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LIME2

Life-cycle Impact assessment Method based on Endpoint modeling

Chapter 3 – Integration of Environmental Impacts

Life-Cycle Assessment Society of Japan

LIME2

Life-cycle Impact assessment Method based on Endpoint modeling

Chapter III
Integration of Environmental Impacts

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Chapter III

Integration of Environmental Impacts

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Chapter III

Integration of Environmental Impacts

3.1 Characteristics of and main approaches to the integration of environmental impacts

Main changes for and characteristics of LIME 2

- Random sampling was adopted to carry out a lower-biased survey.
- Weighting factors representative of the Japanese people's environmental views were gained through a nationwide door-to-door survey covering 1,000 people.
- It was verified that the weighting factors are statistically significant.
- Differences among individuals in terms of their environmental values were quantified by the random parameter logit model (RPL).
- The integration factors were calculated using weighting factors that reflect the above description.
- The representative values of the integration factors were renewed and the amount of statistics was calculated. This made it possible to carry out an uncertainty analysis of the LCIA results during the interpretation of an LCA case assessment.

3.1.1 Usefulness of the integration of environmental impacts

There are various environmental problems around us, including the following: regional problems, such as air pollution and water pollution, which have been regarded as problems in Japan since the high-growth era; global problems, such as global warming and ozone layer destruction; and the problem of resources depletion, which may occur in the future due to resources consumption, which is the fundamental factor behind the above-mentioned problems. When products and systems are planned in order to improve the environment, usually one or several of these environmental problems are identified and attempts are made to reduce their effects. However, even if a product has an enormous effect on an environmental problem, the product may worsen another environmental problem.

LIME makes it possible to obtain the results of characterization and damage assessment at the stage preceding the integration. The results of characterization can be collected for each category indicator, and the results of damage assessment can be collected for each endpoint. Because the results of such a calculation can be obtained for several items, if a trade-off relationship occurs, the comprehensive judgment is left to researchers and other persons concerned. If the integrated environmental impacts can be expressed by a single index after the comparison and measurement of various environmental problems, it is possible to devise measures for reducing such environmental impacts efficiently in an easy-to-understand way.

The use of LCA results is divided into internal use and external use. In the case of internal use, those who receive reports on LCA results are expected to be product developers, supervisors, and decision makers. In the case of external use, general consumers and interested parties are expected to receive such reports. To prevent a company from unfairly taking advantage of the interests of other companies, ISO 14044 (2000) prohibits the imposition of some limits on the use of integration (comparison of the results of integration between the company's product and the rival companies' products and external announcement of the results (which is called comparative assertion)) (see the next section). On the other hand, there is no limitation on uses other than for comparative assertion, such as informing the interested persons within the company of the results of integration (which falls under internal use) and externally announcing the results of a comparison between the company's products by integration. Such integration is allowed under ISO because integration that does not cause a trade-off relationship has been recognized as being easy for general consumers with no special environmental knowledge to interpret the results and is excellent as a communication tool. Recently, integration methods have been highly evaluated as a means of providing information to consumers. For example, the integration results have been published in environmental reports, and environmental accounting has been used for other assessment tools.

In summary, the integration of environmental impacts seems to have the following advantages:

1) Because the results are expressed in a single index, no trade-off relationship occurs.
2) Because interpretation is easy, it is useful as a means of communicating information through environmental reports.
3) It is highly applicable to other environmental assessment tools, such as environmental accounting and environmental efficiency.

3.1.2 Main methods for the integration of environmental impacts

Paying attention to the advantages of integration methods as described in the preceding section, various types of research and development have been carried out so far. In Chapter I, Section 1.2, the theme-oriented methods and the damage-oriented methods were identified as the main integration methods for LCIA and a comparison was made between them. In this section, integration methods will be explained with the addition of substance comparison methods. Table 3.1-1 summarizes the characteristics of each approach.

Under the substance comparison method, a weighting is applied to each of the substances of concern. MIPS (Schmidt-Bleek 1993), CED (VDI-Richtlinien 1997), Ecological Footprint (Wackernagel 1996), Eco-scarcity (Müller-Wenk 1994, and JEPIX (Miyazaki 2003) come under this type of method. Substance comparison methods can be roughly divided into alternative methods and distance-to-target (DtT) methods.

Table 3.1-1: Classification and characteristics of main integration methods proposed so far

	Procedure until integration	Main approach	Main method	Advantage	Problem/issues
Substance comparison method	Inventory ↓ Single index	Alternative methods, (Resource consumption, energy consumption, area of used land), DtT methods	MIPS (Schmidt-Breek 1993) CED (VDI-Richtlinien 1997) Eco-scarcity (Müller-Wenk 1994) Ecological Footprint (Wackernagel 1996) JEPIX (Miyazaki 2003)	• Assessment method is simple. • Development of the method is relatively easy. • The concept is easy to understand. • The meaning of the assessment results is easy to understand (alternative index).	• No consideration is given to the actual environmental impact. • Highly arbitrary and manipulable (DtT method). • Natural scientific knowledge on environmental impacts is abstracted. • Not according to ISO standards.
Theme-oriented method	Inventory ↓ Impact categories (Characterization) ↓ Normalization ↓ Single index	DtT methods Panel methods	Eco-indicator'95 (Goedkoop 1995) Nagata (1994) Itsubo (1997) Matsuno (1998) Yasui (1997) Lee (1998)	• Highly consistent with ISO standards. • Concept is relatively easy to understand. • Development of the method is relatively easy.	• No consideration is given to the actual environmental impact. • Natural scientific knowledge is not fully reflected. • Lack of transparency of the weighting. • Little information for the weighting.
Damage-oriented method	Inventory ↓ Impact categories ↓ Endpoints ↓ Single index	Panel methods Economic assessment methods	Eco-indicator'99 (Goedkoop 2000) EPS (Steen 2000) ExternE (EC 1998) LIME	• Assessment method is highly transparent. • A distinction can be made between the field of natural sciences and the field of social sciences. • Natural scientific knowledge is incorporated as much as possible. • The number of items for weighting can be minimized.	• A great effort is required for the development of the assessment method. • Assessed substances are limited. • Difficult to understand the details of the assessment method.

Alternative methods are based on the assumption that it is difficult to assess environmental impacts in reality and the assumption that energy consumption and the total volume of used substances indirectly expresses environmental impacts. Under MIPS, the alternative index to environmental impacts is the total volume of raw materials used throughout the lifecycle of the product in question. Under CED, the total volume of the energy uses is adopted as an alternative index to environmental impacts. Under the Ecological Footprint method, the area of land required for dealing with the environmental impacts is expressed as an alternative index and was used for assessing the sustainability of modern society.

The Eco-scarcity method was developed by Müller-Wenk as a method for the assessment of corporate eco-balance. This method comes under the category of the DtT method, whereby a comparison is made between the current level and the predetermined target level for each substance and the greater the difference between them means a greater environmental impact. This approach has been widely adopted for theme oriented methods (see Reference Column 3.1-1). Because the current levels (such as the level of the environmental density of a substance) and the target levels (such as the level of environmental standards) are assumed to differ from place to place, European countries have developed their versions of the Eco-scarcity method based on environmental standards. JEPIX is a Japanese version of the Eco-scarcity method.

The substance comparison methods have the following advantages: assessment results (alternative indexes) are easy to understand; the concept is simple and easy to understand; and it is easy to develop integration factors. On the other hand, they have the following problems: no analysis or assessment is carried out concerning actual environmental impacts; this makes it impossible to verify the accuracy of the results of environmental impacts; the methods are not in accordance with ISO standards (characterization and other essential processes are not carried out); and natural scientific knowledge on the rise in temperatures due to warming, health impacts, and other aspects is often abstracted from the assessment. Due to these problems, they are not much used for case studies of the LCIA. However, they can be used to set up standards for the environment performance of companies.

Under themeoriented methods, the potential amount of environmental impact is assessed for each environmental problem, such as global warming, and single indexes are gained through weighting among the environmental problems. Such methods include Eco-indicator 95 (Goedkoop 1995), EDIP (Hauschild 1997), and those developed by Huppes (1997), Walz (1997), Lindeijer (1997), Nagata (1995), Itsubo (2000b), Matsuno (1998), and Yasui (1998). These methods can be roughly classified into panel methods and DtT methods.

Under the panel methods, the degree of importance of each environmental problem is estimated from samples or by an expert panel to gain a weighting factor for the impact categories. Nagata directly questions a specific group of respondents (such as students, industrial associations, and LCA-related persons) about the degree of importance of impact categories. Yasui obtains the weighting factors by questioning respondents about the grace period until a crisis situation and the degree of seriousness of the impact categories. Huppes calculated weighting factors among impact categories through discussions by a panel of policy-related persons. Waltz and Lindeijer calculated it through discussions by a panel of environmental experts.

Eco-indicator 95, EDIP, Matsuno, and Itsubo adopted DtT methods (see Column 3.1-1). Although the basic concept of weighting is the same as in the case of DtT methods of the substance comparison type, these types of DtT methods are different from the substance comparison type in that the weighting factors are developed among environmental problems (impact categories) instead of among substances. To make a comparison among impact categories, non-dimensionalization is made through normalization before weighting. Equation 3.1-1 is a calculation equation for impact assessment based on a general DtT method.

$$SI = \sum_{Impact} \left(\frac{CI^{Impact}}{NV^{Impact}} \times \frac{NV^{Impact}}{T^{Impact}} \right) = \sum_{Impact} \left(\frac{CI^{Impact}}{NV^{Impact}} \times W^{Impact} \right) \qquad (3.1.1)$$

In this equation, *SI* is a single index (non-dimensional). CI^{impact}, NV^{impact}, T^{impact}, and W^{impact} are the characterization results, the normal value, the target value, and the weighting factor in an impact category for the respective *Impact*. The normal value is used for not only for normalization, but also the calculation of the weighting factor as the actual value.

Because, under a theme oriented method, integration is based on the results of characterization, consistency with international standards is high. Moreover, this type of method has the following advantages: the concept of integration is easy to understand and it is relatively easy to develop a weighting factor. However it has the following problems: the number of items to be compared is large (ten or more items); a heavy burden is placed on the respondents (panel method); the weighting factors gained from questionnaire results are not examined in terms of statistical significance (panel method); there is little information for determining the weighting; and the transparency of the weighting is low (for details, see Section 1.2).

Damage-oriented methods compare and integrate the damage expected to be given to an endpoint by the environmental impact (for details, see Section 1.2). LIME belongs to this type of method as with Eco-indicator 99 (Goedkoop 1999), EPS (Steen 1999), and Extern E (EC 1998). These methods can be roughly classified into panel methods and economic assessment methods.

Under a panel method, experts and general consumers assess environmental impacts through questionnaires and group discussions. Under Eco-indicator 99, an integration factor was gained from a weighting derived from experts through a comparison among the three predefined areas of protection (human health, soundness of ecosystems, and resources). This type of method is characterized by setting a weighting for each environmental concept (hierarchism, egalitarianism, and individualism). On the other hand, because the number of the samples is small, it is impossible to ensure the representativeness of the research results.

Economic assessment methods express environmental impact using the monetary amount. Many discussions have been held concerning the environmental impact for the purpose of environmental economics. Under this type of method, knowledge gained in this field is used for LCIA. Environmental economics theories regarding environmental assessment will be described in Section 3.2. Under EPS and Extern E, the willingness to pay gained from the contingent valuation method (CVM) or the like is referred to for the integration of LCIA. Because assessment results are expressed in monetary amounts, they are easy to understand and can be used for cost effectiveness analysis. Therefore, they can be said to be an excellent indicator in its application. On the other hand, the economic assessment of health losses and ecosystems decline as environmental impacts are still under development. It has been pointed out that the economic assessment of health has ethical problems.

The advantages of damage-oriented methods include the following: making it possible to distinguish special categories in the parts based on natural scientific knowledge (until damage assessment of endpoint) with those in the parts based on social scientific analysis (from an endpoint to a single index); improving transparency through clarification of additional assessment items (types of diseases and species of living things); and reduction in the respondents' burden due to the small number of comparison items (see Section 1.2). On the other hand, research has still not been sufficiently developed to fully assess endpoint damage, which serves as a precondition for integration, thus there are the following problems: it takes considerable effort to develop an assessment method; and the assessable range (of substances and endpoints) may be limited. Moreover, because the assessment method is complicated, it takes a lot of time for the users to understand the details of the methodology.

Column 3.1-1:

Distance to Target methods

Distance to Target (DtT) methods are based on the assumption that the difference between the target value and the actual value shows the environmental impact. In the second half of the 1990s, these methods drew considerable attention and many methods were proposed. Figure 3.1-A shows the concept of weighting under the DtT methods. The greater the difference between the predetermined target value and the current environmental impact, the higher the setting of the weighting factor. Because the national government's environmental standards and emissions reduction level are used for setting the target values, the concept of weighting is easy to understand. The setting of the target value is not based on an individual's subjective view but on information authorized by the national government. Therefore, the introduction of a subjective view by the executing agency can be avoided. Moreover, because the parameters used for weighting are only two – the target value and the actual value –, it is relatively easy to set the weighting factor.

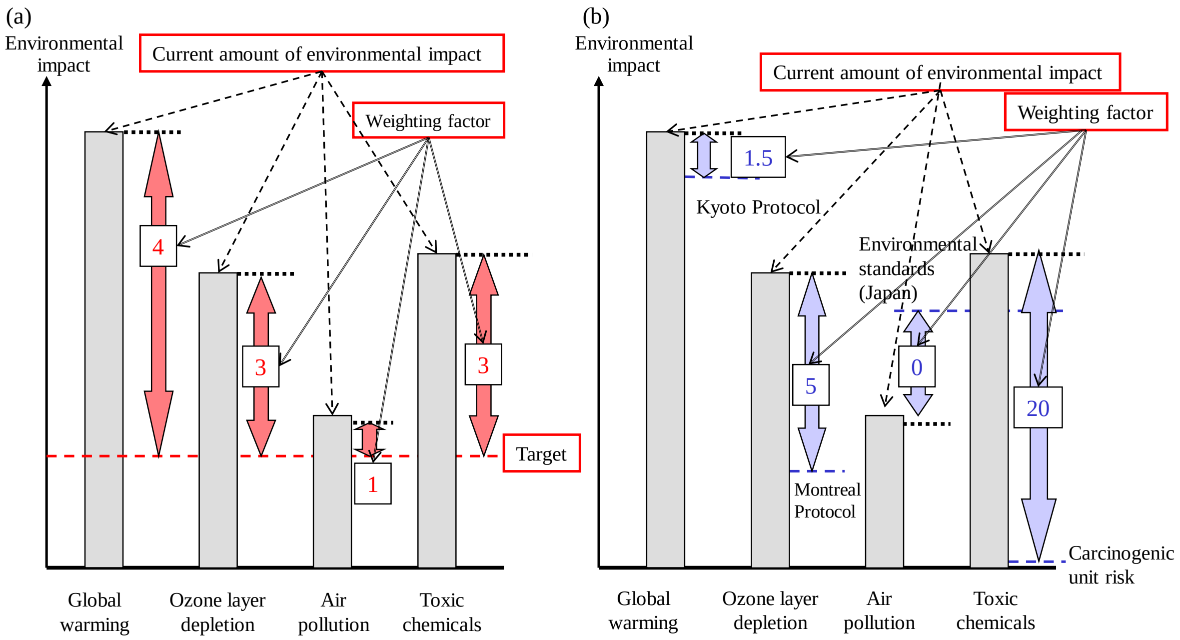


Figure 3.1-A: Concept of the weighting factors under DtT methods

It is desirable to express the difference between the target and current environmental impacts as a weighting factor (a). However, because the method developer separately sets a target for each impact category (b), the actual weighting factors become different from those in (a).

However, DtT methods have some problems. For example, the weighting factor for global warming greatly differs between the target level of the Kyoto Protocol (in Japan, a reduction of 6% from the emissions level in 1990) and a level that hardly causes any impact from warming (in the case of the former, because the weighting factor becomes almost 1, it is often not adopted). In the case of eutrophication, because environmental standards have been established for each lake in Japan, there are eutrophicated lakes and oligotrophic lakes. The weighting factor for eutrophication greatly differs, depending on each lake's target and current levels. For example, if the worst case is applied, the weighting factor will become very large.

In this way, there are many possible target levels. A target level that a method developer considers appropriate is applied from among the levels to determine the weighting factor. This means that setting the weighting factor is highly arbitrary. To avoid such arbitrariness as much as possible, it is desirable to set a common target (for example, conservation of 90% of the forests in Japan, a reduction of deaths to 100 or less, etc.) and discuss at what level the target for the impact category should be set. However, with regard to most of the DtT methods, there has been no discussion about the equivalence among the target levels set for impact categories.

In addition, the assessment equation differs among the DtT methods. For example, under the Eco-scarcity method, the weighting factor is calculated by dividing the current level by the square of the target level (Equation 3.1-A).

$$SI = \sum_S \left(Inv._S \times IF_S \right) = \sum_S \left(Inv._S \times \frac{N_S}{{T_S}^2} \right) = \sum_S \left(\frac{Inv._S}{N_S} \times \left(\frac{N_S}{T_S} \right)^2 \right) \qquad (3.1\text{-A})$$

On the other hand, under many of the theme oriented methods, the results of characterization are normalized (by dividing them by the current level) and multiplied by the ratio of the current level and the target level (therefore, the results of the equation are calculated by dividing the results of the characterization by the reciprocal of the target level; Equation 3.1-1). Therefore, the Eco-scarcity method has a stronger focus on substances whose target level is severer. Because the assumption is that the difference between the current and target levels is regarded as the environmental impact, it is impossible to determine which calculation methods are more realistic.

Due to the situation described above, recent LCIA research has produced few methods that have been developed based on this approach.

3.1.3 Problems in the integration of environmental impacts

Method development research and case studies concerning integration have already been considered to a significant extent, whether in Japan or overseas. Notwithstanding, ISO 14044 divides each of the steps constituting LCIA into essential elements (which must be carried out) and optional elements (which may or may not be carried out according to each user’s purpose) and regards their integration as an optional element.

Whether expressed or not, the integration of various environmental impacts means that the weighting of aspects is influenced by environmental changes, such as human health, plants, biodiversity, farm products, the water industry, etc. Comparison of these cannot be resolved through knowledge based on the natural sciences, but is determined according to how the assessors and users subjectively or collectively understand the environment. If their cultural, academic, or economic backgrounds differ, the sense of value concerning the environment will differ. Since the population for weighting differs among the integration methods proposed so far (in Europe, Japan, etc.), the LCA results were often not consistent, depending on the integration method. Moreover, even if the population to determine the weighting was the same, the results sometimes differed, depending on the integration method used (Itsubo 2000a).

Because of this, there is the fear of malicious use, such as by a company handling the weighting factors so that the assessment results for its product will become better than the products of rival companies, or a disclosure of the results of assessment by a company using methods that favorably assess its product. To restrict such use, ISO

14044 has made integration an optional element and has prohibited the use of integration for comparative assertions.

It is true that there are users who assume a negative attitude towards integration because of what has been described above. However, there are many companies that use integration, placing greater importance on easy-to-understand assessment results and a wide range of application than only on complicated ethical, social, and economic factors. Many pioneer companies carry out assessment through the use of their own weighting factors or existing integration factors and publish the results through environmental reports or websites. Examples of use of LIME by companies are shown in Tables 0.1-2 and 0.1-4. According to these tables, LIME is much used for not only the LCA of products as before, but also for corporate assessment, environmental accounting, and environmental efficiency. These use the single index in LIME as a communication tool. The steps for LCIA, including their integration, have both advantages and disadvantages. In the future, an increase is expected in the number of companies that use the advantages of integration, such as ease of interpretation and greater applicability of the assessment results. It is essential to develop an integration method that can cope with such general-purpose use.

3.1.4 Important issues concerning research on integration

As described so far, there are various types of approaches to the integration of environmental impacts. Each of the approaches has both advantages and disadvantages. Moreover, the existing research on integration not only has the problems described in the preceding section, but also confronts the important issues described below.

(1) Representativeness of value judgments

Many integration methods were developed on the assumption that they would be used for general purposes irrespective of the products or users. Therefore, it is necessary to confirm that the value judgments are representative of the population.

CVM and conjoint analysis, which are usually used for environmental economics, are based on the fusion of economics and inferential statistics. In the case of inferential statistics, a survey is carried out using samples randomly chosen from a certain population (for example, the Japanese people) and a statistical model is applied to the survey results to infer the social preferences of the population by mathematical analysis (Figure 3.1-1). The inference results are inspected to verify not only that they are statistically significant, but also that the statistical model used for the regression to the population has representativeness as a social preference. If the statistical model passes this inspection, it will be used for decision-making for cost-benefit analysis, etc.

Much of the research on the integration of LCA was not conducted in accordance with the process shown in Figure 3.1-1 in the past. Finding a weighting factor that is representative of a population requires various efforts – not only using inferential statistical theories, but also securing a sufficient number of samples and determining whether the respondents have understood the questionnaire. If the mean value is based on a penal or questionnaire for a population with a size of several dozen people, but no inspection is carried out, the mean value should be limited to use within the group of samples, but cannot be used in other groups.

