Evaluation of Multiple Benefits of Artificial Streams Augmented with Recycled Water Using Conjoint Analysis

H. Yamagata1, D. Yamanaka2, M. Ogoshi1 and M. Minamiyama1

1 National Institute for Land and Infrastructure Management (NILIM), 1, Asahi, Tsukuba, Ibaraki, 305-0804, Japan (E-mail: yamagata-h92e6@nilim.go.jp)
2 Shiga Prefectural Sewerage Management Public Corporation, 1-2-1, Matsumoto, Ohtsu, Shiga, Japan

Abstract: This study aims at evaluating multiple environmental and educational benefits of artificial streams augmented with recycled water using conjoint analysis. The survey was carried out at Tadotsu Town in Japan where recycled water is used for augmenting artificial streams to restore habitats for firefly regarded as a symbol of “clean water” and to provide opportunity for environmental education such as firefly-watching.

Marginal willingness-to-pay for the artificial streams for preserving habitats for firefly, securing hygienic safety to allow body contact, enhancing landscape and providing opportunity for environmental education were estimated at 4,419 Japanese yen (JPY) (US$44), 1,375 JPY (US$14), 4,094 JPY (US$41) and 918 JPY (US$9) per household per year. Those who knew or visited the streams had higher marginal willingness-to-pay for preserving aquatic habitats. And those who attended firefly-watching had high marginal willingness-to-pay for both of preserving aquatic habitats and securing hygienic safety. The results indicated the importance of education at the streams such as firefly-watching for public understanding in habitat preservation and hygienic safety of recycled water.

Keywords: Wastewater recycling; artificial streams; benefit evaluation; conjoint analysis

INTRODUCTION

Recycled water can be used to restore dry and neglected urban streams as well as augment surface water for various beneficial purposes. For example, marsh and wildlife sanctuary was developed using recycled wastewater for public access and educational benefits at Arcata, California (Asano et al., 2007). In Japan, reuse of treated wastewater has been practiced for various nonpotable applications though only 1-2 % of effluent of publicly-owned treatment works (POTWs) is recycled. About a half of recycled water from POTWs is used for environmental enhancement for restoring aquatic amenities in the urban environment (Ogoshi et al., 2001; Tajima et al., 2007).

Cost-benefit analysis is required for projects including water recycling for environmental enhancement in Japan, and it is important to evaluate the monetary value of the benefit of environmental enhancement. Contingent valuation methods (Hanemann, 1984; Kuriyama, 1997; Hurlimann and McKay, 2005) and conjoint analysis (Louviere, 1994; Ohno, 2000; Hurlimann and McKay, 2007) has been applied to valuing benefit of aquatic environment as willingness-to-pay. However, few studies were carried out to value benefit of aquatic environment including hygienic safety that is an important factor in streams augmented with recycled water. In addition, though benefit (willingness-to-pay) may vary depending on personal attributes of the respondents such as their experience of visiting the aquatic environment, few studies were carried out to clarify how these personal attributes influence various kinds of benefit quantitatively.

This study aims at evaluating multiple environmental and educational benefits of artificial streams augmented with recycled water. Conjoint analysis was applied to estimate marginal willingness-to-pay for each attribute of the benefits: preserving aquatic habitats, securing hygienic...
safety to allow body contact, enhancing landscape and providing opportunity for environmental education. And the relationship between marginal willingness-to-pay and personal attributes such as the respondents’ experience of visiting the artificial streams and attending firefly-watching at the streams was analyzed to clarify how these personal attributes affect various kinds of benefit quantitatively.

