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Author(s)	Ishii, Kazuei; Furuichi, Toru; Nagao, Yukari
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A Needs Analysis Method for Land-use Planning of Illegal Dumping Sites: A Case Study in Aomori-Iwate, Japan

Kazuei Ishii[1], Toru Furuichi[2] and Yukari Nagao[3]
Faculty of Engineering, Hokkaido University
N13, W8, Kita-ku, Sapporo, Hokkaido, 060-8628, Japan
[1] k-ishii@eng.hokudai.ac.jp, [2] t-furu@eng.hokudai.ac.jp

Corresponding author:
Kazuei Ishii
E-mail: k-ishii@eng.hokudai.ac.jp
Tel: +81-011-706-7284
FAX: +81-011-706-7287
Faculty of Engineering, Hokkaido University
N13, W8, Kita-ku, Sapporo, Hokkaido, 060-8628, Japan

Abstract:

Land use at contaminated sites, following remediation, is often needed for regional redevelopment. However, there exist few methods of developing economically and socially feasible land-use plans based on regional needs because of the wide variety of land-use requirements. This study proposes a new needs analysis method for the conceptual land-use planning of contaminated sites and illustrates this method with a case study of an illegal dumping site for hazardous waste. In this method, planning factors consisting of the land-use attributes and related facilities are extracted from the potential needs of the residents through a preliminary questionnaire. Using the extracted attributes of land use and the related facilities, land-use cases are designed for selection-based conjoint analysis. A second questionnaire for respondents to the first one who indicated an interest in participating in the second questionnaire is conducted for the conjoint analysis to determine the utility function and marginal cost of each attribute in order to prioritize the planning factors to develop a quantitative and economically and socially feasible land-use plan. Based on the results, site-specific land-use alternatives are developed and evaluated by the utility function obtained from the conjoint analysis. In this case study of an illegal dumping site for hazardous waste, the uses preferred as part of a conceptual land-use plan following remediation of the site were (1) agricultural land and a biogas plant designed to recover energy from biomass or (2) a park with a welfare facility and an athletic field. Our needs analysis method with conjoint analysis is applicable to the development of conceptual land-use planning for similar sites following remediation, particularly when added value is considered.

Keywords: illegal dumping sites, land use following remediation, needs analysis method, conjoint analysis

1. Introduction

Several cases of illegal dumping of waste material, including hazardous compounds, have recently occurred in Japan. These incidents have caused serious soil and groundwater contamination. Although the contaminated sites have been cleaned up to reduce their effects on the neighboring environment, the land use of such sites following remediation has not been considered in depth (Ishii et al., 2005). Specifically, in the case of large illegal dumping sites that have been remedied with public funds, the land use of the sites should be discussed by local governments and residents around the sites with the aim of preventing recurring illegal dumping, preventing crime and redeveloping the area (Brooks et al., 2008). It is important to reduce the negative impact of illegal dumping sites on the natural and socio-economic environment. Moreover, potential added value should be considered in the land use of these sites (Furuichi, 2009; Ishii and Furuichi, 2009). Furuichi (2009) suggested that the term "added value" refers not only to economic benefits but also to societal benefits in the broad context of resident participation and environmental education.

The redevelopment of sites contaminated by hazardous compounds, such as old factory sites, has been promoted in certain countries in Europe and several states in the United States, particularly when the redevelopment of the site is economically beneficial (Reisch and Bearden, 2003). Even if the economic advantage is not expected to be significant, national funding through such laws as the Small Business Liability Relief and Brownfields Revitalization Act (US EPA, 2002) in the United States is used for the remediation and redevelopment of contaminated sites. In these cases, the remediation of contaminated sites is financed by the national government, and the redevelopment of the sites following remediation is financed by the private sector. Against this background, the authors of most studies on the land-use planning of brownfields have proposed evaluation models to select the sites to be redeveloped by considering economic, social and environmental aspects of interest to developers (Wedding and Crawford-Brown, 2007; Cheng et al., 2011; Thomas, 2002; Chen et al., 2009; Schädler et al., 2012).

In Japan, as well as in the United States and Europe, municipal solid waste landfill sites are often used for agriculture or recreation following closure. Of particular note is Moerenuma Park in Sapporo, Japan, which was designed by the sculptor Isamu Noguchi and is famous for its incorporation of artwork (Sapporo City, 2005). Many case studies on the redevelopment of brownfields have been reported (e.g., Sousa, 2002). However, there have been few redevelopment cases of brownfields in Japan because the support systems from the Japanese government are insufficient.

For illegal waste dumping sites, land use appears to depend strongly on the remediation method. Most large illegal dumping sites that have been remedied with public funds were formerly normal landfill sites. In such sites, containment of the waste by vertical barriers and capping was intended mainly as a remedial action. In these cases, the long-term management of illegal dumping sites is more important than land use following remediation. Previous papers have described approaches for the long-term management of landfills (Laner et al., 2012; Morris and Barlaz, 2011). However, only a few large illegal dumping sites have applied a method of the removal of all waste and the remediation of contaminated soil and groundwater to a level that meets environmental quality standards. The land use of illegal dumping sites following remediation, with the removal of all dumped waste, has not been considered because such cases are rare.

In land-use planning following the remediation of illegal dumping sites, the needs of various stakeholders should be taken into account and analyzed quantitatively, including the needs of the local governments responsible for remedial activities, cities (or towns or villages) with illegal dumping sites, the property owners and neighboring residents, and the taxpayers who indirectly pay for remediation. In particular, the needs of the residents should be considered in the case of illegal dumping sites because land use following remediation will directly affect their socioeconomic situation. Greenberg and Lewis (2000) reported that most of the respondents to a questionnaire indicated a desire to participate in the redevelopment process of brownfields.

Only a few studies have focused on the needs analysis of residents in favor of brownfields redevelopment. In one such study, Greenberg and Lewis (2000) conducted a questionnaire and found that residents were less interested in industry and business in redevelopment plans and instead preferred community facilities and housing. According to Sousa (2006), who investigated the benefit of brownfields to green space projects, most respondents perceived many benefits related to personal and community quality of life, such as recreational activities and scenic beauty. However, no studies have addressed the land-use planning of illegal dumping sites following remediation, especially with the removal of all waste, based on the needs of residents. Therefore, the present study focused on the needs of residents and development of a method for analyzing residents' potential needs for the land use of an illegal dumping site following remediation by removing all waste.

