym                 | 0.142   | -         | -       |     |
| Medical facilities                                     | Clinic              | 0.708   | 35,200    | 306.09  | *** |
|  | Collective clinics  | 1.142   | 56,900    | 494.78  | *** |
|  | General clinic      | 1.415   | 70,500    | 613.04  | *** |
| Households of Rental Apartment (10households)          |                     | -0.017  | -1,000    | -8.70   | **  |
| Cross product (general clinic x elderly households)    |                     | 0.343   | 17,100    | 148.70  | **  |
| Number of choice (N)                                   |                     |         | 1966      |         |     |
| Likelihood ratio index (LRI)                           |                     |         | 0.122     |         |     |

\*: significant at <10%, \*\*: significant at <5%, \*\*\*: significant at <1%

\$1 = 115 JPY

# Results: Conjoint Analysis 2

## Utility model for the employees

$$V = \beta_{sm} SM + \sum_{d=1}^7 \beta_{rec} REC_d + \sum_{d=1}^3 \beta_{medi} MEDI_d + \beta_{resi} RESI + \beta_{cost} COST$$

$\beta$  : parameters of part-worth  $SM$ : area of Shopping mall (m<sup>2</sup>)  $REC$ : version of Leisure facility (0,1)  
 $MEDI$ : version of medical facility(0,1)  $RESI$ : households of apartment  $COST$ : payment (JPY)

|   |                     | $\beta$ | WTP (JPY) | \$      |     |
|---|---------------------|---------|-----------|---------|-----|
| Payment (10,000yen)                           |                     | -0.323  | -         |         | *** |
| Area of Shopping mall (1000m <sup>2</sup> )   |                     | 0.026   | 800       | 6.96    | *** |
| Leisure facilities                            | Park                | 0.418   | 28,100    | 244.35  | *** |
|   | Restaurant district | 0.907   | 22,800    | 198.26  | *** |
|   | Karaoke             | -0.387  | -12,000   | -104.35 | *   |
|   | Bathhouse           | 0.879   | 27,200    | 236.52  | *** |
|   | Culture school      | -0.273  | -8,500    | -73.91  | *   |
|   | Cinema complex      | 0.853   | 26,400    | 229.57  | *** |
|   | Gym                 | 0.908   | 28,100    | 244.35  | *** |
| Medical facilities                            | Clinic              | 0.576   | 17,800    | 154.78  | *** |
|   | Collective clinics  | 0.810   | 25,000    | 217.39  | *** |
|   | General clinic      | 1.178   | 36,400    | 316.52  | *** |
| Households of Rental Apartment (10households) |                     | -0.002  | -         | -       |     |
| Number of choice (N)                          |                     |         | 1182      |         |     |
| Likelihood ratio index (LRI)                  |                     |         | 0.125     |         |     |

