Chapter 6

Discussion and Conclusion: Effectiveness, Characteristics and Future Prospects of the Methodology

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Additional information is available at the end of the chapter

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Abstract

Following the control system for promoting sustainable home design, we have designed a home and built it. The quantitative evaluations and reactions of the occupants and visitors on the home indicate that if system users closely follow the methodology, they can comprehensively achieve sustainable homes, which have high environmental performance. Meanwhile, the results of the study have suggested that this methodology has several characteristics, besides comprehensiveness. First, the diagram of the control system itself is useful because it concisely explains the whole picture of the sustainable design processes on both new and existing homes. Second, the “sustainable design guidelines” and “sustainability checklist” are user-friendly since the material and spatial elements are equivalent to real parts of homes. Moreover, the “element – variable – desired value” structure in the guidelines and checklist is superior in “adaptability to regional differences” and “flexibility toward changes over time.” We expect that this methodology is widely used, in coordination with the existing methods for sustainable housing. Furthermore, it can be theoretically applied to other categories of human activities, which are regarded as the complex of material and spatial elements.

Keywords: design process, visualization, “element – variable – desired value” structure, comprehensiveness, user-friendliness, adaptability, flexibility

1. Introduction

The last chapter has illustrated a case study in which a home has been designed and constructed, based on the methodology of applying control science to sustainable housing design. Reviewing the methodology and case study, this chapter explores the effectiveness, characteristics, and future prospects of the methodology. The discussion section also examines the capability of the methodology for the two significant changes, namely climate change and aging population, which have been presented in Chapter 1. Furthermore, the same section discusses how this methodology deals with the remaining issues in the existing Japanese systems, which have been raised in Chapter 2. After that, the final section summarizes the conclusions of the studies.

2. Discussion

This section discusses the results of this study from the following five perspectives: (1) effects of the methodology for promoting sustainable home design, (2) characteristics of the methodology, (3) coordination with the existing systems, (4) applicability of the methodology, and (5) future research.

2.1. Effects of the methodology for promoting sustainable home design

As illustrated in the case study, we have designed a detached house, following the methodology for promoting sustainable home design. That is to say, we have designed the house's parts or elements, so that the elements' variables satisfy their desired values as much as possible. After the house began to be used, we have obtained objective evaluations of the home's environmental and sustainability performance as well as various comments on the home from the occupants and visitors.

First, all of the objective and quantitative evaluations have shown that the home has considerably high environmental performance. According to CASBEE for detached houses, a comprehensive assessment system, the home has readily been ranked in the highest "S," with an extremely high score of built environment efficiency (BEE). Subsequently, the house has been classified into the highest "five star" by life cycle carbon minus (LCCM) certification, due to its higher energy saving performance and larger solar energy generation capacity. Meanwhile, the energy usage comparison with the average home has shown that the total energy usage of this home is equal to about 27% of the average home under the same conditions. The water usage comparison with the average home has also proved the higher water saving performance of this home. In addition, such high environmental performance has been highly evaluated when this house received the prize at the Sustainable Housing Awards.

The reactions of the occupants and visitors suggest that following the methodology has produced various favorable effects. On the other hand, any unfavorable side effects of utilizing the methodology have not been observed thus far. "Higher thermal insulation performance" has contributed to improve the occupant's allergy symptoms, as well as improving comfort and reducing demand for heating and air-conditioning. "Placing areas relating to water use and hot water supply" has brought about reduction in time until hot water comes out, in addition to the reduction in materials for piping and energy for hot water supply. "Taking accessible and universal design into spatial elements, such as doorways and main access route to the entrance," has already brought about present safety and comfort, above and beyond preparing the occupants for the future. "Protection of glass against impacts with shutters" has also contributed to prevent crimes and increase thermal performance, in addition to reduce the risk of being damaged by impacts such as fire and serious extreme weather events.