Recently, many studies have used conjoint analysis to evaluate the needs of residents in environmental fields (e.g., Alriksson and Öberg, 2008). In particular, regarding waste management policy, Garrod and Willis (1998) predicted reduction in amenities due to landfill waste disposal using a stated preference experiment. Probert et al. (2005) used conjoint analysis to evaluate preferences regarding the quality of compost in order to develop appropriate marketing strategies. Sasao (2004) applied a multi-attribute utility theory, conjoint analysis, to determine the location of a landfill site on the basis of a questionnaire survey of residents. Sasao (2005) also conducted conjoint analysis of an illegal dumping site to determine the level of remediation, frequency of monitoring and land use following remediation. The study examined the potential of returning the site to its original state, a forest, and did not consider land use with added value following remediation. If added value is included, many aspects of land use must be considered, such as those related to industry, agriculture, business, research and development, education, welfare, and recreation, depending on the needs and conditions of the region, including location, climate, population, and basic industry. Therefore, a preliminary investigation is needed to identify planning factors and to develop a land-use plan following the remediation of illegal dumping sites. Quantitative analysis, such as conjoint analysis, which is capable of evaluating preferences (including economic aspects of preferences), can then be applied to prioritize the planning factors to be included in a land-use plan.

This study identified a new method of analysis that incorporates a preliminary investigation and conjoint analysis to develop a conceptual land-use plan that considers economic and social feasibility based on the potential needs of residents. To verify the effectiveness of the method, it was applied to an actual illegal dumping site for hazardous waste during the removal of waste from the site.

2. Proposal of a new needs analysis method for conceptual land-use planning for an illegal dumping site following remediation

2.1 Overview

We propose a new analysis method to establish a conceptual land-use plan that is rationally based on the potential needs of a region's residents using a two-step questionnaire, as shown in Figure 1. The analysis method is divided into three steps. The first is to extract planning factors for land use, which consist of land-use attributes and related facilities, from the potential needs of residents by using a questionnaire. In Figure 2, the land-use attributes use are attributes A to K, and the related facilities are f1 to f43. The attributes and related facilities were selected according to the general urban planning principles. In the second step, conjoint analysis is applied to determine the utility function and marginal cost using a second questionnaire administered to respondents to the first questionnaire, who selected the extracted planning factors and indicated an interest in a follow-up questionnaire. In the third step, land-use alternatives are developed and evaluated using the utility function obtained in the second step. Based on these three steps, a conceptual land-use plan can be developed that considers economic and social feasibility based on residents' land-use needs.

2.2 First step: A questionnaire to extract planning factors

The first questionnaire features two multiple-choice questions and an open-ended question, as shown in Figure 2. This study assumed the following prerequisites: all waste is removed from illegal dumping sites and the sites are remedied to meet environmental quality standards for soil and groundwater. Therefore, any remaining environmental risk at illegal dumping sites was not considered in the questionnaire. In question 1, we asked respondents to select one or two opinions from 11 prepared statements, as expressed by persons A to K, which correspond to attributes A to K, on possible land uses following remediation of a specified illegal dumping site. We asked respondents to select one or two opinions because most respondents appeared to select the opinion of person K. We expected opinions other than that of person K.

The purpose of question 2 was to extract specific ideas related to buildings or facilities if the opinion selected by the respondent (in question 1) was adopted for the land-use plan following the remediation of the illegal dumping site.

These two questions provide factors for land-use planning following the remediation of a specified illegal dumping site. These planning factors are then used to design the second questionnaire for the selection-based conjoint analysis in the second step.

2.3 Second step: Conjoint analysis to determine the utility function by the second questionnaire

Conjoint analysis was applied to develop a feasible land-use plan that considered economic and social aspects. Conjoint analysis is a cost-benefit analysis method that can consider a trade-off between the cost and level of land use following remediation. In addition, this analysis can evaluate the priority of an attribute as the marginal cost related to land use, based on the utility function.

If a person (*n*) chooses a land-use plan (*i*), then the utility, U_{in}, of land use plan *i* for *n* is divided into two additive parts (Ben-Akiva & Lerman, 1997):

$$U_{in} = V_{in} + \varepsilon_{in}, \qquad (1)$$

where V_{in} is the representative component of the utility of *i* (hearafter, the representative component is simply called the utility function) and ε_{in} is a random term known as the random component. In addition, it is assumed that

$$V_{in} = \beta_1 X_{in1} + \beta_2 X_{in2} + \cdots + \beta_m X_{inm}, \qquad (2)$$

where X_{inm} is an attribute and β_m is a parameter. X_{inm} is determined considering the result of the first step of our method. This study applied a selection-based conjoint analysis that asked respondents to select one preferred plan among land-use plans *I* in a set *C*. The probability that a person selects a plan *i* in set *C* is

$$\begin{aligned} P_i &= \Pr\left(U_i > U_k, \forall k \in C, k \neq i\right) \\ &= \Pr(V_i - V_k > \varepsilon_i - \varepsilon_{k,}\ \forall k \in C, k \neq i) \end{aligned} \qquad (3)$$

The probability P_i can be converted using the conditional logit model, where the random part is independent of *n* and *i*:

$$P_i = \frac{\exp(V_i)}{\sum_{k=1}^{l} V_k} \quad (4)$$

The parameter β can be estimated using the maximum likelihood method. We can write the log likelihood as follows:

$$\log L(\beta) = \sum_{n}^{N} \sum_{k}^{l} d_{nk} P_k \quad , \quad (5)$$

where d_{nk} is a dummy variable (1 or 0). If respondent n chooses land-use plan k, d_{nk} equals 1.

The marginal cost of the increment in an attribute is calculated using the representative component of eq. (2). The total differential form of eq. (2) is

$$dV = \sum_{j}^{m-1} \frac{\partial V}{\partial X_j} dX_j + \frac{\partial V}{\partial X_{\cos t}} X_{\cos t} \quad . (6)$$

Note that X_{cost} is the attribute related to cost. Assuming that V is constant even if an objective attribute X_j only changes by one unit and the other attributes X_k do not change ($dV = 0, dX_k = 0; \forall k \neq j$), the marginal cost is

$$\frac{dX_{\cos t}}{dX_j} = \frac{\partial V}{\partial X_j} \bigg/ \frac{\partial V}{\partial X_{\cos t}} = -\frac{\beta_j}{\beta_{\cos t}} \quad , \quad (7)$$

where β_{cost} is a parameter of the attribute X_{cost}.

