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A Needs Analysis Method for Land-use Planning of Illegal Dumping Sites: A Case Study in Aomori-Iwate, Japan

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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

70 brownfields have proposed evaluation models to select the sites to be redeveloped by
71 considering economic, social and environmental aspects of interest to developers
72 (Wedding and Crawford-Brown, 2007; Cheng et al., 2011; Thomas, 2002; Chen et al.,
73 2009; Schädler et al., 2012).

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

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

93 In land-use planning following the remediation of illegal dumping sites, the needs of
94 various stakeholders should be taken into account and analyzed quantitatively,
95 including the needs of the local governments responsible for remedial activities, cities

96 (or towns or villages) with illegal dumping sites, the property owners and neighboring
97 residents, and the taxpayers who indirectly pay for remediation. In particular, the
98 needs of the residents should be considered in the case of illegal dumping sites because
99 land use following remediation will directly affect their socioeconomic situation.
100 Greenberg and Lewis (2000) reported that most of the respondents to a questionnaire
101 indicated a desire to participate in the redevelopment process of brownfields.
102 Only a few studies have focused on the needs analysis of residents in favor of
103 brownfields redevelopment. In one such study, Greenberg and Lewis (2000) conducted a
104 questionnaire and found that residents were less interested in industry and business in
105 redevelopment plans and instead preferred community facilities and housing. According
106 to Sousa (2006), who investigated the benefit of brownfields to green space projects,
107 most respondents perceived many benefits related to personal and community quality of
108 life, such as recreational activities and scenic beauty. However, no studies have
109 addressed the land-use planning of illegal dumping sites following remediation,
110 especially with the removal of all waste, based on the needs of residents. Therefore, the
111 present study focused on the needs of residents and development of a method for
112 analyzing residents' potential needs for the land use of an illegal dumping site following
113 remediation by removing all waste.
114 Recently, many studies have used conjoint analysis to evaluate the needs of residents
115 in environmental fields (e.g., Alriksson and Öberg, 2008). In particular, regarding waste
116 management policy, Garrod and Willis (1998) predicted reduction in amenities due to
117 landfill waste disposal using a stated preference experiment. Probert et al. (2005) used
118 conjoint analysis to evaluate preferences regarding the quality of compost in order to
119 develop appropriate marketing strategies. Sasao (2004) applied a multi-attribute utility
120 theory, conjoint analysis, to determine the location of a landfill site on the basis of a
121 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

148 and related facilities, from the potential needs of residents by using a questionnaire. In
149 Figure 2, the land-use attributes use are attributes A to K, and the related facilities
150 are f1 to f43. The attributes and related facilities were selected according to the general
151 urban planning principles. In the second step, conjoint analysis is applied to determine
152 the utility function and marginal cost using a second questionnaire administered to
153 respondents to the first questionnaire, who selected the extracted planning factors and
154 indicated an interest in a follow-up questionnaire. In the third step, land-use
155 alternatives are developed and evaluated using the utility function obtained in the
156 second step. Based on these three steps, a conceptual land-use plan can be developed
157 that considers economic and social feasibility based on residents' land-use needs.
158
159 **2.2 First step: A questionnaire to extract planning factors**
160 The first questionnaire features two multiple-choice questions and an open-ended
161 question, as shown in Figure 2. This study assumed the following prerequisites: all
162 waste is removed from illegal dumping sites and the sites are remedied to meet
163 environmental quality standards for soil and groundwater. Therefore, any remaining
164 environmental risk at illegal dumping sites was not considered in the questionnaire. In
165 question 1, we asked respondents to select one or two opinions from 11 prepared
166 statements, as expressed by persons A to K, which correspond to attributes A to K, on
167 possible land uses following remediation of a specified illegal dumping site. We asked
168 respondents to select one or two opinions because most respondents appeared to select
169 the opinion of person K. We expected opinions other than that of person K.
170 The purpose of question 2 was to extract specific ideas related to buildings or facilities
171 if the opinion selected by the respondent (in question 1) was adopted for the land-use
172 plan following the remediation of the illegal dumping site.
173 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:

198 $$P_i = \frac{\exp(V_i)}{\sum_{k=1}^{l} V_k} \quad (4)$$

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

201 $$\log L(\beta) = \sum_{n}^{N} \sum_{k}^{l} d_{nk} P_k \quad , \quad (5)$$

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

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

206 $$dV = \sum_{j}^{m-1} \frac{\partial V}{\partial X_j} dX_j + \frac{\partial V}{\partial X_{cost}} X_{cost} \quad . (6)$$