In this way, we have evaluated the home, which has been designed closely based on the methodology, from both the quantitative analyses and reactions of occupants and visitors. First, all of the quantitative analyses have shown that the home has significantly high environmental performance. The reactions of the occupants and visitors have also suggested that this home is comprehensively sustainable and comfortable. These assessment results indicate that if system users closely follow the methodology, they can comprehensively realize sustainable homes, which have high environmental performance.

2.2. Characteristics of the methodology

The characteristics of the methodology includes (1) visualization of the whole picture for promoting sustainable home design, (2) user-friendliness, (3) comprehensiveness, (4) adaptability to regional differences, and (5) flexibility toward changes over time.

In addition, *Sustainable Design: A critical Guide*, a book on sustainable building design, mentions four conditions of the ideal method for sustainable building design, that is, "holistic," "flexible," "responsive to local conditions," and "not overly complex to administer" [1]. In this context, "holistic" and "not overly complex to administer" are similar to "comprehensive" and "user-friendly," respectively. Therefore, we consider that this methodology covers all of the above-mentioned four conditions that the ideal method requires.

2.2.1. Visualization of the whole picture for promoting sustainable home design

Figure 5 in Chapter 4 has demonstrated the control system for promoting sustainable home design. This figure basically contains "sustainability," "environmental, social, and economic problems," and "disturbances" as system components. Moreover, "adaptation" to disturbances has been incorporated as a route to sustainability, as well as "solution" or "prevention" of the problems. Utilizing this basic scheme, this figure inclusively shows processes for promoting sustainable design on both new and existing homes with the "sustainable design guidelines" and "sustainability checklist."

We consider that Figure 5 in Chapter 4 concisely explains the whole picture of the sustainable design processes with the guidelines and checklist. Accordingly, we expect that this visualization itself helps people concerned to easily understand that whole picture.

2.2.2. User-friendliness

The "material and spatial elements" in the sustainable design guidelines and sustainability checklist are equal to "actual parts of houses." Thus, the system users can smoothly design, check, evaluate, and inspect the house, by easily comparing the drawings or actual house with the guidelines or checklist [2]. In fact, the design process in the case study has supported the user-friendliness of the guidelines and checklist; the designers of the homebuilder readily accepted them and efficiently made the house's drawings [2]. In addition, "correspondence between the elements and actual parts of houses" is unique to this methodology. On the other hand, the major existing Japanese methods, namely the housing performance indication system (HPIS), long-life quality housing (LQH) certification, and CASBEE for detached houses, do not possess this characteristic, as shown in Chapter 2.

Meanwhile, user-friendliness basically requires such methods to be "not complex" and "not long." As cited before, *Sustainable Design: A critical Guide* has mentioned "not overly complex to administer" as a condition of the ideal method [1]. Similarly, *The Checklist Manifesto: How to Get Things Right*, which impresses the value of checklists for avoiding failures, says that "the checklist cannot be lengthy" [3]. We consider that the "sustainable design guidelines" and "sustainability checklist" meet the above basic requirement. The "guidelines" and "checklist" are relatively simple and compact tables. Each of them fits to two pages of this book, although these functions cover all important elements of homes.

2.2.3. Comprehensiveness

Originally, the "sustainable design guidelines" has been aimed comprehensively at showing the relationships between the standard home and sustainability. Therefore, we expected that following this methodology would lead to achieve comprehensive sustainable homes. The evaluation results of the home in the case study have been obtained as we expected. The CASBEE assessment results, namely the very high BEE score and high scores in all the six categories (Figure 14 in Chapter 5), have supported the comprehensiveness of the methodology as well as the comprehensive sustainability of that home.

2.2.4. Adaptability to regional differences

This methodology, more specific the "element - variable - desired value" structure in the "sustainable design guidelines" and "sustainability checklist," originally has a mechanism of easily adapting to regional differences. As shown in Figure 3 in Chapter 3, examining the relationships between important elements and stability conditions, system designers determine the elements' variables and their desired values. This determination process has a mechanism of reflecting a variety of regional characteristics, including natural, geographical, social, and cultural features [2].