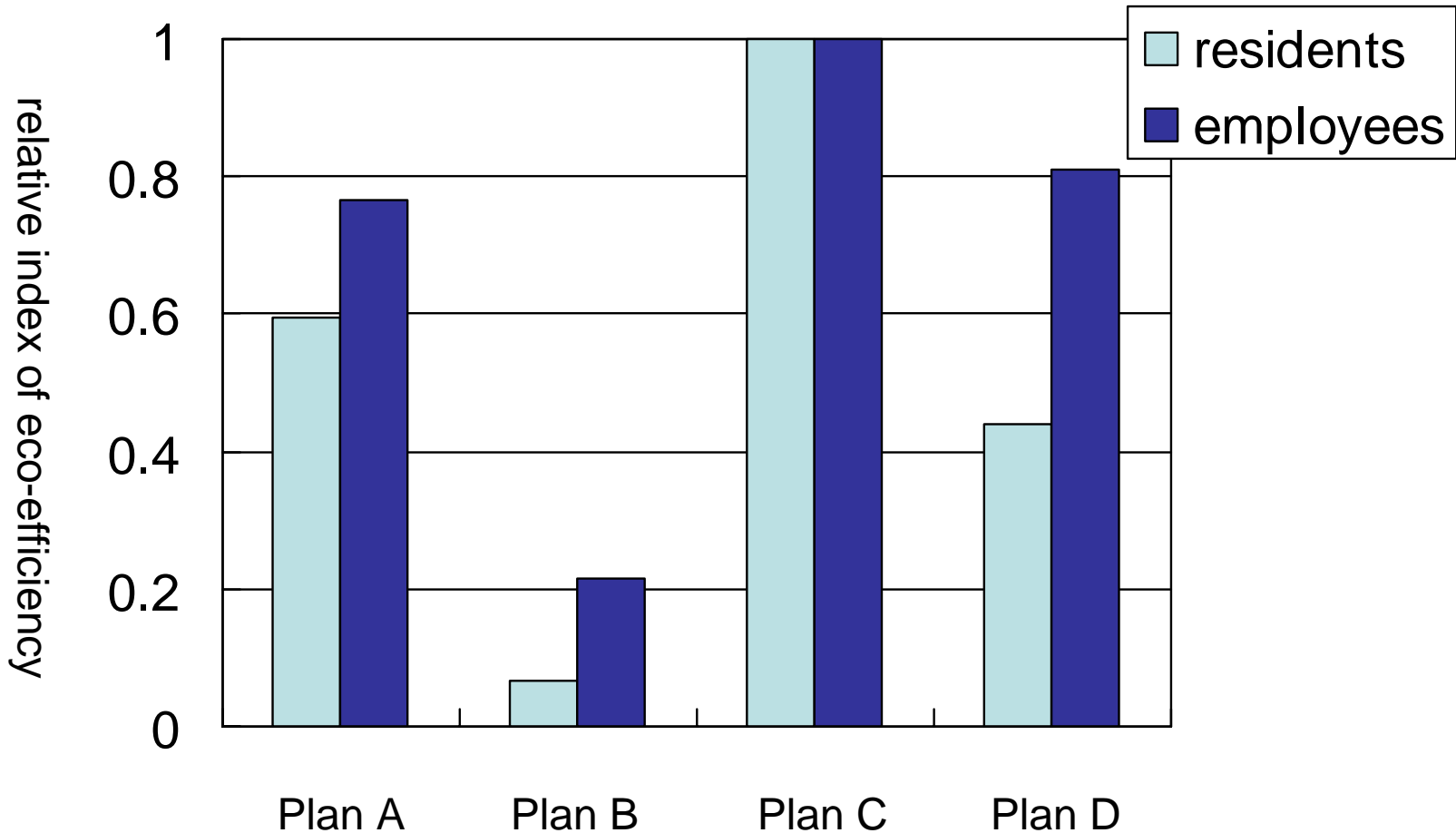
\*: significant at <10%, \*\*: significant at <5%, \*\*\*: significant at <1% \$1 = 115 JPY

# Results: Comparison of some of the proposals

|  | Plan A         | Plan B       | Plan C            | Plan D                           |
|--|----------------|--------------|-------------------|----------------------------------|
| Shopping mall (m <sup>2</sup> )            | 20,000         | 25,000       | 8,000             | 15,000                           |
| Leisure facility                           | bathhouse      | karaoke      | park              | bathhouse<br>restaurant district |
| Medical facility                           | general clinic | clinic       | collective clinic | -                                |
| Rental Apartment (household)               | -              | 100          | 50                | -                                |
| Environmental impact<br>(LIME-million yen) | 351            | 403          | 150               | 280                              |
| Residents benefit (million yen)            | 441            | 57           | 316               | 259                              |
| Employees benefit (million yen)            | 188            | 61           | 105               | 159                              |
| Eco-efficiency (residents)                 | <b>1.256</b>   | <b>0.141</b> | <b>2.107</b>      | <b>0.925</b>                     |
| Eco-efficiency (employees)                 | <b>0.535</b>   | <b>0.151</b> | <b>0.700</b>      | <b>0.568</b>                     |

Note: Benefit of Rental apartment for employee is not significant.  
 Some employees reside in the town.

# Results: Comparison of some of the proposals



Note: plan C's eco-efficiency = 1

# Summary and future plans

- We studied the eco-efficiency index of local development by local governments using LCA and Conjoint analysis.
- From this analysis, it is possible to provide insights relative comparisons between the local development proposals.
- We would like to add another benefit model to this index.