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Development of LCA Tool for Use in Initial Stage of Housing Design Based on Endpoint Modeling of Residents

Part 1 Examination of Assessment Framework

Graduate School of Systems Science and Technology,
Doctoral Course, Akita Prefectural University, Japan
Azusa Takayama

Introduction（1/3）

Life-cycle assessment (LCA) tools for buildings can be classified into two categories.

Characterization LCA tool — It assesses potential effects for specific region of global environmentand human health.

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Integrated LCA tool — It integrates influences to a number of regions and assesses by single index.

The integrated LCA tool can be further classified into two categories.

Problem comparison type ⟷ **Endpoint type**

Introduction（2/3）

- In previous LCA tool for detached house in Japan, there are characterization LCA tool and integrated LCA tool of problem comparison type.
- But there is NOT integrated LCA tool of endpoint type for building in Japan.

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- If there is integrated LCA tool of endpoint type for building and it could comprehensively assess direct influence of building safety and comfort to residents, it could examine cost-effectiveness at local or personal level.
- It promises to use as communication tool for client with architect to determine a direction of housing design for initial stage.

Introduction（3/3）

In this study, we develop an integrated LCA tool of endpoint type for housing assumed that use for initial stage of housing design.

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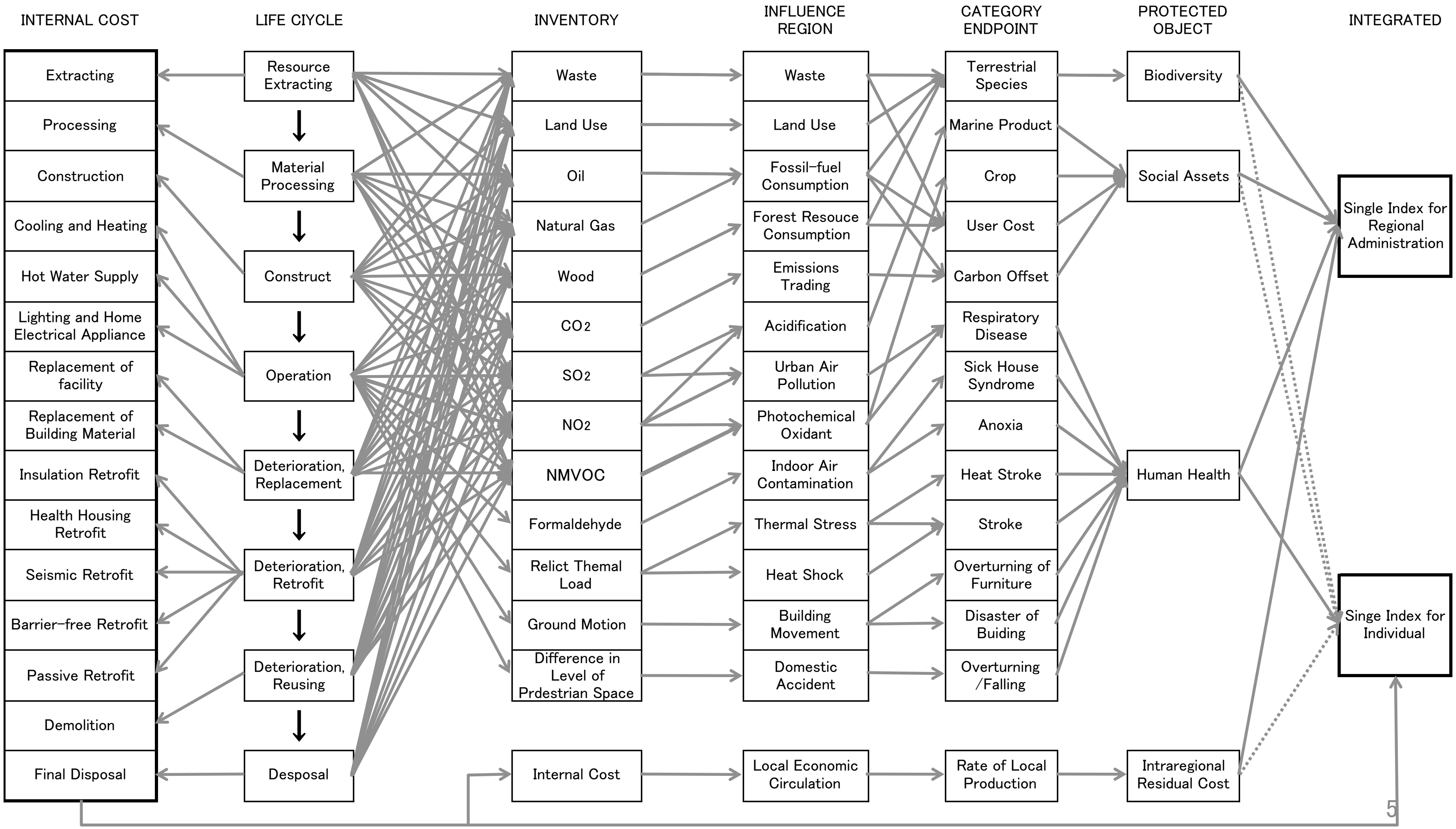
In this part, we adopt method of Japanese version of Life-cycle Impact assessment Method based on Endpoint modeling (LIME2) and examine concerning assessment framework for detached house.