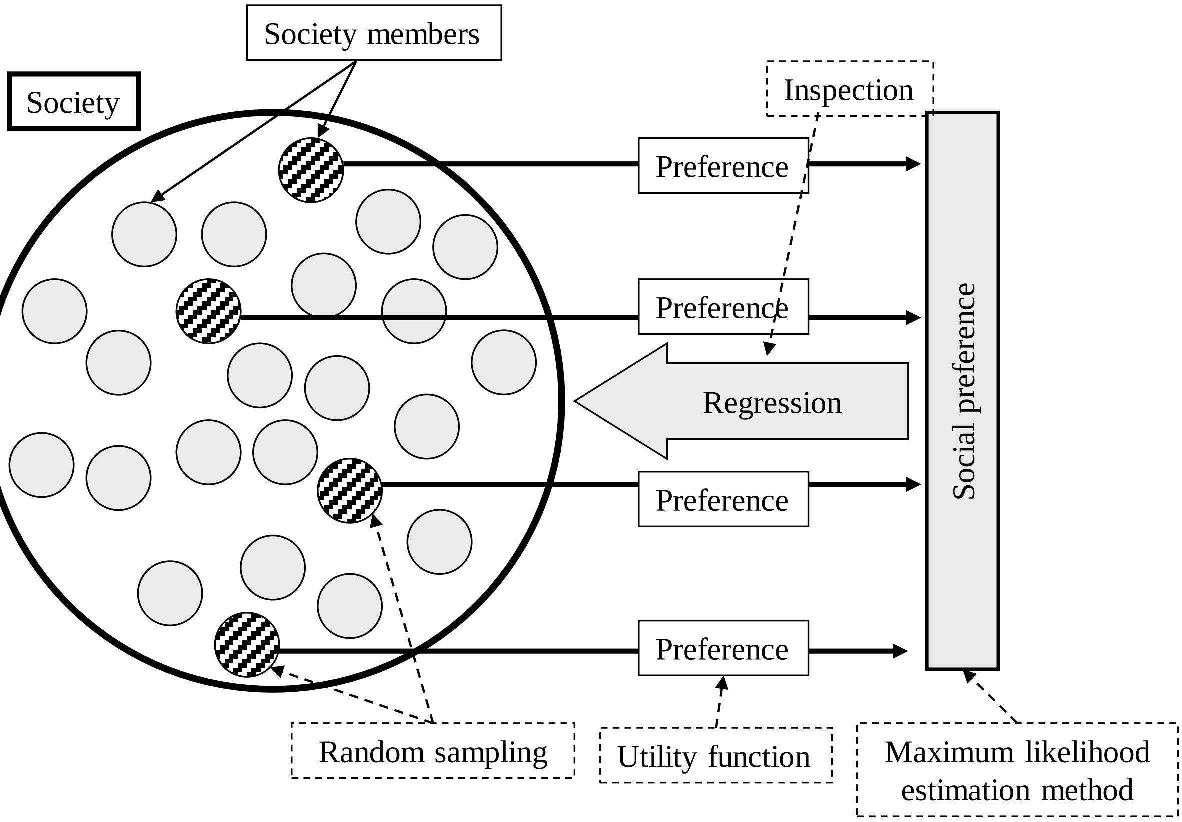


Figure 3.1-1: Procedure for the calculation of social preferences representative of the population using inferential statistics

(2) Individual differences in the weighting

Value judgments differ among the individuals constituting a group. However, the differences are not so great that a trend cannot be ascertained. Their value judgments are distributed within a certain range. In the integration methods so far, including LIME 1, weighting factors representative of the population were inferred, but without taking into consideration individual differences regarding value judgments. Showing how widely individual differences are dispersed is desirable for securing transparency of the weighting factors.

3.1.5 Purpose of research in LIME 2

In LIME 1, research was carried out to apply conjoint analysis, which has drawn attention to the integration of LCIA in the fields of market research and environmental economics. As a result, it has been possible to develop statistically significant integration factors. However, because the following problems were not solved due to limitations on the research costs and other factors at this stage, it is difficult to say that the representativeness of environmental ideas in Japan has been fully secured:

1) Because the target of the research was 400 people in the Kanto region, the research results cannot be said to indicate the sense of environmental values of the Japanese people.

2) Because the mall intercept*[1] procedure was used for the research, the possibility of a bias at the stage of sampling cannot be denied.
3) Although the sense of environmental value differs among individuals, no consideration has been given to the range of variation.

In LIME 2, the problems were solved and consideration was given to developing integration factors with a higher social consensus.

Figure 3.1-2 shows the survey procedure. Firstly, a questionnaire was prepared and pretests were carried out using the questionnaire. The pretests were carried out twice. They used a random sampling method like the main survey. The issues to be resolved to carry out the main survey smoothly were identified and consideration was given to solving these issues. Although some individuals refused to disclose their basic resident register status to protect personal information, there seems to have been no special problems in the implementation of the main survey, since statistically significant results were acquired. The main survey was carried out as a nationwide random survey with about one thousand samples to calculate the weighting factors for the areas of protection.

To achieve the goal, the main survey focused especially on the following:

1) Development of weighting factors that are highly representative and can be used for general purposes
2) Calculation of the amount of statistics concerning the weighting factors

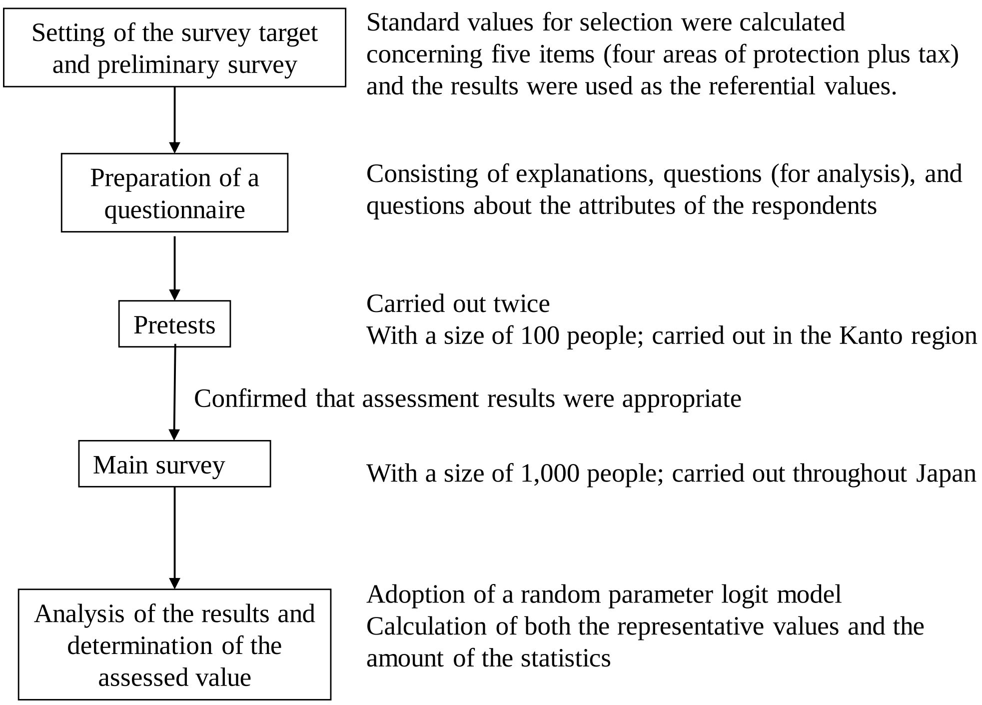


Figure 3.1-2: Procedure for environmental economic assessment under LIME 2

[1] The mall intercept procedure involves requesting people on-the-street to cooperate in a questionnaire survey. Mall intercepts can secure relatively many samples in a short period. However, if there are many people who do not cooperate in the questionnaire survey, a bias may arise due to the small proportion of cooperative people.

(1) Development of weighting factors that are highly representative and can be used for general purposes

To ensure the representativeness of the environmental view of the population (in this research, the Japanese people), it was necessary to (1) adopt an appropriate sampling method and (2) secure a certain number of samples.

In this case, the random sampling method, which can prevent the occurrence of a bias at the stage of sampling, was adopted, since the weighting factors that are representative of the population are extremely important in the use the integration factors for general purposes. Moreover, to improve the representativeness of the Japanese people's environmental views, interviews will be held with about 1,000 respondents selected randomly from throughout Japan to develop integration factors based on an analysis of interview results.

(2) Calculation of the extent of the statistics for the weighting factors

Under LIME 1, with regard to weighting factors, only the representative values were calculated. Under LIME 2, the variability of the weighting factors was also calculated. RPL was adopted for this analysis. Moreover, the amount of statistics for integration factors was calculated through the use of the analysis results and the amount of statistics for damage factors. The Monte Carlo method was used for this analysis.

In Section 3.2, explanations will be given concerning the general procedures and analysis methods for the environmental economic assessment and conjoint analysis. Section 3.3 will describe the survey method for LIME 2 and survey results.

3.2 Environmental economic assessment and the conjoint analysis

3.2.1 Characteristics of the main environmental economic assessment methods

From the viewpoint of a company's design of a product, environmental information on the product is an element of the product function and requires consideration of the various aspects, such as cost and safety, before decision-making. Therefore, it is desirable that environmental information should be simple and clear. From this viewpoint, closer attention has been paid to the integration methods than other methods related to LCIA. Because of the usability of the assessment results and the ease of interpretation, expectations for the development of economic assessment methods have been growing.

These environmental economic assessment methods can be classified as shown in Figure 3.2-1 (Washida 1999a). Firstly, they can be classified into methods for assessing the value of the environment independent (irrespective) of individual preferences (preference-independent type) and methods for assessing the value of the environment dependent on individual preferences (preference-dependent type).

The preference-independent assessment methods include the replacement cost method and the dose-response method. Under the replacement cost method, the target environment is replaced with the cost required to produce an alternative to the environment as the environmental value. For example, if the water-retaining function of a forest is replaced with a dam, the cost of constructing and maintaining the dam is the value of the forest's water-retaining function. Under the dose-response method, if a certain value is created as a result of a change in the environment, the newly gained value is regarded as the lost environmental value. Although the preference-independent assessment methods can result in a relatively easy consideration due to the use of costs and produce highly reliable results, it is hard for them to be socially accepted due to ignorance of the environmental preference of individuals. In particular, if the target has complicated and various functions, such as in an ecosystem, there is a trend towards denial of the existence of an alternative economic behavior itself. Therefore, preference-independent assessment methods have not been used much recently.

The preference-dependent assessment methods are divided into the revealed preference methods and the stated preference methods. The former indirectly determines individual preferences from the actual monetary amount paid by them, while the latter directly ask individuals about their preferences concerning the environment.

The revealed preference methods are divided into the travel cost method and the hedonic price method. The travel cost method assesses the value of the target environment from expenditures paid by people visiting there. The hedonic pricing method assesses the values of various living environments from the prices of real estate, such as land and houses. These revealed preference methods are advantageous in that the results are highly reliable, since an individual's sense of value is inferred from the amount actually paid as in the case of the preference-independent assessment methods. On the other hand, they lack flexibility in their assessment, since they can only assess whether what an individual actually paid can apply to an alternative act, and therefore the range of assessable objects is limited.

The stated preference methods are excellent in that they can assess not only the available values, but also unavailable values, such as inheritance value and existence value. Recently, the stated preference methods have been used for environmental economic assessment more frequently than the revealed preference methods.

The typical stated preference methods are CVM and conjoint analysis. CVM measures the environmental values by directly asking individuals about their willingness to pay (WTP) and willingness to accept (WTA) concerning the environment or by counting the population concerned with the distribution. CVM is the method most frequently used for the assessment of ecosystems, including their existence value, because, depending on the assessor's design of the questionnaires, it can inform the respondents of the characteristics of the environment to be assessed and is highly flexible. Various methods have been devised to identify the respondents' real willingness to pay, and there are guidelines for how to prepare such questionnaires (Federal Register 1993). Table 3.2-1 shows the main cases of environmental assessment using CVM (Kuriyama 2000a). As shown in this table, CVM has already been used for various purposes. The US has not only been using the results of assessment by CVM for cost-benefit analysis, but has also been making efforts to introduce them into the real world. For example, the courts are using it as grounds for the calculation of compensation costs.

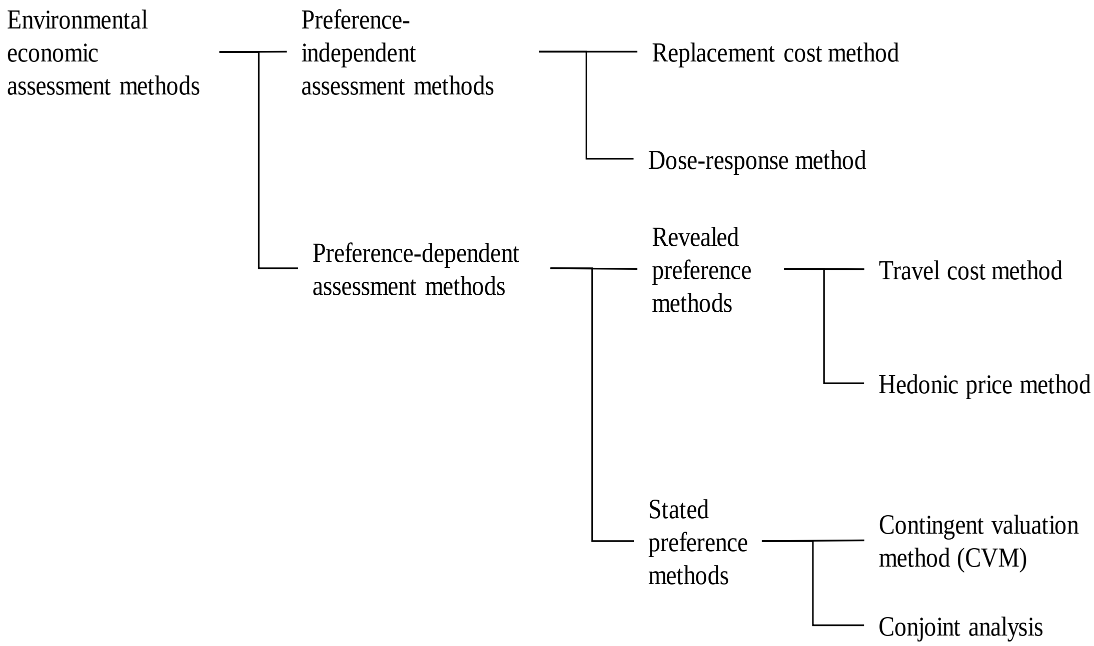


Figure 3.2-1: Classification of environmental assessment methods according to environmental economics (Washida 1999)

Table 3.2-1: Main cases of environmental economic assessment in Japan (Kuriyama 2000a)

Area of assessment		Assessed value	Area of counting	Sources
Forestry ecosystem	Conservation of Yakushima Island, a world natural heritage	248.3 billion yen	Whole Japan	Kuriyama (2000b)
River environment	Natural environment in the lower reaches of the Yoshino River	262.8 billion yen	Whole Japan	Washida (1999c)
Wetland landscape	Landscape of the Kushiro Wetland	14.8 billion yen	Hokkaido	Kuriyama (1998)
Conservation of water source forests	Protection of the water source forest in the upper reaches of Yokohama City	0.7 billion yen	Yokohama City	Yoshida (1996)
Conservation of tidelands	Conservation of Fujimae Tideland	296 billion yen	Whole Japan	Washida (1998)
Global warming measures	Social impact of warming measures	779.5 billion yen	Whole Japan	Iwakura (2000)
Conservation of farmland	Conservation of farmland all over Japan	4,100 billion yen	Whole Japan	Yoshida (1997), Yoshida (1999)
Recycled products	Recycled value of water purifiers	24.5 billion yen	Purchasers	Kuriyama (1999)

Although conjoint analysis directly asks individuals about their opinions as with CVM, it differs greatly from CVM in that it can assess differences in the degree of preference among various attributes of the target environment (Figure 3.2-2).

If the natural environment, the object of assessment, is regarded as having a single attribute, CVM will be used. However, it is often better to regard the natural environment as having many attributes. For example, when the value of a wetland is assessed, analysis that takes into consideration trade-off relationships among various elements (attributes), such as the cost of conserving a natural landscape, organism species, and a wetland, is often advantageous to find the direction of policy decision-making. For such a purpose, it is possible to demonstrate the characteristics of conjoint analysis.

The purpose of integration under LIME is to establish a single index, weighting between four areas of protection. CVM has the following advantages: (1) because it has substantial results, the analysis results can be relatively easily verified; and (2) it is easy for respondents to provide answers because it is based on a paired comparison between the price and the object of assessment. However, if CVM is adopted, it is necessary to assess each of the four items separately. Moreover, although weighting among the items can be gained afterwards from the results of CVM assessment, it is not direct a "weighting" among the areas of protection. Under ISO 14044, integration is called weighting. This seems to express that weighting is made among the items that have to be evaluated when a single index is established. Therefore, conjoint analysis is more consistent with the framework of ISO than CVM, because the former can carry out weighting among the target items and assess the partial utility of each item (Figure 3.2-3). Because of this, under LIME, conjoint analysis was used for calculating integration factors from weighting among the areas of protection.

An explanation will be given below concerning the general methods for conjoint analysis (questioning, methods for analysis of the survey results, methods for the inspection of the analysis results).

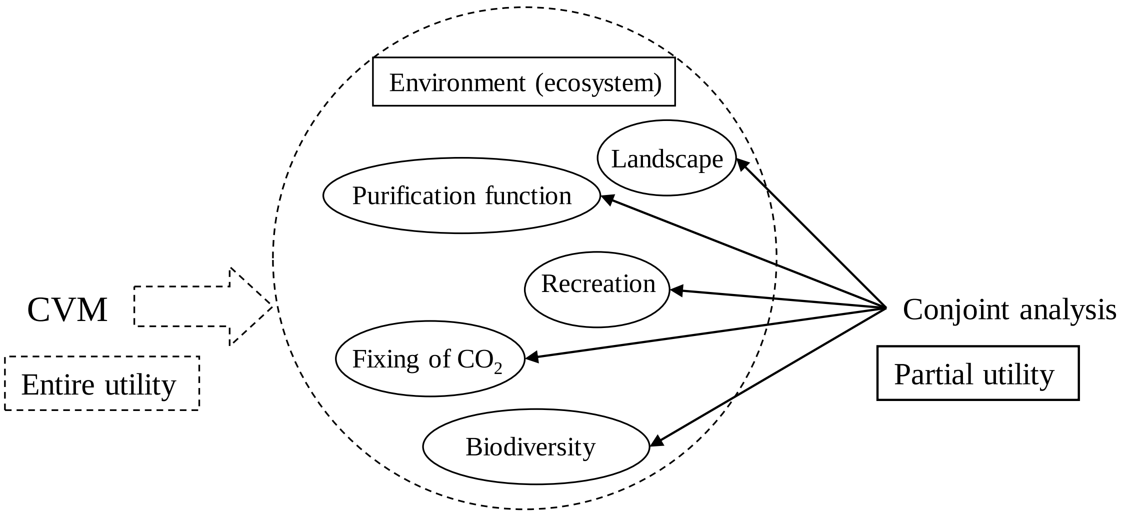


Figure 3.2-2: Difference between CVM and conjoint analysis

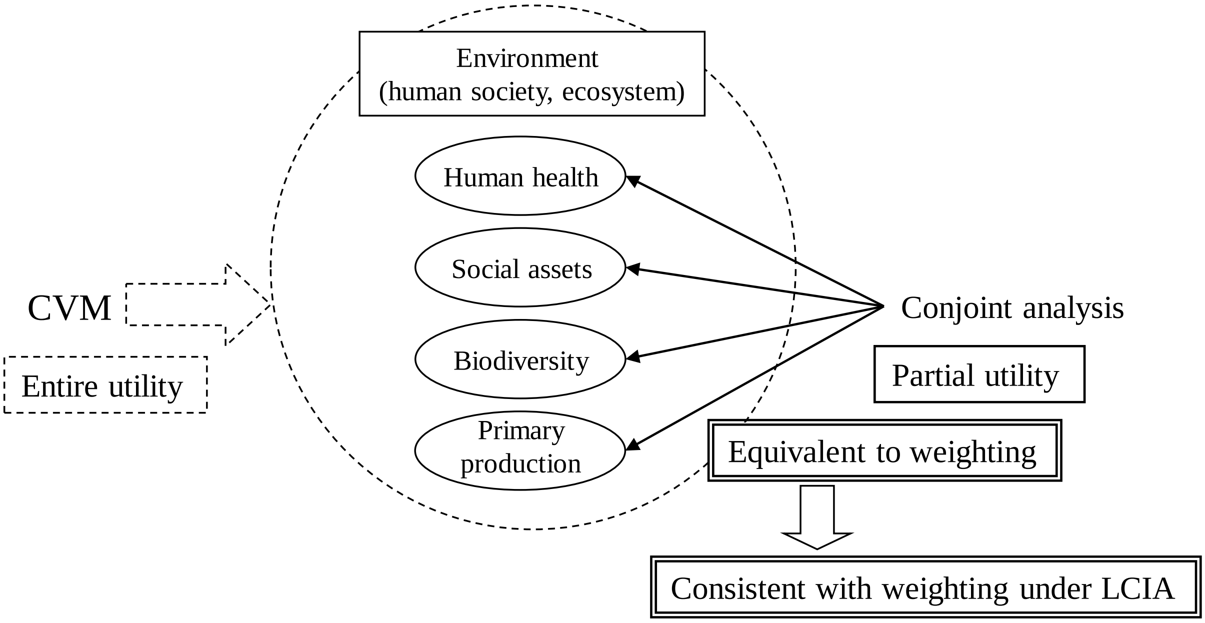


Figure 3.2-3: Difference between CVM and conjoint analysis
Conjoint analysis, which assesses partial availability, is consistent with integration under LCIA.

3.2.2 Method for environmental assessment using conjoint analysis

Figure 3.2-4 shows the procedures for environmental economic assessment using conjoint analysis. The same processes were applied to the calculation of the weighting factors under LIME 2 (Figure 3.1-2).