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

210 $$\frac{dX_{cost}}{dX_j} = \frac{\partial V}{\partial X_j} \Big/ \frac{\partial V}{\partial X_{cost}} = -\frac{\beta_j}{\beta_{cost}} \quad , \quad (7)$$

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

212

213 **2.4 Third step: Evaluation of the utility of alternatives to a land-use plan**

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

219

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

241 the illegal dumping site, and the soil and groundwater will be remedied to a level
242 meeting the environmental quality standards."
243 The questionnaires were sent by mail on November 6, 2006, and were to be returned
244 to us by November 20. There were 250 target households in the town of Takko
245 (population ca. 6,500) - the most important stakeholder, because the illegal dumping
246 site is located there - as well as 2,500 target households in other regions. We distributed
247 the questionnaires in other regions of Aomori Prefecture because we believed that a
248 land-use plan should also represent the taxpayers who would pay for the remediation
249 indirectly.
250 Two people per household were allowed to complete the survey so that answers from
251 people of various ages and genders could be obtained. The target households were
252 randomly selected from the telephone directory, and the number of households selected
253 in each city, town or village was proportional to the population. There were 743
254 responses (response rate = 27%). Because two people per household were allowed to
255 respond to the survey, the number of effective answers was 919, with 141 answers
256 obtained from Takko and 778 answers from other regions. The attributes of the
257 respondents are presented in Table 2. Elderly persons (over 60 years old), who
258 accounted for 49% of the respondents, were presumed to be retired and to receive an
259 annual pension. Therefore, there is little possibility that the high rate of unemployment
260 influenced their answers, such as those regarding business land use.
261 Many respondents were concerned about the illegal dumping sites at the boundary of
262 Aomori and Iwate prefectures; however, most had not been to these sites.
263
264 **3.2.2 Results and discussion**
265 Figure 5 presents the results for questions 1 and 2 for all 919 respondents. There were
266 no differences in the results between Takko and other regions, except that welfare

267 facilities were preferred slightly more in Takko. Therefore, all results of this study
268 reflect the answer of all 919 respondents and are indistinguishable between Takko and
269 other regions.

270 For question 1, to which the respondents could answer in the form of the opinion of
271 one or two persons A-K, 52% (482 of 919) of the respondents identified with the opinion
272 of person K (to return the site to its natural state). The idea of returning the illegal
273 dumping site to its natural state was supported by many respondents. The total number
274 of respondents who identified with one of the value-added opinions of persons A to J was
275 756 (82%). The ideas of person C (welfare facility), person D (infrastructure), person H
276 (recreation facility) and person I (local industries) were strongly supported by a total of
277 658 people.

278 The lower part of Figure 5 shows the predominant answers to question 2 from the
279 respondents who identified with the opinions of persons C, D, H, I or K. Returning the
280 illegal dumping site to a natural environment, green space or forest received support.
281 Among the land uses with added value in the opinions of persons C, D, H and I, many
282 respondents supported the establishment of parks (76%) and welfare facilities (74%).
283 These opinions appeared to have originated from a desire for a community that is
284 integrated with on nature. The responses to the open-ended question included many
285 descriptions of a desirable integration of a welfare facility and park with an athletic
286 field. In addition, a waste treatment facility (46%), an electrical power plant (38%),
287 agriculture (21%), and forest (21%) were supported in terms of infrastructure and local
288 industry. The responses to the open-ended question also included descriptions of a
289 biogas plant receiving industrial organic wastes from the local region to generate
290 electricity. These responses reflected a need for infrastructure to utilize unused
291 resources in the local region and were based on the respondents' awareness of local
292 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