Assessment framework



Case study
Calculation model (1/2)

The cost was calculated for a case study using the assessment framework of LIME2 and the results were analyzed to examine the efficacy of the assessment framework.

Table 1: Resident information

	H1	H2
Number of baths and showers	7 times/ person・week	7 times/ person・week
First year of assessment	Husband: 25 years old, Wife: 23 years old	Husband :55 years old, Wife: 53 years old
Changes in household composition	A girl is born in the sixth year. A boy is born in the eighth year. The girl leaves the house in tthe 24th year. The boy leaves the house in tthe 26th year	Husband dies In the 26th year.

Case study
Calculation model (2/2)

Table 2: Housing information for type of house

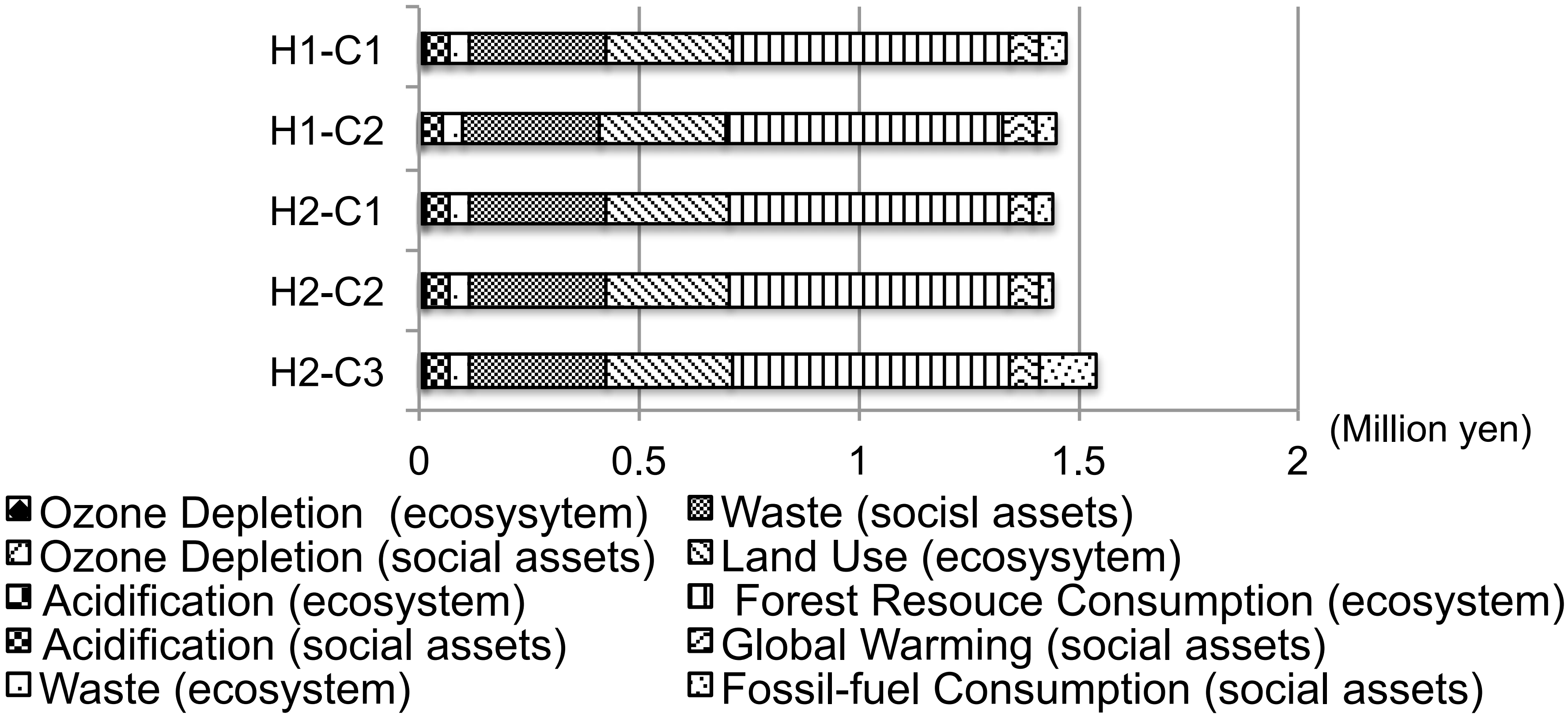
		C1	C2	C3
Insulation (thicknes s)	Ceiling	Glass wool 10K (65mm)	Glass wool 10K (200mm)	Glass wool 10K (200mm)
	Wall	Glass wool 10K (45mm)	Glass wool 10K (100mm)	Glass wool 16K (100mm)
	Floor	Glass wool 10K (40mm)	Glass wool 10K (100mm)	Glass wool 16K (100mm)
Air change rate （time/h）		1.0	0.5	0.5
Heat transmission coefficient （W/㎡ K）		5.8	2.8	2.8
Q valie (W/㎡ K)		4.14	1.87	1.87
Energy saving standerd		Old generation energy saving standard	Future generation energy saving standard	Future generation energy saving standard
Air conditioner location		Parlor only	Parlor only	All rooms
Furniture（height）		High chest (138cm), Microwave oven (35cm), Book shelf (197cm), Shelf (120cm), Kitchen cabinet (192cm), Range stand (120cm), Television (66cm)		