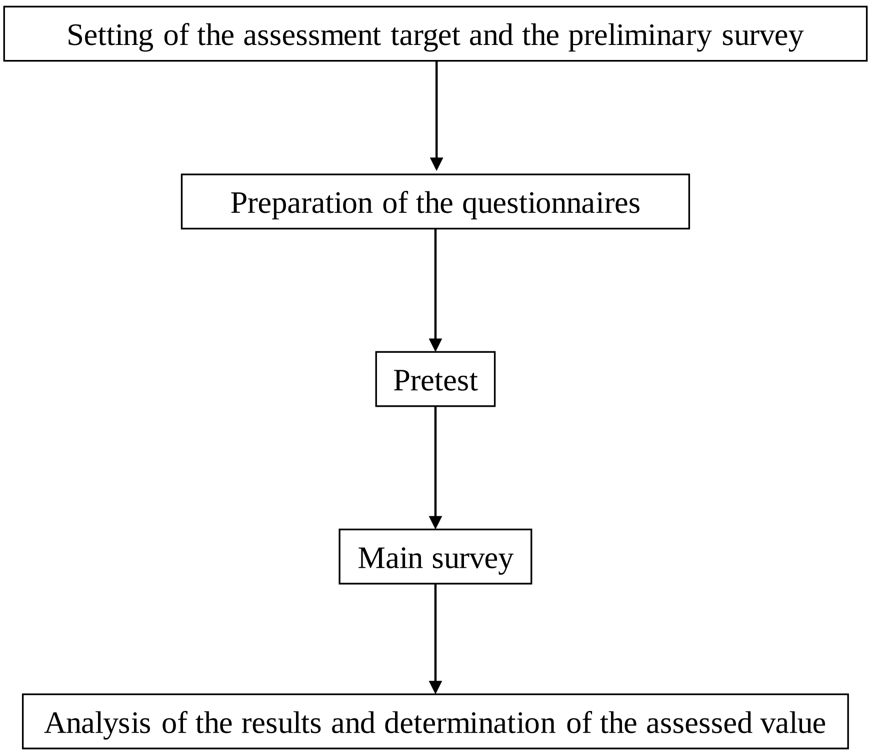


Figure 3.2-4: General procedure for environmental economic assessment by conjoint analysis

(1) Setting of the assessment target and the preliminary survey

Definitions are established concerning the environment as the assessment target, environmental attributes (which are elements of the environment and are assessed by conjoint analysis), and changes in the status of the environmental attributes. To define these, it is important to collect information to present a highly realistic profile (a bundle of information on each attribute).

(2) Preparation of a questionnaire

A profile is designed from information gathered beforehand. When a questionnaire is prepared, consideration is given so that respondents can correctively understand the contents of the profile, a clear explanation of each attribute is included, and questions are added to gain information on the characteristics of the respondents (yearly income, sex, age, etc.). If the respondents cannot understand the contents of the questionnaire or their views cannot be reflected, the survey results will not pass inspection, and highly representative results cannot be gained. Therefore, the preparation of the questionnaire is the most important factor in gaining results with a high social consensus. The questioning method will be described in 3.2.3 “Question format for conjoint analysis.”

(3) Pretests

Pretests must be carried out several times to check whether the respondents could correctly understand the prepared questionnaire and provide answers that reflect their environmental views. This questionnaire survey is carried out with a smaller sample than for the main survey.

(4) Main survey

The main survey is carried out after revision and the completion of the questionnaire based on the results of the pretests. The questionnaire survey can be carried out by interview, telephone, mail, the Internet, or other means. The characteristics vary according to the survey method. Such considerations are taken into account when selecting the most appropriate means for the main survey. For the details of the survey methods, see 3.2.4 “Field survey using conjoint analysis.”

(5) Determination of the assessed value

The acquired results are analyzed by applying the conditional logit model (CL) to the random utility model. The preference strength of each attribute is estimated using the maximum likelihood estimation method. Details of the analysis method will be described in 3.2.5 “Analysis of the questionnaire results.” If the attributes include a monetary attribute, the WTP of the environmental attribute can be gained from the ratio between the environmental attribute and the monetary attribute. In addition, examination is carried out to determine whether the estimated preference strength is appropriate as the representative value.

3.2.3 Question format for conjoint analysis (see Washida, Kuriyama, Takeuchi 1999b)

Conjoint analysis can be divided into the following three types according to the method of questioning: 1) choice; 2) rating; and 3) ranking. At present, the choice type has been frequently used. Each of the types is explained below.

Question: Which car will you purchase, A, B, C, or D?

Attribute \ Car name	A	B	C	D	E
Car type	Coupe	Coupe	Sedan	Wagon	Select none.
Size (passenger capacity)	4	5	6	7	
Fuel costs (km/L)	13	18	11	13	
Engine displacement	2000 cc	1500 cc	2500 cc	2000 cc	
Safety (5 ranks)	3	4	5	4	
Price	2 million yen	1.8 million yen	¥3 million	¥2.5 million	

Attributes

Profile

Level

Figure 3.2-5: Example of a question for choice conjoint

(1) Choice-based conjoint analysis

Choice-based conjoint analysis is also called a choice experiment. This type selects the most desirable one from among the offered choices. This decision-making process is similar to an ordinary purchase behavior – that is, the purchase of a product that seems the best option. This question format is more familiar to general consumers than rating conjoint and ranking conjoint analysis, both of which will be explained later. Because it is easy for consumers to answer questions and there is no significant bias, choice-based conjoint analysis has been frequently used now.

Figure 3.2-5 shows a simple example of questions for a choice conjoint survey. In the case of this example, the respondents are asked to select "the car they most want to purchase." "Car type," "Size," "Fuel cost," "Engine displacement," "Safety," and "Price" are elements characteristic of the cars to be assessed and are called attributes. The combination of the values of the attributes differs among the choices, A, B, C, and D (each of them is called a profile). For example, the profile A's fuel costs are 13 km/L and the price is 2 million yen, while the profile B's fuel costs are 18 km/L and the price is 1.8 million yen. Such values of attributes are called levels. For example, with regard to the attribute of the "Size (passenger capacity)," four levels have been set, ranging from 4 to 7. A profile is established by various combinations of levels of each attribute. In this case, if four levels have been set for each of the other attributes, 45 profiles can be established in total. When a questionnaire is prepared in reality, profiles are designed so that significant results from the analysis can be gained by as few questions as possible.

From among the products about which several levels of attributes are combined, if a respondent selects “C” for example, it can be inferred that the respondent places more importance on the sedan type, safety, and engine displacement than on other attributes. If the answers to questions about other combinations of profiles are statistically analyzed, it can be importance the respondents place on which attributes can be determined. The results are the preference strength of each attribute, which corresponds to the weighting. If such a result can be obtained, the car function that consumers pay attention to can be identified, which is important information for car developers in order to make a decision on what parts R&D expenses should be invested in more. From this viewpoint, conjoint analysis theory was established in the field of computational psychology, and conjoint analysis has been widely used as a methodology for market research.

Another important point is how many attributes should be used for the choice-based conjoint analysis. If the number of attributes is excessive, it is difficult to answer the questions, making it impossible to obtain significant results. Because Miller (1956) shows that it is difficult for human beings to deal with six or more items of data simultaneously from the psychological viewpoint, it seems appropriate to use six or fewer attributes for the conjoint analysis. Because LIME compares four items among the endpoints,*[2] it satisfies this requirement. However, since the theme-oriented methods compare ten or more items among impact categories, it seems difficult to use choice conjoint analysis.

(2) Rating conjoint

Under this method, each respondent to the questionnaire gives a grade (or a subjective probability of purchase) to each of the offered choices. In the case of cars for example, a grade is given to the profile of each car (choice), ranging from 1 to 100 points (Figure 3.2-6). As shown in the Figure 3.2-6, a grade may be given in the form of purchase probability. If a regression analysis is computed with the grade as the explained variable and with the levels of the attributes of the choice as explanatory variables, it is possible to calculate a weight for each attribute.

Question: In the case of the following cars, what is the possibility of your purchasing it? Answer the probability of your purchase as a percentage.

Car type: coupe

Passenger capacity: 4

Fuel costs: 13 km/L

Displacement: 2000 cc

Safety (1 to 5): 3

Price: 2 million yen

Purchase probability _____ %

Figure 3.2-6: Example of a question for rating conjoint

[2] In reality, profiles have been designed using a combination of levels of the five attributes in total – four environmental attributes and the tax attribute.

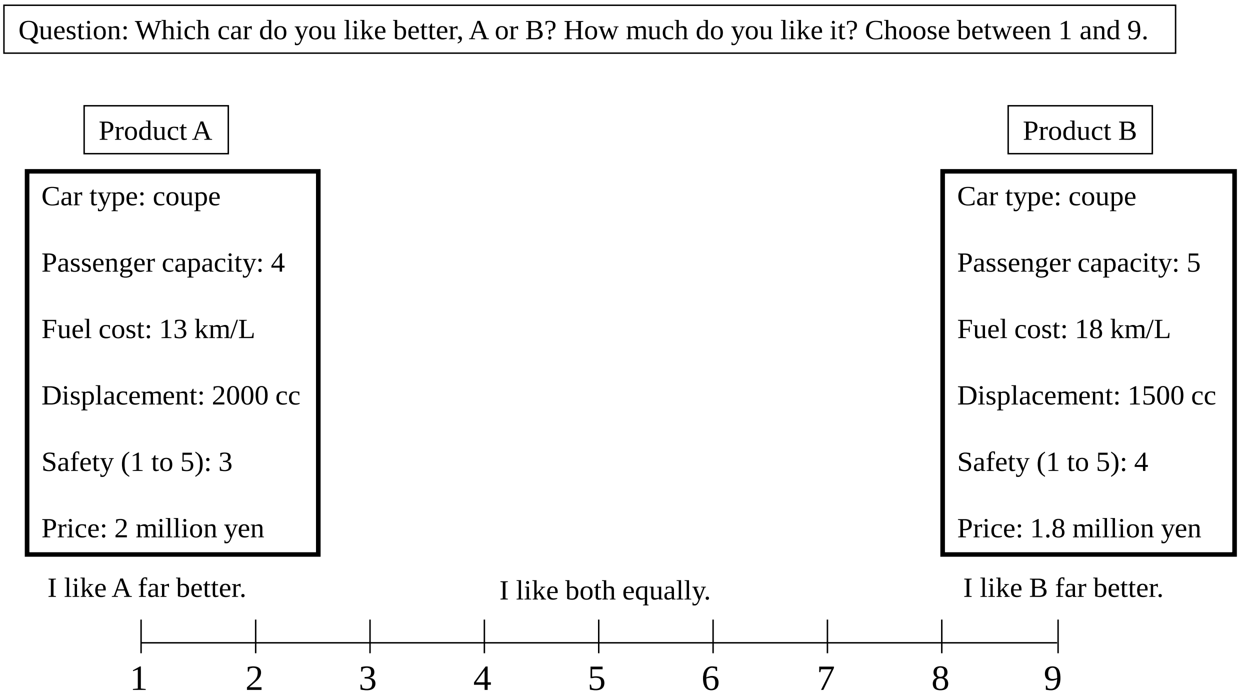


Figure 3.2-7: Example of a question for pair-wise rating

In addition, there is rating called pair-wise rating, whereby respondents have two opposite choices and then answer which and how much they like. Unlike in the case of Figure 3.2-6, a comparison is made between a pair (Figure 3.2-7). For example, the car A and the car B are specified on the left and right. Choose 1 if you like car A very much. Choose 9 if you like car B very much. Choose 5 if you cannot choose either. In this way, choose the degree of likability between 1 and 9.

Because this type of analysis uses “partial profiles,” which only show the attributes that differ between both choices, it is possible to set many attributes. However, attention should be paid to the fact that price and other important attributes tend to be underestimated if there are many attributes (Pinnell 1994). In addition, there is criticism that, because it is rare that only partial profiles are actually used for consumption behavior, the practicability of its use in decision-making may be reduced (Green 1991).

(3) Ranking conjoint

In the case of ranking conjoint, questionnaire respondents rank the choices according to desirability (without rating them). To take cars as an example, respondents are requested to rank the profiles A to D according to their desirability (Figure 3.2-8). Ranking conjoint is divided into the full-ranking type and partial-ranking type.

While only the best one is chosen in the case of a choice conjoint analysis, several choices are taken into consideration in the case of a ranking conjoint analysis. Therefore, even if the number of respondents surveyed in the samples is small, it is possible to gain a relatively significant result. On the other hand, because ranking is a judgment that is different from ordinary consumption behavior, the burden on the respondents may be higher than in the case of choice conjoint analysis.

Question: Rank the products A to D according to how much you like them.

Attribute \ Car name	A	B	C	D
Car type	Coupe	Coupe	Sedan	Wagon
Size (passenger capacity)	4	5	6	7
Fuel costs (km/L)	13	18	11	13
Engine displacement	2000 cc	1500 cc	2500 cc	2000 cc
Safety (5 ranks)	3	4	5	4
Price	2 million yen	1.8 million yen	3 million yen	2.5 million yen
Your ranking (1 to 4)				

Figure 3.2-8: Example of a question for ranking conjoint

3.2.4 Field survey using conjoint analysis

As is known in the field of social survey methods, questionnaire surveys are carried out by mail, direct interviews, telephone, visiting, via computer, the Internet, etc. Each means has advantages and disadvantages.

A survey by mail, for example, can increase the number of samples while saving on cost. However, if many persons do not respond to the questionnaires, it takes a lot of trouble, such as sending postcards to request a response from them. In addition, if the questionnaires are responded to only by persons interested in the survey or the object of the survey, a bias may arise in the group of respondents. Moreover, if the contents of the survey are difficult to understand and respondents do not read important explanations, the result of the assessment may be inaccurate.

Although surveys by telephone require payment for the operators, the personnel costs are relatively low. In addition, because respondents can immediately answer questions while at home, it does not seem to be much trouble. However, because information can often be communicated only by means of paper, other devices are required in order to communicate information plainly so that the respondents can communicate their opinions appropriately.

Interviews are the most suitable for communicating the contents of a survey plainly and secure appropriate samples and answers. However, they have the following problems: the survey costs are high due to the personnel costs and contact costs; regional biases may arise, depending on where interviews are held; and the respondents may be biased due to their impression of the interviewers.

Because each survey method has certain advantages and disadvantages, it is desirable to select the most appropriate means, depending on the purpose of the survey.

It is also important to determine the population of the survey. Samples should be randomly selected in principle. The method of the survey can greatly change depending on whether the population is only Japanese people or only the residents in an area closely related to the object of the assessment. Because the determination of the population varies according to the object of the assessment, it is essential to define the population appropriately and select the samples randomly.

Column 3.2-1:

Respondents who carry out weighting – general consumers and experts

The integration of LCA so far – especially, the integration of environmental impacts using the panel method – is divided into integration based on the results of questionnaire surveys of general consumers (Yasui 1998), integration based on the results of survey questionnaires of experts – especially academic experts (for example, Eco-indicator 99 (Goedkoop 2000)), and integration based on the results of questionnaires to various groups, such as student groups and industrial groups (Nagata 1998).

If the experience and knowledge of experts are necessary in carrying out weighting properly, the weighting of the experts is adopted. For example, in the case of a disability weighting for DALY, it is necessary to assess the QOL (quality of life) of more than 100 symptoms. If general consumers who do not know the actual situation of many diseases are given appropriate explanations about all the symptoms, it is almost impossible to carry out a disability weighting while reflecting their own opinions accurately.

On the other hand, if it is assumed that the population selected for the weighting consists of general consumers, the target of the questionnaire survey is not the experts but the general consumers. In the case of environmental economic assessment, since the social value is assessed according to the general consumers' willingness to pay, the target of the questionnaire is general consumers. In the case of market research, an assessment can be carried out by limiting it to car purchasers for example. However, when the social value of environmental elements in Japan is assessed, there is no economic room for carrying out a questionnaire survey for all Japanese people. Because of this, theories of inferential statistics are used to ensure a statistically significant number of samples to provide accuracy of the survey. In this way, the population differs according the purpose of the assessment.

The development of methods for the integration of LCIA is often aimed at general purpose use. Therefore, it is desirable that the population to be weighted for integration should be the Japanese people. If ten or more impact categories, such as global warming and acid rain, are directly compared, because it can be assumed that general consumers do not fully understand the actual situation of all the environmental problems, it can be considered that discussions should be conducted by a panel of experts. However, it cannot be said that the judgment of experts reflects the view of the population (for example, the Japanese people's view).

The damage-oriented methods compare between entities, such as human beings and plants. Although it is difficult to understand the contents of some attributes, such as biodiversity, it seems possible for general consumers to understand them if appropriate information is provided. In the case of integration in LIME, because importance is placed on the acquisition of indexes with a high level of social consensus, the respondents to a questionnaire survey are samples from the Japanese people – that is, general consumers. It has been confirmed that, even if the target of the questionnaire is actually general consumers, the statistical significance of the analysis results can be verified (see 3.3.5).

3.2.5 Analysis of the questionnaire results

In the case of a choice conjoint analysis, the analysis is carried out using data obtained from respondents through a questionnaire survey – that is, their selection of choices in the questionnaire (discrete data). Therefore, choice conjoint analysis uses a discrete selection model, such as a logit model, which is excellent in that it is consistent with random utility theory and can be discussed in terms of welfare economics.

According to random utility theory, utility is considered to change probabilistically. Given that human beings do not necessarily take action strictly according to economic rationality in the real world (Hagiwara 1999), the view that utility changes probabilistically is not unnatural in the case of such a behavioral analysis model. An explanation will be given about a measurement model for the choice conjoint analysis below. For details, see Ben-Akiva and Lerman (1985) and McFadden (1974).

Figure 3.2-9 shows the procedures for estimating and examining parameters by the use of an estimation model. The procedure starts with the identification of a utility function form, the selection of characteristic variables, and the application of the maximum likelihood estimation method for inferring the preference strength of the environmental attributes. Next, a likelihood ratio test is carried out concerning the estimated volume to verify the accuracy of the analysis results. If the results are statistically significant, integration factors can be gained from the results. Each of the procedures will be described in detail below.

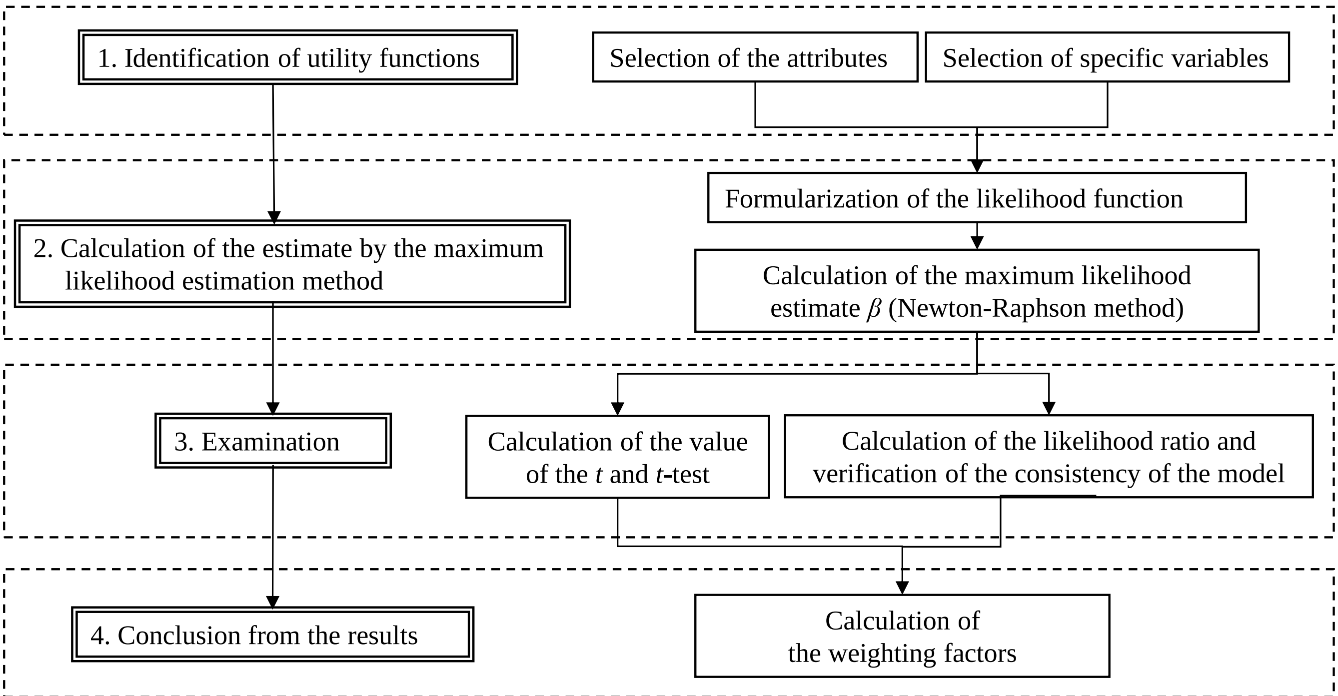


Figure 3.2-9: Procedures for estimating and examining the questionnaire results

(1) Identification of a utility function and the calculation of profile selection probability

First, the random utility function is defined as a utility function (Equation 3.2-1).

$$U_j = V_j(x_j, p_j) + \varepsilon_j \qquad (3.2\text{-}1)$$

When an individual *n* selects profile *j*, utility is U_j. *j* is the profile number selected by the respondent. *V* is the observable fixed term of utility and refers to the portion that does not change probabilistically. ε stands for the unobservable element that changes due to lack of information on the characteristics of choices, the attributes of individuals, etc., and is expressed as a probability term. *xj* is the attribute vector of profile *j* (the passenger capacity of 4, the fuel cost of 13 L, etc. in the case of Figure 3.2-5). P_j is the price of the profile *j*.

$$V_j = \sum_a \beta_a \chi_{aj} \qquad (3.2\text{-}2)$$

The fixed term of utility *V* can be expressed as the sum of products of attribute *a*'s preference strength β_a and each attribute's level x_{aj} as in the above equation. In other words, if it is in a linear shape (which is called a main-effect model), the fixed term *V* in the Equation 3.2-2 can be expressed by separating the monetary attribute as another term as shown in the following Equation 3.2-3:

$$V_j(x, p) = \sum_a \beta_a x_{aj} + \beta_p p_j \qquad (3.2\text{-}3)$$

Typical utility functions include not only linear ones like the above one, but also log-linear ones and ones in the form of CES (constant elasticity of substitution). Among these, the above-described linear utility function is used the most frequently because of its simplicity.