2.4 Third step: Evaluation of the utility of alternatives to a land-use plan

This study investigates economically and socially feasible alternatives for land use following the remediation of illegal dumping sites based on the results of the conjoint analysis. Specifically, we developed alternatives and compared them by calculating the utility function for each alternative. On the basis of our findings, we propose a conceptual land-use plan following the remediation of an illegal dumping site.

3. Application of our method to an actual illegal dumping site

3.1 Site description

The illegal dumping site to be analyzed in our case study is located on the boundary of the town of Takko in the Aomori Prefecture and Ninohe City in the Iwate Prefecture in Japan. As shown in Figure 3, the total volume of illegally dumped waste was 0.88 million m^3, and the total area of the site was 27 ha. The site was the largest illegal dumping site in Japan when it was discovered.

Waste, such as ash, waste oils, sludge, waste plastic and bark, was distributed throughout the site (Figure 4). In addition, many types of contaminants were detected at concentrations exceeding the relevant environmental standards (Table 1).

Illegal dumping at this site appears to have began in 1991, but it may have started earlier. In 2002, an investigative committee and an engineering committee were established to discuss remedial measures for the site. In 2003, the final report of the investigative committee was submitted to the governors of both prefectures, who decided to remove all the waste from the site.

3.2 First step: The first questionnaire to extract planning factors

3.2.1 Procedure

The first questionnaire survey was distributed in Aomori Prefecture (population ca. 1.4 million) using the questionnaire form shown in Figure 2, as described previously. The following description was added to the questionnaire: "All waste will be removed from the illegal dumping site, and the soil and groundwater will be remedied to a level meeting the environmental quality standards."

The questionnaires were sent by mail on November 6, 2006, and were to be returned to us by November 20. There were 250 target households in the town of Takko (population ca. 6,500) - the most important stakeholder, because the illegal dumping site is located there - as well as 2,500 target households in other regions. We distributed the questionnaires in other regions of Aomori Prefecture because we believed that a land-use plan should also represent the taxpayers who would pay for the remediation indirectly.

Two people per household were allowed to complete the survey so that answers from people of various ages and genders could be obtained. The target households were randomly selected from the telephone directory, and the number of households selected in each city, town or village was proportional to the population. There were 743 responses (response rate = 27%). Because two people per household were allowed to respond to the survey, the number of effective answers was 919, with 141 answers obtained from Takko and 778 answers from other regions. The attributes of the respondents are presented in Table 2. Elderly persons (over 60 years old), who accounted for 49% of the respondents, were presumed to be retired and to receive an annual pension. Therefore, there is little possibility that the high rate of unemployment influenced their answers, such as those regarding business land use.

Many respondents were concerned about the illegal dumping sites at the boundary of Aomori and Iwate prefectures; however, most had not been to these sites.

3.2.2 Results and discussion

Figure 5 presents the results for questions 1 and 2 for all 919 respondents. There were no differences in the results between Takko and other regions, except that welfare facilities were preferred slightly more in Takko. Therefore, all results of this study reflect the answer of all 919 respondents and are indistinguishable between Takko and other regions.

For question 1, to which the respondents could answer in the form of the opinion of one or two persons A-K, 52% (482 of 919) of the respondents identified with the opinion of person K (to return the site to its natural state). The idea of returning the illegal dumping site to its natural state was supported by many respondents. The total number of respondents who identified with one of the value-added opinions of persons A to J was 756 (82%). The ideas of person C (welfare facility), person D (infrastructure), person H (recreation facility) and person I (local industries) were strongly supported by a total of 658 people.

The lower part of Figure 5 shows the predominant answers to question 2 from the respondents who identified with the opinions of persons C, D, H, I or K. Returning the illegal dumping site to a natural environment, green space or forest received support. Among the land uses with added value in the opinions of persons C, D, H and I, many respondents supported the establishment of parks (76%) and welfare facilities (74%). These opinions appeared to have originated from a desire for a community that is integrated with on nature. The responses to the open-ended question included many descriptions of a desirable integration of a welfare facility and park with an athletic field. In addition, a waste treatment facility (46%), an electrical power plant (38%), agriculture (21%), and forest (21%) were supported in terms of infrastructure and local industry. The responses to the open-ended question also included descriptions of a biogas plant receiving industrial organic wastes from the local region to generate electricity. These responses reflected a need for infrastructure to utilize unused resources in the local region and were based on the respondents' awareness of local industries, such as agriculture and forestry. Therefore, based on the results of the first step of our method, the planning factors for a conceptual land-use plan following remediation of the illegal dumping site were extracted. The combination of attributes of land use and the related facilities obtained were follows: attribute C (welfare) and welfare facilities, attribute D (infrastructure) and biogas plants, attribute H (recreation) and parks with athletic fields, and attribute I (local industry) and agriculture and forest. In addition, we categorized the attributes of welfare and recreation as community and categorized the attributes of infrastructure and local industries as local industry because it is easy to design the conjoint analysis in the next step and because the desires of the respondents can be divided into the two categories.

The second questionnaire was distributed to the respondents who agreed with persons C, D, H or I and who indicated an interest in completing an additional questionnaire. This category comprised 87% (658 of 756) of the respondents who desired land use with added value. The respondents were divided into three groups - a group with a high regard for local industry, a group with a high regard for community and a group with a high regard for both local industry and community - in order to analyze differences in prioritization of land-use needs following the remediation of the illegal dumping site.

3.3 Second step: Conjoint analysis to determine the utility function using the second questionnaire

3.3.1 Procedure

Conjoint analysis was applied as described in section 2.3. The attributes and their levels were determined, as shown in Table 3, by considering the two extracted planning factors of industry (ind.) and community (com.), and by considering the related facilities that were strongly supported in question 2 (Figure 5). In addition, employment (emp.) related to land use and the cost (cost) of land use were added as attributes related to economic considerations. The levels of employment and cost were determined by considering a realistic situation so that respondents could understand the scale of the project and easily select a preferred land use case.

Table 4 shows the land-use cases that were developed by combining the different levels of each attribute. In this study, there were four attributes and four levels (Table 3). Therefore, the number of possible land-use cases was 256 (= 4^4). According to the orthogonal array method of experimental design and by removing unfeasible land-use cases, 13 land-use cases were selected for the conjoint analysis, as shown in Table 4.

