Development of New Sustainability Indicators for EcoTopia Society

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Abstract: In recent years, a variety of sustainability indicators have been developed all over the world. However, there are few indicators that comprehensively assess the impacts and risks of social, economic, environmental and human factors. In this context, The EcoTopia Science Institute (2007) has been trying to develop new sustainability indicators, namely, "Indicators for EcoTopia Society (IES)" which try to evaluate various impacts and risks from the perspective of the level of the achievement of the EcoTopia society that is an ideal and sustainable future society. The IES is developed by utilizing some existing sustainability indicators, and is based on the concept of life cycle assessment (LCA). The IES is structured in terms of "QoSL (Quality of Sustainable Life)" and "Negative impacts on the environment". The QoSL is a new concept that is developed based on the idea of QoL (Quality of Life). The assessment elements of QoSL used for the IES are composed of human, social and economic factors. Meanwhile, the assessment items of "Negative impacts on the environment" include the consumption of materials, the decrease and degradation of ecosystem services, the risks to human health, the emissions of greenhouse gases (GHGs), and others. The purpose of this study is to propose new sustainability indicators and conduct a case study on the comparison of wooden houses and steel framed houses in Aichi prefecture, Japan. As a result, this study could assess the impacts on the QoSL and "Negative impacts on the environment".
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Key Words: *Sustainability Indicator, Life Cycle Assessment, Quality of Sustainable Life, ORT*

1. Introduction

The EcoTopia Science Institute (2007) has been engaging in the development of "Indicators for Sustainable EcoTopia Society (IES)" - sustainability indicators to be used for assessing the level of achievement of the "EcoTopia" which is a concept of an ideal future society in order to develop a sustainable society co-existing with nature in the 21st century. The IES is intended to be used to assess the impacts of a new science, technology and/or a social system. The important points for the development of the IES can be summarized as follows (the EcoTopia Science Institute, 2007):

(i) it includes the assessment of environment, economic, social and human factors;
(ii) it takes into consideration life cycle perspective; and
(iii) it assesses carrying capacity from the perspective of the achievement level of the EcoTopia society.

In order to develop the IES, some existing indicators as the follows were reviewed and compared from the perspective of environmental, economic, social and human factors (K. Hayashi et al., 2009):

- Gross Domestic Product (GDP);
- Green GDP that monetizes the impacts by net natural capital consumption, resource depletion, environmental degradation, and protective and restorative environmental initiatives, be subtracted from traditional GDP;
- Genuine Progress Indicator (GPI) that is designed to take fuller account of a nation's economy by incorporating environmental and social factors which are not measured by GDP;
- Human Development Index (HDI) that provides a composite measure of three dimensions of human development, namely, living a long and healthy life, being educated and having a decent standard of living;
- Human Satisfaction Measure (HSM) that is a sustainable social welfare indicator including

labor, health, education, gender, environment and economic categories;

- Life Cycle Assessment (LCA) that assesses environmental impacts associated with all the stages of a product's life from-cradle-to-grave;
- Ecological Footprint (EF) that evaluates humanity's demand on nature; and
- Environmental Sustainability Index (ESI) that is a measure of overall progress towards environmental sustainability.

Results showed that there were only few indicators which covered the wide range of the factors comprehensively. The EF is noteworthy that it analyzes and assesses the consumption of natural resources by human activities (Nakano and Wada, 2007) and therefore evaluates the impacts of human activities from the perspective of ecology and carrying capacity. The LCA was developed to assess a product and then was improved to assess a social system (Inaba, 2001; Itsubo, 2004). It is recognized as a useful tool to assess impacts by considering the entire life cycle of a targeted product or a social system from the raw material extraction to the waste disposal stage.

The IES was defined as the function of the "Negative Impacts on the environment" and "QoSL (Quality of Sustainable Life)" (EcoTopia Science Institute, 2007). "Negative Impacts on the environment" include various environmental impacts such as the emissions of greenhouse gases (GHGs), the consumption of materials, the decrease and degradation of ecosystem services, and the impacts on human health, etc. In order to assess the impacts on "QoSL" quantitatively, we chose three assessment categories, namely, economic aspects, social aspects and a human factor relating to the people's level of satisfaction from a psychological perspective.

In this study, we tried to test the IES in relation to wooden and steel framed houses hypothetically constructed in Aichi prefecture, Japan in order to assess the impacts of QoSL and "Negative Impacts on the environment" as a case study.