P_j, the probability of respondents selecting profile *j* from among group *c* of profiles (= 1, 2, …, *m*), is expressed as P_r, the probability of U_j becoming higher than other products *k*'s utility U_k.

$$\begin{aligned} P_j &= \Pr(U_j > U_k, \forall k \in C) \\ &= \Pr(V_j - V_k > \varepsilon_k - \varepsilon_j, \forall k \in C) \end{aligned} \qquad (3.2\text{-}4)$$

If the error term in Equation 3.2-4 follows type-1 extreme value distribution (Gumbel distribution), probability P_j can be gained from the following Equation 3.2-5 (which is called a logit model):

$$P_j = \frac{e^{\lambda V_j}}{\sum_i e^{\lambda Vi}} \qquad (3.2\text{-}5)$$

In this equation, λ is the scale parameter, which is usually standardized at 1.
The Gumbel distribution is expressed by a distribution function as in the following equation:

$$F(\varepsilon) = \exp[-e^{-w(\varepsilon-\eta)}],\ \omega > 0 \tag{3.2-6}$$

Such a Gumbel distribution is used because the error term is approximate to the usually used normal distribution and is easier to handle for analysis than the normal distribution.

(2) Estimation of the preference strength using the maximum likelihood estimation method

The Equation 3.2-5 expresses the probability of each sample's selection of a specific profile. Parameter β_a can be estimated by having the equation correspond to the results of a questionnaire survey and applying the maximum likelihood estimation method. To explain the method to analyze the results of a survey, it is assumed that the survey has been conducted on one hundred persons. Table 3.2-2 shows an image of the results. In this case, the first sample shows the selection of the second profile from among three profiles, and the second sample shows the selection of the first profile. In addition, the table shows the probability of each sample's selection according to the survey results. The probability of sample 1's selection of the second profile is $P^1_{2.3}$, and the probability of sample 2's selection of the first profile is $P^2_{1.3}$.

Table 3.2-2: Examples of answers gained through a questionnaire survey and the probability of each sample providing the answer

Sample	1	2	3	4	5	6	· ·	99	100
Answer	2	1	2	3	1	2	· ·	1	2
Probability	$P^1_{2.3}$	$P^2_{1.3}$	$P^3_{2.3}$	$P^4_{3.3}$	$P^5_{1.3}$	$P^6_{2.3}$	· ·	$P^{99}_{1.3}$	$P^{100}_{2.3}$

$P^n_{i.3}$: probability of the sample *n*'s selecting the *i*th profile from among the three profiles

If the maximum likelihood estimation method is applied, it can be considered that the questionnaire survey resulted as shown in Table 3.2-2 because the joint probability of creating that selection pattern is high. Moreover, the method asserts that the value of β_a that maximizes the joint probability of creating the pattern is the estimate $\hat{\beta}_a$ of desirable β_a. The probability of gaining the combination of survey results shown in Table 3.2-2 can be expressed as the product of the probabilities of the samples' answers.

$$L^* = \prod_{n=1}^{100} P^n_{i.3} \tag{3.2-7}$$

The Equation 3.2-7 is called the likelihood function. The maximum likelihood estimate $\hat{\beta}_a$ can be found by calculating $\hat{\beta}_a$ that maximizes the log likelihood function L =1n L^*, a natural logarithm that substitutes L^*. This is because $\hat{\beta}_a$ that maximizes L^* is the same as $\hat{\beta}_a$ that maximizes 1n L^*, and the logarithm makes the analysis easier.

$$L = \ln L^* = \sum_{n=1}^{100} \ln P_{i.3}^{n} = \sum_{n=1}^{100} \ln\left(\frac{e^{V_j}}{\sum_{i=1}^{3} e^{V_i}}\right) = \sum_{n=1}^{100} \ln\left(\frac{\exp\left(\sum_a \beta_a \chi_{a,j}\right)}{\sum_{i=1}^{3} \exp\left(\sum_a \beta_a \chi_{a,i}\right)}\right) \qquad (3.2\text{-}8)$$

Equation 3.2-8 proves that the unknown parameter vector β_a is generally a convex function. Therefore, the β_a that makes L the largest – that is, the maximum likelihood estimation method $\hat{\beta}_a$ – is the solution to simultaneous equations whereby the results of the differentiation of Equation 3.2-8 in terms of B_a is zero. A numerical calculation method is applied to this solution method. The typical and frequently-used numerical calculation method is the Newton-Raphson method. For details, see Polak (1971).

The resultant $\hat{\beta}_a$ is the preference strength of each of the attributes that constitute a profile. In the case of the integration of LCIA – that is, if a profile consists of a combination of endpoints –, $\hat{\beta}_a$ is just the social preference strength of the endpoints.

(3) Examination of the estimates

It is necessary to examine whether the estimates obtained from the maximum likelihood examination method can be used for indicating a society's (the population's) preference. There are various examination methods. Below, explanations will be given of the *t*-test and likelihood ratios, both of which are typical examination methods and were used for assessment under LIME.

A *t*-value is the estimate $\hat{\beta}_a$ divided by its estimated standard deviation $\sqrt{v_a}$.

$$t_a = \frac{\hat{\beta}_a}{\sqrt{v_a}} \qquad (3.2\text{-}9)$$

If the absolute value of t_a is equal to or larger than 1.96 (2.576), null hypothesis $\hat{\beta}_a = 0$ can be rejected at a significant level of 5% (1%). Therefore, if $t_a \geq 1.96$ (2.576), the corresponding *a* is regarded as a factor that influences the choice probability at a confidence level of 95% (99%). In other words, it is possible to prove its statistical significance. On the other hand, if $t_a \leq 1.96$ (2.576), because hypothesis $\hat{\beta}_a = 0$ cannot be rejected, it is desirable to estimate the parameters again, excluding attribute *a*.

ρ^2 is called a likelihood ratio or McFadden's coefficient of determination. Like the square of the coefficient of correlation, ρ^2 is between 0 and 1. If ρ^2 is nearer to 1, it is more consistent with the model – in this case, the logit model. However, unlike the coefficient of correlation used for regression analysis, it is acceptable to judge that the consistency of ρ^2 is sufficiently high if ρ^2 is between 0.2 and 0.4.

Display of these examination results together with estimates gained by statistical analysis is an extremely important requirement for showing the representativeness of the society's preference strength.

3.2.6 Uncertainty of the preference strength using the random parameter logit model

This section explains the analysis through the use of the random parameter logit model (RPL). RPL can be regarded as a model developed as a result of the improvement of problems in CL. Any analysis that uses this model makes it possible to achieve a level of explanatory inference for the results, taking into consideration the uncertainty of the preference strength.

Firstly, explanation is given regarding the problems in CL.

(1) Problems in the conditional logit model (CL)

Although CL is an analysis model widely used in the field of environmental assessment, it has two significant problems: IIA and the homogeneity of utility.

Firstly, an explanation is given regarding IIA. The above-described choice probability ratio of CL, *Pj/Ph*, can be expressed by Equation 3.2-10:

$$\frac{P_j}{P_h} = \frac{e^{Vj}}{\sum_k e^{Vk}} / \frac{e^{Vh}}{\sum_k e^{Vk}} = \frac{e^{Vj}}{e^{Vh}} \qquad (3.2\text{-}10)$$

This equation shows that choices other than *j* and *h* do not influence the choice probability (Train 2003). This characteristic is called independence from irrelevant alternatives (IIA). Because the red bus/blue bus problem is often used as an example for IIA, a brief explanation is given regarding this problem.

Suppose that when a person chooses a transportation means, there are two choices: the person’s own car or a bus (red bus). If the person’s preference is equally divided between both modes, the preference probability is fifty-fifty. Suppose that there is another choice: a blue bus. Because these buses differ only in their color, the preference is equally divided between the red or the blue bus. In this case, the probability of choosing a bus does not change and is equally divided between both buses. That is, the probability is one-fourth for each of them. However, if CL is applied, because of independence from irrelevant alternatives (IIA), the choice probability for each of the three choices becomes one-third. In this case, the buses are overestimated. Generally, if CL is applied, the choice probability for similar choices is overestimated (Train 2003).

On the other hand, IIA also has advantages. Due to independence from other irrelevant choices, in the case of a subset from which some unselected choices are excluded, factors can be estimated while maintaining consistency (Train 2003). This characteristic is widely used for the discrete hedonic method and the discrete travel cost method.

Brief explanation should be given also to the other problem – homogeneity of utility. In the case of CL, which is based on random utility theory, homogeneity of utility is assumed among individuals. However, because it is appropriate to think that utility differs among individuals, it is a little too hypothetical to assume homogeneity of utility.

As described above, there are two great problems in CL– IIA and homogeneity of utility. To overcome the problems – that is, to ease IIA and take into consideration heterogeneity of utility –, various constructive models have been developed so far. Below, explanation will be given to a typical construct model, RPL.

(2) Outline of the random parameter logit model

RPL*[3] is a model whereby β, a factor to be inferred, is supposed to fluctuate probabilistically. This can be considered according to the case mentioned in this paper. For example, if probabilistic variation (distribution) is allowed for the health damage factor of the attribute variables, this means that utility to health damage differs among the respondents – in other words, factor β_i differs for each individual *i* and is distributed according to some conditions. This indicates that the assumption of the homogeneity of utility in CL has been eased and the heterogeneity of utility among individuals has been taken into consideration as mentioned above. Moreover, this model can ease IIA of CL (Train 2003). To certify this, Equation 3.2-11 below can be used to find the choice probability rate. As pointed out in Kuriyama and Shoji (2005), because a term (the denominator of P_{ji}) contains all the choices, it is clear that IIA has been eased. This makes it possible to say that RPL is a developmental model that can solve the problems in CL. Probability in RPL can be formulized as follows. This is expressed by integral calculation that uses logit probability P_{ji} and the density function of arbitrary distribution $f(\beta)$.

$$P_{ji}^{*} = \int P_{ji}(\beta) f(\beta \mid \Theta) d\beta \qquad (3.2\text{-}11)$$

In this equation,
P_{ji}^{*}: probability of an individual *i*'s selecting choice *j*
Θ: parameter of probability density function for β (average or dispersion)

$$P_{ji} = \frac{\exp(V_{ji})}{\sum_k \exp(V_{ki})}$$

For the purpose of RPL, continuous distribution is assumed for $f(\beta)$ distribution. The main types are normal distribution, log-normal distribution, and triangular distribution. Log-normal distribution is often used if surveyors can assume signs of the variables beforehand.

Because integral calculation of choice probability like the above equation is difficult, this integration is approximated for estimation by the following simulation method (Train 2003).*[4] In this case, choice probability is formulized as the following SP (simulated probability):*[5]

$$SP_{ji} = \frac{1}{R} \sum_r P_{ji}(\beta^r) \qquad (3.2\text{-}12)$$

---

[3] This is also often called a mixed logit model. For details of various models for improving problems in conditional logit model, including explanation of this model, see Kuriyama and Shoji (2005). In addition, for details of this model, see the careful explanation in Train (2003).

[4] What is used for the sampling of β is random draws, which simply carry out random sampling, or Halton draws, which have been defined by prime numbers (Train 2003).

[5] For details of the nature of the SP, see Train (2003).

R: number of times of sampling
B^r: the rth random sampling from the density function $f(\beta)$

This is used to assume the following long likelihood function (SLL) and estimate a parameter Θ that specifies a distribution that maximizes the function (Train 2003).

$$SLL = \sum_i \sum_j d_{ji} \ln\left(SP_{ji}\right) \qquad (3.2\text{-}13)$$

In this equation, d_{ji} is a dummy variable that becomes 1 if individual i selects the choice j.

This calculation makes it possible to gain a distribution function for which differences in preference strength among individuals are quantified.

3.3 Integration of environmental impacts by conjoint analysis

3.3.1 Adopted question format and survey method

As described in the preceding section, there are three types of question formats for conjoint analysis (choice, rating, and ranking). The rating type is divided into the complete profile type (see Figure 3.2-6) and the pair-wise type (see Figure 3.2-7).

In the case of the complete profile rating type, the fixing of purchase probability and the arrangement of profile are not usually carried out by respondents when they purchase goods. Therefore, it is difficult for them to answer the questions, resulting in many invalid answers. The protected goods to be assessed this time are inferred to be more difficult to understand than functions that consumers can actually understand using their five senses. Therefore, if this approach is applied to this research, a sufficient number of valid answers may not be gained.

Because the pair-wise rating type makes it possible to show a partial profile that only includes some of the attributes, it is effective when the number of attributes is large. However, there is a criticism that such a question format, which only shows a partial profile, is unrealistic (Green 1991). Choice from scales of desirability under this approach is not made during ordinary consumption. It is hard to say that this approach is appropriate for profiles whose attributes are difficult to understand.

It can be said that choice conjoint is a highly realistic question format, for choice of the most favorable from among two or more articles of goods is extremely similar to daily consumption behavior. In addition, the number of attributes for this research is five in total – four attributes to be protected plus tax. The number is at an acceptable level for the use of choice conjoint. On the other hand, in the case of ranking conjoint, ranking all choices is different from ordinary consumption behavior and may increase respondents' burden.

Responding to the discussions described above, a decision was made to adopt choice conjoint, giving priority to maximum reduction of respondents' burden.

As described in 3.2.4 “Field survey using conjoint analysis,” there are various survey means, such as mail, direct interviews, telephone, visiting, via computers, and the Internet. Under LIME, because the environment to be assessed is abstract unlike products on the market, interviews were adopted, placing importance on a careful explanation of the object of assessment so that any misunderstanding on the part of the respondents can be avoided. Although meetings of residents in the suburbs of Tokyo were held because of the limited survey costs under LIME 1, it was decided to adopt a nationwide random sampling survey and a visit to target households for LIME 2.

3.3.2 Survey methods

The ultimate goal of this research is to gain integration factors for general-purpose use by measuring the social preference for the endpoints of the four items set under LIME.

Figure 3.3-1 shows the survey procedure, which roughly consists of the following four processes:

1) Sampling: sampling of target households. Nationwide random sampling was adopted.
2) Preparation of questionnaire: A questionnaire is prepared for the purpose of interviews. A questionnaire refers sheets that display questions and information that respondents should know before answering the questions and include explanations about environmental attributes, profiles for conjoint analysis, and questions about the respondents’ attributes.
3) Interview survey: Surveyors visit target households, explain the contents of the questionnaire, and receive answers. In the interview survey, surveyors familiar with the contents of the questionnaire visited the respondents’ houses, explained the contents of the questionnaire in detail, and received answers.
4) Calculation: The answers are statistically analyzed to calculate weighting factors. The results are used for calculating integration factors.

   One of the main purposes of the integration under LIME 2 is to disclose a list of factors for uncertainty analysis by LCA. During the main survey, the amount of statistics of the weighting factors also was calculated. The results were used for carrying out uncertainty analysis of the integration factors, and a list was made also about the results of the uncertainty analysis.

   The contents of each stage shown in Figure 3.3-1 will be described in detail below.

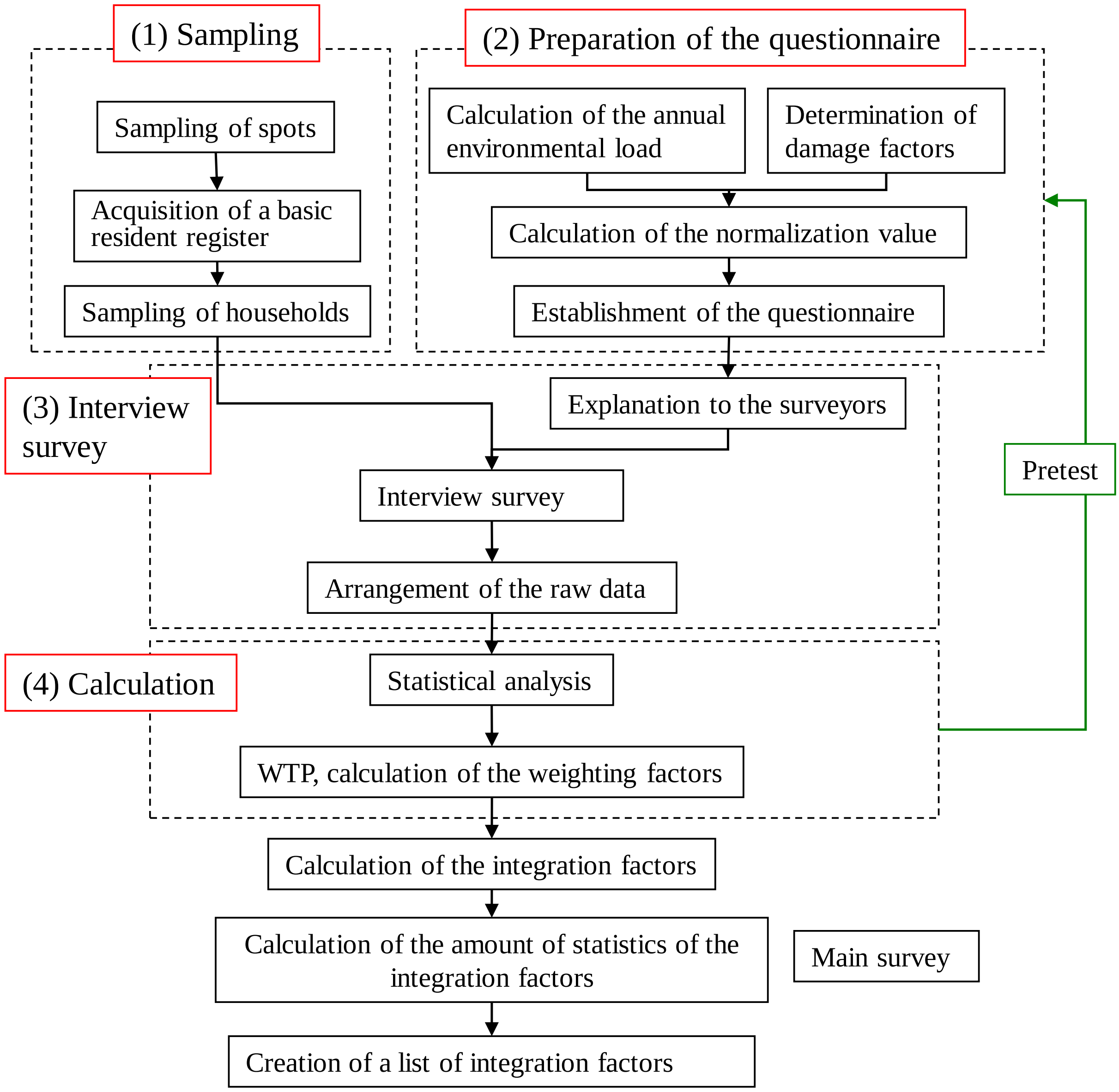


Figure 3.3-1: The survey procedure
The survey roughly consists of sampling, the preparation of a questionnaire, an interview survey, and the calculation.

3.3.3 Outline of the sampling

The sampling was carried out as follows:

1) Sampling method: two-stage random sampling
2) Population: households throughout Japan
3) List used for sampling: basic resident register
4) Planned number of samples: 2,040 samples (households)
5) Number of spots: 147 spots *[6]
6) Number of samples per spot: 14 samples (households)

The two-stage random sampling method was adopted for the main survey. Under this method, spots were selected before choosing samples (households). After the selection of spots, samples (households) were chosen. Because the spots are selected beforehand, sampling becomes easier using the basic resident registers. Consideration was given not to making the number of collected samples less than 1,000 (assuming that the collection rate would be about 50%), and about 2,000 samples were taken.

To take about 2,000 samples, the number of spots was fixed at 180. However, to protect personal information, some local governments have recently not cooperated in perusing their basic resident registers. As a result, households were chosen at 147 spots under the jurisdiction of local governments that approved perusal of them. Based on the estimated number of samples (about 2,000), it was decided that 14 samples would be taken at each of the spots (2040 ÷ 147 = 13.9). Figure 3.3-2 shows the method of taking samples for the main survey. The sampling will be described in detail below.