This study applied selection-based conjoint analysis (also called the choice experiment), as shown in Figure 6, in which respondents selected a preferred land-use case from three cases, including land-use case 1, in which land is used without value being added, as in land-use plan I. The two remaining cases, II and III, were selected from land-use cases 2 to 13 in Table 4. This study selected the method of conjoint analysis described above to allow the respondents to choose their favorite among two or three alternatives; moreover, allowing for the selection of a status quo alternative would be easier for respondents than other ways of collecting data, such as the rating and ranking method, in which respondents are required to be consistent with their selection (Hanley et al, 1998; Hanley et al, 2001). The 20 forms with random combinations of land-use cases 2 to 13 were developed, shown in Figure 6, and the four different forms were mailed to the target households.

The target households were those of the respondents who agreed with the opinions of persons C, D, H or I in the first step of the investigation and who indicated an interest in further participation in the survey. There were 45 such households in Takko and 347 such households in other regions. As in the first step of the investigation, two people per household were allowed to complete the second questionnaire. The second questionnaire was sent by mail on December 26, 2006, and was to be returned by mail by January 8,

2007. The response rate was 59%, and the number of effective answers was 282, with 36 answers received from Takko and 246 from other regions. A group of 105 respondents had a high regard for industry, a group of 139 respondents had a high regard for community, and a group of 38 respondents had a high regard for both industry and community. The response rate in this conjoint analysis was higher than 50% because the two-step questionnaire was used. Winslott Hiselius (2005) reported that the response rate, 45 – 60%, was usually high given the difficulty of the study. It should be noted that if the non-response rate of a conjoint analysis exceeds 70%, the design of the analysis may not have been sufficiently thorough, and a dropout study can be completed to identify the probable reasons for the low response rate (Winslott Hiselius, 2005; Alriksson and Öberg, 2008).

3.3.2 Results and discussion

Table 5 shows the summary of the conjoint analysis, including β_m, its t-value and p-value and the result of a likelihood ratio test for four utility functions, namely the three target respondent groups and the combination of the three groups (total). Note that all results include the answers of respondents in both Takko and other regions because there were fewer respondents in Takko than in other regions.

The significance level of β_m for each attribute was generally high, except for the attributes of forest, agricultural land, agricultural land and biogasification, and employment. According to the likelihood ratio test, all four utility functions were highly significant at the 1% or 5% level.

Figure 7 shows the marginal cost of each attribute obtained from eq. (7). The marginal cost of employment is the cost when a person is newly employed. The other marginal cost is the cost when one facility or function is introduced.

In the group with a high regard for industry, the marginal cost of the agricultural land and biogasification plant was nearly 4 billion JPY, which was much higher than the marginal cost of forest.

In the group with a high regard for community, the marginal cost of the welfare facility in a park was nearly 4 billion JPY, which is slightly higher than that of the welfare facility and athletic field in a park. The absolute values of the marginal costs for the group with a high regard for both industry and community were larger than those for the other groups. This finding suggests that the respondents in that group were more concerned about land use with added value. The marginal cost for a welfare facility and an athletic field in a park was approximately 7.5 billion JPY.

3.4 Third step: Evaluation of the utility of alternatives to a land-use plan

The four utility functions - the three target respondent groups and the combination of the three groups (total) - were obtained from the parameters in Table 5. On the basis of the utility function, feasible land uses with high utilities are discussed. Table 6 shows the eight land-use alternatives developed in this study. The following section explains how these alternatives were developed.

For industry-related land uses, only agricultural land and the biogas plant were considered because their marginal costs were much higher than those of forest and agricultural land, as shown in Figure 7. For community-related land uses, all three attributes (a park, a welfare facility in a park, and a welfare facility and an athletic field in a park) were introduced because there was no significant difference in the marginal costs between the three attributes. In addition, the levels of employment and costs were assumed by considering the feasibility of taxpayers in Aomori Prefecture paying these costs. Values of zero for all attributes in alternative A1 indicate that there is no added value for the land use and the site is simply returned to its original state. In this case, the utility function is zero.

Figure 8 presents the representative component of the utility function for each land-use alternative. The total line for the three groups shows that all of the utility values were positive. This result suggests that, overall, the respondents view land use with added value as having higher merit than simply returning the site to its original state. In particular, the utility values for alternatives A6 and A8 were relatively high. These alternatives should be considered in conceptual land-use planning following the remediation of the illegal dumping site.

In this case study, development of agricultural land and a biogas plant to recover energy from biomass or a park with a welfare facility and athletic field were preferred as part of a conceptual land-use plan following the remediation of the illegal dumping site.

4. Applicability of our method to other sites

The new needs analysis method for land-use planning shown in Figure 1 was proposed for development of a conceptual land-use plan following remediation of contaminated sites, particularly illegal dumping sites, where all waste would be removed completely and contaminated soil and groundwater would be remedied to a level meeting environmental quality standards. The absence of waste and contamination in future land use is a prerequisite for the application of our method to the other sites. In this context, our method might have limited applicability. However, even in cases in which waste is contained or contaminants remain at levels slightly higher than those delineated by environmental standards, our method can be used after the modification of the questionnaire described in Figure 2. For example, planning factors that are impossible to implement because of the associated risk can be omitted, such as residential district and welfare facilities, when waste will still remain at sites.

Essentially, our needs analysis method with conjoint analysis is applicable to the development of conceptual land-use planning for similar sites following remediation, particularly when potential added value is taken into account.

5. Conclusion

On the basis of this study, we propose a new needs analysis method for developing a conceptual land-use plan following the remediation of illegal dumping sites by considering economic and social aspects based on the potential needs of the region's residents. The following novel results were obtained by applying our method to an actual illegal dumping site.

1) As a result of the first step followed to extract planning factors consisting of land-use attributes and related facilities, 52% of the respondents expressed a desire to return the site to a natural state, such as green land or forest, and 82% of the respondents expressed a desire for land use with added value rather than simply returning the site to its original state. In addition, 87% of the latter indicated a preference for either local industry-related land uses (infrastructure, such as a biogas plant, and local industry, such a forest and agriculture) or community-related land uses (welfare, such as welfare facilities, and recreation, such as parks and athletic fields). Therefore, the preferred land-use attributes and related facilities as planning factors were extracted to conceptually plan land-use following remediation of the illegal

dumping site.

