

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

**4,800**

Open access books available

**122,000**

International authors and editors

**135M**

Downloads

Our authors are among the

**154**

Countries delivered to

**TOP 1%**

most cited scientists

**12.2%**

Contributors from top 500 universities



**WEB OF SCIENCE™**

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.

For more information visit [www.intechopen.com](http://www.intechopen.com)



# An Approach to Sustainable Development by Applying Control Science

Kazutoshi Fujihira  
*Institute of Environmentology*  
*Japan*

## 1. Introduction

Nowadays, humankind is facing various environmental and social problems; for example, global warming, the destruction of ecosystems, an increase of areas where water supplies are insufficient, the tight supply-demand situation for oil and metals, poverty, economic crises and conflicts. It is our ultimate goal as humans to solve or prevent environmental and social problems and achieve “sustainable development” or “sustainability.”

In order to solve or prevent such problems and achieve sustainable development, “human beings must **control** their activities appropriately,” I wrote in my books titled *An Introduction to Environmentology* (Fujihira, 1999) and *A Short Introduction to Environmentology* (Fujihira, 2001). In 2001, when I published the second book, I conceived the idea of applying the science of “control” to this ultimate challenge of humankind. “Control” is generally defined as “purposive influence toward a predetermined goal” (Beniger, 1986). Moreover, control science can be applied to all goal-oriented tasks. In fact, control science is applied to a variety of fields such as engineering, economics, agriculture, and medicine; especially control engineering has a long history and has produced remarkable results. Accordingly, it is a rational and reliable approach to apply control science to the task of achieving sustainable development.

Quickly realizing this point, I started conducting research. After that, I obtained cooperation from experts, including a leading scientist in control engineering. The finished research has shown the basic control system for sustainable development and an educational methodology for sustainable development with case studies (Fujihira et al., 2008; Fujihira & Osuka, 2009). The results of the case studies have demonstrated the validity of that basic control system as well as that educational methodology.

Recently we have aimed to show a methodology of designing practical control systems for sustainable development. Here this study, as the first step, discusses a method for promoting smooth design of such control systems. Chapter 2 again shows the basic control system for sustainable development. Chapter 3 provides the two-step preparatory work for smooth control system design. In Chapter 4, we apply this method to homes and demonstrates a case study. Chapter 5 examines the results of this case study and shows the effectiveness of this method.

## 2. The basic control system for sustainable development

Fig. 1 shows the basic control system for sustainable development (Fujihira et al., 2008; Fujihira & Osuka, 2009). 'Controlled objects' are human activities which cause environmental or social problems; the units of human activities are various. 'Controlled variables' are the variables that relate to the human activities and need to be controlled for solving or preventing the problems. 'Disturbances' are harmful influences on controlled objects which are caused by environmental and social problems. Examples of the disturbances are damage caused by environmental pollution, flood or landslide damage resulting from unbridled land development, and various kinds of damage caused by global warming.

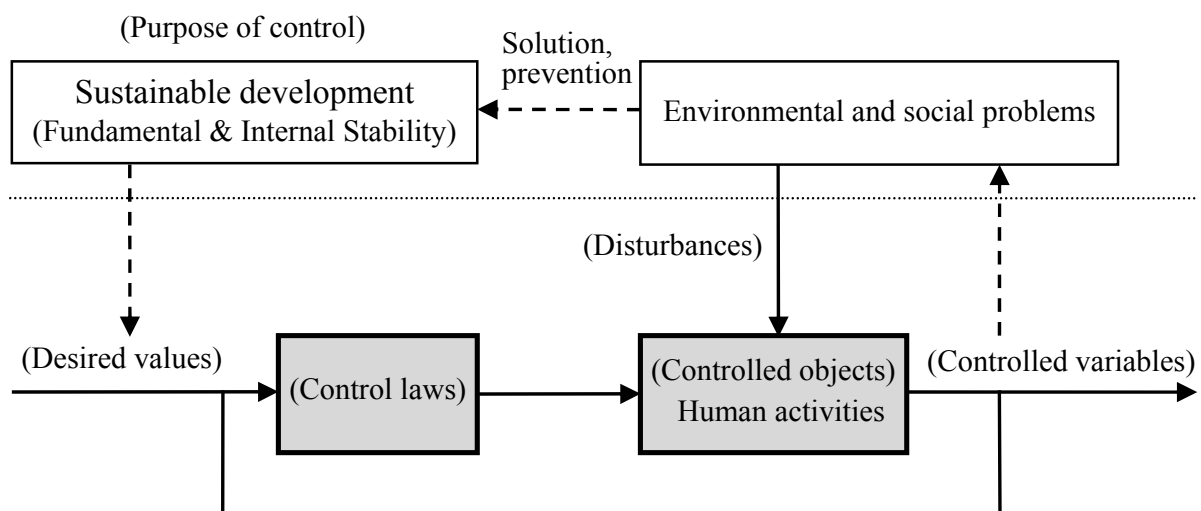


Fig. 1. The basic control system for sustainable development

Desired values are derived from the purpose of control, that is to say, sustainable development. The model of sustainable development (Fig. 2) demonstrates that sustainable development requires both 'Fundamental Stability' and 'Internal Stability,' in order to accomplish the long-term well-being of all humankind, or ultimate end, within the finite global environment and natural resources, or absolute limitations (Fujihira et al., 2008; Fujihira & Osuka, 2009). 'Fundamental Stability' means environmental stability and a stable supply of natural resources; the conditions for Fundamental Stability are environmental preservation and the sustainable use of natural resources. On the other hand, 'Internal Stability' means social and economic stability; the conditions for Internal Stability are health, safety, mutual help and self-realization, which are essential for well-being of humans. In addition, natural science, social science and human science, which are placed between Absolute Limitations, Fundamental Stability, Internal Stability and Ultimate End, are necessary to investigate the respective relationships.

The control objective is to adjust the controlled variables to their desired values. Furthermore, the control system requires designing and implementing 'control laws,' or measures for achieving the control objective.