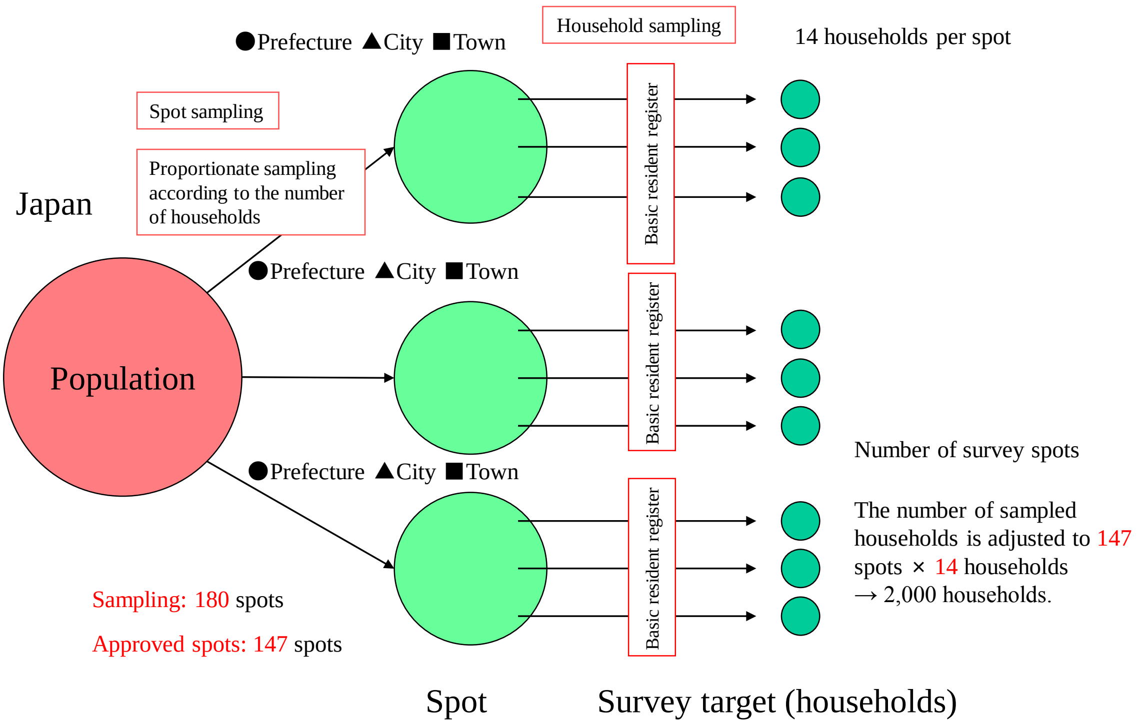


Figure 3.3-2: Sampling method for the main survey

Two-stage random sampling was adopted. Spots were sampled first. Households were sampled based on basic resident registers with the cooperation of the local governments in whose jurisdiction the sampled spots were located.

[6] Although applications for perusal of basic resident registers were filed at 180 spots, applications were refused at 33 spots due to recent restrictions on the perusal of them. As a result, target households were chosen at 147 spots.

3.3.4 Sampling procedure

(1) Sampling of survey spots (first-stage sampling)

Probability proportionate sampling was applied to choose 180 spots according to the number of households among the population (as of April 1, 2005). The following is the concrete calculation method:

Sampling interval = number of household in population ÷ number of survey spots

This number is defined as sampling interval for determining spots. A smaller number than the number of intervals was designated by random number selection and was defined as the starting number. Sampling intervals and a start number were set from the number of households in municipal databases, and survey spots were determined. The arrangement sequence of municipalities was in accordance with the municipal codes in FY2005.

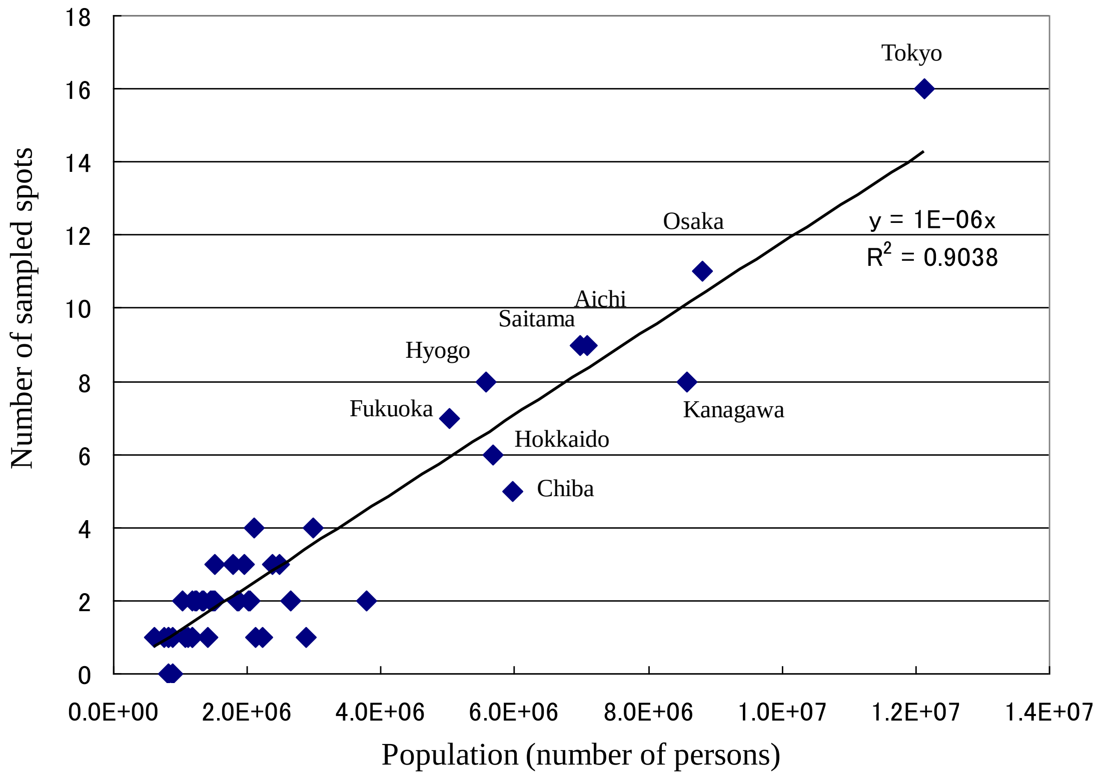


Figure 3.3-3: Relationship between the number of spots sampled in each prefecture and the population

Because the relationship is correlative, it can be said that the results of the spot sampling for this survey reflect the population distribution in Japan.

(2) Sampling of the target households (second-stage sampling)

An interval was set at "five households" to make it possible to sample target households within the extent of each survey spot (designated by town, district, house number, etc.) and avoid sampling of neighboring households or sampling only from the same apartment house, and households were sampled from basic resident registers by the systematic sampling method.

It has been assumed that the main survey is based on the sampling of households and that the purpose of the question format is to find the amount of willing to pay per household. Therefore, it is desirable that the respondents should be household representatives – that is, the heads of the households. However, because the heads of the households are not shown in basic resident registers and cannot be identified accurately, it was assumed for convenience that the oldest persons of the households are the heads.

(3) Spot sampling result

Figure 3.3-3 shows the results of the sampling of municipalities (first stage sampling). In this way, the population of each prefecture was taken into consideration in this sampling, which has made clear a correlative relation between the number of times of sampling and the population of each prefecture.

(4) Determination of the target households

Surveyors visited the sampled households after sending requests. In principle, requests for response were made to the heads of the households. However, to prevent a decrease in the collection rate, when heads were absent or had difficulties in making a response, requests were made to household members aged between 20 and 59 as the household representatives.

3.3.5 Preliminary survey (calculation of normalization values)

When a profile is designed, it is necessary to show quantitative information on each attribute. Under choice conjoint, which was adopted for this research, a profile consists of the current amounts of environmental impacts in principle. Profiles in which the amount of environment impact of a certain attribute is changed to a certain extent are used for comparison with the current profile. Therefore, as a preliminary survey, consideration was given to the preparation of a profile that shows the current situation of environmental impacts.

Here, the result of calculation of the environmental impact on each area of protection that accompanies the annual economic activities in Japan was used as the current profile. Under LCA, the amount of environmental impact generated through the environmental load in a specific area during a certain period (for example, one year) is called a normalization value, which is used for the normalization of LCIA. Normalization is one step that corresponds to an added element of LCIA. This refers to non-dimensionalization by dividing the result of the characterization for each impact category by the normalization value and is frequently used as a preliminary process for weighting.

$$N^{Impact} = \frac{CI^{Impact}}{NV^{Impact}} = \frac{\sum_X \left(CF^{Impact}(X) \times Inv(X)\right)}{\sum_X \left(CF^{Impact}(X) \times AnnualEnvironmentalLoad(X)\right)} \qquad (3.3\text{-}1)$$

In this equation, N^{Impact} is the result of normalization of the impact category *Impact*. CI^{Impact} is the result of the characterization – that is, a category indicator. In the case of global warming, for example, this can be gained from the sum of products of the amount of emissions *Inv* (*X*) of a greenhouse effect gas *X* and the characterization factor

$CF^{GlobalWaming}$ (*X*) (global warming index). NV^{Impact} is the normalization value of the impact category *Impact* and is calculated using the sum of the products of the annual environmental load *Anual Environmental Load* (*X*) of the substance of concern *X* and the corresponding characterization factor CF^{Impact} (*X*).

Normalization has so far been carried out mainly concerning the result of characterization in each impact category. This is normalization carried out using a theme oriented method (Equation 3.3-1). In the case of a damage-oriented method of LCIA, including LIME, because the result of the damage assessment is gained for each area of protection, a normalization value also is calculated for each area of protection.

The normalization value was gained using the sum of the products of the annual environmental load in Japan for each substance of concern *Annual Environmental Load* (*X*) and the corresponding damage factor *DF* (*Safe*, *X*).

$$NV(Safe) = \sum_{IImpact} \left(DF(Safe, X) \times AnnualEnvironmentalLoad(X) \right) \qquad (3.3\text{-}2)$$

In this equation, *NV* (*Safe*) is the normalization value (annual potential damage) of the area of protection *Safe*. *DF* (*Safe*, *X*) refers to the damage factor (potential damage to the area of protection *Safe* due to the environmental load per unit of the substance X_1).

Table 3.3-1: Substances of concern included in the calculation of the normalization value and the relevant impact categories and areas of protection

Areas of protection	Impact category	Target substances
Human health	Global warming	CO_2, CH_4, N_2O, CFCs (5 substances), HCFCs (6 substances), HFCs, CCl_4, Halon 1301, PFCs, SF_6
	Ozone layer depletion	HCFC-21, HCFC-22, HCFC123, HCFC-124, HCFC-133, HCFC-141b, HCFC-142b, HCFC-225, CH_3Br, CCl_4, 111-TCE, CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon1301
	Photochemical oxidants	NMVOCs
	Urban air pollution	PM2.5, PM10, SO_2 (primary, secondary), Nox (point source primary, radiation source primary, secondary)
	Toxic chemicals (Including heavy metals)	80 substances, including arsenic, benzene, cadmium, hexavalent chrome, nickel, nickel compound, 2,3,7,8-TCDD, CCL_4, 1,1,2-trichloroethane, methyl chloride, trichloroethylene, dichloromethane, 1,2-dichloroethane, 1.1-dichloroethane, formaldehyde, acetaldehyde, 1,3-butadiene, acrylonitrile, ethylene oxide, PCBs, 1,4-dioxane, and chloroform
	Indoor air pollution	Formaldehyde, NOx, SO_2, PM10, PM2.5
	Noise	Car noise
Biodiversity	Eco toxicity	85 substances, including arsenic, benzene, cadmium, hexavalent chrome, nickel, 2,3,7,8-TCDD, 1,1,2-trichloroethane, methyl chloride, trichloroethylene, dichloromethane, 1,2-dichloroethane, 1.1-dichloroethane, cyanogen compound, lead, copper, 1,1,1-TCE, tetrachloroethylene, 1,3-dichloropropene, thiuram, simazine, thiobencarb, selenium, fluorine, and boron
	Land use	Land transformation (for each form of land use)
	Resource consumption	24 substances, including limestone, rock, gravel, coal, oil, natural gas, aluminum, copper, iron, lead, molybdenum, nickel, tungsten, tin, zinc, silver, gold, and wood
	Waste	Total waste volume
Primary production	Ozone layer depletion	HCFC-21, HCFC-22, HCFC-123, HCFC-124, HCFC-133, HCFC-141b, HCFC-142b, HCFC-225, CH_3Br, CCl_4, 111-TCE, CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon1301
	Oxidization	NOx, SO_2, NH_3, HCl
	Photochemical oxidant	NMVOCs
	Land use	Land transformation (for each form of land use), land maintenance (9 types)
	Resource consumption	24 substances, including limestone, rock, gravel, coal, oil, natural gas, aluminum, copper, iron, lead, molybdenum, nickel, tungsten, tin, zinc, silver, gold, and wood
	Waste	Total waste volume
Social assets	Global warming	CO_2, CH_4, N_2O, CFCs (5 substances), HCFCs (6 substances), HFCs, CCl_4, Halon 1301, PFCs, SF_6
	Ozone layer depletion	HCFC-21, HCFC-22, HCFC123, HCFC-124, HCFC-133, HCFC-141b, HCFC-142b, HCFC-225, CH3Br, CCl_4, 111-TCE, CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon1301
	Oxidization	NOx, SO_2, NH_3, HCl
	Eutrophication	Total nitrogen, total phosphorus
	Photochemical oxidant	NMVOCs
	Resource consumption	23 substances, including limestone, rock, gravel, coal, oil, natural gas, aluminum, copper, iron, lead, molybdenum, nickel, tungsten, tin, zinc, silver, and gold (excluding wood)
	Waste	Total waste volume

Table 3.3-2: Results of the calculation of normalization values

These can be obtained from the sum of products of the annual environmental load and the damage factor.

Area of protection		Human health	Social assets	Primary production	Biodiversity
Impact category (↓), unit (→)		DALY	Yen	kg	EINES
Global warming		1.68E+05	7.77E+11		
Ozone layer depletion		7.95E+03	5.34E+08	1.71E+09	
Oxidization			3.53E+11	1.87E+09	
Eutrophication			4.56E+10		
Photochemical ozone		1.29E+04	5.02E+10	6.66E+09	
Urban air pollution		2.68E+05			
Toxic chemicals		3.11E+04			
Indoor air pollution		8.38E+04			
Eco toxicity					3.70E-02
Land use				5.12E+10	3.27E-01
Resource consumption	Non-metals, metals, fossil fuels		2.95E+12	1.21E+10	7.07E-03
	Biological resources			1.08E+11	5.49E-01
Waste			7.53E+11	1.70E+09	6.17E-03
Noise		6.89E+4			
Normalization value (total)		**6.40E+5**	**4.92E+12**	**1.83E+11**	**9.27E-1**
Reference LIME1		4.80E+5	2.61E+12	1.98E+11	7.90E-1

With regard to data on annual emissions, if there are documents that record annual emissions in Japan, these were cited. In the case of substances for which no documents exist, the annual environmental load was calculated with reference to existing documents. Table 3.3-1 shows the substances of concern used for the calculation of the normalization value and the relevant impact categories and areas of protection. Table 3.3-2 shows the results of normalization values calculated by Equation 3.3-2.

The annual amount of potential environmental impacts of economic activities in Japan can be gained from the normalization values. In addition, this construction makes it possible to extract impact categories and substances of concern. Therefore, compared with the normalization values in LIME 1, the values for human health and social assets are greater. The value for human health became greater because the amount of damage due to indoor air pollution and noise was added. The value for social assets became greater due to the addition of the impact of land loss resulting from waste landfill and the review of user cost due to the consumption of fossil fuels and mineral resources. Appendix 3 shows the interpretation of the results in Table 3.3-2.

the calculation of normalization values are used as basic data on the profiles constituting the questionnaire (for details of the use method, see 3.3.4). Questionnaires by CVM often use photographs and images to facilitate the understanding of the survey contents for the respondents. With regard to the environmental attributes in this research, it is difficult to show photographs as in the case of a natural landscape. Consideration was given to make the explanations of the attributes simple and clear, for example, by attaching graphs showing the results of normalization values.

3.3.6 Preparation of the questionnaire

(1) Construction of the questionnaire

Because environmental value judgments differ from daily consumption behavior, respondents often have trouble in answering the questionnaire. Therefore, preparation of a questionnaire that enables the respondents to understand the contents of the questions easily is essential for gaining highly reliable survey results. Among others, a questionnaire for conjoint analysis, which requires simultaneous comparison among two or more environmental attributes is troublesome for the respondents. To reduce the burden respondents as much as possible, attention was paid to the following when a questionnaire was prepared for this research:

1) Provision of information before questioning for conjoint analysis to facilitate the understanding of the respondents concerning the contents of the environmental attributes (the areas of protection in the case of LIME)

2) If explanations are redundant, it is difficult to convey the message of the questionnaire to the respondents. Because of this, the panel method has been adopted for the questionnaire. The surveyors show a panel to the respondents to facilitate their understanding of important points.

3) The questionnaire consists of the following four parts:
   - Background
   - Explanations and simple questions about environmental attributes (areas of protection)
   - Questions for conjoint analysis
   - Questions about personal attributes

Concrete The concrete contents of the panel are described in Appendix 2.

The main contents of each part are described below.

(2) Background

This part places importance on having the respondents recognize this survey as a questionnaire survey about environmental problems and understand that environmental problems are varied and environmental impacts vary according to which measures are taken. In addition, with regard to the conjoint analysis to be carried out during this research, profiles are presented as a hypothetical combination of information on the areas of protection. To make it easy to understand the contents, the profiles have been related to the central government’s environmental policies. Figure 3.3-4 shows the first page of the questionnaire panel used for the main survey.

Next, the following panel was presented (Figure 3.3-5). The respondents were informed that there were four environmental attributes and subsequent panel sheets would give explanations and questions about them so that the respondents could have the full picture of the questionnaire.

[Panel 1]

To all of you who are requested to answer the questions

Thank you for your cooperation in this questionnaire.

Today's Japan has various environmental problems, such as the destruction of nature, waste problems, and air and water pollution. As a result, damage has occurred to important human health and rich natural environments.

The purpose of this questionnaire is to investigate how much importance you give to environmental problems.

The results of the questionnaire will be used as a guide for the environmental activities of industries. Your cooperation will greatly influence Japan's environmental policies. We would appreciate it if you could give us your cooperation.

Figure 3.3-4: Questionnaire panel (page 1)
A brief explanation is given about the contents of the questions for the main survey.

[Panel 2]

Environmental problems have various impacts. Research so far have found that they have impacts on the following:

(1) Human health
(2) Social assets
(3) Biodiversity
(4) Plant growth

Below, explanations will be given about the current situation of these environmental impacts. After that, we would like you to answer the questions.

Figure 3.3-5: Questionnaire panel (page 2)
The environmental attributes covered by the main survey are presented.

(3) Explanations about environmental attributes (areas of protection)

Next, an explanation is given about the contents of each area of protection and the current situation of environmental impacts. Based on this information, a question about whether the environmental impact is serious or not is asked so that the respondents can give preliminary consideration to answering the questions that will be asked for the purpose of conjoint analysis.

To take an example from human health, the panel consists of the following: 1) explanation of the environmental attribute; 2) summary of the current situation of the environmental impact; 3) visual illustration of the situation; and 4) questions about the situation.

The panel starts with an introduction to the environmental attribute (Figure 3.3-6). The introduction states that impact on human health is related to various environmental problems, such as climate warming and air pollution, and that the following panels will explain how much the impact has occurred through environmental problems.

Next, the point is displayed about information on the amount of damage to human health (Figure 3.3-7). The point makes it possible to imagine how much environmental problems impact on human health and explains that the loss of life expectancy is used as an index for understanding of the amount of damage. Because the information is used also for the questionnaire for conjoint analysis, it is extremely important for the respondents to understand the information.

To explain the reliability of what has been described above, details of the results and the grounds for the assessment are displayed (Figure 3.3-8). To take an example from human health, details can be described as follows. The result can be gained by dividing the normalization value of 640,000 years (total amount of impact on human health caused by the Japanese people's economic activities for a year) by the total population of Japan. The result shown in 3.3.5 is used as the normalization value.

[Panel 3]

Impact on human health

Pollutants discharged through our daily life activities causes various environmental problems, such as global warming and air pollution, and have become a factor that causes damage to human health.
If the current situation continues, environmental problems are expected to have an impact on human health.

Human health 1/4

Figure 3.3-6: Questionnaire panel (page 3)
Explanation about an environmental attribute (human health)

[Panel 4]

Impact of environmental problems on human health

Your life expectancy has been falling by about two days every year.

If this situation continues for 50 years, the life expectancy of the Japanese people, including you and other people dear to you, will decrease by three months.

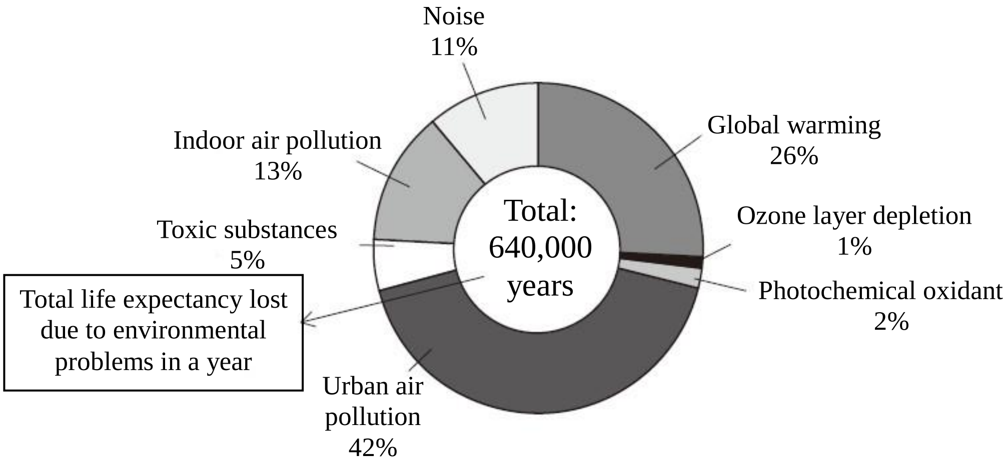
Human health 2/4

Figure 3.3-7: Questionnaire panel (page 4)
Summary of the current situation of the environmental impact on an environmental attribute (human health)

[Panel 5]

The following are grounds for the assessment:

Health loss from economic activities in Japan and their contribution to environmental problems



Population of Japan ⇒ $\frac{\text{640,000 years}}{\text{About 120 million people}}$ = loss of about 2 days per person

Human health 3/4

Figure 3.3-8: Questionnaire panel (page 5)
Grounds for the assessment of the environmental impact on an environmental attribute (human health)

[Panel 6]

Question 1

What do you think Japan's environmental policy for human health should be in the future? Choose one of the following:

1. It should be treated as a very important problem.
2. It is necessary to treat it equally to other important issues.
3. Priority should be placed on other important issues.
4. I don't know.