319 economic considerations. The levels of employment and cost were determined by
320 considering a realistic situation so that respondents could understand the scale of the
321 project and easily select a preferred land use case.
322 Table 4 shows the land-use cases that were developed by combining the different
323 levels of each attribute. In this study, there were four attributes and four levels (Table 3).
324 Therefore, the number of possible land-use cases was 256 (= 4^4). According to the
325 orthogonal array method of experimental design and by removing unfeasible land-use
326 cases, 13 land-use cases were selected for the conjoint analysis, as shown in Table 4.
327 This study applied selection-based conjoint analysis (also called the choice
328 experiment), as shown in Figure 6, in which respondents selected a preferred land-use
329 case from three cases, including land-use case 1, in which land is used without value
330 being added, as in land-use plan I. The two remaining cases, II and III, were selected
331 from land-use cases 2 to 13 in Table 4. This study selected the method of conjoint
332 analysis described above to allow the respondents to choose their favorite among two or
333 three alternatives; moreover, allowing for the selection of a status quo alternative would
334 be easier for respondents than other ways of collecting data, such as the rating and
335 ranking method, in which respondents are required to be consistent with their selection
336 (Hanley et al, 1998; Hanley et al, 2001). The 20 forms with random combinations of
337 land-use cases 2 to 13 were developed, shown in Figure 6, and the four different forms
338 were mailed to the target households.
339 The target households were those of the respondents who agreed with the opinions of
340 persons C, D, H or I in the first step of the investigation and who indicated an interest
341 in further participation in the survey. There were 45 such households in Takko and 347
342 such households in other regions. As in the first step of the investigation, two people per
343 household were allowed to complete the second questionnaire. The second questionnaire
344 was sent by mail on December 26, 2006, and was to be returned by mail by January 8,

345 2007. The response rate was 59%, and the number of effective answers was 282, with 36
346 answers received from Takko and 246 from other regions. A group of 105 respondents
347 had a high regard for industry, a group of 139 respondents had a high regard for
348 community, and a group of 38 respondents had a high regard for both industry and
349 community. The response rate in this conjoint analysis was higher than 50% because
350 the two-step questionnaire was used. Winslott Hiselius (2005) reported that the
351 response rate, 45 – 60%, was usually high given the difficulty of the study. It should be
352 noted that if the non-response rate of a conjoint analysis exceeds 70%, the design of the
353 analysis may not have been sufficiently thorough, and a dropout study can be completed
354 to identify the probable reasons for the low response rate (Winslott Hiselius, 2005;
355 Alriksson and Öberg, 2008).
356
357
358 **3.3.2 Results and discussion**
359 Table 5 shows the summary of the conjoint analysis, including β_m, its t-value and
360 p-value and the result of a likelihood ratio test for four utility functions, namely the
361 three target respondent groups and the combination of the three groups (total). Note
362 that all results include the answers of respondents in both Takko and other regions
363 because there were fewer respondents in Takko than in other regions.
364 The significance level of β_m for each attribute was generally high, except for the
365 attributes of forest, agricultural land, agricultural land and biogasification, and
366 employment. According to the likelihood ratio test, all four utility functions were highly
367 significant at the 1% or 5% level.
368 Figure 7 shows the marginal cost of each attribute obtained from eq. (7). The