**METHODS**

**Selection of Artificial Streams Augmented with Recycled Water to be Evaluated**

One of the Japan’s recent large scale water recycling for various applications including environmental enhancement is practiced at Tadotsu Town (total population: 23,618 in 2005) in Kagawa Prefecture. Under the frequent drought and the lack of available surface water, Tadotsu Town began to reuse tertiary-treated wastewater (10,000 m$^3$/day) for agricultural irrigation, groundwater recharge, river flow augmentation and restoring artificial streams (“seseragi”) as aquatic habitats in 2004 (Tadotsu Town, 2000). The artificial streams named “Yawata-no-mori hotaru-no-sato” (“Yawata Firefly Forest” in English) (Length = 120 m) was developed to restore habitats for firefly that is considered as a symbol of “clean water” using recycled water (Figure 1). Dechlorinated tertiary-treated wastewater is disinfected with UV at the stream for protecting public health and aquatic organisms. Environmental educational activities are carried out at the stream. For example, the citizen organization named “Tadotsu-hotaru-no-kai” (Tadotsu firefly association) including children cleans the streams, weeds, breeds larvae of firefly since the streams was restored (Shikoku Shimbun, 2008). And public firefly-watching is held almost every spring. 1,570 citizens participated in the firefly-watching at the stream on May 21, 2005. In this study, the artificial streams named “Yawata-no-mori hotaru-no-sato” were selected for benefit evaluation using conjoint analysis.

![Figure 1: Artificial streams “Yawata-no-mori hotaru-no-sato” (“Yawata Firefly Forest” in English) using recycled water. (Courtesy of Tadotsu Town)](image)

**Conjoint Analysis**

Conjoint analysis is one of the market research methods suitable for assessing consumers’ multiple preferences on goods, and also there needs to be used to value environmental benefits with multiple attributes. For example, public preferences and willingness-to-pay for removing saltiness, color and odor of recycled water for various usages were evaluated using conjoint analysis in Australia (Hurlimann and McKay, 2007). Therefore, conjoint analysis was thought to be suitable for evaluating multiple environmental and educational benefits of artificial streams augmented with
recycled water. In this study, questionnaire was designed according to the approach of “choice experiment” (“choice-based conjoint analysis”) (Louviere, 1994; Ohno, 2000) that respondents choose most desirable option in the profiles (all the possible attribute combinations) of benefits and willingness-to-pay of the artificial streams. In the questionnaire, willingness-to-pay was defined as an annual donation for each household to maintain the artificial streams at the levels of the benefits. Questionnaire was designed and analyzed as follows.

**Design of Profiles**

Profiles were designed based on combination of levels of attributes of the artificial streams shown in Table 1. Attributes of artificial streams to be tested were preserving aquatic habitats, securing hygienic safety, enhancing landscape and providing opportunity for environmental education. These attributes were selected as important benefits of the artificial streams based on the discussion with staffs of Tadotsu Town Hall. For example, preserving aquatic habitats especially for firefly and providing opportunity for environmental education were main goals of restoring the artificial streams. Enhancing landscape was considered one of the important factors as waterscape. Water quality was also important because recycled water was used, so securing hygienic safety to allow body contact through UV disinfection was selected as an attribute. In addition, willingness-to-pay was set with 4 levels: “1,000 JPY (Japanese yen) /household-year”, “3,000 JPY /household-year”, “5,000 JPY /household-year” and “10,000 JPY/household-year” based on the pre-test of the questionnaire to the staffs of Tadotsu Town Hall.

**Table 1:** Attributes of artificial streams and the levels of the attributes set for conjoint analysis.

<table>
<thead>
<tr>
<th>Attributes of artificial streams</th>
<th>Preserving aquatic habitats</th>
<th>Securing hygienic safety</th>
<th>Enhancing landscape</th>
<th>Providing opportunity for environmental education</th>
<th>Willingness-to-pay for maintenance of artificial streams (JPY /household-year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels</td>
<td>Firefly habitats are preserved (due to tertiary treatment)</td>
<td>Human contact is allowed (due to disinfection).</td>
<td>Green and waterway are maintained cleanly.</td>
<td>Environmental education opportunity is provided.</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>Firefly habitats are NOT preserved.</td>
<td>Human contact is NOT allowed.</td>
<td>Green and waterway are dirty.</td>
<td>Environmental education opportunity is NOT provided.</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
</tbody>
</table>