For instance, "resistance to earthquakes," a variable of the framework, reflects a geological feature of Japan, namely "earthquake-prone." This mechanism also enables the system designers to readily vary the guidelines, according to the region's characteristics [2]. For example, if the region is in a strong wind area or snowy area, they can easily adjust the guidelines to the region, by adding "resistance to wind" or "resistance to snow load" as a variable of the framework [2].

Another example of reflecting regional features is "heat insulation" of the bathtub. We have attached importance to this variable, due to a Japanese cultural feature. Reducing heat loss from bath is important in Japan since people frequently take a bath and usually share the same hot water in the bathtub with their family members. On the other hand, in societies without such a lifestyle, it is easy for system designers to simply omit this variable.

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2.2.5. Flexibility toward changes over time

The "element – variable – desired value" structure in the guidelines and checklist also leads to flexibility toward changes over time. **Figure 1** explains this characteristic, mainly focusing on two major global changes progressing in the twenty-first century, namely "climate change" and "aging population."

First, the course from "climate change" toward the materials or spatial elements passes through "mitigation measures/adaptation measures." This course shows that system designers can take necessary mitigation/adaptation measures against climate change, by adjusting relevant elements, variables, and desired values. For example, when taking a measure of "improving thermal insulation performance," we have added a variable "thermal insulation performance" to two material elements, namely "thermal insulation" and "windows and doors." Similarly, we have easily taken an adaptation measure, by adding "protection of glass against impact" and "with shutters" as a variable and its desired value of the material element, "windows and doors."

In addition, the broken dividing line between "mitigation measures" and "adaptation measures" in the block means that the two types of measures overlap each other. Such overlapping measures include "improving thermal insulation performance," "harnessing natural energy," "utilizing rainwater," and "improving natural ventilation." For instance, "improving thermal insulation performance" contributes to not only saving energy through reducing demand for heating and air-conditioning but also increasing resilience in extreme weather and crises.