2) Utility functions with high significance in conjoint analysis were developed. The functions revealed that, although the marginal costs differed significantly among the three groups of respondents (a group with a high regard for local industry, a group with a high regard for community and a group with a high regard for both local industry and community),the marginal costs of agricultural land and a biogas plant as part of local industry-related land use, or a welfare facility in a park as part of community-related land use were high.

3) Agricultural land, a biogas plant and a park with 15 employees costing 1 billion JPY, and agricultural land, a biogas plant, a welfare facility and an athletic field in a park with 50 employees costing 3.5 billion JPY appeared to be preferred as land uses following the remediation of the illegal dumping site.

This study demonstrated the possibility of using our novel needs analysis method with conjoint analysis to produce economically and socially feasible conceptual land-use plans based on the highly diverse potential needs of residents and its applicability to other similar sites following remediation when considering added value. In addition, the study showed that residents preferred not only returning the sites to their natural state but also land use with added value in terms of economic and social benefits to the region.

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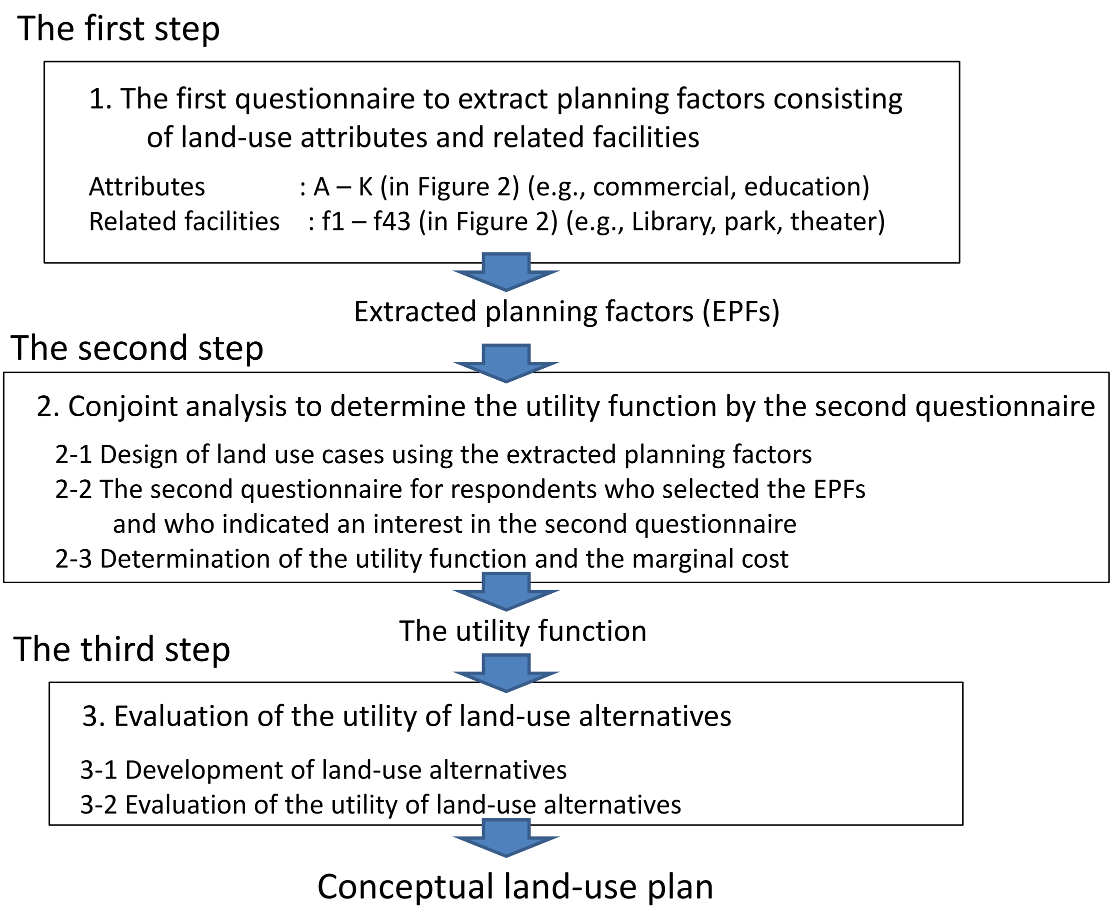


Figure 1 Method for land-use planning following the remediation of illegal dumping sites

Question 1

Persons A to K have commented on land use at Aomori-Iwate illegal dumping sites.
Please select one or two comments that you agree with.

Land use related to everyday life	
Person A (Attribute A)	Recently, I heard that a big supermarket was built at an old factory site in Osaka. Our town also needs such **commercial facilities** because there are few places for shopping in our town.
Person B (Attribute B)	There are cases where condominium buildings are constructed on old factory sites. An idea to use the remedied land for **a residential district** might be possible.
Person C (Attribute C)	This region is rapidly aging. **Welfare facilities** might be needed.
Person D (Attribute D)	How about **infrastructure,** such as public transportation or biogasification facilities that recover electricity from industrial waste biomass in the region?
Land use related to recreation	
Person E (Attribute E)	Recently, a museum was built in Aomori city. Our town might need such **educational centers**.
Person F (Attribute F)	I heard that golf couses or football grounds were developed at closed landfill sites. How about **leisure facilities**?
Person G (Attribute G)	Our town has promoted activities involving citizens, international exchanges, and links between rural and urban areas. The site could be used for various types of **communication**.
Person H (Attribute H)	How about **recreation facilities** based on the rich natural environment? In Sapporo city, a natural park with art was built at a closed landfill site.
Land use related to industrial activities	
Person I (Attribute I)	The site can be used to promote **local industries,** such as agriculture and food industry. The UK government promoted the use of old factory sites for forest industry.
Person J (Attribute J)	My opinion is that not only existing industries but also **new industries** should be promoted using the site. For example, in Vancouver, a old factory site was turned into a magnet for tourists where there were many art studios.
Return to the natural state	
Person K (Attribute K)	I think that we do not have to spend much money for land use at the site. I just hope the site would **return to nature** by remediation of the contaminated soil and water.