Profiles are combination of all possible attributes, so the number of possible profiles were 64 (= 2⁴ x 4¹). To minimize the number of profiles, 16 profiles were selected from the possible profiles using the orthogonal array methods (Lorenzen and Anderson, 1993). Then, choice sets consisting of 2 profiles selected randomly from the 16 selected profiles and 1 “stay” profile (“Do nothing” option) were prepared (Figure 2) (Louviere et al., 2000). Each respondent answered 4 choice sets. The response rate of the questionnaire was 30.3% (302 respondents).

**Test on Lexicographic Preferences**

In the questionnaire on willingness-to-pay such as CVM, some respondents always show zero or infinity as willingness-to-pay because they refuse to make trade-off between environmental features and money or place absolute values on environmental preservation. These responses called...
“lexicographic preferences” are excluded from analysis in many CVM studies (Gowdy and Mayumi, 2001). In this study, lexicographic preferences were excluded as follows.

Please choose the most desirable alternative from the profiles 1, 2 and 3 in terms of the artificial streams.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Profile 1</th>
<th>Profile 2</th>
<th>Profile 3 (“stay profile”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preserving aquatic habitats</td>
<td>Firefly habitats are preserved.</td>
<td>Firefly habitats are preserved.</td>
<td>Firefly habitats are NOT preserved.</td>
</tr>
<tr>
<td>Securing hygienic safety</td>
<td>Human contact is allowed.</td>
<td>Human contact is NOT allowed.</td>
<td>Human contact is NOT allowed.</td>
</tr>
<tr>
<td>Enhancing landscape</td>
<td>Green and waterway are maintained cleanly.</td>
<td>Green and waterway are dirty.</td>
<td>Green and waterway are dirty.</td>
</tr>
<tr>
<td>Providing opportunity for environmental education</td>
<td>Environmental education opportunity is provided.</td>
<td>Environmental education opportunity is NOT provided.</td>
<td>Environmental education opportunity is NOT provided.</td>
</tr>
<tr>
<td>Willingness to pay</td>
<td>10,000 JPY/household-year</td>
<td>1,000 JPY/household-year</td>
<td>0 JPY/household-year</td>
</tr>
</tbody>
</table>

(4 choice sets were presented in one questionnaire. There were 4 types of questionnaires. 16 profiles were assessed in all the questionnaires.)

Figure 2: Example of a choice set in the questionnaire.

If respondents chose “stay” profiles for all 4 choice sets, they were asked the reasons for the answer. Options of the reasons were: “(1) It costs too much for any profiles.”, “(2) Maintenance of the artificial streams is not valuable.”, “(3) It is important to maintain the artificial streams, but willingness-to-pay cannot be decided with the shown information.”, “(4) It is important to maintain the artificial streams, but I disagree to the payment method (donation to foundation).” and “Other reasons”. Then respondents choosing (3) or (4) were excluded from analysis because they refused payment not for disagreement of the benefits of the artificial streams but for disagreement of the payment method (donation).

If respondents never choose “stay” profiles for all 4 choice sets, they were asked whether they agreed any alternatives of maintenance of the artificial streams regardless of the price. Then respondents answering “yes” to the question were excluded from analysis because they always agree to pay regardless of the price.