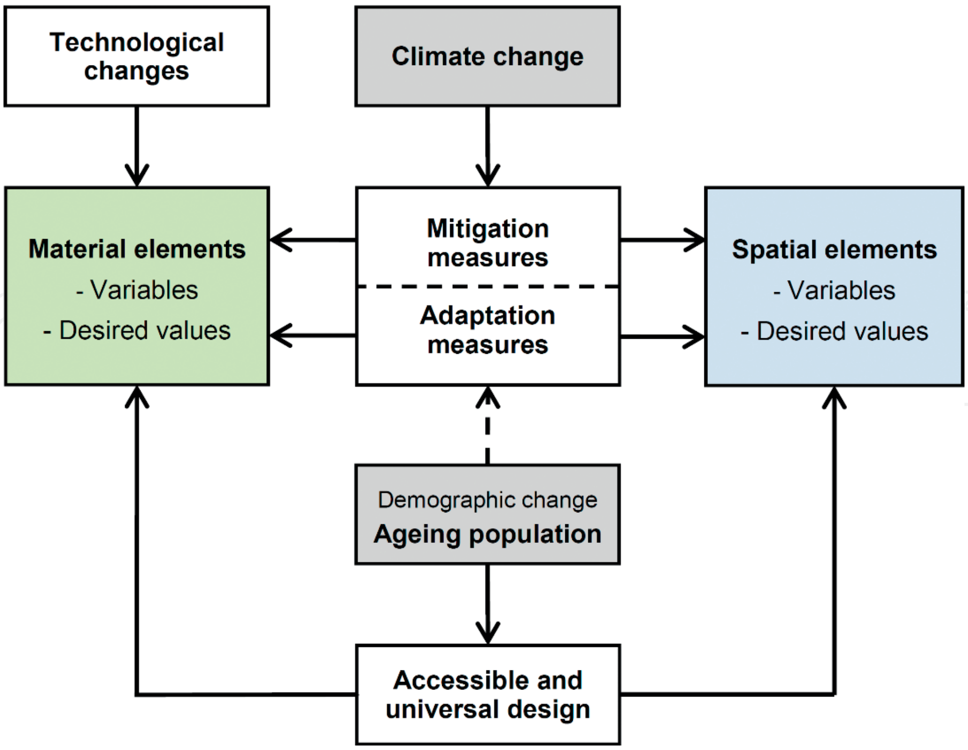

Figure 1. Flexibility of the methodology toward changes over time.

On the other hand, **Figure 1** shows two courses from "aging population" toward the material or spatial elements, that is, the routes through "mitigation measures/adaptation measures" and "accessible and universal design." The broken line that connects "aging population" and "mitigation measures/adaptation measures" means that some of mitigation/adaptation measures benefit elderly people's health. For example, "improving thermal insulation performance" can reduce the number of elderly people's deaths and illnesses resulting from indoor coldness in cold weather. Likewise, "improving thermal insulation performance" and "improving natural ventilation" are expected to decrease heat stroke patients and deaths of the elderly in hot weather.

Meanwhile, the course through "accessible and universal design" represents that system designers can adopt accessible and universal design, by adjusting relevant elements, variables, and desired values. To be concrete, when compiling the guidelines, we first identified spatial elements related to such design, including "specified bedroom," "doorways," "stairs," and "slope." Subsequently, we have added necessary variables to these elements and set their desired values, so as to adopt accessible and universal design.

Furthermore, **Figure 1** contains another change over time, that is, "technological changes." Technological changes, including innovation in technology, are directly related with material elements; therefore, system designers can efficiently take such changes to relevant material elements. For instance, in the latest revision, we have easily taken "LED" as the desired value of "type of light" of "lighting fixtures."

2.3. Coordination with the existing systems

From the beginning, we have intended that this methodology is not used independently but coordinated with the existing Japanese systems that have been shown in Chapter 2. Such coordination is expected to exert favorable influences on the utilization of not only this methodology but also the existing methods.

First, when compiling the "guidelines" and "checklist," we have aimed to provide reliability and incentives to utilize them. The guidelines and checklist use standard grades in the Japan housing performance indication standards (JHPIS) and assessment levels in CASBEE for detached houses, as the desired values of many variables. The JHPIS and CASBEE for detached houses, both of which are national systems, include technical information related to sustainable housing in the descriptions of the standard grades or assessment levels. Accordingly, when referring to the relevant descriptions in the JHPIS and CASBEE for detached houses, system users can obtain reliable related information or technical knowledge about the matters. Meanwhile, following the guidelines enables system users to receive a long-life quality housing (LQH) certification and higher ratings in CASBEE for detached houses. Obtaining a LQH certification leads to preferential treatment from the government, including tax credits; therefore, it can be an incentive for people to use the functions. Moreover, LQH-certified houses and CASBEE higher rated houses have a possibility of competitive superiority in the real estate market. Certified green or sustainable buildings have not yet gained obvious advantages in asset values in the Japanese real estate market, as shown in Chapter 2. However, such competitive superiority is expected to be established sooner or later also in Japan; therefore, it must be another incentive to use the functions.

On the other hand, the utilization of the user-friendly guidelines and checklist has a possibility of promoting the use of the existing public methods. Since the guidelines and checklist refer to CASBEE for detached houses, using these functions naturally leads to the utilization of this trustworthy system but relatively unknown system. Furthermore, when using the "checklist" for inspection or evaluation of existing homes, as a matter of course, "people involved" refer to the "JHPIS (for existing homes)" and "CASBEE for detached houses (existing building)," both of which have hardly been used thus far. The above coordination is expected to produce a synergy effect toward promoting sustainable housing design.