369 marginal cost of employment is the cost when a person is newly employed. The other
370 marginal cost is the cost when one facility or function is introduced.
371 In the group with a high regard for industry, the marginal cost of the agricultural
372 land and biogasification plant was nearly 4 billion JPY, which was much higher than
373 the marginal cost of forest.
374 In the group with a high regard for community, the marginal cost of the welfare
375 facility in a park was nearly 4 billion JPY, which is slightly higher than that of the
376 welfare facility and athletic field in a park. The absolute values of the marginal costs for
377 the group with a high regard for both industry and community were larger than those
378 for the other groups. This finding suggests that the respondents in that group were
379 more concerned about land use with added value. The marginal cost for a welfare
380 facility and an athletic field in a park was approximately 7.5 billion JPY.
381
382 **3.4 Third step: Evaluation of the utility of alternatives to a land-use plan**
383 The four utility functions - the three target respondent groups and the combination of
384 the three groups (total) - were obtained from the parameters in Table 5. On the basis of
385 the utility function, feasible land uses with high utilities are discussed. Table 6 shows
386 the eight land-use alternatives developed in this study. The following section explains
387 how these alternatives were developed.
388 For industry-related land uses, only agricultural land and the biogas plant were
389 considered because their marginal costs were much higher than those of forest and
390 agricultural land, as shown in Figure 7. For community-related land uses, all three
391 attributes (a park, a welfare facility in a park, and a welfare facility and an athletic field
392 in a park) were introduced because there was no significant difference in the marginal
393 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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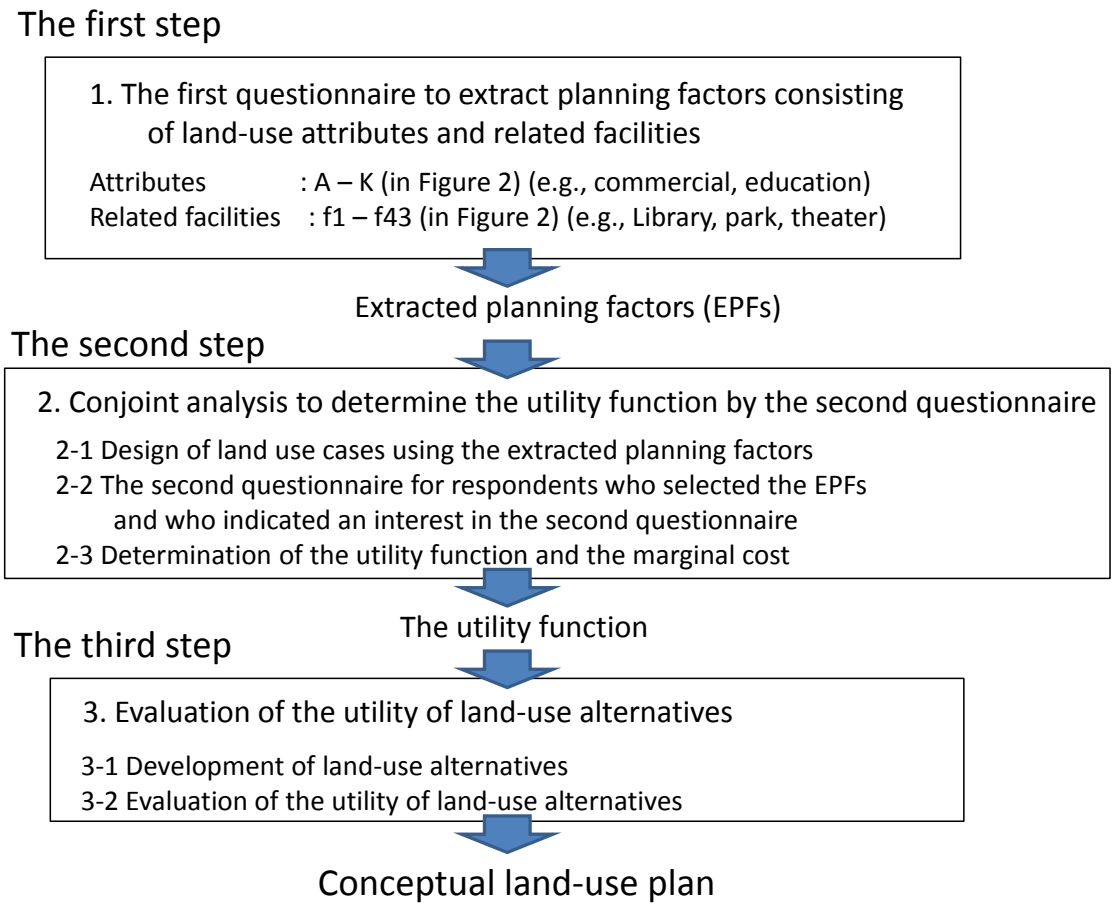


Figure 1 Method for land-use planning following the remediation of illegal dumping sites

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

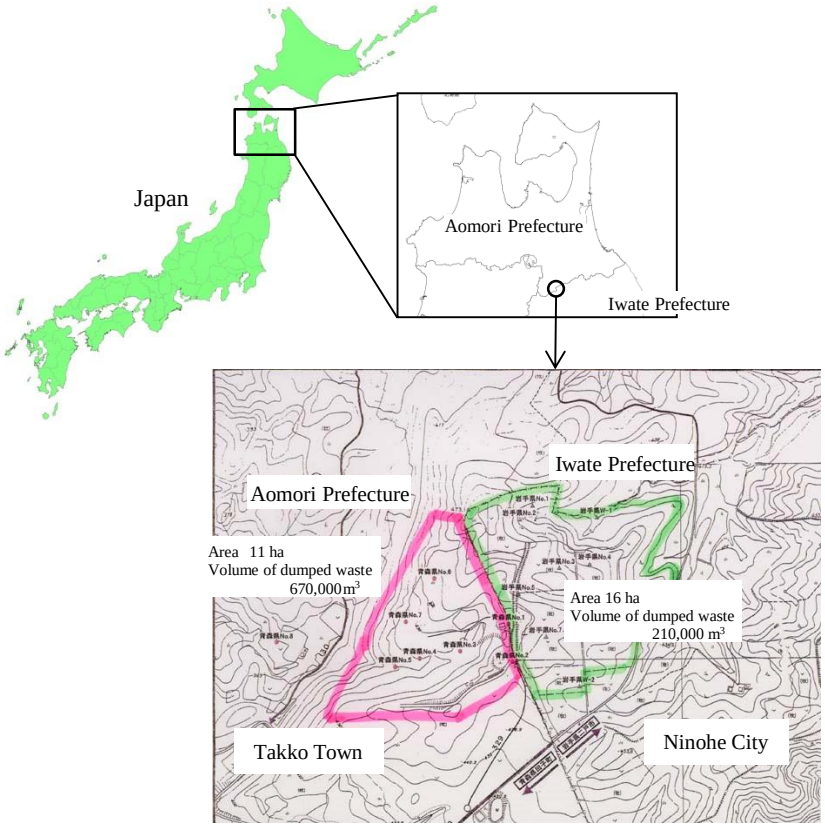
Which facilities do you prefer if the opinion you choose in question 1 is adopted for land use following remediation of the site? Please select one for each opinion chosen in question 1.