Methods of Questionnaire Survey
Survey area was determined as the areas where the residents may have benefits from the artificial streams. Whole of Tadotsu Town was included to the survey area because residents of Tadotsu Town seem to have high interests in the artificial streams through advertisement by the Town Hall. In addition, the areas within 2 km from the artificial streams outside of Tadotsu Town were included to the survey area where residents can walk to the artificial streams. 1,000 households (7.3 % of total households) within the survey area were randomly selected using the official registers of electors to distribute the questionnaire. Questionnaires were mailed to 1,000 selected households on September 22nd, 2006. All respondents were asked to answer the questionnaires and return them by October 9th. The response rate of the questionnaire was 30.3% (302 respondents). The responses covered 40 districts in 43 total districts of the survey area, which means the respondents represented almost all residences.
Estimation of Marginal Willingness-to-pay

Marginal willingness-to-pay for each benefit attribute was estimated based on random utility model (Louviere, 1994; Ohno, 2000; Shoji et al., 2005). Based on random utility model for choice experiment, total utility \((U_k)\) of respondents for choosing profile \(k\) can be defined as follows.

\[
U_k = V_k + \varepsilon_k = \beta_{HAB} x_{HAB} + \beta_{HYG} x_{HYG} + \beta_{LSC} x_{LSC} + \beta_{EDU} x_{EDU} + \beta_{WTP} x_{WTP} + \varepsilon_k
\]  

(1)

where \(V_k\) indicates the systematic components of the utility for choosing profile \(k\); \(\varepsilon_k\) is a random component for choosing profile \(k\). \(x_{HAB}\) is the level of benefit attribute for preserving aquatic habitats, taking the value of 1 for “firefly habitats are preserved” and 0 for “firefly habitats are not preserved”. \(x_{HYG}\) is the level of benefit attribute of securing hygienic safety, taking the value of 1 for “human contact is allowed due to disinfection” and 0 for “human contact is not allowed”. \(x_{LSC}\) is the level of benefit attribute for enhancing landscape, taking the value of 1 for “green and waterway are maintained cleanly” and 0 for “green and waterway are dirty”. \(x_{EDU}\) is the level of benefit attribute for opportunity of environmental education, taking the value of 1 for “environmental education opportunity is provided” and 0 for “environmental education opportunity is not provided”. \(x_{WTP}\) is willingness-to-pay for the artificial streams, taking the value of 0, 1000, 3000, 5000 and 10000 JPY/household-year. \(\beta_{HAB}, \beta_{HYG}, \beta_{LSC}, \beta_{EDU}, \beta_{WTP}\) are coefficients for variables \(x\).

Assuming that error terms \(\varepsilon_k\) follow a Gumbel distribution, the probability \((Pr_k)\) for choosing profile \(k\) from 3 profiles in each choice set can be expressed as the conditional logit model (Louviere, 1994) as follows:

\[
Pr_k = \frac{\exp(V_k)}{\sum_j \exp(V_j)} = \frac{\exp(\beta_{HAB} x_{HAB,k} + \beta_{HYG} x_{HYG,k} + \beta_{LSC} x_{LSC,k} + \beta_{EDU} x_{EDU,k} + \beta_{WTP} x_{WTP,k})}{\sum_j \exp(\beta_{HAB} x_{HAB,j} + \beta_{HYG} x_{HYG,j} + \beta_{LSC} x_{LSC,j} + \beta_{EDU} x_{EDU,j} + \beta_{WTP} x_{WTP,j})}
\]

(2)

where \(j\) is the number of all profiles shown in one choice set. The coefficients \((\beta)\) of variables \((x)\) can be estimated by maximizing the likelihood function \((L)\) that is summation of choice probabilities for all respondents \((i)\). The coefficients \((\beta)\) were estimated based on results of the questionnaire using the software TSP 5.0.

\[
\ln L = \sum_i \sum_k \delta_{ik} \ln Pr_k
\]

\[
= \sum_i \sum_k \delta_{ik} \ln \left( \frac{\exp(\beta_{HAB} x_{HAB,i,k} + \beta_{HYG} x_{HYG,i,k} + \beta_{LSC} x_{LSC,i,k} + \beta_{EDU} x_{EDU,i,k} + \beta_{WTP} x_{WTP,i,k})}{\sum \exp(\beta_{HAB} x_{HAB,j,i,k} + \beta_{HYG} x_{HYG,j,i,k} + \beta_{LSC} x_{LSC,j,i,k} + \beta_{EDU} x_{EDU,j,i,k} + \beta_{WTP} x_{WTP,j,i,k})} \right)
\]