Assessments of ecosystem and social assets Calculation method

Table 3: Assessment framework of ecosystem and social assets

Influence region	Waste, Land Use, Forest Resource Consumption, Fossil-fuel Consumption, Ozone Depletion, Global Warming, Acidification
Inventory	Waste, Land Use, Wood, Oil, Natural Gas, CFC, CO_2, SO_2, NO_2

Assessments of ecosystem and social assets Results and discussion



- The costs of ozone depletion and global warming were small in the ecosystem and social assets.

Assessments of human health
Calculation method

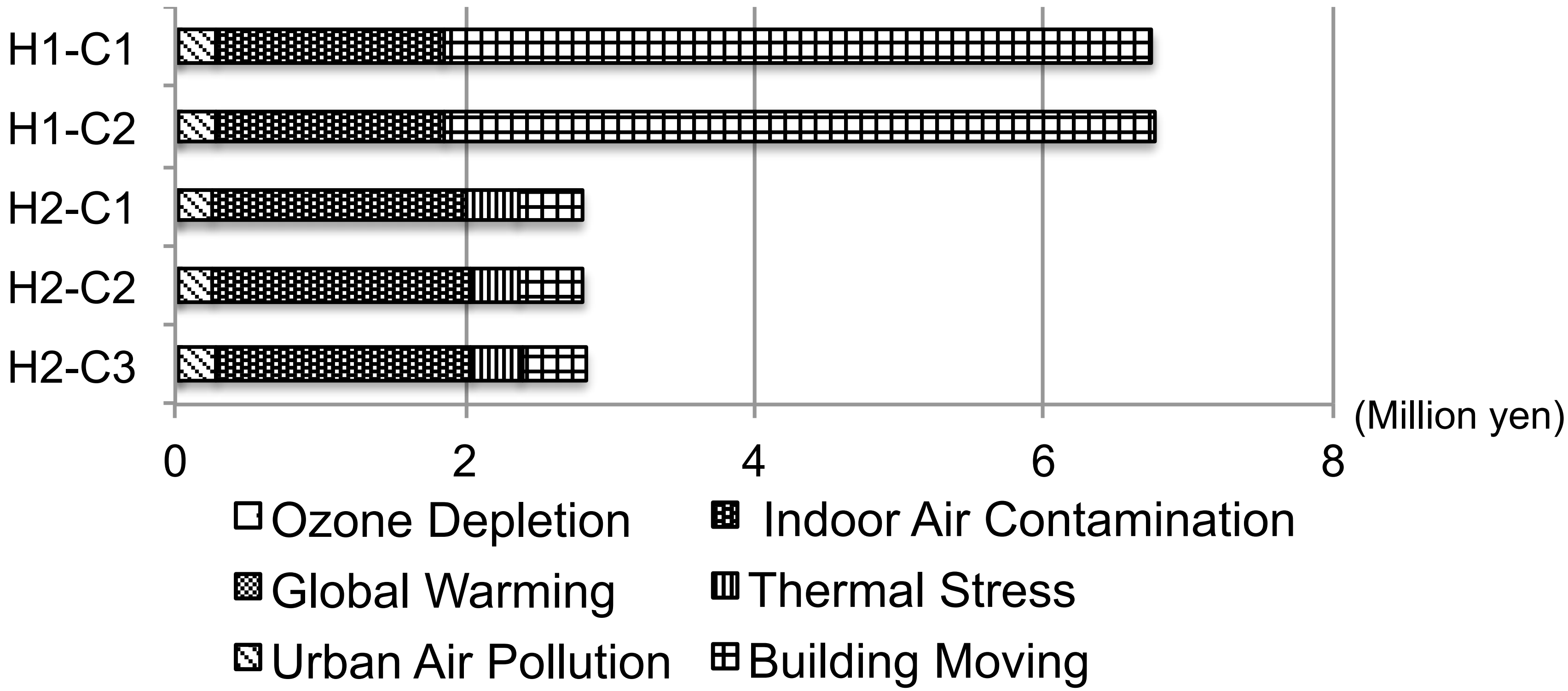
Table 4: Assessment framework of human health

Influence region	Ozone Depleting, Global Warming,Urban Air Pollution, Indoor Air Contamination, Thermal Stress, Building Movement
Inventory	CO_2, CFC, NO_2, SO_2, Formaldehyde, Relict Themal Load, Ground Motion

- Damage cost of human health is calculated by converting damage quantities into DALY.