f1. Large commercial facilities	f9. School	f21. Restaurants	f32. Drinking water treatment plant
f2. Boutique	f10. Research institute	f22. Coffee house	f33. Sewage treatment plant
f3. Supermarkets	f11. Library	f23. Hotel	f34. Waste treatment facility
f4. Convenience stores	f12. Internet café	f24. Theater	f35. Electrical power plant
	f13. Resource center	f25. Leisure facility	f36. Gas supply facility
f5. Residential district	f14. Museum	f26. Theme park	
f6. Hospitals	f15. Art gallery		f37. Temple, shrine
f7. Nursery, kindergarten	f16. Community center	f27. Agricultural land	f38. Church
f8. Welfare facilities	f17. Athletic field	f28. Forest	f39. Cemetery, crematorium
		f29. Industrial factory	
	18. Park	f30. Distribution center	f40. Bank
	19. Green space	f31. Office	f41. Post office
	20. Market		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.

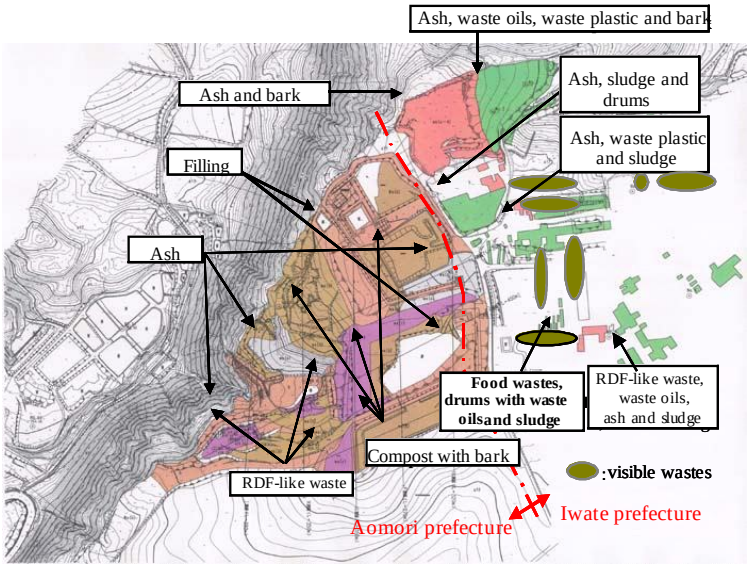
Figure 2 Content of the questionnaire in the first step



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554 Figure 3 Map of the Aomori - Iwate illegal dumping site

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

558 (RDF: Refuse derived fuel)

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561 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	

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

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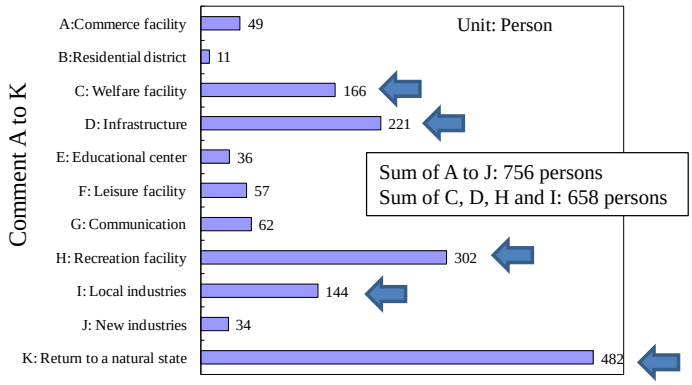
		All regions (N = 919)	Only Takko town (N = 141)
Age (years)	10 – 19	0.3%	0%
	20 – 29	2%	1%
	30 – 39	5%	7%
	40 – 49	12%	12%
	50 – 59	31%	35%
	60 – 69	25%	21%
	70 – 79	19%	16%
	80 – 89	4%	6%
	90 – 99	1%	1%
	Unknown	0.7%	1%
Gender	Male	72%	74%
	Female	27%	25%
	Unknown	1%	1%
Occupation	Company employee	27%	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%