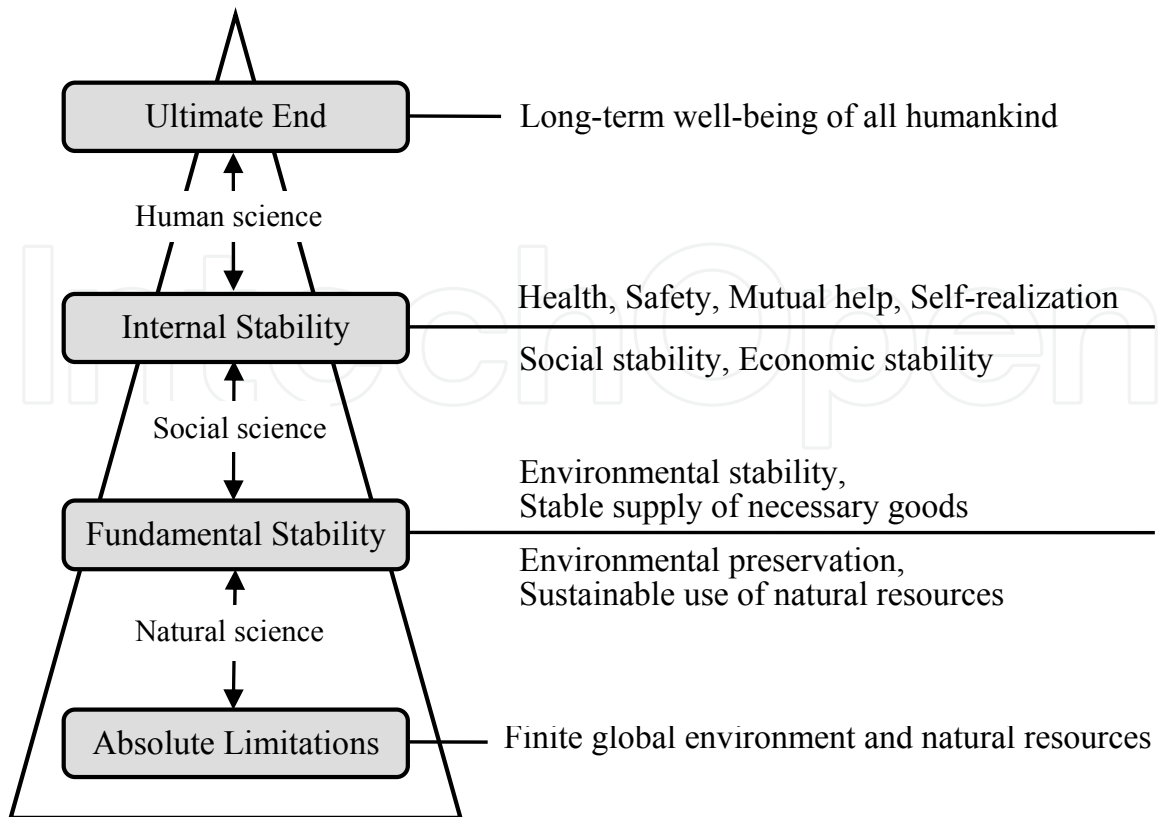


Fig. 2. The model of sustainable development

### 3. Two-step preparatory work for smooth control system design

There is a standard procedure that can be applied to the design of most control systems. Fig. 3 shows main steps in this procedure: 1) identifying a controlled object and control objective, 2) understanding the controlled object and control objective, 3) designing control laws, 4) implementing control laws. The first step “identifying a controlled object and control

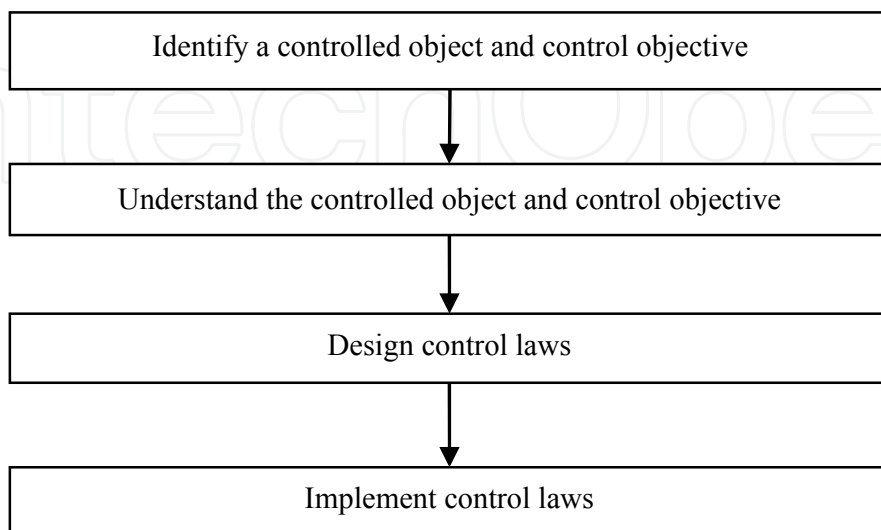


Fig. 3. Main steps in designing control systems

objective” requires designers of practical control systems for sustainable development to identify controlled variables and their desired values as well as a controlled object. Therefore, preparatory work for designing such control systems is primarily intended to identify these system components. This preparatory work consists of two steps: (1) determining the relationship between the standard human activities and sustainable development, (2) sustainability checkup on human activities as an object (Fujihira & Osuka, 2010, 2011).

### 3.1 Determining the relationship between the standard human activities and sustainable development

The first step aims to comprehensively determine the relationship between the standard human activities and sustainable development. The standard human activities means typical human activities among human activities which belong to one group and the same unit. Fig. 4 demonstrates the concept of this step.