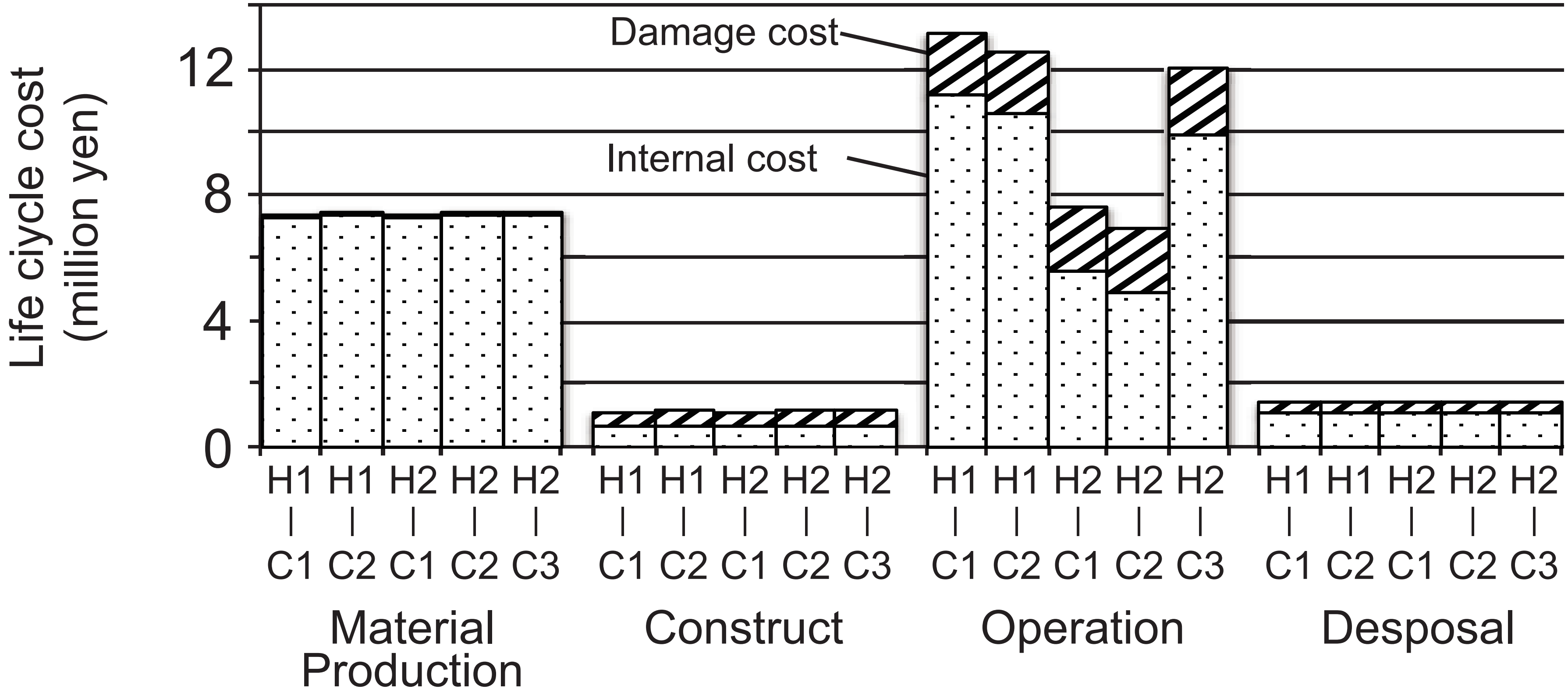
Source : https://en.wikipedia.org/wiki/Disability-adjusted_life_year

Assessments of human health
Results and discussion



- The amount of damage associated with toppling furniture is highest in the case of H1.
- The damage associated with ozone depletion and global warning are small.

Full-cost assessment



- It is thought that a full-cost assessment would encourage the client to choose housing using the cost-effectiveness estimate from the LCA.

Conclusion

- In this part of the study, we have proposed a new housing LCA tool that can comprehensively assess potential damage to residents, and we have tested the assessment framework in this tool.
- We carried out a case study to confirm the utility of this tool.
- According to the case study, the overall trend of the results showed that operational costs were the highest costs.

Assessment framework
Protected objects

In LIME2

"Human Health", "Biodiversity", "Social Asset" and "Primary Production."

- Since users of this tool are residents, Primary Production is excluded from protected object because it is considered that have low influence on decision-making of housing specification.
- Because required cost of housing (internal cost) is considered that have great influence on decision-making of housing specification, "Intraregional Residual Cost" contributed to local economy of internal cost is defined as protected object.

In this tool

"Human Health", "Biodiversity", "Social Asset" and "Intraregional Residual Cost."

Assessment framework Category endpoint (1/2)

- In this tool, it is premise of usage environment that house and housing ambient environment fulfills Building Standards Act and various environmental standards.

Biodiversity

Terrestrial species.

Social Assets

Crops, marine products, user cost and the carbon offset from CO_2 emissions trading.

Intraregional Residual Cost

The rate of local production for local consumption

Assessment framework Category endpoint (2/2)

- Noise, sunshine, daylight, and fire

  The assumptions made about the usage of housing in this tool.
- Vibration, humidity, and water

  Insufficient evidence about their influence.
- Radiation

  It represents a highly special case.
- Sound and color

  There are established solutions and these factors are routinely considered by almost every architect in the initial stage of housing design.

Human Health

Heat, air, and force and events related to these elements.

Assessment framework
Influence region

Biodiversity

Land use, fossil-fuel consumption, consumption of forest resources, and waste

Social Assets

Additional fossil-fuel consumption and consumption of forest resources, acidification, photochemical oxidants, waste and emissions trading.