Question 2

Which facilities do you prefer if the opinion you choose in question 1 is adopted for land use following remediation of the site? Please select one for each opinion chosen in question 1.

f1. Large commercial facilities
f2. Boutique
f3. Supermarkets
f4. Convenience stores

f5. Residential district
f6. Hospitals
f7. Nursery, kindergarten
f8. Welfare facilities

f9. School
f10. Research institute
f11. Library
f12. Internet café
f13. Resource center
f14. Museum
f15. Art gallery
f16. Community center
f17. Athletic field

18. Park
19. Green space
20. Market

f21. Restaurants
f22. Coffee house
f23. Hotel
f24. Theater
f25. Leisure facility
f26. Theme park

f27. Agricultural land
f28. Forest
f29. Industrial factory
f30. Distribution center
f31. Office

f32. Drinking water treatment plant
f33. Sewage treatment plant
f34. Waste treatment facility
f35. Electrical power plant
f36. Gas supply facility

f37. Temple, shrine
f38. Church
f39. Cemetery, crematorium

f40. Bank
f41. Post office
f42. Administrative institution
f43. Police station or firehouse

Question 3 (Open-ended question)

Please write if you have any proposal on land use following remediation of the site.

Figure 2 Content of the questionnaire in the first step

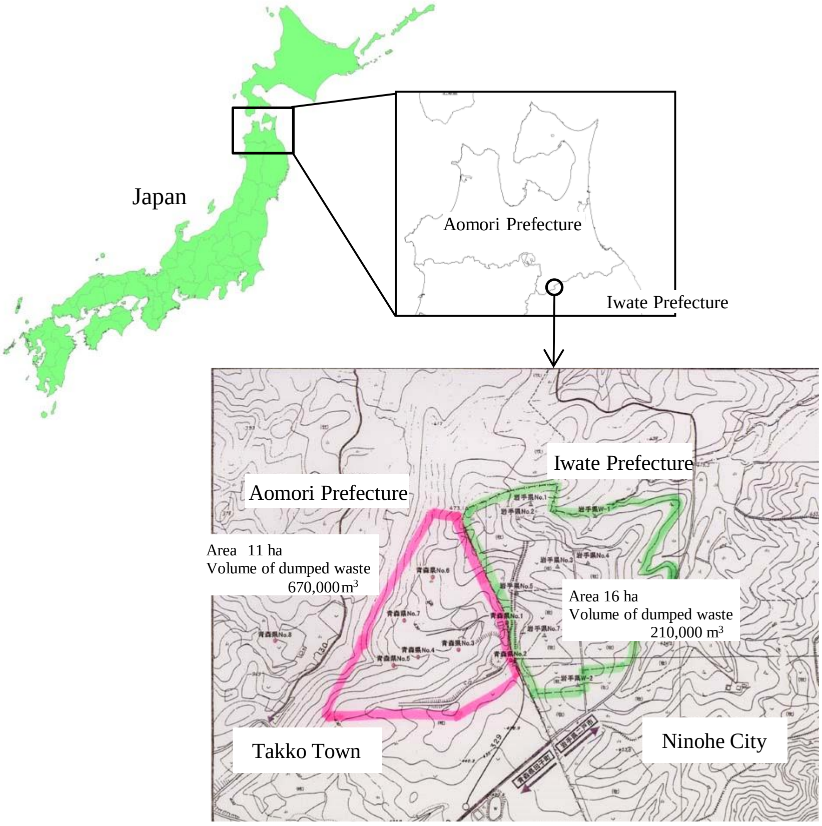


Figure 3 Map of the Aomori - Iwate illegal dumping site

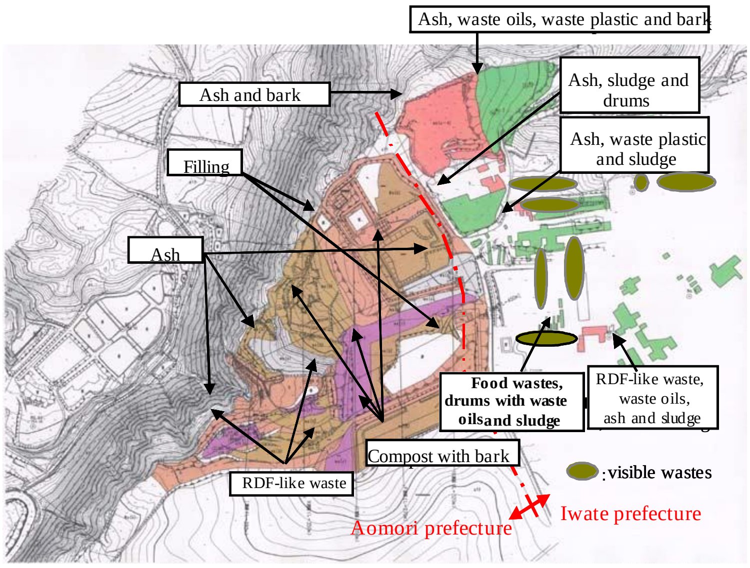


Figure 4 Waste distributions at the Aomori-Iwate illegal dumping site

(RDF: Refuse derived fuel)

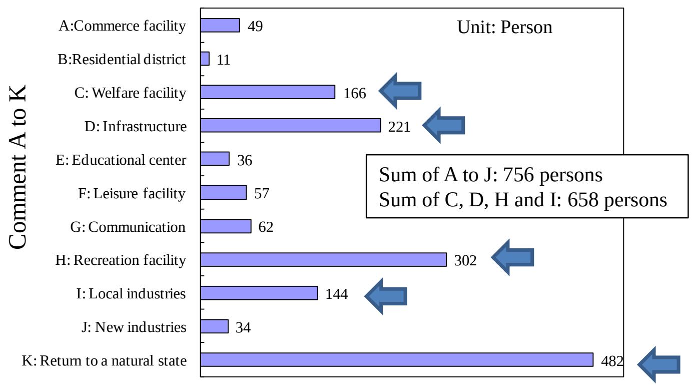
Table 1 Contaminants detected at the Aomori-Iwate illegal dumping site