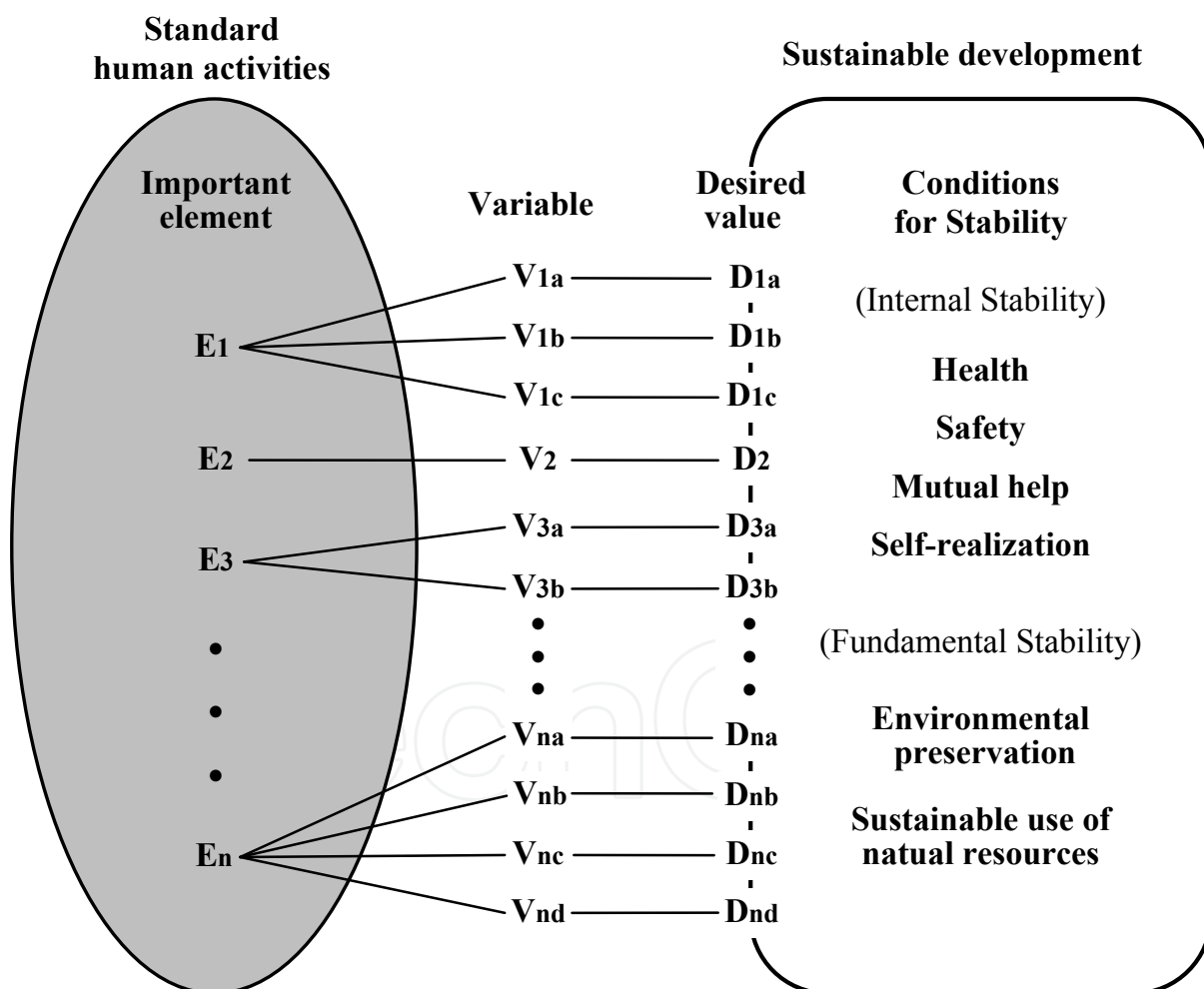


Fig. 4. The concept diagram of determining the relationship between the standard human activities and sustainable development

The first step starts with selecting important elements from the standard human activities. Human activities in one group and the same unit include almost the same elements.

Accordingly, system designers first select such common elements from the standard human activities. In this connection, if system designers find one or more factors which influence the selection, the selection work will be more efficient. In addition, the elements which are expected to closely relate to sustainable development should always be added to a set of important elements, regardless of whether such elements are common or not. For example, when the 'building' is chosen as a unit of human activities, "equipment for harnessing natural energy" should be selected as an important element, even if it is uncommon in present ordinary buildings.

After selecting important elements, system designers determine the relationship between such elements and sustainable development. This work consists of three processes: 1) considering the relationship between each element and the conditions for both Fundamental Stability and Internal Stability, such as health, safety and environmental preservation; 2) identifying variables which can indicate the degree of stability; 3) setting the desired values of the variables that can achieve stability. As shown in Fig. 4, the number of variables which connect to one element is not necessarily one, but can be many. In addition, both identifying variables and setting desired values need to be conducted on the basis of the latest scientific knowledge, technology and social conditions.

### 3.2 Sustainability checkup on human activities as an object

In the second step, system designers conduct a sustainability checkup on human activities as an object. To be concrete, they first measure or estimate the aforementioned variables of human activities as an object. Next, they compare the measured or estimated values with the desired values and assess the degree of stability.

After the assessment, the variables that are lower than the desired values need to be identified as "controlled variables." The variables that fall substantially below the desired values are especially required to be identified as "controlled variables." In addition, human activities as an object which include one or more controlled variables are naturally identified as a "controlled object."

In addition, this sustainability checkup is applied to both "new" and already "existing" human activities. *Oxford Dictionary of English* defines 'activity' as "a thing that a person or group does or has done" (Oxford Dictionaries, 2010). In this context, "new" human activities are equivalent to "things that people or groups do," and "existing" human activities correspond to "things that people or groups have done." When the object of a sustainability checkup is new human activities, system designers conduct it by examining the plan or blueprint for such activities. On the other hand, when the object is existing human activities, system designers conduct a checkup by inspecting the actual human activities. In the latter case, if system designers can obtain the plan or blueprint of such activities, it is desirable to examine it as well as the actual human activities. Furthermore, if both new and existing human activities are checked and controlled for sustainable development, the goal will be achieved more smoothly.

## 4. Case study

We have conducted a case study, selecting the home as a unit of human activities. In this case, the preparatory work consists of two steps: 1) determining the relationship between

the standard home and sustainable development, 2) sustainability checkup on a home as an object.

#### 4.1 Determining the relationship between the standard home and sustainable development

In the first step, system designers need to select important elements of the standard home and determine the relationship between such elements and sustainable development.

##### 4.1.1 Two factors on selecting elements of the standard home

In order to determine important elements of the standard home, we have analyzed two main factors in making our selection. They are “material” and “space,” as shown in Table 1 (Fujihira, 2011). The first factor “material” regards the home as an object which contains material elements such as framework, exterior, interior and piping. Moreover, when observing the details of such material elements, they can be broken down further into smaller material elements; for example, framework includes pillars and beams. On the other hand, the other factor “space” regards the home as an object which consists of spatial elements such as rooms and areas. If regarding the home as a mass of rooms, we can find more specific spatial elements; for instance, a living room, dining room, kitchen and bedroom.

In this case study, we have observed the standard home based on both of these factors. As a result, we have determined important elements, as shown in the central column of Table 2-1 and Table 2-2. “Material elements” are from ‘framework’ to ‘fence;’ “spatial elements” are from ‘rooms used at daytime’ to ‘garden area,’ which are demonstrated in the bottom of Table 2-2.

Factor	Material	Space
Examples of elements (details)	(a) Framework (pillar, beam, etc.) (b) Exterior (roof, outer wall, etc.) (c) Interior (floor, inner wall, ceiling, etc.) (d) Piping (water pipe, gas pipe, etc.)	(a) Room (living room, dining room, bedroom, kitchen, bathroom, etc.)  (b) Area (garden area, exterior area, etc.)

Table 1. Two factors on selecting elements of the home

##### 4.1.2 Relationship between the standard home and sustainable development

After selecting the elements of the standard home, we have determined the relationship between these elements and sustainable development. The left side of Table 2-1 and Table 2-2 shows the relationship between the elements and Fundamental Stability; the right side demonstrates the relationship between the elements and Internal Stability. Considering the relationship between each element and the stability conditions, we have identified variables which indicate the degree of stability. In addition, we have set the desired values of these variables that can achieve stability.

The rest of this section briefly describes the relationship between each element and sustainable development, in order from the top of Table 2-1.



**[Material elements]**

- **Framework**

Considering the relationship between “framework” and ‘sustainable use of natural resources,’ a condition for Fundamental Stability, we have identified ‘durability’ and ‘raw materials’ as variables. The desired values of ‘durability’ and ‘raw materials’ are the ‘deterioration resistance grades’ of the *Japan Housing Performance Indication Standards* (JHPIS) (Japanese Ministry of Land, Infrastructure and Transport, 2001), and the ‘assessment levels of resources saving’ of *CASBEE for Home*, or *Comprehensive Assessment System for Building Environmental Efficiency for Home (Detached House)* (Japan GreenBuild Council & Japan Sustainable Building Consortium, 2008), respectively.

On the other hand, considering the relationship with ‘safety,’ a condition of Internal Stability, we have selected ‘resistance to earthquakes’ and ‘wind resistance’ as variables, and the ‘seismic resistance grades’ and the ‘wind-resistant grades’ of the JHPIS as their desired values (Japanese Ministry of Land, Infrastructure and Transport, 2001). In Japan the strength of framework against earthquakes is regarded as extremely important since Japan is a major quake-prone country.

Furthermore, in areas of heavy snowfall, ‘resistance to snowfall’ needs to be included as a variable, although it is excluded from the table. In this way, variables and their desired values can be changed or varied with the surrounding environment.

