Estimation of the health effects and economic benefits of an improved residential environment

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Abstract. Costs are a barrier to improving residential environments during new construction and renovation. Previous research suggests that improving residential environments may contribute to improved health. If such health effects are quantified and recognized as economic benefits (lower medical costs and income from absenteeism), increased investment in residential improvements can be expected. Therefore, this study aimed to quantify the benefits of improving health through improvement of residential environments considering individual and household attributes. The effects of residential environment improvements were quantified at the individual and household levels. Data were collected via nationwide surveys of more than 45,000 residents in 15,000 households in Japan. Health status was compared between good and poor residential environments. Results showed that an improved residential environment contributed to reducing the likelihood of the onset of cardiovascular, allergic and other diseases. The annual economic benefit of improving the thermal insulation of windows for a man living alone was 7,000 JPY for example. This study contributes to promoting residents’ health by quantifying the economic benefits of the health effects of good-quality residential environments, which then contributes to achieving Sustainable Development Goals 3 and 11.

1. Introduction
The high costs of improving the residential environment are a disincentive for housing investment. Numerous studies have investigated the relationship between the residential environment and residents’ health and found that improving the residential environment contributes to health promotion [1]. If such health effects of improving the residential environment are quantified and recognized as economic benefits, then housing investment will be promoted.

Therefore, this study aimed to quantify the economic benefits of residents’ health through improvement of their residential environment.

2. Methods
This study used the data of two previous online questionnaire surveys. Survey outline is shown in table 1. The residential environment was assessed using the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) tool called the CASBEE Health Checklist, which can comprehensively evaluate the residential environment of houses from the viewpoints of residents’ health promotion.
Table 1. Overview of surveys.

| Survey 1 | Survey 2 |
|----------|----------|
| **Target** | Residents of **detached** houses nationwide | Residents of **apartment** houses nationwide |
| **Survey method** | Internet survey | Internet survey |
| **Survey period** | November 2010, February 2011 | February 2012 |
| **Final number of valid responses** | 5,325 households | 9,820 households |
| **15,145 households in total** |

Common
1. Attributes of respondents and family members living together
2. Basic house information

**Survey items**
3. Evaluation of house performance of housing (CASBEE Health Checklist)
4. Health status of respondents and family members living together
   · Hypertension
   · Conjunctivitis

Target diseases
- Arthritis
- Conjunctivitis

3. Results

3.1. Estimating the health benefits gained through improvement of the residential environment
First, the results of estimating the presence/absence of heart disease is shown in table 2 as an example. The probability of the onset of heart disease was reduced by improving the residential environment (higher Health score). A similar tendency was confirmed for all other diseases considered, suggesting that the improvement of the residential environment reduces the probability of the occurrence of these diseases.

Table 2. Logistic regression analysis results for heart disease.

| Explanatory variables | β    | Significance | EXP(B) |
|-----------------------|------|--------------|--------|
| Age [Year]            | 0.060| p<0.01       | 1.062  |
| Sex [1) Male 2) Female] | -0.959| p<0.01       | 0.383  |
| Smoking and drinking [0) Yes 1) No] | 0.033| n.s.         | 1.033  |
| Regular dietary habits [0) No 1) Yes] | 0.015| n.s.         | 1.015  |
| Moderate exercise [0) No 1) Yes] | -0.185| n.s.         | 0.831  |
| Diabetes [0) No 1) Yes] | 1.240| p<0.01       | 3.456  |
| Hypertension [0) No 1) Yes] | 0.567| p<0.01       | 1.763  |
| Health checklist [Point] | -0.014| p<0.01       | 0.986  |
| Housing type [1) Detached house 2) Apartment] | -0.111| n.s.         | 0.865  |
| Constant               | -4.669| p<0.01       | 0.009  |
| Hosmer-Lemeshow goodness-of-fit test |                  | 0.966  |

Second, the prevention ratio for each disease accompanying improvement the residential environment was predicted using equations (3.1) and (3.2).

\[
P_x = \frac{1}{1+\exp(-\left(b_0 + \sum b_n x_n \right))}
\]

(3.1)

Here, \( P_x \) is the predicted disease ratio for disease \( x \), \( b_0 \) is a constant, \( b_n \) is a standardized partial regression coefficient and \( x_n \) is an explanatory variable.

\[\Delta P_x = 1 - P_{ax} / P_{bx}\]

(3.2)