Compounds	Measured	Standard	Note
Waste (Elution test)			
PCE	5.2 mg/L	0.1 mg/L	
Dichloromethane	9.5 mg/L	0.2 mg/L	
Benzene	3.4 mg/L	0.1 mg/L	
Dioxins	4,700 pg-TEQ/g	3,000 pg-TEQ/g	Content
Soil (Elution test)			
Dichloromethane	3.6 mg/L	0.02 mg/L	
cis-1,2-dichloroethylene	3.2 mg/L	0.04 mg/L	
Dioxins	2,000 pg-TEQ/g	1,000 pg-TEQ/g	Content
Surface water			
Dichloromethane	2.9 mg/L	0.2 mg/L	Effluent
cis-1,2-dichloroethylene	1.3 mg/L	0.4 mg/L	standard
Groundwater			
Dichloromethane	436 mg/L	0.02 mg/L	
1,2-dichloroethane	0.95 mg/L	0.004 mg/L	
cis-1,2-dichloroethylene	7.8 mg/L	0.04 mg/L	
1,1,1-trichloroethane	3.0 mg/L	1 mg/L	
1,1,2-trichloroethane	1.2 mg/L	0.006 mg/L	
TCE	27.7 mg/L	0.03 mg/L	
PCE	30.5 mg/L	0.01 mg/L	
Dioxins	100 pg-TEQ/L	1 pg-TEQ/L	

Table 2 Attribute of respondents to the questionnaire in the first step

		All regions (N = 919)	Only Takko town (N = 141)
Age (years)	10 – 19	0.3%	0%
	20 – 29	2%	1%
	30 – 39	5%	7%
	40 – 49	12%	12%
	50 – 59	31%	35%
	60 – 69	25%	21%
	70 – 79	19%	16%
	80 – 89	4%	6%
	90 – 99	1%	1%
	Unknown	0.7%	1%
Gender	Male	72%	74%
	Female	27%	25%
	Unknown	1%	1%
Occupation	Company employee	27%	22%
	Government employee	9%	3%
	Agriculture, forestry and fisheries	11%	36%
	Independent business	7%	9%
	Home manager	9%	8%
	Student	0.30%	0%
	Unemployment	31%	18%
	Other	4%	0%
	Unknown	1.7%	4%
Experience of seeing the illegal dumping site	Yes	13%	62%
	No	85%	36%
	Unknown	2%	2%
Concern about the illegal dumping problem	Yes	60%	67%
	No	6%	7%
	Neither	27%	23%
	Don't know the problem	5%	1%
	Unknown	2%	2%

Question 1: Please select one or two comments that you agree with.



Question 2: Which facilities do you prefer if the comment you chose in question 1 is adopted for land use following remediation of the site?

Selected comment A to K in question 1	Facilities	Answer
Person C	Welfare facilities	74%
(Welfare facility)	Hospitals	12%
Person D	Waste treatment facilities	46%
(Infrastructure)	Electric power plants	38%
Person H	Parks	76%
(Recreation facility)	Green space	13%
Person I	Agricultural land	21%
(Local industries)	Forest	21%
	Industrial factories	13%
	Distribution centers	13%
Person K	Green space	41%
(Return to nature)	Forest	37%

Figure 5 Results of the questionnaire administered in the first step

Table 3 Attributes and levels of the conjoint analysis performed in the second step

Attribute	Level
Industry (ind.)	None
	Forest
	Agricultural land
	Agricultural land and biogasification plant
Community (com.)	None
	Park
	Welfare facility in park
	Welfare facility and athletic field in park
Employment (emp.)	0 person
	10 persons
	20 persons
	50 persons
Cost (cost)	0 JPY
	100 million JPY (1,000 JPY/household)
	2 billion JPY (4,000 JPY/household)
	5 billion JPY (10,000 JPY/household)

Table 4 Land-use cases for the illegal dumping site in the conjoint analysis performed in the second steps

Land-use case	Industry	Community	Employment	Cost
1	None	None	0 person	0 JPY
2	None	Park	10 persons	4,000 JPY/household
3	None	Welfare facility in park	20 persons	10,000 JPY/household
4	None	Welfare facility and athletic field in park	50 persons	1,000 JPY/household
5	Forest	None	10 persons	1,000 JPY/household
6	Forest	Park	0 person	10,000 JPY/household
7	Forest	Welfare facility in park	50 persons	4,000 JPY/household
8	Agricultural land	None	20 persons	4,000 JPY/household
9	Agricultural land	Welfare facility in park	0 person	1,000 JPY/household
10	Agricultural land	Welfare facility and athletic field in park	10 persons	10,000 JPY/household
11	Agricultural land and biogasification plant	None	50 persons	10,000 JPY/household
12	Agricultural land and biogasification plant	Park	20 persons	1,000 JPY/household
13	Agricultural land and biogasification plant	Welfare facility and athletic field in park	0 person	4,000 JPY/household

Question: Which land-use plan do you prefer as a land-use case following remediation of the illegal dumping site?

	Land-use case I	Land-use case II	Land-use case III
Industry	None	Agricultural land and biogasification plant	Agricultural land
Community	None	Park	Welfare facility in park
Employment	0 persons	20 persons	10 persons
Cost	0 JPY	1,000 JPY/household	10,000 JPY/househould

Figure 6 Form for the selection-based conjoint analysis

Table 5 Summary of the results of the conjoint analysis

	Total					Group with a high regard for industry				
	β	t-value	p-value	Significance	$-\beta_i/\beta_{cost}$	β	t-value	p-value	Significance	$-\beta_i/\beta_{cost}$
Forest	-0.161	-1.254	0.210		-11.500	0.195	0.908	0.364		13.000
Agricultural land	-0.184	-1.505	0.133		-13.143	0.050	0.244	0.807		3.333
Agricultural land and biogasificaiton plant	0.147	1.234	0.217		10.500	0.556	2.804	0.005	***	37.067
Park	0.192	1.678	0.094	*	13.714	-0.177	-0.921	0.358		-11.800
Welfare facilities in park	0.26	2.344	0.019	**	18.571	-0.458	-2.290	0.023	**	-30.533
Welfare facilities and athletic field in park	0.386	3.238	0.001	***	27.571	0.022	0.115	0.909		1.467
Cost	-0.014	-5.387	0.000	***	-	-0.015	-3.444	0.001	***	-
Employment	0.004	1.761	0.078	*	0.286	0.003	0.829	0.407		0.200
Likelihood ratio test										
Sample number	1100					420				
Log likelihood L(β)	-1182.58					-443.798				
Log likelihood (L(0): all coefficient β =0)	-1208.47					-461.417				
-2(L(0)-L(β))	51.79					35.24				
χ2 distribution value: χ2 (0.01, 8)	20.09					20.09				
χ2 distribution value: χ2 (0.05, 8)	15.51					15.51				
Significance	***					***				