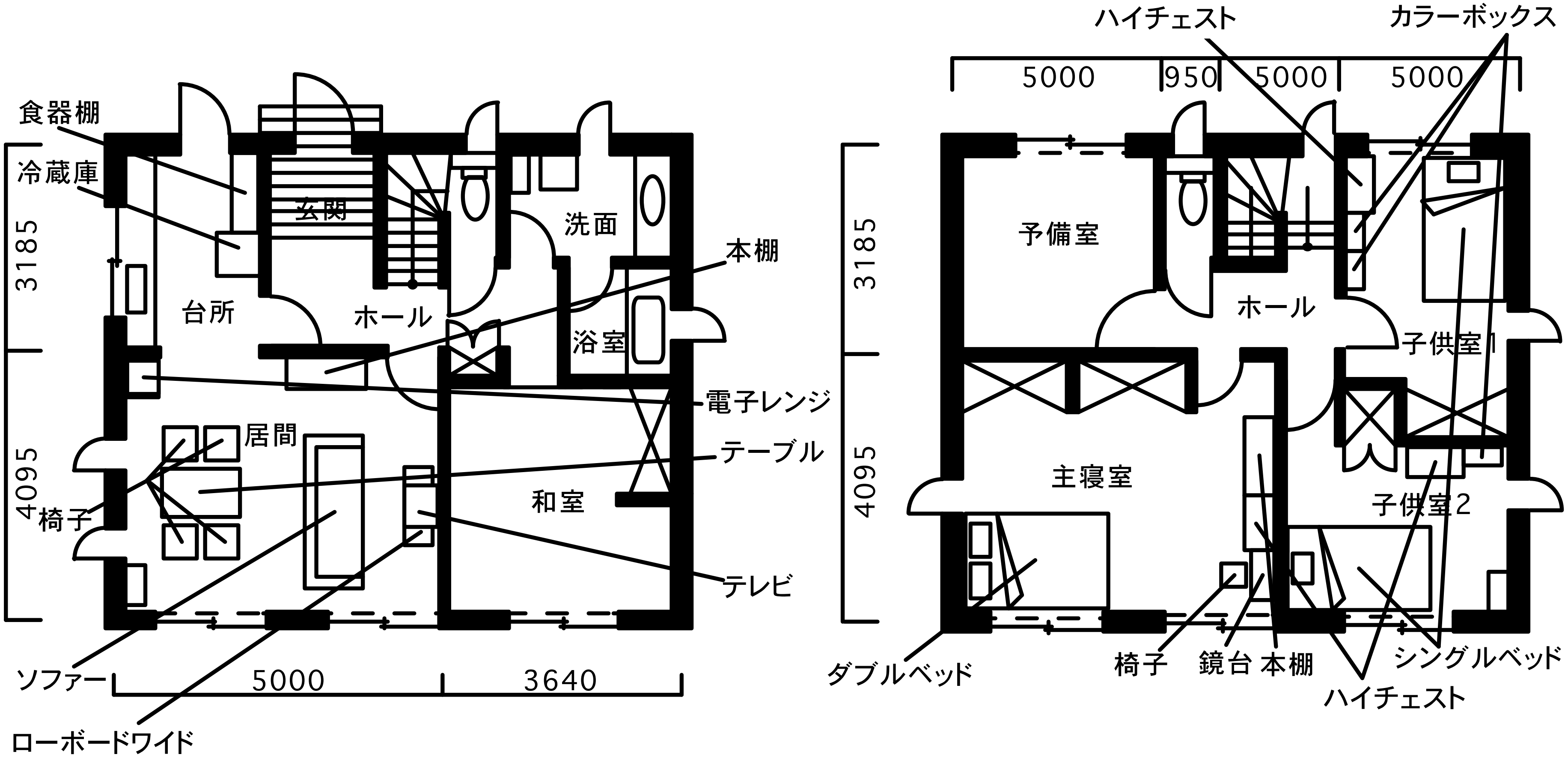
Intraregional Residual Cost

Local Economic Circulation.

Human Health

Thermal stress, heat shock, urban air pollution, photo-chemical oxidants, indoor air contamination, building movements, and domestic accidents.