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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

575 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)

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

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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/household

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587 Figure 6 Form for the selection-based conjoint analysis

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589 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	***					***				

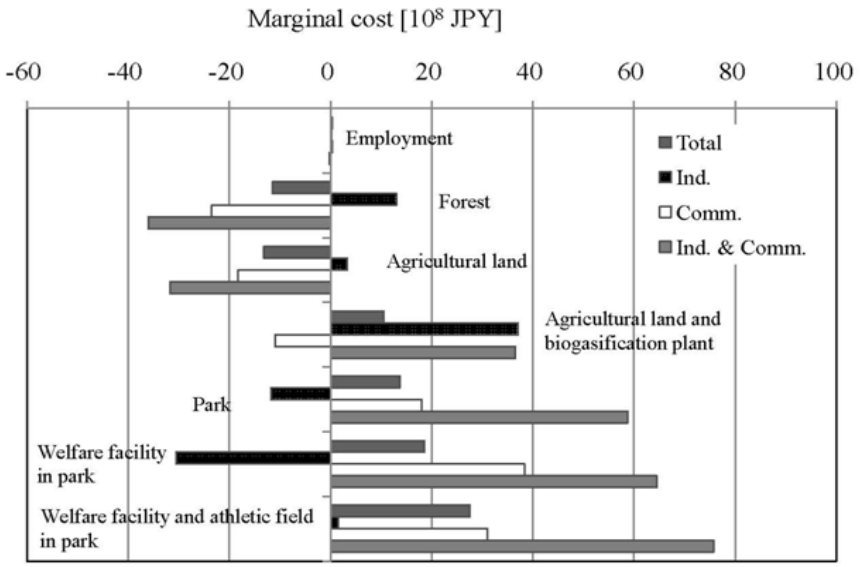
*significant < 0.1, **significant < 0.05, ***significant < 0.01

	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	***					**				

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

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

595 step

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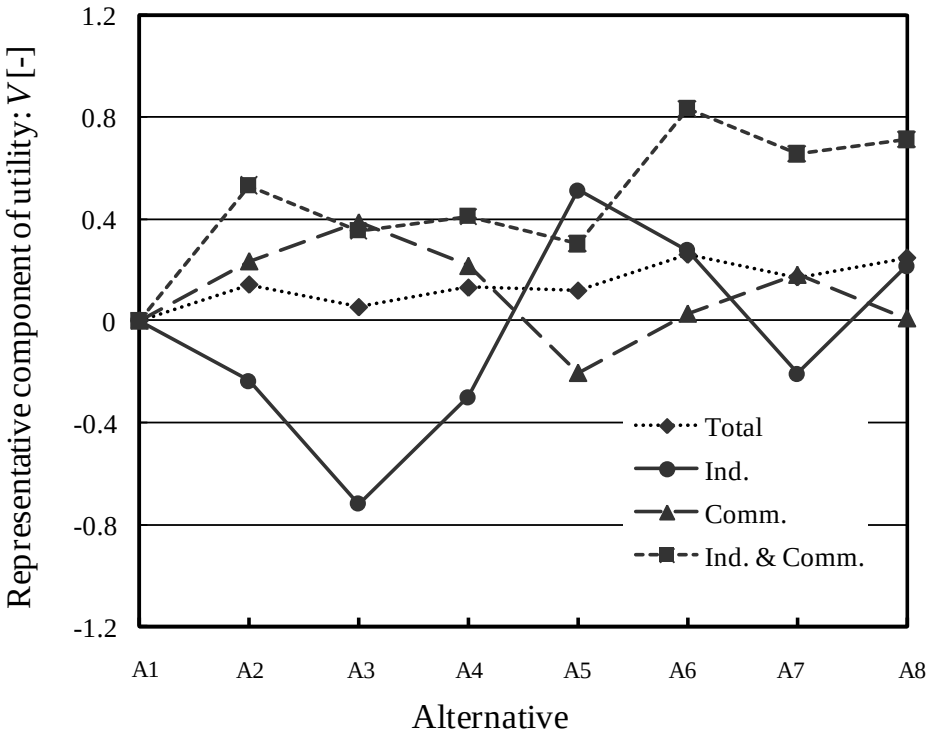
598 Table 6 Eight alternatives for the utility function analysis performed in the third step

599

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

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602

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

605