Human health 4/4

Figure 3.3-9: Questionnaire panel (page 6)
Question about the respondent's personal impression of the current situation of the environmental impact on the environmental attribute (human health)

Moreover, a question is asked about the respondent's impression of the results (Figure 3.3-9). Although their answers do not directly influence the results of the conjoint analysis, asking a simple question makes it possible for the respondents to make their own answers based on the information provided so far, leading them to indicate their views about the later questions for the conjoint analysis.

These four panels complete a serious from the provision of information on the environmental impact on human health to questions about the impact. Other panels of the same construction have been prepared for other environmental attributes, such as social assets, primary production, and biodiversity.

(4) Questions for the conjoint analysis

A summary explanation about each area of protection is followed by questions for the conjoint analysis. The panel shown in Figure 3.3-10 was used to explain that questioning would continue through the use of a profile that consists of five attributes – the above-described four attributes and tax*[7]. *[8] The concept of the construction of a profile will be explained later.

Before the questioning for the conjoint analysis, the Figure 3.3-10 Questionnaire panel instructs the respondents to consider the combination of four environmental attributes and tax.

[Panel 20]

The combination of the above-mentioned four issues is considered in relation with tax expenditures.

Issue	Policy target/standard
Loss of life expectancy per person	2 days
Loss of social assets per person	20,000 yen
Disappearance of species of organisms	One species newly disappeared
Inhibition of plant growth	200 million tons
Additional tax (per household, per year)	Addition of 10,000 yen per year

Figure 3.3-10: Questionnaire panel (page 20)

Before the questioning for the conjoint analysis, the respondents are instructed to consider the combination of four environmental attributes and tax.

[7] The monetary attribute can be either a fund or tax. The normalization value used as quantitative information on environmental attributes is the amount of damage per year. If economic activities remain the same in the future, the same amount of damage will continue to occur. Therefore, in the case of the monetary attribute, the scenario of paying each year is more consistent with the information indicated by environmental attributes than the scenario of paying only once and seems to be able to avoid any misunderstanding by the respondents. Therefore, the scenario of paying an environmental tax has been adopted for the monetary attribute.

[8] Consideration was given to constituting a profile of only four environmental attributes. However, when assuming environmental policy, it is easier for the respondents to examine the trade-off between the improvement of environmental attributes and the cost of the improvement than to compare only among the environmental attributes. Therefore, a profile is constituted of five attributes in total – the four environmental attributes and a monetary attribute.

[Panel 21]

Example of the questionnaire

Issue	Policy 1	Policy 2	Policy 3
Loss of life expectancy per person	Half (1.5 months in 50 years)	None (No loss of life expectancy)	Maintaining the current situation (Loss of 3 months in 50 years)
Loss of social assets per person	1/4 (Loss of 500,000 yen in 50 years)	Maintaining the current situation (Loss of 2 million yen in 50 years)	Maintaining the current situation (Loss of 2 million yen in 50 years)
Disappearance of species of organisms	Half (Disappearance of 25 species in 50 years)	No additional disappearance (No disappearance of species in 50 years)	Maintaining the current situation (Disappearance of 50 species in 50 years)
Inhibition of plant growth	1/4 (Loss of 1.3% of the forests in Japan in 50 years)	Half (Loss of 2.5% of the forests in Japan in 50 years)	Maintaining the current situation (Loss of 5% of the forests in Japan in 50 years)
Additional tax amount (per year, per household)	Addition of 20,000 yen each year (1 million yen in 50 years)	Addition of 10,000 yen each year (500,000 yen in 50 years)	No additional expenditures

Figure 3.3-11: Questionnaire panel (page 21)

An example of a panel for a survey for conjoint analysis. Instruct the respondents to choose the most favorable from among several policy profiles.

Next, the panel in Figure 3.3-11 was shown as an example of questionnaire for conjoint analysis. According to this, the respondents were instructed to choose what they think is the most desirable from among two or more policy profiles.

The following questionnaire for conjoint analysis was not a panel. A printed sheet of paper was handed to each respondent to have them orally answer which profile was the most desirable. Because the time needed to make an answer differed among the respondents, consideration was given so that they could make an answer at their own pace.

As shown in Figure 3.3-11, the questionnaire for conjoint analysis shows quantitative information for each of the attributes that constitute a profile. Four levels were set for each area of protection, using the normalization value as the standard. Table 3.3-3 shows the levels adopted for the main survey. L.1 corresponds to the current profile. In this construction, data converted from the normalization value are presented for each area of protection, and there is no additional expenditure as tax. L.2 to L.4 assume scenarios of reducing the environmental impact to a certain level (1/2, 1/4, 0). It is assumed that environmental tax is an annual increment in the direct and indirect taxes necessary for reducing the amount of damage to the areas of protection. The level of tax has been fixed at 5,000 to 20,000 yen as a realistic tax amount.

Table 3.3-3: Level for each area of protection used for the setting of profiles

	L.1 (current)	L.2	L.3	L.4
Human health	Maintaining the current situation (Loss of 3 months/50 years)	Half (1.5 months/50 years)	1/4 (20 days/50 years)	None
Social assets	Maintaining the current situation (Loss of 2 million yen/50 years)	Half (1 million yen/50 years)	1/4 (500,000 yen/50 years)	None
Primary production	Maintaining the current situation (5% of forests in Japan/50 years)	Half (2.5% of forests in Japan/50 years)	1/4 (1.3% of forests in Japan/50 years)	None
Biodiversity	Maintaining the current situation (Disappearance of 50 species/50 years)	Half (25 species/50 years)	1/4 (13 species/50 years)	None
Tax	No tax increase	5,000 yen/year	10,000 yen/year	20,000 yen/year

Table 3.3-4: Example of the profiles used for the questionnaire for the main survey

Issue	Policy 1	Policy 2	Policy 3
Loss of life expectancy per person	Half (Loss of 1.5 months in 50 years)	None (No loss of life expectancy)	Maintaining the current situation (Loss of 3 months in 50 years)
Loss of social assets per person	Half (Loss of 1 million yen in 50 years)	Maintaining the current situation (Loss of 2 million yen in 50 years)	Maintaining the current situation (Loss of 2 million yen in 50 years)
Loss of habitats	1/4 (Loss of 1.3% of forests in Japan in 50 years)	Half (Loss of 2.5% of forests in Japan in 50 years)	Maintaining the current situation (Loss of 5% of forests in Japan)
Loss of plant species	Half (Disappearance of 25 species in 50 years)	No additional extinction	Maintaining the current situation (Disappearance of 50 species in 50 years)
Additional tax amount (per year; per household)	Addition of 10,000 yen each year (500,000 yen in 50 years)	Addition of 5,000 yen each year (250,000 yen in 50 years)	No additional expenditures

A profile can be made through a combination of choices selected arbitrarily from the four levels in Table 3.3-3. Table 3.3-4 shows an example of a profile. Eight versions of the profile for the conjoint analysis have been prepared by orthogonal design. Each of the versions has eight question lists. Therefore, 64 types (8 × 8) of question lists have been prepared as shown in Table 3.3-4, and eight questions consisting of a different combination of profiles are given to each respondent. The current profile is shown as Policy 3, while hypothetical profiles into which the current profile is altered are shown as Policy 1 and Policy 2. The current profile has been included in all the question lists so that the respondents will be always conscious of the contrast between the current and hypothetical situations. In addition, to enhance the understanding of the respondents, the profiles are displayed in terms of not only the annual amount of latent damage, but also the amount of damage per person and the total amount of damage that can occur if the annual damage continues for 50 years.

(5) Questions about personal attributes

Lastly, questions were asked about the attributes of the respondents themselves. The yearly income, the number of household members, and the age were confirmed as attributes that may be related to their environmental views.

3.3.7 Door-to-door interview survey

An interview survey was adopted for this research, since it was difficult for the respondents to imagine the contents of the environmental attributes to be assessed unlike cars and home electrical appliances, and it was most important to avoid answers based on a misunderstanding of the objects of assessment.

During the interview survey, the surveyors were required explain the contents of the questionnaire so that the respondents can accurately understand them. Before the survey, meetings to provide an explanation were held several times to ensure that the contents of the questionnaire and the explanation method were understood by the surveyors. The surveyors prepared a script concerning the contents of the questionnaire and then explained the contents to the respondents according to the script. Moreover, pretests were held to check that the surveyors were able to sufficiently explain the contents so that the respondents could fully understand them. Table 3.3-5 summarizes the guidelines for the pretests and the main survey.

Pretests The pretests were held twice. In the first pretest, sampling was carried out at two points in Tokyo and Yamanashi Prefecture to compare differences between urban and suburban areas. In the second pretest, consideration was given to the feasibility of random sampling for the whole of the Tokyo Metropolis. The number of samples was about 100 to 200 due to budgetary restrictions.

The door-to-door interview method was adopted for the pretests and the main survey. It is a method whereby surveyors directly visit the respondents. Sampling is inefficient under the meeting method in the suburbs, and uncooperative respondents tend to refuse to give answers under the mall intercept sampling method. In both methods, respondent bias may occur at the time of sampling. Because of this, the door-to-door interview method was adopted. Before the visit, a written visiting schedule was sent to the respondents.

In addition, to effectively provide explanations to the respondents, scripts of the explanations were distributed to the surveyors beforehand. Moreover, explanatory meetings were held at 11 places throughout Japan before the main survey so that the surveyor could fully understand the contents of the questionnaire and the explanation scripts.

Table 3.3-5: Comparison of the methods between the pretests and the main survey

		Pretest (1st)	Pretest (2nd)	Main survey
Purpose		Check the validity of the questionnaires	Check the validity of the methods for sampling and surveys	Calculation of the weighting factors and the integration factors
Survey year		2004	2005	2006
Target area		2 points in Kanto (Suginami-ku, Tokyo; Ryuo-cho, Yamanashi)	Tokyo (23 wards; cities)	Throughout Japan
Sampling	Samples (Collection rate)	100 (unknown)	217 (47%)	1,000 (50%)
	Population	Residents aged 20-60 in each area	Residents aged 20-60 in Tokyo	Residents aged 20-60 in municipalities
	Method	Random walk	Random sampling	Random sampling
Survey	Method	Interview method used by the surveyors		
	Question-naire	The surveyors directly explain the contents of the questionnaire to the respondents through the use of panels.		

3.3.8 Calculation results

Statistical analysis was carried out based on the answers gained from the interview survey. After verification, representative values of the weighting factors that indicate social preferences were gained. For the purpose of the analysis, RPL was applied to the probability term of the random utility function to obtain the results of the calculation. Table 3.3-6 shows the results of 952 samples (147 spots throughout Japan). The estimate is the result gained by the maximum likelihood estimation method ($\hat{\beta}_a$), which indicates the value compared with the standard in the table. In this case, it indicates that the utility decreases by 0.215 in the case of one day's loss of life expectancy. All the estimates are negative. Because the utility decreases when damage increases, it can be found that the sign condition is consistent with common sense. The fact that all the attributes are significant at a level of 5% indicates that the people have found environmental values in the four areas of protection. In addition, because the likelihood ratio, which indicates PRL's power of explanation, exceeds 0.2, it can be said that the goodness of fit is sufficiently high.

Table 3.3-7 shows the results of the calculation of economic values against a unit amount of damage based on the results of Table 3.3-6. The number of households is 49,529, and the population is 128 million (FY2005 census). Assuming that the loss of social assets is equivalent to an economic loss, the weighting factor WF_1 for each area of protection was calculated from the relationship between the estimated value of social assets and that of the other environmental assets. For example, the economic value for one year's loss of life expectancy was calculated to be about 15 million yen. The amount of damage can be converted into a monetary value by multiplying WF_1 by the damage factor. The use of this makes it possible to calculate the integration factor IF_1 (see 3.3.9).

The use of the weighting factor WF_1 and the normalization value NV makes it possible to calculate the nondimensional weighting factor WF_2 (Equation 3.3-3). This can be gained by multiplying WF_1 by the normalization value and normalizing the result so that the sum total will become 1.

$$WF2(Safe) = \frac{WF1(Safe) \times NV(Safe)}{\sum_{Safe} \left(WF1(Safe) \times NV(Safe) \right)} \quad (3.3\text{-}3)$$

Table 3.3-6: Results of an analysis of the answers obtained from the interview survey (952 respondents)

The negative estimates indicate that the utility will decrease if damage or payment occurs.

Area of protection	Estimate	Standard	*t*-value
Human health	-2.15E-1	1day/p/h1)	-4.88
Social assets	-5.35E-2	10,000JY/p/h2)	-2.92
Primary production	-5.48E+0	%/h3)	-6.99
Biodiversity	-5.95E-1	1EINES/h4)	-7.03
Tax	-4.00E-5	1JY/h	-23.0

N:952; log likelihood: -6481.5; likelihood ratio:0.22: average annual income: 8.31 MJY; p: person; h: household; JY: Japanese yen

t-value is significant if it is 2 or more and at a level of 5%.

1) Change in the utility per household if a person loses one day in life expectancy

2) Change in the utility per household if a person suffers an economic loss of 10,000 yen

3) Change in the utility per household if plant biomass in Japan decreases by 1%

4) Change in the utility per household if a species disappears

Table 3.3-7: Results of the calculation of the weighting factors

WF1 is the economic value per unit area of protection and WF2 is the relative importance between the areas of protection based on the annual damage value. The annual damage value was obtained from the sum total of the annual environmental load multiplied by the damage factor.

Area of protection	Standard (unit)	Weighting factor (WF_1) Economic value (JY/unit)		Annual damage value	Weighting factor (WF_2)	
		LIME 2	LIME 1 (conducted in 2003)		LIME 2	LIME 1(2003)
Human health	1 DALY (year)	1.47E+7	9.70E+6	9.39E+12	0.26	0.31
Social assets	10,000 (JY)	1.00E+4	1.00E+4	4.92E+12	0.14	0.21
Primary production	1 ton	4.63E+4	2.02E+4	8.48E+12	0.24	0.23
Biodiversity	1 specie	1.42E+13	4.80E+12	1.32E+13	0.37	0.26

Total: 3.60E+13 yen (about 7% of GDP)

Column 3.3-1:

Willingness to pay for loss of life expectancy

The economic value of endpoints is used for the economic assessment of environmental impacts. With regard to human health, other methods have examined the calculation of willingness to pay (WTP) for the loss of life expectancy. Table 3.3-A shows the results of comparison among the methods. The values in the table are the economic values of loss of life expectancy per year.

Extern E (EC 2005) takes into consideration time discounting. For reference, it also shows values without time discounting. Because neither EPS nor LIME 2 adopts time discounting, representative values are about 10 million to 15 million if the values without time discounting are compared. All the methods mentioned herein have adopted the stated preference method. Because Extern E and EPS cover Europe, the results gained by these methods seem relatively similar to those gained by LIME 2.

WTP is supposed to differ according to the social and economic background. Many integration assessment models extrapolate per capita GDP (Y) for calculating D_i, the amount of damage in a specific region, and calculating D_{WORLD}, the amount of damage in the world, including other regions.

$$D_{WORLD} = \sum_{region} \left(Y_{WORLD} / Y_{region} \right)^{\varepsilon} \cdot D_i$$

ε is income elasticity and is often -1 or between 0 to -1.

However, because discussions about the calculation of the WTP are insufficient during LCIA research, a lot of time seems to be needed to proceed with research for finding level of WTP that reflects differences in economic conditions among countries and regions.

Table 3.3-A: Comparison concerning the economic value of the loss of life expectancy

Method	Basic economic assessment method	Unit	Representative value		Maximum value	Minimum value
			Discount (3%)	No discount		
ExternE	CVM	VSL (person)	1.05 M€ (160 million yen)			
		VOLY (year)	50,000€ (7.5 million yen)	74,627€ (11 million yen)	225,000€ (34 million yen)	27,240€ (4.1 million yen)
EPS	CVM	YOLL (year)		85,000€ (12.8 million yen)		
LIME	Conjoint analysis	DALY (year)		14.7 million yen	18 million yen	10 million yen

* VSL: Value of Statistical Life, VOLY: Value of the Life Year, YOLL: Years of Life Lost, DALY: Disability Adjusted Life Years

Column 3.3-2:

The total value of the environmental impacts of economic activities in Japan

If the results of conjoint analysis are applied to the results for the normalization value, the economic value of the environmental impacts is that generated through Japan's economic activities in a year (Table 3.3-7). According to this, the value of the environmental impacts is estimated to be about 36 trillion yen. This is equivalent to about 7% of Japan's GDP (520 trillion yen (2006)).

Such a test calculation is carried out for other research. Environmental costs were calculated every five years between 1970 and 1990 under the System of Environmental-Economic Accounting (SEEA), whose purpose is to grasp the level of deterioration of the environment (environmental pollution) based on the System of National Accounts (SNA), a system for measuring the volume of economic activities. Although the resultant values differed according to assessment period, the loss of asset values due to environmental changes is estimated to be four to six trillion yen under any method. This is far smaller than the value gained by LIME 2. According to SEEA, environmental costs are called imputed environmental costs and refer to the costs necessary for reducing the environmental load to maintain a specific level. Although the value of the environment consists of utility value and non-utility value, imputed environmental costs do not include non-utility value. Note that because the value of the environment under LIME includes both utility value and non-utility value, there is a difference in the scope of the calculation.

According to this result, it is clear that biodiversity and human health were highly weighted. The results indicate that, in Japan and other advanced countries, many people think that quantitative resources are provided to a satisfactory extent in human society, while the values of qualitative items, such as health, biodiversity, and forests, also are relatively high.

In addition, the annual amount of damage was estimated to be about 36 trillion yen. This is equivalent to about 7% of Japan's GDP. Compared with the results of LIME 1 in 2003, it can be found that the economic values of many areas of protection increased. This is because of differences in the targets of the sampling, the survey method, and the survey period. LIME 1 was carried out mainly in Tokyo due to the limited number of samples. Because a nationwide survey is carried out under LIME 2, it can be considered that suburban people's environmental views will greatly influence the results.

Because a door-to-door interview survey has been adopted for LIME 2, the respondent bias is less than in the case of the mall intercept method adopted for LIME 1. The mall intercept method is prone to choosing a certain type of respondent. Because this type of respondent is relatively cooperative in the survey, the results of the analysis are likely to be relatively stable, but it is difficult to conclude that the results reflect the population's environmental views. Even if random sampling is adopted, respondent bias cannot be ignored if the collection rate is low. However, because the collection rate was almost 50% in the main survey, it can be considered that respondent bias was reduced to the minimum. On the other hand, although the possibility of choosing samples that are not relatively positive about the survey is higher than in the case of other methods, this does not seem a great problem, since highly explainable results could be obtained.

Next, Table 3.3-8 shows a comparison between the results of an estimation under RPL and the results under CL.*[9] With regard to RPL, a normal distribution is assumed for all the attributes except the tax attribute, and Halton draws are used for the simulation.

Table 3.3-8: Comparison of the calculation results of the weighting factors
(a) conditional logit model; (b) random parameter logit model
Figures in parenthesis are the estimated factors of the standard deviation.

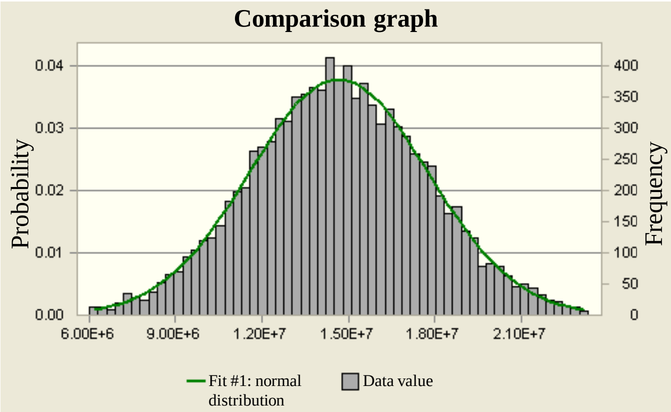
Attribute	Standard	(a) Conditional logit model			(b) Random parameter logit model		
		Factor	*t*-value	*p*-value	Factor	*t*-value	*p*-value
Human health	1 day/p/h	-1.86E-1	-7.90	<0.0001	-2.15E-1 (1.80E-2)	-4.88 (17.9)	<0.0001 (<0.0001)
Social assets	10,000 yen/p/h	-4.75E-2	-4.29	<0.0001	-5.35E-2 (6.14E-3)	-2.92 (11.9)	0.0035 (<0.0001)
Primary production	%/h	-3.98E+0	-9.60	<0.0001	-5.48E+0 (3.21E-1)	-6.99 (15.9)	<0.0001 (<0.0001)
Biodiversity	1EINES/h	-4.75E-1	-11.4	<0.0001	-5.95E-1 (3.64E-2)	-7.03 (19.2)	<0.0001 (<0.0001)
Tax	1yen/h	-3.00E-5	-25.3	<0.0001	-4.00E-5	-23.0	<0.0001 (<0.0001)
Remarks		Log likelihood: -7921.1 Likelihood ratio: 0.05			Log likelihood: -6481.5 Likelihood ratio: 0.22		

The likelihood ratio calculated by RPL improved more significantly than the results of CL (to 0.05-0.22), which clearly shows improvement in the estimation model’s power of explanation. The mean value is similar to the result of CL. On the other hand, RPL is characterized by the gaining of factors for the estimation of standard deviation, which cannot be gained by CL. Because all the factors are statistically significant, it can be confirmed that the results of analysis using RPL are valid. It can be said that RPL, whereby each attribute variable can quantitatively display the degree of preference among individuals, is extremely effective for gaining integration factors, including the statistical values.