- **Exterior**

As for “exterior,” which includes roofs and outer walls, we have selected ‘durability,’ ‘raw materials’ and ‘sunlight reflectivity’ as variables relating to Fundamental Stability. ‘Raw materials’ is excluded from the table, for reasons of space. The desired value of sunlight reflectivity has been set at ‘0.3 or over’ because good sunlight reflectivity prevents the exterior of homes from accumulating the heat of sun and leads to the mitigation of the heat island phenomenon. On the other hand, we have identified ‘fire resistance,’ ‘shape’ and ‘color’ as variables relating to Internal Stability. In order to restrain the spread of fire, the exterior needs to satisfy a high fire resistance grade. Meanwhile, the shape and color of the roof and walls are necessary to harmonize with the surrounding landscape.

- **Thermal insulation**

We have identified ‘thermal insulation performance’ and ‘raw materials’ as the variables of “thermal insulation.” ‘Raw materials,’ which relates to Fundamental Stability, is excluded from the table, for reasons of space. ‘Thermal insulation performance’ is especially significant since it relates to both Fundamental Stability and Internal Stability. An increase in thermal insulation performance leads to environmental preservation and sustainable use of natural resources through a decrease in energy usage for air conditioning and heating. Meanwhile, it also promotes the health of occupants through the stabilization of the indoor temperature. The desired value of thermal insulation performance has been set at the highest grade in the “Energy-Saving Action Grades” of JHPIS (Japanese Ministry of Land, Infrastructure and Transport, 2001). In addition, there are six area classifications for the thermal insulation standards for specific values in Japan, depending on the climate.



Relationship between the element and Fundamental Stability			Element	Relationship between the element and Internal Stability		
Stability condition	Desired value	Variable		Variable	Desired value	Stability condition
Sustainable use of resources	JHPIS Sec. 3-1: Grade 2 or over	Durability	Framework	Resistance to earthquakes	JHPIS Sec. 1-1: Grade 2 or over	Safety
Sustainable use of resources	CASBEE LR <sub>H2</sub> 1.1: Level 4 or over	Raw materials		Wind resistance	JHPIS Sec. 1-4: Grade 1 or over	Safety
Sustainable use of resources	JHPIS Sec. 3-1: Grade 2 or over	Durability	Exterior (roof, outer wall, etc.)	Fire resistance	JHPIS Sec. 2-6: Grade 3 or over	Safety
Enviro-preserve	0.3 or over	Sunlight reflectivity		Shape	Harmony with surrounding landscape	Health
Enviro-preserve			Color			
Enviro-preserve Sustainable use of resources	JHPIS Sec. 5-1: Grade 4	Thermal insulation performance	Thermal insulation	Thermal insulation performance	JHPIS Sec. 5-1: Grade 4	Health
Sustainable use of resources	JHPIS Sec. 3-1: Grade 1 or over	Durability	Windows & doors	Area of window openings	20% of the floor area or more	Health
Enviro-preserve Sustainable use of resources	Consideration for natural lighting	Position & Shape		Wind resistance	JIS Grade: S-2 or over	Safety
Enviro-preserve Sustainable use of resources	Consideration for ventilation			Measures to prevent intrusions	CASBEE Q <sub>H1</sub> 2.6: Level 4 or over	Safety
Enviro-preserve Sustainable use of resources	JHPIS Sec. 5-1: Grade 4	Thermal insulation performance		Thermal insulation performance	JHPIS Sec. 5-1: Grade 4	Health
Enviro-preserve Sustainable use of resources	JIS Grade: A-3 or over	Airtightness		Sound insulation performance	JHPIS Sec. 8-4: Grade 2 or over	Health
Enviro-preserve Sustainable use of resources	CASBEE Q <sub>H1</sub> 1.1.2: Level 4 or over	Sunlight adjustment capability		Sunlight adjustment capability	CASBEE Q <sub>H1</sub> 1.1.2: Level 4 or over	Health
				Floor	Sound insulation performance	JHPIS Sec. 8-1&2: Grade 3 or over
			Differences in level		No differences	Safety Health

[Note] (1) JHPIS is an abbreviation for the Japan Housing Performance Indication Standards. (2) CASBEE means Comprehensive Assessment System for Building Environmental Efficiency for Home (Detached house) - Technical Manual 2007 Edition. (3) JIS is an abbreviation for Japanese Industrial Standard.

Table 2-1. Relationship between the standard home and sustainable development

Relationship between the element and Fundamental Stability			Element	Relationship between the element and Internal Stability		
Stability condition	Desired value	Variable		Variable	Desired value	Stability condition
Sustainable use of resources	CASBEE LR <sub>H2</sub> 1.4: Level 4 or over	Raw materials	Interior	Formaldehyde emission	JHPIS Sec. 6-1: Grade 3	Health
Enviro-preserve	Insulated	Heat insulation	Bathtub			
Sustainable use of resources	JHPIS Sec. 4-1: Grade 3 or over	Consideration for maintenance	Piping			
Enviro-preserve	Header type	Type of piping	Hot-water piping			
Sustainable use of resources	Insulated	Heat insulation				
Enviro-preserve	90% or more	Primary energy efficiency	Water heater			
Sustainable use of resources	CASBEE LR <sub>H1</sub> 3.1: Level 4 or over	Water-saving functions	Water-using equipment			
Sustainable use of resources	10% or more of the total water usage	Rainwater usage	Equipment for rainwater use	Rainwater usage	10% or more of the total water usage	Health Safety (in crises)
Enviro-preserve	100% or more	Energy-saving achievement rate	Lighting fixtures & appliances			
Enviro-preserve	Energy usage of the whole home or more	Harnessed natural energy	Equipment for harnessing natural energy	Harnessed natural energy	Energy usage of the whole home or more	Health Safety (in crises)
Enviro-preserve	Indigenous species	Species	Garden plants	Fire resistance	High or mid fire resistance	Safety
Enviro-preserve	Hedge or Resources-saving materials	Material	Fence	Form	Not blocking sight line	Safety
					Not blocking communication	Mutual help
Enviro-preserve	Places receiving a lot of sunlight	Places in the home	Rooms used at daytime			
			Specified bedroom	Relation with toilet & bath	On the same floor	Health Safety
Enviro-preserve	Building close together	Places in the home	Rooms where water is used			
			Doorways	Differences in level	No differences	Safety Health
				Width		
Enviro-preserve	40% or more	Ratio to the exterior area	Garden area			

Table 2-2. Relationship between the standard home and sustainable development

- **Windows and doors**

We have identified a large number of items as the variables of “windows and doors;” for example, an area of window openings, sunlight adjustment capability, thermal insulation performance, and sound insulation performance. It is necessary to obtain sufficient brightness and appropriate sunlight through windows. On the other hand, windows need sufficient thermal insulation performance and sound insulation performance. In this way, windows need to meet a variety of conflicting requirements, which indicates that designing windows is extremely difficult. Furthermore, in order to meet such a variety of requirements, related elements, such as glass, eaves, awnings, blinds, shutters, and curtains, are often required to work together.

- **Floor**

“Floors” require two variables, that is, ‘sound insulation performance’ and ‘differences in level,’ both of which relates to Internal Stability. The floor of the rooms is necessary to satisfy sufficient sound insulation performance against the noise from the upper floor. The other variable ‘differences in level’ need to be removed from the floor, in order to allow elderly and handicapped people to move around safely and lead a normal life. Recently this variable has become more important in Japan due to a rapidly aging society.