2. Case Study of Wooden House and Steel Framed House

2.1 Assessment of "QoSL" and "Negative Impacts on the Environment" by IES

Regarding the "Negative Impacts on the Environment" in this case study, three assessment approaches are employed, namely the Occupancy Ratio Time (ORT) proposed by Fujii, Hayashi and Ito (2010), biodiversity and ecosystem service assessment, and human health impact assessment.

According to Fujii, Hayashi and Ito (2010), the ORT assessment covers the consumption of materials, the emissions of pullutants including GHGs, the land occupation and the labor occupation. The ORT is the ratio of occupancy for a specified time period to total capacity to obtain a given amount of function. Occupancy is defined as a reversible use of something (in a sense it can be handed over to others after use) such as piece of land, material as well as a capacity for water supply or pollutant removal etc. over a period of time. For example, in order to assess the consumption of materials by the ORT, it is defined as the ratio of the amount and time period of occupation of the relevant materials to that of total capacity, in the process of consumption of it to obtain a given amount of function (eq 1). However, in this case study, the ORT is employed as a method for assessing only the impacts of consumption of materials including iron, wood, and cement, and CO_2 emissions for a case study of wooden and steel-framed houses. The consumption data of the materials in this study is calculated based on constructing life cycle inventory under LCA.

$$ORT = \frac{OA \times TM}{TA} \qquad \text{(eq 1)}$$

Where, (in the case of material)

ORT: Occupancy Ratio Time (years),

OA: amount of occupation of a material (kg, km^2, or person, depending on the aspect),

TM: period of occupation of a material (years),
TA: total capacity of relevant material (kg, km^2, or person, depending on the aspect), that is the sum of stock in a society and recoverable reserves for the material

Second we are developing a new assessment approach for ecosystem services by taking into account the life cycle of a product development. We estimated total impacted area in each land category through the life cycle of a product development based on the life cycle inventory constructed in the ORT assessment stage. Although there were various land categories related to this case stidy such as forest, coastal wetland, desert and sea, this case study focused only on forest and coastal wetland in Japan. That is because those two categories have bigger impacts on ecosystem services than that of others in this case, and also there are data limitations. After calculating the total impacted area, we multiplied it by the economic value estimated by Ito et al., (2012) and Ota and Hayashi (2011) to convert it into monetary values for estimating the total impacts on the society.

Thirdly regarding the impacts of human health, we tried to estimate the total external costs caused by air pollutants such as NOx, SOx, HC, CO and CH_4 simply based on the data from Delucchi (2000) and Japan Research Institute (1998).

To assess the QoSL quantitatively, factors such as the satisfaction and happiness of an averaged personal life, social sustainability, economic sustainability and psychological human factors should be included. However, it is beyond the scope of this study to assess those factors comprehensively at present. Thus, for our purposes, an internet survey about the purchase intent of wooden and steel framed houses was conducted, in order to indicate one part of human factors of the QoSL in Aichi prefecture. We also estimated the life cycle costs of wooden and steel framed houses for assessment of economic sustainability. Regarding the assessment of social sustainability, we assumed that the social impacts between wooden house and steel framed house were same.

2.2 Results of "Negative Impacts" and "QoSL"

We set up the functional unit such that "total floor space is $116m^2$ per a house that people can live for 120 years, and both a wooden house and a steel-framed house will be rebuilt every 30 years and 40 years respectively" because of a fair comparison under same function. Under those preconditions, we constructed a life cycle inventory including all consumed and exhausted materials based on the LCA concept.

Regarding the assessment of the QoSL, Figure 1 shows the results of human factors and total life cycle costs. The horizontal line of human factors indicates the average score of purchase intent in five-point scale. For assessing the score of QoSL simply, we asked the purchase intent of each house by questionnaire survey. The result showed that the total score of a wooden house was higher than that on a steel framed house.

In addition, total life cycle cost was estimated based on the cost data of all life cycles from Statistics Bureau of Ministry of Internal Affairs and Communications. As the result, the total life cycle costs per a house for both two houses were not so different, but the number of reconstruction of wooden house and steel framed house was 4 times and 3 times respectively in 120 years in functional unit. Thus, total life cycle cost of a wooden house in 120 years was higher than that of a steel framed house.