(3)

where \(\delta_{ik}\) is a dummy variable that is 1 if the respondent chooses profile \(i\) and is 0 if not. Marginal willingness-to-pay \((MWTP_a)\) for each benefit attribute \((a)\) can be expressed as the ratio of the coefficient \((\beta_a)\) for the attribute \(a\) to that for willingness-to-pay \((\beta_{WTP})\) as follows:

\[
MWTP_a = \frac{dx_{WTP}}{dx_a} = -\frac{dV}{dx_a} \left/ \frac{dV}{dx_{WTP}} \right. = \frac{-\beta_a}{\beta_{WTP}}
\]

(4)

Analysis of Relationship between Marginal Willingness-to-Pay and Personal Attributes

The relationship between marginal willingness-to-pay and personal attributes on recognition and experience of visit to the artificial streams and recognition of using recycled water at the streams was analyzed. These personal attributes were asked in the questionnaire as questions: “Do respondents know the artificial streams?”, “Have respondents ever visited the artificial streams?”, “Have respondents ever attended the firefly-watching at the streams?” and “Do respondents know
Recycled water is used at the streams?” Results of the questionnaire were segmented based on personal attributes, and then marginal willingness-to-pay was estimated for each segment of personal attributes.

RESULTS AND DISCUSSION

Estimation of Willingness-to-Pay for Benefit Attributes

The response rate of the questionnaire was 30.3% (302 respondents). 1,039 samples for choice sets were obtained in 1,208 expected samples (= 302 respondents × 4 choice sets). After excluding lexicographic preferences, 727 samples were used for estimation of marginal willingness-to-pay for each attribute of the artificial streams. Coefficients ($\beta$) of the attributes were shown in Table 2. Preserving aquatic habitats ($\beta_{HAB}$) and enhancing landscape ($\beta_{LSC}$) were statistically significant parameters at the 1% significance level ($p$-value < 0.01). Securing hygienic safety ($\beta_{HYG}$) was statistically significant parameter at the 5% significance level ($p$-value < 0.05). Providing opportunity for environmental education ($\beta_{EDU}$) was statistically significant parameter at the 10% significance level ($p$-value < 0.10).

Marginal willingness-to-pay for preserving aquatic habitats, securing hygienic safety, enhancing landscape, providing opportunity for environmental education were estimated at 4,419 JPY (US$44) /household-year, 1,375 JPY (US$14) / household-year, 4,094 JPY (US$41) /household-year and 918 JPY (US$9) /household-year using equation (4) (US$1 = 100 JPY , April 6, 2009). It was suggested that preserving aquatic habitats for firefly and enhancing landscape were main benefit attributes of the tested artificial streams at Tadotsu Town. And it was suggested that securing hygienic safety and providing opportunity for environmental education were recognized as parts of benefits of the artificial streams by respondents. Summation of 4 MWTPs for the artificial streams at Tadotsu Town were 10,806 JPY (US$11), which is almost same as summation of MWTPs measured at urban parks in Japan using conjoint analysis (Takeda, et al., 2004).

Table 2: Coefficient ($\beta$) estimates of utility function for artificial streams using recycled water.