2.4. Applicability of the methodology

2.4.1. Application to other regions and countries

As demonstrated in Section 2.2.4., this methodology, more specific the "sustainable design guidelines" and "sustainability checklist," has a feature of being adaptable to regional differences. Accordingly, it will be not difficult for system designers in another region to adapt these practical functions for that region [2]. That is to say, the system designers can make its regional version, through the examination of the elements and the adaptation of the elements' variables and their desired values to the region's characteristics [2].

As a matter of course, this methodology can be applied to other countries, as well as other regions. When system designers make the guidelines and checklist in other countries besides Japan, they specify variables and their desired values, referring to systems related to buildings and housing used in that country. In such cases, there are two main approaches: (1) specification based on the standards required by building codes and (2) use of criteria shown in voluntary systems related to sustainable housing.

(1) Specification based on the standards required by building codes

If the variables are within the scope of the country's building codes, it is necessary for the system designers to search the building codes for the variables' desired values. Building codes specify the "minimum standards" for constructed objects, in order to protect public health, safety, and general welfare [4]. If system designers consider that the standard value required by the building codes is insufficient for the desired value, they make an addition to the standard value, so as to suit the desired value. On the other hand, if they consider that the standard value is suitable to the desired value, they can use it as it is. In the latter case, the variable and its desired value can be omitted from the guidelines and checklist, for people who naturally conform to the building codes, which have legal force.

In fact, Tables 2 and 4 in Chapter 4 also include variables and their desired values, which have been specified based on the above approach. For example, when determining the desired value of "ratio of total window area to floor area in each living space," a variable of "position and area of windows," we have made an addition to the standard value required by the Building Standards Act of Japan, namely "1/7 (14.3%) or more," and set the desired value at "20% or more." Moreover, "JHPIS 1.1: Grade 2 or over," the desired value of "resistance to earthquakes" of "framework," has been originally determined, based on the standard required by the building code. To be concrete, “Grade 2” in this desired value means 1.25 times the strength of an earthquake stipulated in the Building Standards Act of Japan. In addition, “resistance to winds” and “resistance to snow load” are possible variables of “framework” that have been omitted from the tables, because the standards for these two required by the building code have been considered to be suitable to their desired values.

(2) Use of criteria shown in voluntary systems related to sustainable housing

The second approach is to utilize criteria shown in voluntary systems related to sustainable housing, which is especially important outside the scope of building codes. Various kinds of systems or methods for sustainable housing, including assessment and rating systems, standards, and guidelines, are used in many countries of the world [5]. Moreover, energy conservation standards or energy consumption labeling systems for appliances and equipment are also used in many countries [6]. Such voluntary systems or methods usually include criteria, such as grades, levels, classes, target figures, or guideline values. Accordingly, referring to such existing voluntary systems, system designers can select suitable criteria to the desired values of variables. In addition, even if there are not exactly suitable criteria, referring to relevant systems and criteria usually provide system designers with information closely related to the variables and their desired values and help them determine the desired values.

In Tables 2 and 4 of Chapter 4, a high percentage of variables’ desired values have been specified, based on this second approach. In particular, referring to the JHPIS and CASBEE for detached houses, we have selected appropriate grades or levels to the desired values of many variables. We have also used the long-life quality housing (LQH) certification criteria, when setting the desired values of several variables, including “total floor area.” When determining the variable of “appliances” and its desired value, we have utilized the energy-saving labeling system of Japan. Furthermore, consulting several accessible and universal design guidelines has led us to specify the desired values of variables related to universal design, such as “grade of steepness” (slope).

In short, system designers in each country can compile the guidelines and checklist, referring to compulsory and voluntary systems related to buildings and housing used in that country.