*significant < 0.1, **significant < 0.05, ***significant < 0.01

	Group with a high regard for community					Group with a high regard for both industry and community				
	β	t-value	p-value	Significance	$-\beta_i/\beta_{cost}$	β	t-value	p-value	Significance	$-\beta_i/\beta_{cost}$
Forest	-0.376	-2.012	0.045	**	-23.500	-0.360	-1.089	0.278		-36.000
Agricultural land	-0.292	-1.691	0.091	*	-18.250	-0.317	-0.877	0.382		-31.700
Agricultural land and biogasificaiton plant	-0.175	-0.999	0.318		-10.938	0.365	1.170	0.244		36.500
Park	0.289	1.765	0.078	*	18.063	0.587	1.946	0.054	*	58.700
Welfare facilities in park	0.614	3.896	0.000	***	38.375	0.645	2.256	0.026	**	64.500
Welfare facilities and athletic field in park	0.497	2.914	0.004	***	31.063	0.757	2.246	0.026	**	75.700
Cost	-0.016	-4.402	0.000	***	-	-0.010	-1.362	0.175		-
Employment	0.005	1.463	0.144		0.313	-0.002	-0.245	0.807		-0.200
Likelihood ratio test										
Sample number	556					152				
Log likelihood L(β)	-587.59					-158.86				
Log likelihood (L(0): all coefficient β =0)	-610.83					-166.99				
-2(L(0)-L(β))	46.48					16.26				
χ2 distribution value: χ2 (0.01, 8)	20.09					20.09				
χ2 distribution value: χ2 (0.05, 8)	15.51					15.51				
Significance	***					**				

*significant < 0.1, **significant < 0.05, ***significant < 0.01

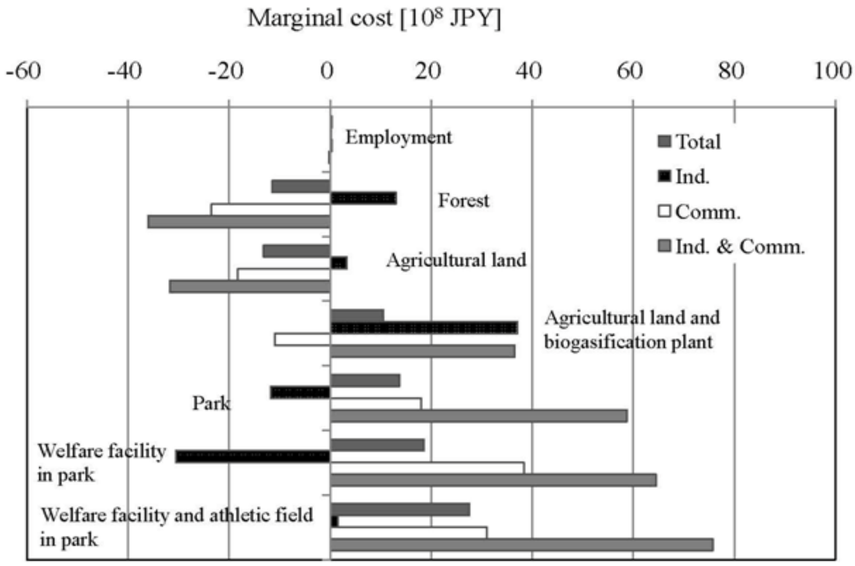


Figure 7 Marginal cost of each attribute in the conjoint analysis performed in the second step

Table 6 Eight alternatives for the utility function analysis performed in the third step

Alternatives	Cost [10^8 JPY]	Employment [person]	Agricultural land and biogasification plant	Park	Welfare facility in park	Welfare facility and athletic field in park
A1	0	0	0	0	0	0
A2	5	5	0	1	0	0
A3	25	35	0	0	1	0
A4	30	40	0	0	0	1
A5	5	10	1	0	0	0
A6	10	15	1	1	0	0
A7	30	45	1	0	1	0
A8	35	50	1	0	0	1

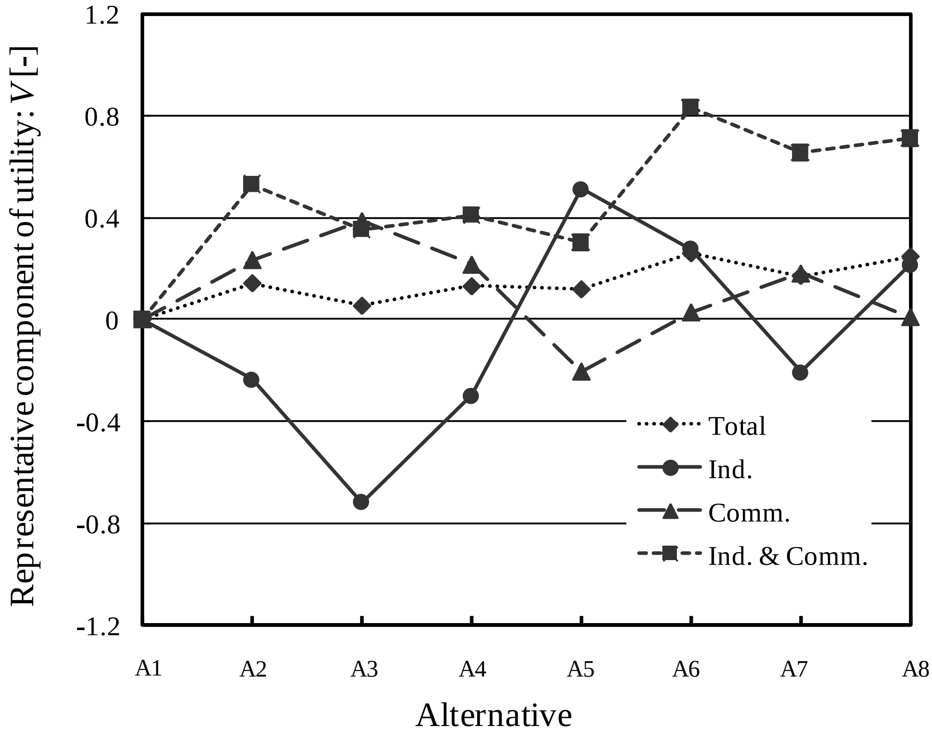


Figure 8 Representative component V in the utility function analysis performed in the third step