\( \Delta P_x \) is the predicted prevention ratio, \( P_{ax} \) is the predicted disease ratio after residential environment improvement and \( P_{bx} \) is the predicted disease ratio before residential environment improvement.
3.2. Estimating the economic benefits of improving the residential environment

Economic benefits due to improvement of the residential environment were estimated using the predicted prevention ratio mentioned in the previous section by using equations (3.3), (3.4) and (3.5). The total amount of medical expenses and the number of days of treatment are based on the Statistics of Medical Care Activities in Public Health Insurance [2], and the number of affected individuals is based on the Patient Survey [3].

\[
B = \sum_x \{(m_x + f_x) \times \Delta P_x\} \\
\]

(3.3)

Here, \(B\) is the economic benefits due to residential environment improvement [yen/(year-person)], \(m_x\) is the medical expenses per person due to disease \(x\) [yen/(year-person)] and \(f_x\) is the income loss per person due to disease \(x\) [yen/(year-person)].

\[
m_x = M_x r_x \\
\]

(3.4)

\(M_x\) is the total national medical expenses for disease \(x\) [yen/year], \(r_x\) is the number of patients in the country with disease \(x\) [persons].

\[
f_x = D_x r_x \times F \\
\]

(3.5)

\(D_x\) is the number of medical treatment days for disease \(x\) [(days·person)/year] and \(F\) is income per person per day [yen/(day-person)].

The following shows an example of estimating economic benefits due to improvement of the residential environment for the conditions in table 3. The subjects are set as 30-year-old men living in Tokyo, and their income was based on the 2017 Private Salary Survey [4]. Also, the Health Checklist score was set as 90 points, the average in Japan.

| Health Checklist score (Before improvement → After improvement) | 30 years old | 50 years old | 65 years old |
|---------------------------------------------------------------|--------------|--------------|--------------|
| Detached house                                                | 90 points (Before improvement) | 115 points (After improvement) |
| Smoking and drinking                                          | 0            | 0            | 0            |
| Regular dietary habits                                        | 0            | 0            | 0            |
| Moderate exercise                                             | 0            | 0            | 0            |
| Diabetes                                                      | 0            | 1            | 1            |
| Conjunctivitis                                                | 0            | 1            | 1            |
| Hypertension                                                  | 0            | 1            | 1            |
| Heart disease                                                 | 0            | 1            | 1            |
| Brain disease                                                 | 0            | 1            | 1            |
| Allergic rhinitis                                             | 0            | 1            | 1            |
| Pneumonia                                                     | 0            | 1            | 1            |
| Asthma                                                        | 0            | 1            | 1            |
| Atopic dermatitis                                             | 0            | 1            | 1            |
| Arthritis                                                     | 0            | 1            | 1            |

Economic benefits due to improvement of the residential environment were estimated (figure 1). The economic benefits of improving the thermal insulation of windows (an increase of 10 points in Health Checklist score [5]) was about 7,000 [yen/(year-person)]. This is equivalent to about 1/12 of the annual per capita medical expenses of 84,400 yen. Furthermore [6], the economic benefits of moving to a high-performance home (increase of 25 points in Health Checklist score [5]) was about 16,000 [yen/(year-person)]. Thus, the economic benefits of improving the residential environment were confirmed.
Finally, changes in the amount of economic benefits due to improvement of the residential environment were estimated by gender and age (figure 2). Economic benefits were greater for men than for women at the same age. This gap was due to the gender difference in average annual income.

![Figure 1](image1.png) **Figure 1.** Economic benefits due to improvement of the residential environment.

![Figure 2](image2.png) **Figure 2.** Changes in economic benefits by age.

4. Conclusions
The economic benefits of health effects due to the improvement of the residential environment were estimated in the study. In the future, a model will be developed that can estimate the health effects brought about by improvement of the residential environment on a larger scale (e.g., city or country level) using other public statistical information. Estimation of such economic benefits will support residents, house contractors, local governments, policy makers and all other stakeholders in recognizing the importance of promoting health, providing high-performance houses and considering effective policy measures. The accumulation of such research will contribute to achieving Sustainable Development Goals 3 and 11.

5. Acknowledgements
The authors express their sincere gratitude for the cooperation from all the persons concerned, especially those who responded to the online questionnaires. This study was also supported by JSPS Grant-in-Aid for Scientific Research(S) JP17H06151 and Scientific Research(C) JP19K04740.

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