2.4.2. Application possibility to other categories

Theoretically, the methodology can be applied to various categories of human activities. In other words, in the control system for promoting sustainable home design (Figure 5 in Chapter 4), “homes” in the block of “controlled objects” can be replaced with other categories of human activities [2]. Possibility of such replacement depends on if the table of relationships or the “sustainable design guidelines” can be compiled or not [2].

It will be probably easy to apply it to other types of buildings besides the home, because the structure is similar to one another [2]. It is also possible in theory to apply it to other kinds of infrastructure, including roads and parks [2]. Moreover, we consider it possible to apply the methodology to more large-scale and complex objects, including the city and town, for they are also considered as the complex of material and spatial elements [2].

2.5. Future research

2.5.1. Further case studies

The case study has supported the effectiveness of the methodology for promoting sustainable housing design. However, we are necessary to conduct further case studies, applying it to both new and existing houses. We expect that the increase of application cases also leads to an increase in the reliability of the methodology and help it to be widely used [2].

2.5.2. Revision of the guidelines and checklist

The "sustainable design guidelines" and "sustainability checklist" need to be updated, as occasion requires. Such occasion is projected to occur due to several causes, for instance, changes in the natural and social environment, developments in related sciences, innovations in related technologies, and response to the results of case studies [2]. Moreover, through such revision or update processes, we are going to investigate how to revise them efficiently.

3. Conclusion

This study has demonstrated the methodology for sustainable housing design by applying control science, with a case study. The main point of the methodology is the control system for promoting sustainable housing design with the sustainable design guidelines and sustainability checklist. Utilizing this methodology, we have actually designed a home and built it. The evaluations of the home indicate that closely following the methodology leads to comprehensively achieving sustainable homes with high environmental performance.

Meanwhile, we have pointed out several characteristics of the methodology, in addition to comprehensiveness. First, the diagram of the control system itself is beneficial because it concisely shows the whole picture of the sustainable design processes on both new and existing homes. Second, the "sustainable design guidelines" and "sustainability checklist" are user-friendly since the material and spatial elements are equivalent to real parts of homes. Moreover, the "element – variable – desired value" structure in the guidelines and checklist is superior in "adaptability to regional differences" and "flexibility toward changes over time."

In the twenty-first century, homes need to be transformed into those which contribute to deal with various issues, including climate change and financial problems due to aging population. Curbing the progress of climate change is a global challenge; therefore, mitigation measures have to be taken into homes all over the world. On the other hand, type and severity of impacts caused by climate change are different, depending on the region. Accordingly, appropriate adaptation measures need to be adopted in homes, in accordance with the predicted impacts in that region. Meanwhile, progressing aging population requires the inclusion of accessible and universal design into homes, in order to increase mobility of occupants and prevent injuries. Homes are used for a very long time; homes which are built or renovated now are expected to be used throughout the twenty-first century. Accordingly, such considerations toward sustainability need to be comprehensively taken into homes from the beginning.

Facing these circumstances, this user-friendly, comprehensive, adaptable, and flexible methodology is effective to promote sustainable housing design in various regions and countries. The guidelines and checklist shown in Tables 2 and 4 in Chapter 4 have been already compatible with climate change and aging population. These tables, which have been compiled to suit features in Japan, can be easily modified to fit features in other regions. Due to the same characteristic of this methodology, these tables can also be readily customized, so as to adapt to predicted impacts in each region caused by climate change. Hence, we expect that this methodology is used in various regions and countries, so as to facilitate sustainable home design.

The case study has successfully demonstrated the effects of the methodology on achieving sustainable homes. However, in order to confirm the effects, we need to conduct more case studies, applying it to both new and existing homes. Moreover, we will have to revise the "guidelines" and "checklist," as the occasion arises. Through such revision processes, we are planning to examine how to revise them efficiently. Meanwhile, it is theoretically possible to apply this methodology to other categories of human activities, which are regarded as the complex of material and spatial elements. We are also aiming to apply this methodology to more complex and larger scale human activities, such as the city and town.

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