In order to estimate the impacts of GHGs and materials by the ORT, we inputted various data into above the ORT equation 1. The results of the GHGs (namely CO_2) assessment and the ORT materials assessment were that both the ORT value of the GHGs and the materials of steel-framed house were higher than that of wooden house because of CO_2 emissions in the smelting process of iron ore and the consumption amount of energy resources (Figure 2).

Figure 3 shows the external costs of health damage. These were calculated by summing up the total external costs caused by air pollutants such as NOx, SOx, HC, CO and CH_4 simply based on the data from Delucchi (2000) and Japan Research Institute (1998). As the result, although the amount of emissions of NOx was the highest among all pollutants, the total external cost of SOx was the largest.

That is because the external cost per 1kg of SOx is higher than that of NOx.

Figure 4 indicates the economic losses of each ecosystem service. As shown in this figure, the loss of total ecosystem services of wooden house was larger than that of steel-framed house because the economic value of ecosystem services of forest was bigger than that of coastal wetlands.

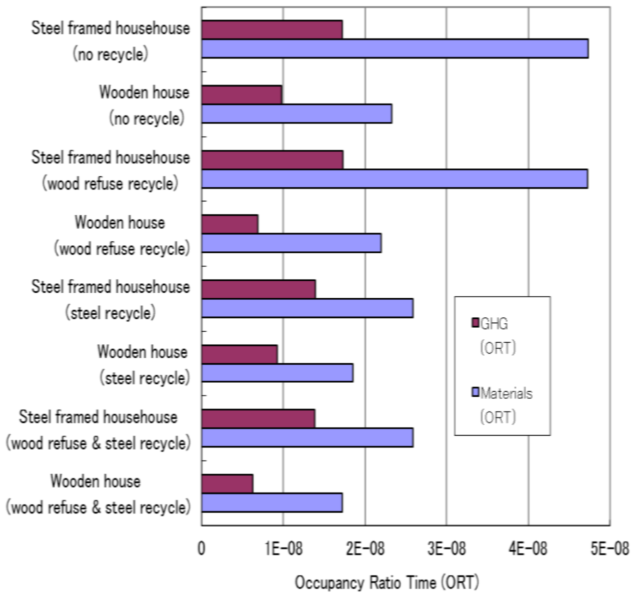

Figure 2 Results of GHGs and Materials by ORT

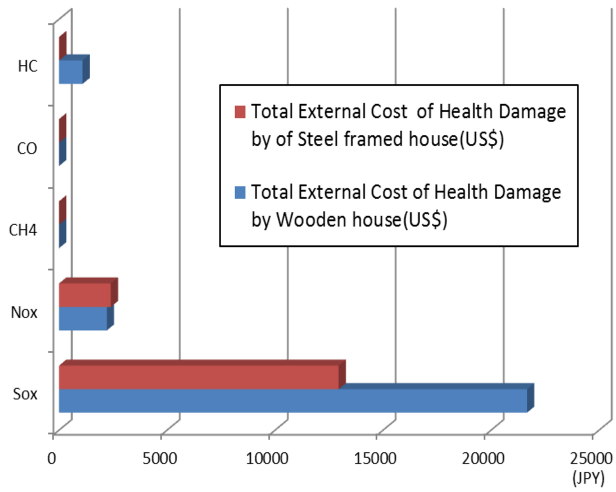

Figure 3 Total External Cost of Health Damage

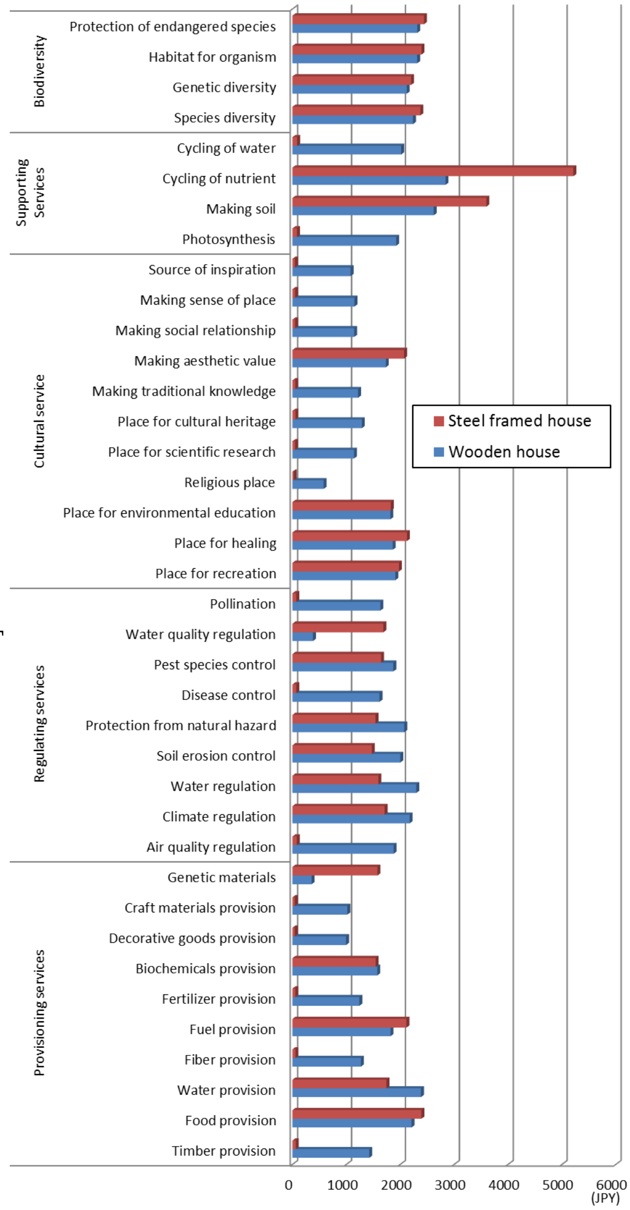

Figure 4 Economic Losses of Ecosystem Services

Figure 1 Results of Human Factors (left) and Total Life Cycle Cost (right)

2.3 Results of Comprehensive Assessment

The comparative assessment was carried out by standardizing the impact of steel-framed house as 100 based on the estimation results of each assessment. If the score is more than 100, it means that wooden house is better than that of steel-framed house in the QoSL assessment. Figure 5 shows the results of a cobweb chart. As a result, in this case the total score of the "QoSL" was less than 100, and we could indicate that steel-framed house was better than wooden house from the perspective of the QoSL.