<table>
<thead>
<tr>
<th>Utility function: $V = \beta_{HAB} x_{HAB} + \beta_{HYG} x_{HYG} + \beta_{LSC} x_{LSC} + \beta_{EDU} x_{EDU} + \beta_{WTP} x_{WTP}$</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preserving aquatic habitats ($\beta_{HAB}$)</td>
<td>1.100</td>
<td>0.117</td>
<td>9.409</td>
<td>0.000</td>
</tr>
<tr>
<td>Securing hygienic safety ($\beta_{HYG}$)</td>
<td>0.342</td>
<td>0.137</td>
<td>2.508</td>
<td>0.012</td>
</tr>
<tr>
<td>Enhancing landscape ($\beta_{LSC}$)</td>
<td>1.019</td>
<td>0.115</td>
<td>8.854</td>
<td>0.000</td>
</tr>
<tr>
<td>Providing opportunity for environmental education ($\beta_{EDU}$)</td>
<td>0.229</td>
<td>0.120</td>
<td>1.911</td>
<td>0.056</td>
</tr>
<tr>
<td>Willingness-to-pay for the artificial streams ($\beta_{WTP}$)</td>
<td>-0.000249</td>
<td>0.0000215</td>
<td>-11.592</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Number of samples: 727, Log-likelihood: - 644, BIC (Schwarz Baysian information criterion) : 661

Analysis of Relationship between Marginal Willingness-to-Pay and Personal Attributes

Coefficients ($\beta$) of benefit attributes ($x$) were estimated for each segment of personal attributes. Then, marginal willingness-to-pay for benefit attributes whose coefficient ($\beta$) was statistically significant at 10% significance level ($p$-value < 0.10) was calculated using equation (4) (Figure 3).

Marginal willingness-to-pay for securing hygienic safety existed for those who knew the artificial streams though that didn’t exist for those who did not. Similarly, marginal willingness-to-pay for securing hygienic safety existed for those who knew that recycled water is used at the streams though that didn’t exist for those who did not. It was shown that those who knew the artificial
streams and that recycled water is used at the streams recognized the needs for securing hygienic safety at the artificial streams.

Marginal willingness-to-pay for preserving aquatic habitats for firefly for those who had visited the artificial streams was more than twice higher than that for those who not. Marginal willingness-to-pay for preserving habitats for firefly for those who attended the firefly-watching at streams was also more than twice higher than that for those who not. It was shown that those who visited the artificial streams or attended the firefly-watching at the streams recognized the needs for preserving habitats for firefly at the artificial streams. Especially, marginal willingness-to-pay for securing hygienic safety for those who attended the firefly-watching at the streams was also high, showing that the needs for both of preserving aquatic habitats and securing hygienic safety were recognized by the attendee of firefly-watching at the streams. Therefore, it was suggested that firefly-watching at the artificial streams using recycled water could have significant educational effects on preserving aquatic habitats and securing hygienic safety of recycled water in the region.

![Figure 3: Marginal willingness-to-pay for multiple environmental benefits of the artificial streams augmented with recycled water in Tadotsu Town for various personal attributes.](https://iwaponline.com/wpt/article-pdf/5/3/wpt2010067/382671/67.pdf)

**CONCLUSIONS**

This study aims at evaluating multiple environmental and educational benefits of artificial streams augmented with recycled water quantitatively. Conjoint analysis that is one of the market research methods to assess consumers’ multiple preferences on goods was applied to evaluate the multiple benefits. The survey was carried out at Tadotsu Town in Japan where recycled water is used for augmenting artificial streams to restore habitats for firefly regarded as a symbol of “clean water” and to provide opportunity for environmental education through firefly-watching. As a result, marginal willingness-to-pay for preserving habitats for firefly, securing hygienic safety to allow body contact, enhancing landscape and providing opportunity for environmental education were estimated at 4,419 JPY (US$44), 1,375 JPY (US$14), 4,094 JPY (US$41) and 918 JPY (US$9) per household per year. Those who visited the streams had higher marginal willingness-to-pay for preserving aquatic habitats. And those who attended firefly-watching had high marginal willingness-to-pay for both of preserving aquatic habitats and securing hygienic safety. The results
indicated the importance of education at the streams such as firefly-watching for public understanding in habitat preservation and hygienic safety of recycled water.

ACKNOWLEDGEMENTS
Authors thank to staffs of Tadotsu Town, Marugame City and Zentsuji City and respondents to the questionnaire for their kind cooperation.

REFERENCES