Figure 3.3-12 (a) to (d) show the frequency distribution of WF_1 of the areas of protection, together with the statistical values. With regard to all the areas of protection, the distribution is symmetrical and is consistent with the normal distribution. Among the areas, the variation coefficient of the weighting factor for social assets is high, which indicates that individual difference is relatively large.

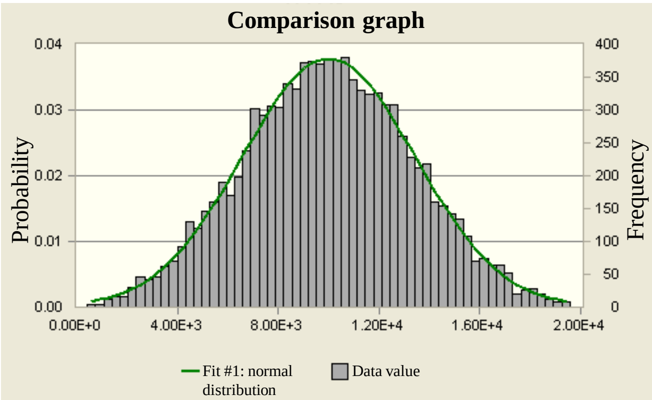
Table 3.3-9 shows the correlation matrix among the weighting factors in the areas of protection. The important area of protection differs among individuals. According to this table, although all the correlations are negative, the degree of negativity differs among the areas of protection.

[9] Because examination of the resultant estimate itself and economic assessment made by the use of it have already been carried out, pay attention to the relative comparison with CL in this table.



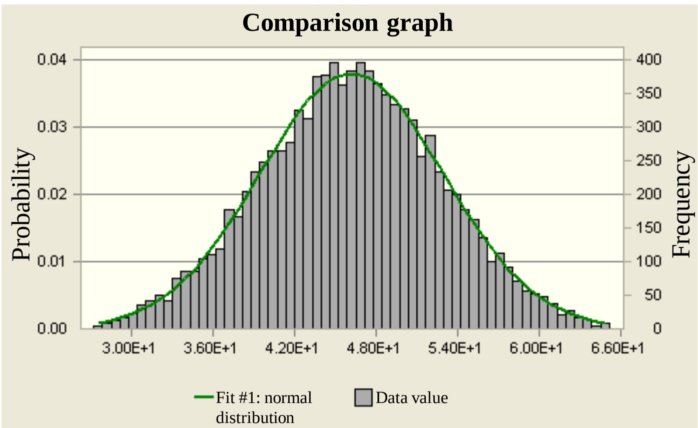
Distribution profile	Normal distribution
Mean	1.47E+7
Median	1.47E+7
Standard deviation	3.08E+6
Variation coefficient	0.21
Kurtosis	3
Skewness	0

Figure 3.3-12 (a): Frequency distribution and statistical values of the weighting factor for human health WF1 (yen/DALY)



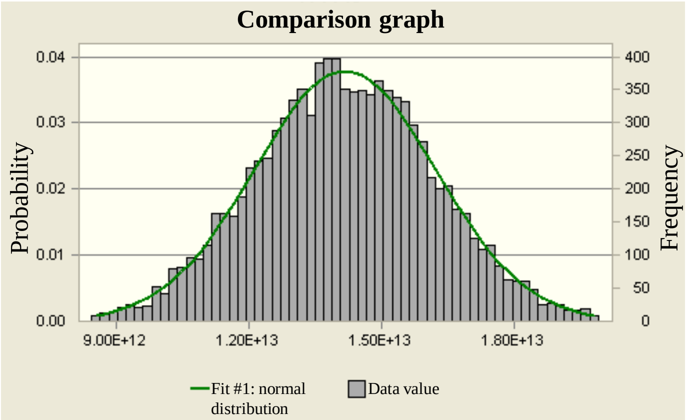
Distribution profile	Normal distribution
Mean	1.00E+4
Median	1.00E+4
Standard deviation	3.43E+3
Variation coefficient	0.34
Kurtosis	3
Skewness	0

Figure 3.3-12 (b): Frequency distribution and statistical values of the weighting factor for social assets WF1 (yen/10,000 yen)



Distribution profile	Normal distribution
Mean	4.62E+1
Median	4.62E+1
Standard deviation	6.77E+0
Variation coefficient	0.147
Kurtosis	3
Skewness	0

Figure 3.3-12 (c): Frequency distribution and statistical values of the weighting factor for primary production WF1 (yen/kgDW)



Distribution profile	Normal distribution
Mean	1.42E+13
Median	1.42E+13
Standard deviation	2.05E+12
Variation coefficient	0.145
Kurtosis	3
Skewness	0

Figure 3.3-12 (d): Frequency distribution and statistic values of the weighting factor for biodiversity WF1 (yen/EINES)

Table 3.3-9: Correlation matrix of the weighting factors

	Human health	Social assets	Primary production	Biodiversity
Human health		-0.13*1	-0.12*1	-0.05*2
Social assets			-0.13*1	-0.13*1
Primary production				-0.06*1
Biodiversity				

*1: Significant at the 1% level; *2: Significant at the 5% level

Examination of the decorrelation is an examination of a hypothesis that there is no correlation between the two variables. If the correlation is judged to be significant, the hypothesis is rejected and “there is a correlation between two variables” that has statistical verifiability.

3.3.9 Uncertainty analysis of integration factors

If results can be gained concerning not only an estimation of the population, but also the variation in the estimate, uncertainty analysis of the integration factors can be carried out by applying variation in the damage factor. Because of this, LIME 2 shows the results of uncertainty analysis of integration factors using the statistical values of the weighting factor WF_1 gained from RPL.

The integration factor IF_1 can be gained from the sum of products of the weighting factor WF_1 and the damage factor.*[10]

[10] An integration factor can be gained from the sum of products of the damage factor and the weighting factor. The representative value can be calculated by two methods: 1) calculation is made by the median of the weighting factor WF_1 and the median of the damage factor *DF*; and 2) the median is gained from analysis of the sum of the products of the weighting factor WF_1 and the damage factor *DF* using the Monte Carlo method. Under LIME 2, the median gained by the

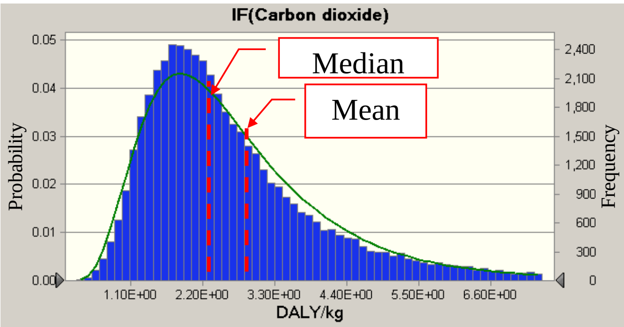
$$IF_1^{Impact}(X) = \sum_{Safe} \left(DF^{Impact}(Safe, X) \times WF1(Safe) \right) \quad (3.3\text{-}4)$$

In this equation,
DF^{Impact} (*Safe*, *X*): the damage factor of the substance *X* against the area of protection *Safe* through the impact category *Impact* [unit amount of damage/kg]
WF_1 (*Safe*): economic value [weighting factor] of the damage per unit of the area of protection *Safe* [yen/unit amount of damage]
IF_1^{Impact} (*X*): integration factor (version 1) of the substance *X* [yen/kg]

The integration factor was statistically analyzed by performing the calculation of Equation 3.3-4 using the Monte Carlo method several times.*[11] As an example, Figure 3.3-13 shows the results of calculation of the integration factor for CO_2 (global warming). In the case of CO_2, although the impact of warming on health and social assets is assessed, the figure also shows statistical values, such as the mean and the median. In addition, it also shows the results of fitting the frequency distribution and the continuous function. According to the results of calculations performed 50,000 times, the lognormal distribution is the most consistent.

Moreover, Figure 3.3-14 shows the sensitivity analysis results of the integration factor for CO_2. Because a rank correlation coefficient is shown for each type of variable used for the calculation of the integration factor, it is possible to extract variables that influence the uncertainty of the calculation result.

The integration factor of CO_2 is highly correlated with the D-R factor of malaria, the climatic sensitivity, and the weighting factor for human health. This indicates that these parameters greatly influence the uncertainty of the final results. Although many other parameters are used for the calculation of integration factors, improvement of the reliability of the above-mentioned variables seem to make it possible to reduce the uncertainty of integration factors.



Distribution profile	Lognormal
Number of times performing the calculation	50,000
Mean	2.77 yen/kg
Median	2.33 yen/kg
Standard deviation	1.65
Variation coefficient	0.596

Figure 3.3-13: Frequency distribution and statistic values of the integration factor for CO2 [yen/kg]

method 2) is used as the representative value of the integration factor IF_1. Note that the results are not the same.

11 Under LIME 2, there are three types of integration factors (IF_1, IF_2, IF_3). The normalization value is used for the calculation of IF_2, nondimensional factor (see 3.3.10). With regard to the annual environmental load, which is used for the calculation of the normal value, because information on uncertainty could not be gained, the representative value of IF_2 is shown without having been analyzed. With regard also to IF_3, a factor based on CO_2, only the representative value is shown.

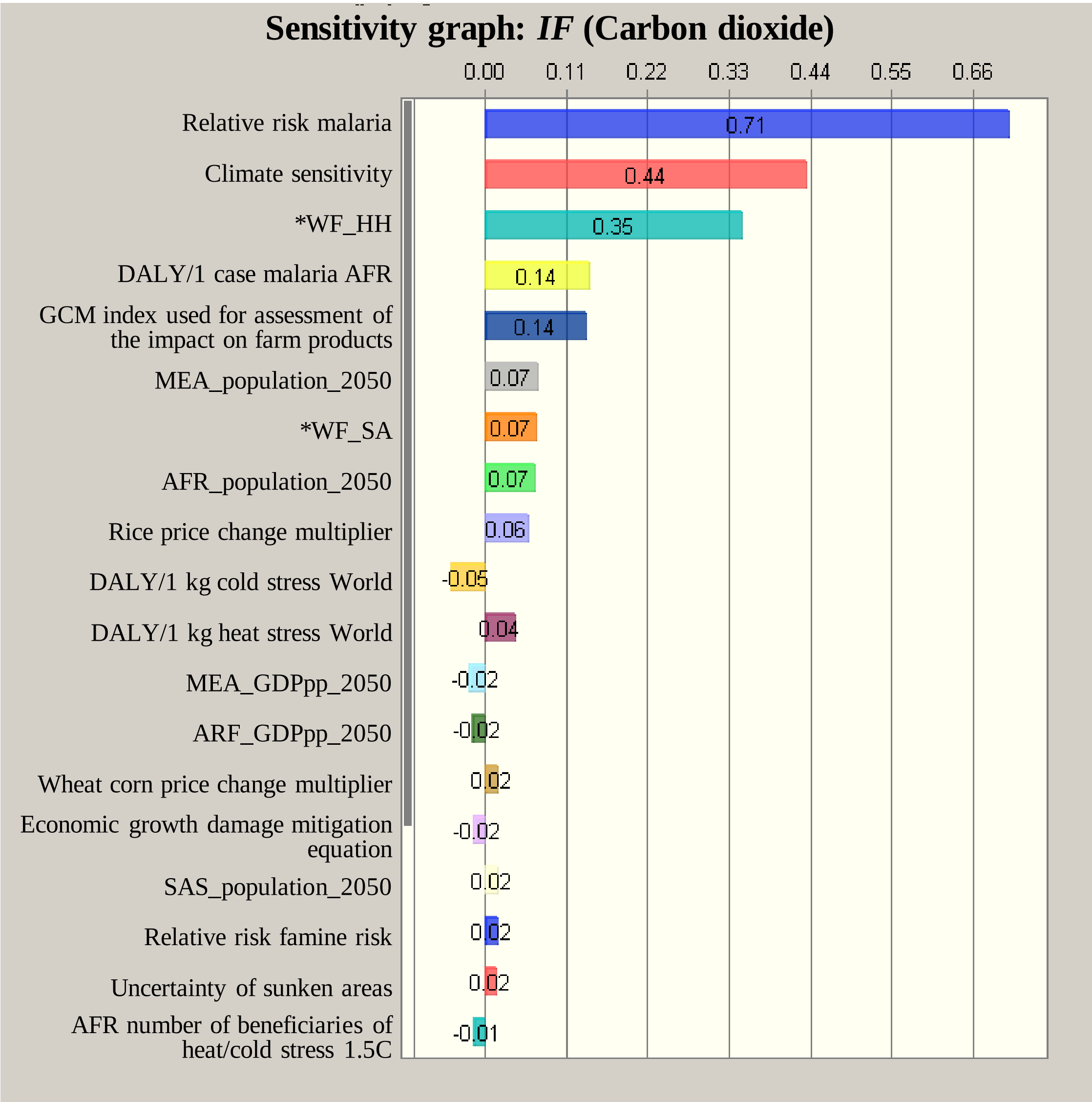


Figure 3.3-14: Results of a sensitivity analysis of the integration factor for CO2 [yen/kg]
The horizontal axis indicates the rank correlation coefficient, while the vertical axis indicates variables with a high rank correlation coefficient.

Column 3.3-3:

The integration factor for CO_2 and SCC

Under LIME 2, the integration factor for CO_2 (the economic value of environmental impacts per kg of emitted CO_2) was calculated at 2.3 yen/kg (the mean is 2.8 yen). Various institutes have attempted to calculate the economic value per unit of CO_2. In this column, comparison will be made with other methods.

The excessive amount of economic damage from additional emissions per unit of CO_2 is called SCC (social cost of carbon) by the IPCC Fourth Report Working Group II (IPCC WG2 2007). The report mentions SCC as the indicator that attracts the greatest attention from research on the assessment of the entire global impact of CO_2, and introduces many SCC research cases, including Tol (2002), Hope (2005), and Stern (2006).

This column compares the integration factor calculated under LIME 2 and the above-described SCC. Table 3.3-B summarizes the comparison between SCC gained by the integrated assessment model and the integration factor for LCIA. SCC can be roughly divided into that of about $30 (Nordhaus, Tol, Hope) and that of nearly or more than $100 (Stern, EPS). Under LIME 2, the result is similar to the former. Confidence has been examined in many of these assessments. According to the results using LIME, the confidence interval seems narrow.

Next, Figure 3.3-A shows a comparison with the structure of Tol's SSC in terms of the breakdown of the integration factor. Both have common points: consideration is given to not only damage, but also benefits; and various items are covered, including health and farm products. However, they also have differences. The following are the main differences:

1) The scope of the assessment differs. Although LIME 2 does not cover economic impacts on forestry and water, Tol covers them. On the other hand, LIME 2 covers the impacts of disasters and malnutrition on health, while Tol does not cover them.
2) Although damage from infection is the greatest among all types of damage under LIME 2, Tol suggests that the greatest damage is that from the maldistribution of water resources.

Moreover, the results of a sensitivity analysis were compared to find whether the recognition concerning important parameters is consistent. Table 3.3-C shows the results of Hope's sensitivity analysis for SCC (IPCC WG2 2007). According to the table, as in the case of the results of LIME 2 (Figure 3.3-14), it can be considered that climate sensitivity and willingness to pay for matters that cannot be handled in the market (such as human health) are important. However, items related to value judgments, such as the discount rate and Equity Weighting (adjustment for consideration of the economic gap between advanced countries and developing countries), are frequently not included under LCIA methods, including LIME.

Table 3.3-B: Comparison of the calculation results for the SCC

SCC can be roughly divided into costs based on the integrated assessment model and costs based on the LCIA method.

Model	SCC (US$/ton CO_2)	
	Mean	Confidence interval (5%, 95%)
DICE (Nordhaus et al. (2000))	$6	
FUND (Tol (1999))	$25	-$10, $350
PAGE (Hope (2006))	$19	$4, $51
ExternE (2005)	$11	-$0.5, $40 (10%, 90%)
Stern report (2006)	$85	
EPS (2000)	$150 (108€)	
LIME 2 (2009)	$28	$17, $47 (10%, 90%)

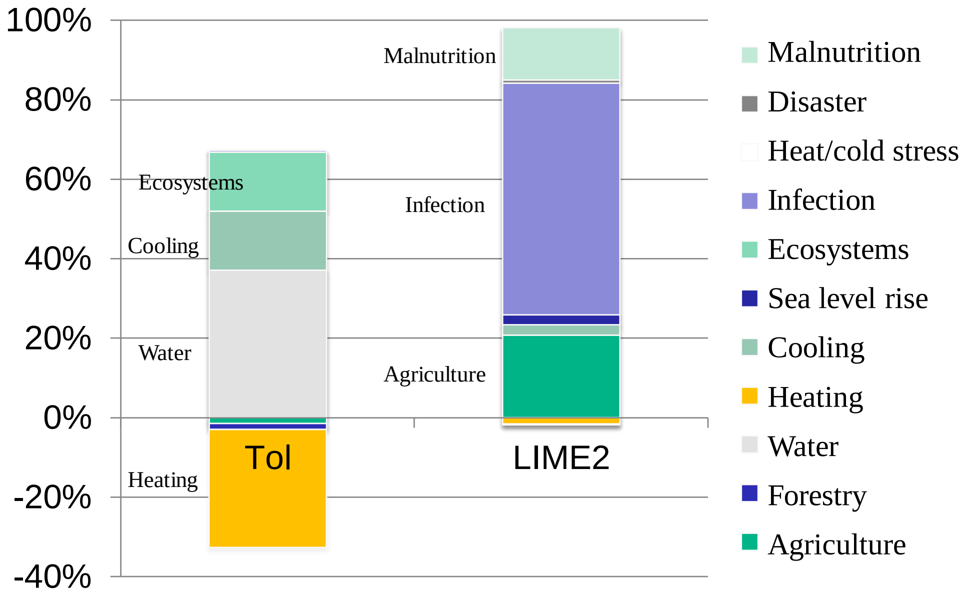


Figure 3.3-A: Comparison in terms of the scope of the research and the breakdown of the SCC
The breakdown differs between them

Table 3.3-C: Results of a sensitivity analysis regarding the SCC (using the integrated assessment model PAGE)
Not only climate sensitivity and non-market goods (such as the health impact), but also the discount rate and Equity Weighting (adjustment of values between advanced countries and developing countries) are important.

Parameter	Sign	Degree of importance
Climate sensitivity	+	100
Discount rate	-	66
Economic value (non-market goods)	+	57
Equity Weighting	-	50
Atmospheric lifetime	-	35
Economic impact (market goods)	+	32

IPCC AR4 (2007)

Therefore, to discuss the integration factor for CO_2 based on an LCIA method such as the SCC described in the IPCC, it seems necessary not only to see the values, but also to consider whether to take into consideration the scope of the research, the breakdown of SCC, the prospects for SCC, and north-south gaps when calculating SCC. In addition, the discount rate and the like are not taken into consideration when integration factors for LCIA are calculated, the uncertainty shown in Table 3.3-B is expected to increase relatively if these are taken into consideration.

Column 3.3-4:

Control costs and damage costs

With regard to CO_2, the economic indicators can be roughly classified into damage costs and control costs. The integration factors proposed by LIME, Extern E, and EPS are a monetary conversion of the damage that can occur in a society due to the generation of CO_2 and fall under the category of damage costs. All the SCC mentioned in the previous column also fall under the category of damage costs. The Ministry of the Environment and the Central Environment Council announced the control costs necessary for restraining the emission of a unit of CO_2. This column explains them.

In October 2004, the Ministry of the Environment (2004) proposed that the carbon tax should be 2,400 yen/carbon ton (650 yen/t-CO_2). The main purpose of the introduction of a carbon tax is to reduce emissions. The introduction is expected to reduce this greenhouse gas by 43 million tons, a little more than 3.5% on the base year of 1900. If the target is a 6% reduction, this will require a higher cost.

The Central Environment Council's Global Environment Committee "Goal Achievement Scenario Subcommittee's Interim Report" (2001) shows the relationship between the amount of reduction necessary for realizing the COP3 agreement with the full use of domestic CO_2 control technologies and the cost of this reduction. Oka et al. (2002) used the information to calculate the marginal reduction costs. Assuming that the target amount to be achieved in 2010 is 310 million carbon tons, down by 6% on 1990, they fixed the reduction target at 26.7 million tons (98 million t-CO_2), deducting a forest sink of 3.7% and a credit of 1.8% under the Kyoto mechanism. The highest cost of reduction technologies to be introduced for the achievement of the target was fixed at 4,600 to 11,700 yen (t-CO_2).