- **Interior**

“Interior,” which includes a floor, wall and ceiling, requires ‘formaldehyde emission’ and ‘raw materials’ as its variables. Formaldehyde is a major harmful pollutant; therefore, the desired value of formaldehyde emission is set at the level which is harmless to the health of the occupants.

- **Bathtub**

We have attached importance to ‘heat insulation’ as a variable of the “bathtub” since insulated bathtubs can reduce heat loss of the hot water. This consideration results from a Japanese lifestyle, that is, taking a bath every day.

- **Piping**

“Piping,” including drainage pipes, water pipes and gas pipes, need ‘consideration for maintenance’ as an important variable toward a long service life. The ‘maintenance grades’ of the JHPIS, which has been identified as the desired value, requires consideration for making maintenance easier, such as not burying piping under concrete and creating openings for cleaning and inspection (Japanese Ministry of Land, Infrastructure and Transport, 2001).

- **Hot-water Piping**

We have identified ‘type of piping’ and ‘heat insulation’ as the variables of “hot-water piping,” both of which relates to Fundamental Stability. If ‘header type’ hot-water piping is used, normally the diameter of piping leading from the header to the faucets of sinks and baths can be reduced. As a result, wastage of hot water can be decreased, as compared with the front-end-branching type. Moreover, if hot-water piping is ‘insulated,’ heat loss is further reduced.

- **Water heater**

We have identified 'primary energy efficiency' as a key variable of the "water heater." The desired value of the primary energy efficiency has been set at '90% or more.' This level can be realized by utilizing high energy-efficient water heaters, including electric heat-pump water heaters.

- **Water-using equipment**

"Water-using equipment," including toilet bowls, faucets and shower heads, requires 'water-saving functions' as its key variable. The desired value, the water-saving assessment levels of CASBEE, can be satisfied if two or more water-saving efforts are adopted from the following four choices: water-saving type toilets, bathroom thermostat type water faucet plus water-saving shower head, dish washer, and other water-saving methods (Japan GreenBuild Council & Japan Sustainable Building Consortium, 2008).

- **Equipment for rainwater use**

If "equipment for rainwater use" is installed, it can reduce the quantity of water supply and contributes to sustainable use of natural resources. We have set the desired value of 'rainwater usage' at '10% or more of the total water usage.' Storing rainwater also contributes to health and safety in crises, by securing emergency water.

- **Lighting fixtures and home appliances**

Lighting fixtures and home appliances such as refrigerators and televisions need to be energy-saving devices. We have identified the variable of such appliances as the 'energy-saving standard achievement rate' and set their desired value at '100% or more.' Japan's energy-saving standard achievement rate for each appliance is open to the public in the manufacturers' catalogue and the latest "Energy Conservation Equipment Catalogue" of the Energy Conservation Center, Japan (Energy Conservation Center, Japan, n.d.).

- **Equipment for harnessing natural energy**

Concerning "equipment for harnessing natural energy" such as solar panels, we have identified 'harnessed natural energy' as a variable relating to Fundamental Stability, and 'energy usage of the whole home or more' as its desired value. This desired value means achieving self-sufficiency in energy. Equipment for harnessing natural energy also contributes to health and safety in crises, by generating emergency energy.

- **Garden plants**

We have determined 'species' and 'fire resistance' as the variables of "garden plants." If indigenous or local species of plants are selected, such selection contributes to preserving the region's ecological environment. On the other hand, highly fire-resistant plants are effective to prevent the spread of fire. In general, evergreen trees and plants with thick leaves which contain large amounts of water have high fire resistance.

- **Fence**

As for "fence," 'material' has been identified as a variable relating to Fundamental Stability, and ecological materials such as a hedge as its desired value. On the other hand, 'form' has been selected as a variable relating to Internal Stability and 'not blocking sight line' and 'not

blocking communication' as its desired values. These selections are based on the following ideas: good visibility brings 'safety' through preventing crimes and face-to-face communication leads to 'mutual help' in local community.

#### [Spatial elements]

- **Rooms used at daytime**

"Rooms used at daytime," which usually include a living room and dining room, should be preferentially planned in places receiving a lot of sunlight in the home. Such arrangement is effective to reduce the energy for lighting by utilizing sunlight efficiently. On the other hand, rooms used only at night-time such as bedrooms can be planned in places with little sunlight.

- **Specified bedroom**

A "specified bedroom" means a bedroom which is used or expected to be used by elderly or wheelchair users. Such a room and the bathroom area should be arranged on the same floor. This arrangement enables such occupants to use the toilet and bath easily.

- **Rooms where water is used**

"Rooms where water is used" includes a kitchen, bathroom, toilet, and washing room. If these rooms are built close together, the total length of water piping and drainage piping can be reduced. Moreover, this consideration helps reduce heat loss from hot-water piping.

- **Doorways**

A "doorway" is a space where a door opens and closes. 'No differences in level' in doorways allow elderly and wheelchair users to pass through them smoothly. On the other hand, '80cm or more,' the desired value of the 'width' of a doorway, is suitable for movement of a wheelchair.

- **Garden area**

The "garden area" is an area with plants such as trees, shrubs, herbs, grasses, and vegetables. A larger garden area is favourable for environmental preservation, including mitigation of heat island phenomenon, and a higher level of biodiversity. We determined its variable as the 'ratio of the garden area to the exterior area,' and set its desired value at '40% or more.' In addition, the garden area includes any planted area not only on the ground but also on the roof.

#### 4.2 Sustainability checkup on a home as an object

In the second step, system designers measure or estimate the variables of a home as an object and assess them by comparing with the desired values. Table 3-1 and Table 3-2 demonstrate an example of sustainability checkup on a home as an object; Fig. 5 shows the external appearance of the home on which the checkup was done. In this case, the checkup results have been assessed in three grades: A, B and C. "A" means that the variable reaches the desired value. "B" signifies that the variable falls below the desired value. "C" means that the variable falls substantially below the desired value.



Here I view the checkup results, choosing several elements from Table 3-1 and Table 3-2. As for “framework,” two of the four variables, ‘durability’ and ‘resistance to earthquakes’ have been assessed at B because they are lower than the desired values. The ‘performance’ of the “thermal insulation” has been assessed at C since it falls substantially below the desired value. The “water heaters” used in this home are old-typed gas heaters and their ‘primary energy efficiency’ is much lower than the desired value; therefore, it has been assessed at C. The “natural energy” harnessed by “equipment for harnessing natural energy” has been assessed at C because such equipment is not installed. The two variables of “fence,” ‘material’ and ‘form,’ have been assessed at A, for hedge and resources-saving materials are utilized and the form does not block both sight line and communication. The variable of the “specified bedroom” has been assessed at A because both the specified bedroom and bathroom area are placed on the same ground floor. The variable of the “rooms where water is used” has been assessed at A since the kitchen, toilet, bath and the place for a washing machine are close together.

In the above example, the object of sustainability checkup has been an existing home. When checkup is done on existing homes, it is desirable to examine both the actual home and its design drawings. On the other hand, this checkup method can be applied to homes which are planned or designed for the future. In the latter cases, planners and designers estimate the values of variables, by examining the scheme drawings or design drawings.