Figure 5 also shows the assessment results of the GHGs emissions, human health impacts, the consumption of materials, ecosystem services and other impacts. On the contrary to the QoSL, lower score means that steel-framed house is better than that of wooden house in each assessment in "Negative Impacts on the Environment". As a result, the scores of the GHGs emissions and the consumption of materials were better than that of steel framed house, but human health impacts and biodiversity & ecosystem services were worse.

We also calculated the IES by dividing the total score of the QoSL by "Negative Impacts on the environment". As a result, we could conclude that steel framed house is better than that of wooden house in this case study. However, this result showed only one part of scenarios of this case study. The result will be changed depending on scenarios. The detailed analysis of several scenarios will be presented in the near future.

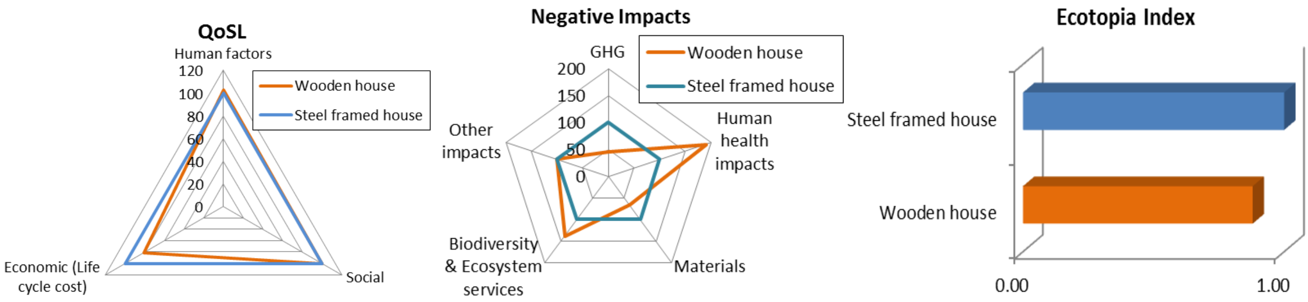

Figure 5 Results of Comprehensive Evaluation by Cobweb Chart and Ecotopia Index

3. Conclusion and for Further Study

In this study, the IES developed as one of new sustainability indicators was tested to apply to wooden houses and steel-framed houses constructed as a case study. In conclusion, we could indicate the basic comprehensive assessment method by the IES through the case study. For further study, it is necessary to expand each assessment indicator including human factors and social impacts, and then consider how to feedback the results with the evaluation of trade-off among various factors.

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