In addition to the damage costs, Extern E also calculated the control costs, since the scope of the assessment could not be sufficiently assured. In this research, the cost of introducing the technologies necessary for complying with the guideline values specified in the Kyoto Protocol was estimated to be 19 euros. If a stricter target of limiting the temperature rise to within 2 degrees centigrade is set, further limitations will need to be imposed on CO_2 emissions. As a result, the cost of limiting CO_2 emissions was estimated to increase to 95 euros (14,250 yen) per ton of CO_2 reduction.

Table 3.3-D summarizes the control costs.

In this way, the economic value of CO_2 changes according to the goal of the control cost. Pay special attention to the great difference in the marginal reduction costs between the goal of complying with the Kyoto Protocol and the goal of limiting temperature rise within two degrees centigrade.

On the other hand, there are many problems regarding calculation of the damage costs. Improvement is required in matters related to value judgments, such as WTP and the discount rate, and natural scientific parameters, such as climate sensitivity.

The control costs will be used as a measure of the effects of cost-benefit analysis. For the purpose of cost-benefit analysis, a reduction in the damage costs provides a social benefit. The calculation method, the concept, and the resultant meaning differ according to the control costs and the damage costs. Therefore, it is necessary to use different LCIA methods according to the purpose of the assessment, taking into consideration the limits of their use.

Table 3.3-D: Comparison between the integration factor for CO2 and the marginal reduction costs (avoidance costs)

Method	Unit	Cost per ton of CO_2 reduction	
		Representative value	Remarks
ExternE	Damage costs	9€ (1,350 yen)	Coastal areas, agriculture, forestry, energy, water resources, natural ecosystems, health
	Avoidance costs	19€ (2,850 yen)	If the goal is to comply with the Kyoto Protocol
		95€ (14,250 yen)	If the goal is to limit the temperature rise to within 2 degrees centigrade
Ministry of the Environment	Avoidance costs	650 yen	Goal: reduction of more than 3.5% on the base year of 1990
Oka et al.	Avoidance costs	8,000 yen	Goal: reduction of 6% on the base year of 1990; cited from the Central Environment Council
LIME 2	Damage cost	2,330 yen	Health, energy, agriculture, coastal area

3.3.10 Integration procedure

The integration factor can be gained by multiplying the weight factor by the damage factor. The results of the integration of environmental impacts can be expressed in monetary units by multiplying the integration factor by LCI.

$$I_1 = \sum_{Impact}\sum_{Safe}\sum_{X}(Inv(X)\times DF^{Impact}(Safe,X)\times EV(Safe)) = \sum_{Impact}\sum_{X}(Inv(X)\times IF_1^{Impact}(X)) \qquad (3.3\text{-}5)$$

In this equation,

I_1: result of integration based on economic assessment (external cost) [yen]

Inv (*X*): life cycle inventory of the substance *X* [kg]

DF^{Impact} (*Safe*, *X*): the damage factor of the substance *X* against the area of protection *Safe* through the impact category *Impact* [unit amount of damage/kg]

EV (*Safe*): economic value of the damage per unit of the area of protection *Safe* (economic value conversion factor) [yen/unit amount of damage]

IF_1^{Impact} (*X*): integration factor for the substance *X* (version 1) [yen/kg] *[12]

The integration factor (IF_1^{Impact} (*X*)) is shown in Appendix A3.

[12] In the appendix, the representative values for damage and integration factors reflect the results of the uncertainty analysis. To obtain the integration factor, the sum of the products of the damage and weighting factors is calculated using the Monte Carlo method. Therefore, note that, strictly speaking, the median of the integration factor (which is treated as the representative value under this method) is different from the sum of the products of the medians of the damage and weighting factors.

The use of the weighting factor WF_2 in Table 3.3-7 makes it possible to calculate the nondimensional integration factor IF_2. IF_2 can be gained by dividing the damage factor by the normalization value and multiplying the result by the weighting factor. It is thus possible to integrate LCIA. The use of these factors makes it possible to also express the integration result as a nondimensional indicator.

$$\begin{aligned} I_2 &= \sum_{Impact} \sum_{safe} \sum_{X} \left(\frac{Inv(X) \times DF^{Impact}(Safe, X)}{NV(Safe)} \times WF_2(Safe) \right) \times C \\ &= \sum_{Impact} \sum_{X} \left(Inv(X) \times IF_2^{Impact}(X) \right) \end{aligned} \tag{3.3-6}$$

I_2: nondimensional result of the integration of environmental impacts (nondimensional)
NV (*Safe*): normalization value of the area of protection *Safe* (annual amount of latent damage)
WF_2 (*Safe*): weighting factor for the area of protection *Safe* gained as shown in Table 3.3-7 (nondimensional)
IF_2^{Impact} (*X*): integration factor for the substance *X* (version 2) [kg^{-1}]
C: constant for adjusting the unit of the integration factor (10^{14})

The integration factor (IF_2^{Impact} (*X*)) is shown in Appendix A3.

Gaining two types of integration factors in this way is a characteristic of conjoint analysis. If the integration factor IF_1 is used to express the result as a monetary value, the result can be used for various purposes, such as cost-benefit analysis, environmental efficiency, and environmental accounting. Moreover, the expression of the result as a monetary unit, which is used in people's everyday life, is one of the indicators most suitable for activating environmental communication. However, because research on the estimation of willingness to pay is still immature, assessed values may change greatly in the future. Repeated discussions mainly by experts are essential to determining the extent to which the results obtained in this exercise can be used for general purposes.

On the other hand, the integration factor IF_2 is highly consistent with the weighting procedure specified in the international standards that use normalization and weighting factors. In addition, the expression of assessment results by economic indicators may be avoided, depending on users' purposes. However, because there is no information on the uncertainty of the normalization value (*NV*), which is one of the parameters used for the calculation of IF_2, note that there are no statistical values. Users can select integration factors that suit the purpose of their assessment, such as to calculate external costs, to carry out integration according to international standards, and to clarify the relationship with CO_2 emissions. *[13]

[13] LIME 1 used two types of weighting methods: conjoint analysis and AHP (Analytic Hierarchy Process) (Itsubo 2005). The CL used for conjoint analysis is consistent with random utility theory and is excellent in that it can be discussed from the viewpoint of welfare economics. Moreover, weighting factors, which can be gained as analysis results, enable the analysis of statistical significance and verify the power of explanation of the model as a whole.
On the other hand, AHP has been frequently used as a decision-making support tool. Some research has used AHP for the integration of LCIA. Because the respondents make a pair comparison between elements, the effort required of the respondents is less than making a comparison between the profiles used in conjoint analysis. However, the analysis results of the answers are sample averages. Therefore, because it is impossible to verify whether they are representative of the population, it is unreasonable to use integration factors obtained from AHP for LCIA.
In addition, because AHP uses pair comparison in the questioning, its questioning style is different from that of conjoint analysis. Because obtaining the answers in two styles when conducting a survey increases the burden on the respondents,

In addition, LIME 2 also shows the integration factor (IF_3) based on CO_2 (=1). The results of calculation using IF_3 is expressed as the amount equivalent to CO_2 emissions, as with the Global Warming Potential (GWP).

$$I_3 = \sum_{Impact} \sum_{X} \left(Inv(X) \times \frac{IF_2^{\,Impact}(X)}{IF_2^{\,globalwarming}(\mathrm{CO_2})} \right)$$
$$= \sum_{Impact} \sum_{X} \left(Inv(X) \times IF_3^{\,Impact}(X) \right)$$

Appendix A3 shows the integration factor ($IF_3^{Impact}(X)$).

However, note that IF_3 is an integration factor and is not as accurate as the GWP.

Table 3.4-1: Main differences between LIME 1 and LIME 2 is in the integration factor calculation procedures and the results

	LIME 1	LIME 2	Purpose of improvement under LIME 2
Survey method	Interview survey (Meeting survey)	Interview survey (Door-to-door survey)	Development of highly representative and general-purpose weighting factors
Sampling method	Mall intercept	Random sampling	
Number of sample answers	400	952	
Survey place	Tokyo	Throughout Japan	
Matters acquired due to calculation	Representative value	Representative value and statistical values	Calculation of the statistical values of the weighting factors
Model	Conditional logit model	Random parameter logit model	

3.4 Conclusion

The integration, the final process of LIME, makes it possible to express as a single index the amount of damage to the areas of protection presented as a result of the damage assessment through the application of a weighting to the areas of protection. Therefore, it was necessary to give consideration to obtaining weighting factors for the areas of protection that are representative of social views and are highly persuasive.

Attention was focused on conjoint analysis as a highly feasible method. Although conjoint analysis was developed in the fields of computational psychology and market research, it has recently drawn particular attention as a method of assessing the environment from the viewpoint of economics. It was judged that the methodology of conjoint analysis, which is based on theories of both statistics and economics, satisfies

it may be difficult to obtain stable survey results.
As a result, LIME 2 adopted conjoint analysis, whose method is based on theories of inferential statistics and about which the representativeness of the population has been verified, and a decision was made not to calculate the weighting factors using AHP.

the purpose of gaining highly representative weighting factors among the areas of protection.

Choice-based conjoint analysis was adopted for the conjoint analysis. Under this choice conjoint method, the most suitable policy draft is selected from among the several policy drafts specified in the questionnaire. A policy profile was established here, consisting of five attributes – the four environmental attributes defined as areas of protection for the purpose of this research (human health, social assets, biodiversity, and primary production) and a tax. The normalization value gained from the damage factors and the annual environmental load were adopted for the current baseline policy draft.

Table 3.4-1 summarizes the integration processes under LIME 1 and LIME 2 and the differences in the processes between them. The following summarizes the characteristics of LIME 2.

Households were sampled from throughout Japan using random sampling to obtain weighting factors that reflect the Japanese people's environmental views. Following this, surveyors acquainted with the contents of the survey visited the households and conducted interviews. When explaining the questionnaire, they made efforts to reduce any misunderstanding of its contents and avoid introducing any bias as far as possible, such as by showing panels clearly explaining the contents and reading the explanatory script aloud.

A certain number of respondents is necessary for estimating highly accurate weighting factors. In the main survey, interviews were held with about 1,000 respondents, and a statistical analysis was carried out based on the data. This was the first time such a large-scale survey for the calculation of weighting factors had been carried out for research on LCIA and research on environmental economic assessment.

RPL was applied to the responses. The economic value per unit of area of protection was gained by the maximum likelihood estimation method. All the results concerning the areas of protection were statistically significant, and it was confirmed that the applied model's power of explanation was high. This indicated that the respondents gave their answers in light of their own environmental views after understanding well the explanations about the questionnaire. In addition, not only the estimates, but also the statistical values were calculated during the survey. This resulted in success in making visible differences in the environmental values among individuals.

According to the results of the survey, the greatest importance was placed on biodiversity, followed by human health and primary production, while relatively little importance was placed on social assets. This is a difference from LIME 1, where the greatest importance was placed on human health. Moreover, the economic values of the areas of protection increased from those under LIME 1. Although the results between both cannot be compared unconditionally due to various differences in the survey period, the class of respondents, the data entered in the questionnaire, etc., the results are assumed to reflect the recent increase in people's awareness of the environment and the effect of carrying out the survey in the suburbs.

Main The main issues and problems concerning the integration of environmental impacts are dealt with below.

If environmental views differ among individuals, areas of protection are weighted differently. Eco-indicator 99 established weighting factors after classifying people with environmental views into three types (hierarchist, egalitarian, and individualist). LIME did not classify weighting factors according to people's environmental views or the attributes of individuals. This is because the survey found that the model's power of explanation is sufficient even if the utility functions of the population are not classified according to environmental views. In addition, there is the fear that if a list of factors classified according to environmental views is made, users might become confused by an increasing number of types. However, this does not deny the possibility of obtaining more consistent results if environmental views are classified. If the purpose is to obtain more accurate factors, the classification of environmental views is expected to serve as an effective approach.

The questionnaire explains the purpose of the survey and the current situation of the environmental impacts on each area of protection before asking the questions for the conjoint analysis. Because the way of assessing the environment by the respondents may change depending on the explanation, it is desirable to examine the extent to which the answers may change according to the means of presenting the information.

There are two types of integration factors gained through this analysis (economic indicators and nondimensional weighting factors). Which to use depends on the purpose of each user. If the purpose is cost-benefit analysis, environmental accounting, or full cost assessment, it is effective to use integration factors based on economic indicators. On the other hand, if integration is carried out as provided in ISO-LCA, if the results of integration are used for environmental efficiency, or if there is no reason for the positive use of economic indicators because the purpose is an external announcement, non-dimensional factors will be applied. At present, the relationship between LCIA and economic analysis, such as cost-benefit analysis, has not been sufficiently explored. In future, research on economic assessment of the environment is expected to develop to acquire more accurate integration factors and use these for decision-making concerning the selection of environmentally-oriented products.

[References for Chapter III]

(Ben-Akiva 1985) Ben-Akiva, M. and S .R. Lerman (1985): Discrete Choice Analysis, MIT Press
(Clarkson 2002)Clarkson, R., Deyes, K (2002): Estimating the Social Cost of Carbon Emissions, Environment Protection Economics Division Department of Environment, Food and Rural Affairs: London, 2002 January
(Downing 2005) Downing, T., Anthoff, D., Butterfield, R., Ceronsky, M., et.al, Social Cost of Carbon (2005): A Closer Look at Uncertainty, Department for Environment, Food and Rural Affairs, 2005
(EC 1998) European Commission (1998): ExternE Externalities of Energy Vol.7 Methodology 1998 update
(EC 2005) European Commission (2005): ExternE, Externalities of Energy, Methodology 2005 Update, Edited by Peter Bickel and Rainer Friedrich
(Federal Register (1993): Report of the NOAA panel on Contingent Valuation, Washington, D.C., US Government, 58 (10) 4601-4614
(Goedkoop (1995): The Eco-indicator 95. NOH report 9523. Pré Consultants, Amersfoort
(Goodkoop 1999) M. Goedkoop and R. Spriensma (1999): The Eco-indicator 99, A damage oriented method for Life Cycle Impact Assessment, Methodology Report
(Green 1991) Green, P. E., Krieger, A. M. and Agarwal, M. K. (1991): Adaptive Conjoint Analysis, Some Caveats and Suggestions, Journal of Marketing Research, 28, 215-222
(HaHauschild, M., Wenzel, H. (1997): Environmental Assessment of products. Volume 2: Scientific background. Chapman & Hall, London
(Huppes 1997) Huppes. G.,Sas, de Haan, E., Kuyper, J. (1997): Efficient environmental investments. Paper presented at the SENSE International Workshop, 20 Feb., Amsterdam
(Hope 2006) Hope, C. (2006): The Marginal Impact of CO_2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern, IAJ, Vol. 6, (1), pp. 9–56
(ISO 14040 (2006): International standard, Environmental management - Life cycle assessment - Principles and framework
(ISO 14042 (2000): International standard, Environmental management – Life cycle assessment- Life cycle impact assessment
(ISO 14043 (2000): International standard, Environmental management – Life cycle assessment- Life cycle interpretation
(ISO 14044 (2006): International standard, Environmental management - Life cycle assessment - Requirements and guidelines
(Itsubo, N., Inaba, A., Matsuno, Y., Yasui, I., Yamamoto, R. (2000a): Current Status of Weighting methodologies in Japan, Int. J. LCA 5 (1) 5-11
(Itsubo 2000b) Itsubo, N. (2000b): Screening Life Cycle Impact Assessment with Weighting Methodology Based on Simplified Damage Functions, Int. J. LCA 5 (5) 273-280
(Itsubo 2004) Itsubo, N., Sakagami, M., Washida, T., Kokubu, K., Inaba, A. (2004): Weighting Across Safeguard Subjects for LCIA through the Application of Conjoint Analysis, Int. J. LCA, 9, 196-205
(IPCC WG2 (2007): IPCC WG2 AR4, Climate Change 2007, Impacts, Adaptation and Vulnerability
(Lindeijer 1997) Lindeijer, E.(1997): Results try-out Japanese/Dutch LCA valuation questionnaire 1996, Amsterdam, IVAM
(McFadden 1974) McFadden, D (1974): 'Conditional Logit Analysis of Qualitative Choice Behavior', in P. Zarembka eds., Frontiers in Econometrics, Academic Press, 105-142
(Miller 1956) Miller, G. A. (1956): The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information, The Psychological Review
(Müller-Wenk (1994): The Ecoscarcity Method as a Valuation instrument within the SETAC-Framework, in Integrating Impact Assessment into LCA, SETAC-Europe, Bruxelles 115-120
(Nagata 1997) Nagata, K., Fujii, Y., Ishikawa, M., Yokota, R., Ureshino, M. (1997): Developing an impact assessment methodology using panel data, Summary report prepared for RITE International Workshop on Total Ecobalance, Tokyo
(Pearce 2003) Pearce, D (2003): The Social Cost of Carbon and its Policy Implications, Controlling Global Warming, Special Issue of Oxford Review of Economic Policy
(Pinnell 1994) Pinnell, J. (1994): Multi-Stage Conjoint Methods to Measure Price Sensitivity, in Sawtooth News, Sawtooth Software, Inc., edited by Weiss, S., 10 (2) 5-6
(Polak 1971) Polak, E. (1971): Computational Methods in Optimization, A Unified Approach, Academic Press, pp. 28-66
(Schmidt-Bleek, F (1993) : Wieviel Umwelt braucht der Mensch – MIPS, das Maß für ökologisches Wirtschaften, Birkhäuser, Basel, Boston, Berlin
(Steen 1999) Steen B. (1999): A Systematic Approach to Environmental Priority Strategies in Product Development (EPS) Version 2000 – Models and Data of the Default Method

(Stern 2006) Stern B. (2006): Stern Review, The Economics of Climate Change, HM Treasury, 2006 October
(Tol 2002) Tol, R. (2002): Estimates of the Damage Costs of Climate Change, Environmental and Resource Economics 21: 135–160
(Tol 2005) Tol, R.(2005): The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties, Energy Policy 33 (2005) 2064–2074
(Train,K. (2003): Discrete Choice Model with Simulation
(VDI-Richtlinien (1997): Cumulative Energy Demand – Terms, Definitions, Methods of Calculation. VDI – Guideline 4600, Beuth Verlag GmbH, Berlin
(VOLVO (2004): Environmental Product Declaration, http://www.v-eco.com/pdfs/VOLVO2003.pdf, p.12
(Wackernagel 1996) Wackernagel, M., Rees, W. (1996): Our Ecological Footprint, Reducing Human Impaction the Earth, New Society Publishers
(Walz (1997): Ecotoxicological impact assessment and the valuation step within LCA, Pragmatic approaches, Karlsruhe, Germany, Fraunhofer-Institut
(Yasui 1998) Yasui, I. (1998): A new Scheme of Life Cycle Impact Assessment Method Based on the Consumption of Time, p.89, 3rd Int. Conf. on Ecobalance, Tsukuba
Asahi Beer (2003): Asahi Beer Group Environmental Communication Report 2002, http://www.asahibeer.co.jp/eco/eco2002/pdf/ecr02data.pdf, p.15
Itsubo N, Sakagami M, Kuriyama K, Washida T, Kokubu K, Inaba A (2003): Development of LCIA Integration Factors Conjoint Analysis by the Application of Conjoint Analysis, Journal of Society of Environmental Science, Japan, 16 (5): 357 - 368
Itsubo N, Inaba A (2005): Life Cycle Environmental Impact Assessment Method, LIME-LCA, Environmental Accounting, Assessment Methods and Database for Environmental Efficiency, Japan Environmental Management Association for Industry
Iwakura S (2000): Trial Calculation of the Basic Unit of the Social Costs of Global Warming Based on Several CV Surveys – Considering its Application to Cost-Benefit Analysis in the Transport Sector, 2 (4): 2 - 11
Ministry of the Environment (2004): Concrete Plan for an Environment Tax, November 2004
Kuriyama K (1998): Value of the Environment and Assessment Methods, Hokkaido University Press, p. 205 - 206
Kuriyama K, Ishii Y (1999): Environmental Value and Market Competitiveness of Recycled Goods – Assessment by Conjoint Analysis, Journal of the Society of Environmental Science, Japan, 12 (1): 17 - 26
Kuriyama K (2000a): Illustration of Environmental Value and Environmental Accounting, Nippon Hyoron Sha
Kuriyama K, Kitabatake Y, Oshima Y (2000b): Economics of World Heritages, Keiso Shobo
Kuriyama K, Shoji Y (2005): Economic Value of Sightseeing and the Environment, Keiso Shobo
Takara Shuzo (2003): Takara Environmental Financial Report 2003,
http://www.takarashuzo.co.jp/green03/index.htm
Tokyo Electric Power (2004): The Earth, People, and Energy – TEPCO Environmental Action Report 2004,
http://www.tepco.co.jp/env/environment/report/Pages/tog_6769-j.html
Hagiwara K (1999): Assessment of Waterfront Environments in Urban Areas, (edited by Washida T, Kuriyama K, Takeuchi K), Environmental Assessment Workshop, The Current Status of Assessment Methods, Part II Chapter 3, Tsukiji Shokan
Matsuno Y (1998): Development of Impact Assessment Integration Indexes in Japan – Integration Indexes by the Use of the Distance to Target Method and Examples of their Application, Journal of Japan Institute of Energy, 77 (12): 1139 - 1147
Miyazaki N, Siegenthaler C, Kumagai S, Shinozuka E, Nagayama A (2003): Japan Science and Technology Agency Report, Environmental Performance Assessment Factor (JEPIX), Development of Eco-factors in Japan based on Environmental Policy Laws and Ordinances
Yoshida K, Takeda Y, Goda M (1996): Analysis of Information Effects in the Assessment of the Benefits of Water Source Forests, Quarterly Journal of Agricultural Economics, 50 (3): 1