After the sustainability checkup, the variables that have been assessed at B or C need to be identified as “controlled variables.” The variables assessed at C are especially required to be identified as “controlled variables.” In addition, this home has naturally been identified as a “controlled object” because it includes controlled variables. Moreover, such a sustainability checkup table enables system designers to find at a glance the following: the elements which should be controlled, controlled variables and their desired values. Therefore, it enables them to understand both what should be controlled and the courses of control.



Fig. 5. The external appearance of the home on which a sustainability checkup was done



Relationship between the element and Fundamental Stability				Element	Relationship between the element and Internal Stability			
Desired value	Ass- ess.	Measured or estima- ted value	Variable		Variable	Measured or estima- ted value	Ass- ess.	Desired value
JHPIS Sec. 3-1: Grade 2 or over	B	40 years	Durability	Frame- work	Resistance to earthquakes	JHPIS Sec. 1-1: Grade 1	B	JHPIS Sec. 1-1: Grade 2 or over
CASBEE LR <sub>H</sub> 2 1.1: Level 4 or over	A	Domestic wood	Raw materials		Wind resistance	JHPIS Sec. 1-4: Grade 1	A	JHPIS Sec. 1-4: Grade 1 or over
JHPIS Sec. 3-1: Grade 2 or over	B	30 years	Durability	Exterior (roof, outer wall, etc.)	Fire resistance	JHPIS Sec. 2-6: Grade 3	A	JHPIS Sec. 2-6: Grade 3 or over
0.3 or over	A	0.55	Sunlight reflectivity		Shape Color	Harmony with landscape	A	Harmony with landscape
JHPIS Sec. 5-1: Grade 4	C	JHPIS Sec. 5-1: Grade 1	Thermal insulation performance	Thermal insulation	Thermal insulation performance	JHPIS Sec. 5-1: Grade 1	C	JHPIS Sec. 5-1: Grade 4
JHPIS Sec. 3-1: Grade 1 or over	B	30 years	Durability	Windows & doors	Area of window openings	18% of the floor area	B	20% of the floor area or more
Consideration for natural lighting	A	Adequate conside- ration	Position & Shape		Wind resistance	JIS Grade: S-2	A	JIS Grade: S-2 or over
Consideration for ventilation	A	Adequate conside- ration			Measures to prevent intrusions	CASBEE Q <sub>H</sub> 1 2.6: Level 3	B	CASBEE Q <sub>H</sub> 1 2.6: Level 4 or over
JHPIS Sec. 5-1: Grade 4	C	JHPIS Sec. 5-1: Grade 2	Thermal insulation performance		Thermal insulation performance	JHPIS Sec. 5-1: Grade 2	C	JHPIS Sec. 5-1: Grade 4
JIS Grade: A-3 or over	A	JIS Grade: A-3	Airtightness		Sound insulation performance	JHPIS Sec. 8-4: Grade 1	B	JHPIS Sec. 8-4: Grade 2 or over
CASBEE Q <sub>H</sub> 1 1.1.2: Level 4 or over	B	CASBEE Q <sub>H</sub> 1 1.1.2: Level 3	Sunlight adjustment capability		Sunlight adjustment capability	CASBEE Q <sub>H</sub> 1 1.1.2: Level 3	B	CASBEE Q <sub>H</sub> 1 1.1.2: Level 4 or over
				Floor	Sound insulation performance	JHPIS Sec. 8-1&2: Grade 1	C	JHPIS Sec. 8- 1&2: Grade 3 or over
					Differences in level	No dif- ferences	A	No differences

[Note] (1) JHPIS is an abbreviation for the Japan Housing Performance Indication Standards. (2) CASBEE means Comprehensive Assessment System for Building Environmental Efficiency for Home (Detached house) – Technical Manual 2007 Edition. (3) JIS is an abbreviation for Japanese Industrial Standard.

Table 3-1. An example of sustainability checkup on a home as an object

Relationship between the element and Fundamental Stability				Element	Relationship between the element and Internal Stability			
Desired value	Ass-ess.	Measured or estimated value	Variable		Variable	Measured or estimated value	Ass-ess.	Desired value
CASBEE LR <sub>H2</sub> 1.4: Level 4 or over	A	CASBEE LR <sub>H2</sub> 1.4: Level 4	Raw materials	Interior	Formaldehyde emission	JHPIS Sec. 6-1: Grade 3	A	JHPIS Sec. 6-1: Grade 3
Insulated	C	Not insulated	Heat insulation	Bathtub				
JHPIS Sec. 4-1: Grade 3 or over	B	JHPIS Sec. 4-1: Grade 2	Consideration for maintain	Piping				
Header type	C	Front-end-branching	Type of piping	Hot-water piping				
Insulated	C	Not insulated	Heat insulation					
90% or more	C	50%	Primary energy efficiency	Water heater				
CASBEE LR <sub>H1</sub> 3.1: Level 4 or over	C	CASBEE LR <sub>H1</sub> 3.1: Level 2	Water-saving functions	Water-using equipment				
10% or more of the total water usage	C	0 (Zero)	Rainwater usage	Equipment for rain-water use	Rainwater usage	0 (Zero)	C	10% or more of the total water usage
100% or more	C	60 - 85%	Energy-saving achievement rate	Lighting fixtures & appliances				
Energy usage of the whole home or more	C	0 (Zero)	Harnessed natural energy	Equipment for natural energy	Harnessed natural energy	0 (Zero)	C	Energy usage of the whole home or more
Indigenous species	A	Indigenous species	Species	Garden plants	Fire resistance	High & mid fire resistance	A	High or mid fire resistance
Hedge or Resources-saving materials	A	Hedge & Resources-saving materials	Material	Fence	Form	Not blocking sight line	A	Not blocking sight line
						Not blocking communication	A	Not blocking communication
Places receiving a lot of sunlight	A	Receiving a lot of sunlight	Places in the home	Rooms used at daytime				
				Specified bedroom	Relation with toilet & bath	On the same floor	A	On the same floor
Building close together	A	Building close together	Places in the home	Rooms where water is used				
				Doorways	Difference in level	No differences	A	No differences
					Width	72cm	B	80cm or over
40% or more	A	45%	Ratio to the exterior area	Garden area				

Table 3-2. An example of sustainability checkup on a home as an object

## 5. Discussion

This study has shown a method for smooth design of practical control systems for sustainable development with a case study. In Chapter 3, we have provided the method, that is, the two-step preparatory work for designing such control systems: (1) determining the relationship between the standard human activities and sustainable development, (2) sustainability checkup on human activities as an object. Chapter 4 has demonstrated a case study, applying this method to homes. This chapter discusses the results of the case study from three viewpoints: (1) the effects of the method on control system design, (2) the value of the case study itself, (3) future work.

### 5.1 The effects of the method on control system design

The results of the case study have shown that the two-step preparatory work facilitates control system design in three ways, as shown in Fig. 6 (Fujihira & Osuka, 2011; Fujihira, 2011). First, as I intended at the beginning, this method can identify a controlled object, controlled variables, and their desired values. Therefore, it enables system designers to ‘identify a controlled object and control objective.’