Case study
Calculation model



Assessments of ecosystem and social assets Calculation method

Table 3: Assessment framework of ecosystem and social assets

Influence region	Waste, Land Use, Forest Resouce Consumption, Fossil-fuel Consumption, Ozone Depletion, Global Warming, Acidification
Inventory	Waste, Land Use, Wood, Oil, Natural Gas, CFC, CO_2, SO_2, NO_2

1) Damage to ecosystem and social assets

- Oil consumption was calculated from the heating load using a transient systems simulation pro-gram (TRNSYS).
- Schedules of cooling and heating were set using an automatic program for life-style scheduling (SCHEDULE).
- Natural gas consumption was estimated from the consumption of hot water using a previously reported formula (Sawachi, 1994).

Assessments of ecosystem and social assets Calculation method

The regression formulae

- Concrete: $y_c = 0.2073x_1 + 2.6164$ ･･･(1)
- Reinforcing bar: $y_r = 6.5011\ x_1 – 153.47$ ･･･ (2)
- Lumber: $y_w = 0.0464x_2 – 0.1596$･･･ (3)

y_c is concrete quantity, y_r is reinforcing bar quantity, y_w is lumber quantity, x_1 is the ground floor space, x_2 is total floor space.

The formula for the amount of damage

(Damage quantity) = (Damage coefficient) × (Inventory quantity)

Assessments of ecosystem and social assets Calculation method

2) Internal cost

- Costs of cooling and heating were converted from the cooling load and heating load calculated using TRNSYS.
- To determine the costs of hot-water supply and lighting, the energy consumption was calculated using a previously reported formula (Sawachi, 1994), and these were converted to costs.
- The costs of city gas and heating oil were three yen/MJ and 22 yen/kWh for electrical power.
- The costs associated with materials manufacturing, construction, and disposal were calculated using the detached house version of the LCA tool for buildings from the Architectural Institute of Japan.

Assessments of human health Calculation method

- As in LIME2, the conversion of DALY to yen was 14.7 million yen/DALY, which represents the cost of a reduction in life expectancy.
- This value does not include medical costs, and this will be addressed in future studies.

1）Damage quantities caused by indoor air contamination and thermal stress

- The cost of sick house syndrome was calculated using a previously reported formula (Narita, et al., 2005).
- The release rate of formaldehyde from floors is 20 μg/m^2h and from walls/ceilings is 5 μg/m^2h.

Assessments of human health Calculation method

- The annual indoor temperature was calculated, and the DALY resulting from heat stress and cold stress was calculated using a previously reported formula (Honda, et al., 1998)
- The indoor temperature was modified to reflect improvements in the indoor temperature.

(Modified daily maximum temperature)

= (Daily maximum temperature)

× (Mean indoor temperature of measured house)

/ (Mean indoor temperature of standard house)

Assessments of human health Calculation method

2）Damage caused by building moving

This damage was estimated by earthquake intensity and indoor condition. DALY was calculated according to the damage level, as shown below.

DALY = YLL + YDL ・・・ (6)

YLL = N × L ・・・ (7)

YDL = I × DW × L’ ・・・(8)

YLL is the number of years lost by premature death, YDL is the number of healthy years lost by disability, N is the number of deaths, L is the average life expectancy at the age of death, I is the number of accidents, DW is the injury weight, L’ is the average number of years until being cured or until death.

Assessments of human health
Calculation method

In this study, the formula for calculating the damage caused by toppling furniture is shown below.

YLL' = N × L ×(Mortality rate)
× (Earthquake occurrence probability) ・・・ (9)

YDL' = I × DW × L' × (Injury rate)
× (Earthquake occurrence probability) ・・・ (10)

YLL' is the number of years lost by premature death caused by toppling furniture, YDL' is the number of healthy years lost by disability caused by toppling furniture.

Assessments of human health Calculation method

The potential earthquake is off the coast of Akita prefecture (magnitude of 7.5) on the eastern margin of the Japan Sea.

- The expected earthquake intensity is a seismic intensity of six or lower (Akita prefecture disaster prevention council, 2011).
- The annual earthquake occurrence probability is 0.1%, and accumulates annually.
- The amount of damage accounts for the house-hold composition in the year it is calculated.
- The most damage is the result of toppling furniture.