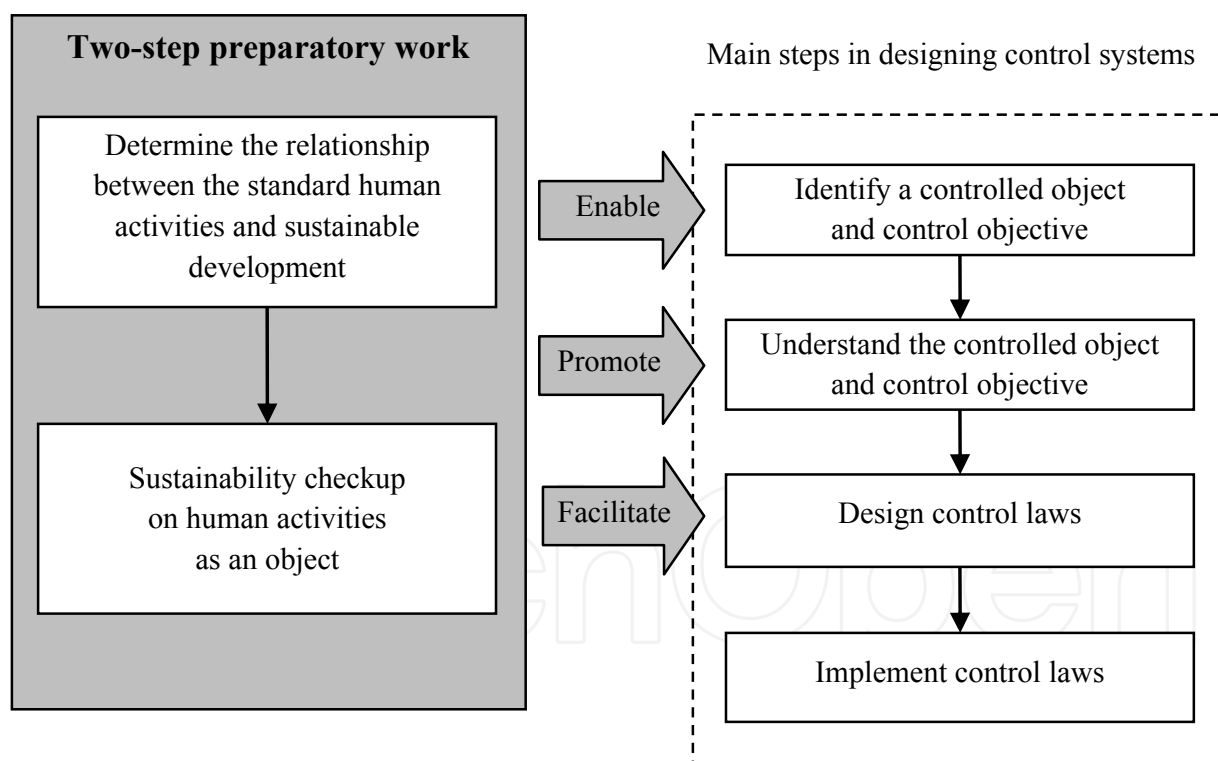


Fig. 6. The effects of the two-step preparatory work on control system design

In addition, this method also promotes ‘understanding the controlled object and control objective.’ Through sustainability checkup, system designers can comprehensively understand the relationship between important elements of an object and sustainable development. As a result, they can obtain overall and balanced understanding about the controlled object and control objective.

Moreover, this method also facilitates 'designing control laws.' Sustainability checkup enables system designers to understand both what should be controlled and the courses of control so that they can easily design control laws.

## 5.2 The value of the case study itself

This section examines the value of the case study itself, by comparing it with existing assessment systems for sustainable homes which are used in Japan and the world.

In Japan, the *Japan Housing Performance Indication Standards (JHPIS)* and *Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) for Home (Detached House)*, both of which I mentioned in Chapter 4, are used as public performance assessment systems for homes. Japanese Ministry of Land, Infrastructure and Transport provided JHPIS in 2001, aiming to improve housing conditions and sustainability of the built-environment (Building Center of Japan, 2009). JHPIS assesses and indicates housing performance from a variety of angles: structural stability, fire safety, mitigation of degradation, measures for maintenance, thermal environment, indoor air environment, luminous and visual environment, acoustic environment, consideration for the aged and others, security against intrusion (Japanese Ministry of Land, Infrastructure and Transport, 2001). Meanwhile, CASBEE was developed by a committee set up in the Institute for Building Environment and Energy Conservation under the initiative of Japanese Ministry of Land, Infrastructure and Transport. *CASBEE for Home*, one of CASBEE tools, assesses the environmental performance of detached houses from two viewpoints: 'environmental quality (Q)' and 'environmental load (L).' Each of Q and L has three assessment categories: comfortable, healthy and safe indoor environment (Q1), ensuring a long service life (Q2), creating a richer townscape and ecosystem (Q3), conserving energy and water (L1), using resources sparingly and reducing waste (L2), consideration of the global, local and surrounding environment (L3) (Japan GreenBuild Council & Japan Sustainable Building Consortium, 2008).

Other countries of the world are also promoting such assessment systems, including *EcoHomes* of BREEAM in the United Kingdom, *LEED for Homes* in the United States, and *Green Star* in Australia. BREEAM, or Building Research Establishment Environmental Assessment Method, is one of the most comprehensive and widely recognized measures of a building's environmental performance (BREEAM, 2010a). *EcoHomes*, a version of BREEAM for homes, assesses the performance of homes in the following areas: energy, transport, pollution, materials, water, land use and ecology, health and well-being, management (BREEAM, 2010b). LEED, or Leadership in Energy and Environmental Design, is an internationally recognized green building certification system (U.S. Green Building Council, 2011). *LEED for Homes*, a home version of LEED, measures the overall performance of a home in eight categories: innovation and design process, location and linkages, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, awareness and education (U.S. Green Building Council, 2008). *Green Star*, which was developed by the Green Building Council of Australia, is a comprehensive, national, voluntary environmental rating system for buildings. Green Star tools, which include Multi Unit Residential, assess nine categories: management, indoor environmental quality, energy, transport, water, materials, land use and ecology, emissions, innovation (Green Building Council of Australia, 2011).

The above public assessment systems contain a variety of essential information; therefore, we referred to them when conducting this case study. On the other hand, as compared with these existing assessment systems, generally, the method in this case study has the following advantages (Fujihira, 2011).

1. Simplicity and clarity

Table 2 is easy to understand because it simply and clearly shows the relationship between the standard home and sustainable development.

2. Systematic

Table 2 systematically demonstrates the relationship between the material and spatial elements of the standard home and both the natural environment and humans' well-being. Accordingly, it provides balanced and comprehensive understanding of such relationship.

3. Ease of use

All of the elements shown in Table 3 are equivalent to real parts of homes. Therefore, when conducting a checkup on a home by using a checkup sheet like Table 3, designers simply check the home's parts which correspond to the elements. As a result, they can easily assess the variables of the elements.

4. Ease of finding measures for improvement

The results of a sustainability checkup like Table 3 show the elements which should be controlled, controlled variables, and their desired values, all at the same time. Therefore, such checkups enable designers to understand both what should be improved and the courses of improvement and help to find measures for improvement.

The above advantages show that the case study itself has sufficient practical use. Moreover, these advantages indicate the superiority of the method, or the two-step preparatory work for smooth control system design.

### 5.3 Future work

Our future work includes the following three tasks: (1) further research on sustainable homes, (2) direct support methods for designing control laws, (3) further case studies.

1. Further research on sustainable homes

Table 2 has successfully demonstrated the essence of sustainable homes, by determining the relationship between important elements of the standard home and sustainability conditions. However, this table probably has a room for improvement. We need to continue making efforts to improve this table through further research on sustainable homes.

In addition, it is also necessary to update this table, as occasion arises. The elements, variables, and their desired values which are shown in Table 2 can be changed or varied, in response to developments in related sciences, innovations in related technologies, and changes in social conditions. Therefore, we need to update this table, responding to such developments, innovations and changes.



## 2. Direct support methods for designing control laws

The two-step preparatory work enables system designers to identify and understand a controlled object and control objective as well as helps design control laws. However, our final goal is to establish a methodology of designing control systems for sustainable development. For this purpose, it is also necessary to show methods for supporting the design of control laws more directly.

## 3. Further case studies

In this study, we have conducted a case study, selecting the home as a unit of human activities. In order to increase reliability of this method, it is necessary to conduct further case studies. In the future case studies, we should select other units of human activities; for example, the city or town.

## 6. Conclusion

This study has shown the two-step preparatory work for smooth control system design for sustainable development with a case study. Chapter 3 has provided the two-step method: (1) determining the relationship between the standard human activities and sustainable development, (2) sustainability checkup on human activities as an object. Chapter 4 has applied this method to homes and demonstrated a case study. First, after selecting important elements of the standard home on the basis of the two factors, material and space, we have determined the relationship between such elements and sustainable development. Next, as the second step, we have conducted a sustainability checkup on a home as an object. The results of the case study have demonstrated the effectiveness of this method, for it enables system designers to identify and understand a controlled object and control objective as well as helps them design control laws. Furthermore, the usefulness of the case study itself has also indicated the effectiveness of this method. Our future work includes further research on sustainable homes, showing direct support methods for designing control laws, and further case studies.

## 7. Acknowledgement

I would like to thank Mr. Vance Carothers for his valuable advice and suggestions on the English expression of this paper.

## 8. References

- Beniger, J.R. (1986). *The Control Revolution - Technological and Economic Origins of the Information Society*, Harvard University Press, ISBN 0-674-16986-7, Cambridge, Massachusetts, USA
- BREEAM (2010a). What is BREEAM?, In: *BREEAM*, 03.10.2011, Available from: <http://www.breeam.org/page.jsp?id=66>
- BREEAM (2010b). EcoHomes, In: *BREEAM*, 03.10.2011, Available from: <http://www.breeam.org/page.jsp?id=21>
- Building Center of Japan (2009). Publication in English, In: *The Building Center of Japan*, 03.10.2011, Available from: <http://www.bcj.or.jp/en/services/publication.html>



- Energy Conservation Center, Japan (n.d.). Information on Energy-Saving Products (in Japanese), In: *Energy Conservation Center, Japan*, 03.10.2011, Available from: <http://www.seihinjyoho.jp/index.php>
- Fujihira, K. (1999). *An Introduction to Environmentology*, Nihon-Keizai-syuppansha, ISBN 4-532-14743-3, Tokyo, Japan (in Japanese)
- Fujihira, K. (2001). *A Short Introduction to Environmentology*, Kamogawa-syuppan, ISBN 4-87699-626-1, Kyoto, Japan (in Japanese)
- Fujihira, K. (2011). An Approach to Sustainable Homes by Applying Control Science, *Advanced Materials Research*, ISSN 1022-6680, online available since 2011/Nov/29, DOI: 10.4028/www.scientific.net/AMR.403-408.2087, Trans Tech Publications, Switzerland
- Fujihira, K. & Osuka, K. (2009). An Educational Methodology for Sustainable Development, *ICCAS-SICE 2009 Final Program and Papers*, ISBN 978-4-907764-33-3, Fukuoka, Japan, August 18-21, 2009
- Fujihira, K. & Osuka, K. (2010). How do we synthesize control systems for sustainability?, *Proceedings of Society of Environmental Science Annual Convention 2010*, p. 56, Tokyo, Japan, September 16-17, 2010 (in Japanese)
- Fujihira, K. & Osuka, K. (2011). An Approach to Designing Control Systems for Sustainable Development, *Proceedings of SICE Annual Conference 2011*, ISBN 978-4-907764-38-8, Tokyo, Japan, September 13-18, 2011
- Fujihira, K.; Osuka, K.; Yoshioka, T. & Hayashi, N. (2008). An Educational Methodology for Sustainable Development Applying Control Theory and Confirming its Validity, *Environmental Education*, Vol. 18-1, pp. 17-28, 2008 (in Japanese)
- Green Building Council of Australia (2011). What is Green Star?, In: *GBCA*, 03.10.2011, Available from: <http://www.gbca.org.au/green-star/green-star-overview/>
- Japanese Ministry of Land, Infrastructure and Transport (2001). *Japan Housing Performance Indication Standards*, Japanese Ministry of Land, Infrastructure and Transport (in Japanese)
- Japan GreenBuild Council & Japan Sustainable Building Consortium (2008). *Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) for Home (Detached House)– Technical Manual 2007 Edition*, Institute for Building Environment and Energy Conservation, Tokyo, Japan
- Oxford Dictionaries (2010). *Oxford Dictionary of English Third edition*, Oxford University Press, ISBN 978-0-19-957112-3
- U.S. Green Building Council (2008). LEED for Homes Rating System, In: *USGBC*, 03.10.2011, Available from: <http://www.usgbc.org/ShowFile.aspx?DocumentID=3638>
- U.S. Green Building Council (2011). What LEED Is, In: *USGBC*, 03.10.2011, Available from: <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1988>



**Sustainable Development - Policy and Urban Development -  
Tourism, Life Science, Management and Environment**

Edited by Prof. Chaouki Ghenai

ISBN 978-953-51-0100-0

Hard cover, 478 pages

**Publisher** InTech

**Published online** 24, February, 2012

**Published in print edition** February, 2012

The technological advancement of our civilization has created a consumer society expanding faster than the planet's resources allow, with our resource and energy needs rising exponentially in the past century. Securing the future of the human race will require an improved understanding of the environment as well as of technological solutions, mindsets and behaviors in line with modes of development that the ecosphere of our planet can support. Sustainable development offers an approach that would be practical to fuse with the managerial strategies and assessment tools for policy and decision makers at the regional planning level.

**How to reference**

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Kazutoshi Fujihira (2012). An Approach to Sustainable Development by Applying Control Science, Sustainable Development - Policy and Urban Development - Tourism, Life Science, Management and Environment, Prof. Chaouki Ghenai (Ed.), ISBN: 978-953-51-0100-0, InTech, Available from:

<http://www.intechopen.com/books/sustainable-development-policy-and-urban-development-tourism-life-science-management-and-environment/an-approach-to-sustainable-development-by-applying-control-science>

**INTECH**

open science | open minds

**InTech Europe**

University Campus STeP Ri  
Slavka Krautzeka 83/A  
51000 Rijeka, Croatia  
Phone: +385 (51) 770 447  
Fax: +385 (51) 686 166  
[www.intechopen.com](http://www.intechopen.com)

**InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen