Chapter 24

Assessing Public Preference for Construction of Giant Seawalls Using the Best–Worst Scaling Approach

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Abstract Giant seawalls have been constructed in areas stricken by the 2011 Great East Japan Earthquake to protect nearby townships from tsunamis, but their construction has caused great controversy. This study conducted a survey using the best–worst scaling (BWS) method in Iwate and Miyagi Prefectures, where the seawalls are constructed to understand what specific factors citizens think should be taken into consideration during construction. The results revealed that the negative impacts on the natural environment and seawall height (safety) were ranked most highly. Additionally, the results of regression analysis with respondents' B-W scores for the negative impacts on the natural environment and seawall height (safety) as the explained variables demonstrated that people who less strongly recognized the need for a seawall were more likely to think the negative impact on the natural environment should be taken into consideration than did people who strongly recognized the need for a seawall; however, people who did not know much about seawalls were more likely to think seawall height should be considered than people who did. The regression analysis also found that people who more strongly felt there was a need to build seawalls were more likely to think seawall height should be a key consideration, whereas people who personally had suffered harm in the tsunami following the Great East Japan Earthquake were more likely to think seawall height should be a key consideration than did those who were not personally affected.

Keywords Seawall · Great East Japan Earthquake · Best–Worst Scaling · Preference

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24.1 Introduction

Following the Great East Japan Earthquake, which caused the death or disappearance of 18,425 people (as of March 10, 2021, according to a National Police Agency press release), Japan's Central Disaster Management Council designated high-frequency but low-impact tsunamis that occur every few decades to 100 or so years as Level 1 (L1) Tsunamis, and low-frequency but high-impact giant tsunamis like the Great East Japan Earthquake tsunami that only occur once in several 100 or even 1000 years as Level 2 (L2) Tsunamis (Central Disaster Management Council 2011; Onuma 2015). The council determined to develop coastal protection facilities, including seawalls and seaside protection forests, to protect human life, safeguarding residents' assets, stabilizing the regional economy, and securing efficient production bases if an L1 tsunami occurs. However, because the prevention of an L2 tsunami using artificial structures is unrealistic both from the perspective of the costs required to maintain facilities and the impact on the coastal environments and their usage, the council limited the focus of tsunami countermeasures solely to the protection of residents' lives related to evacuation (Central Disaster Management Council 2011; Onuma 2015).

Iwate, Miyagi, and Fukushima Prefectures were seriously damaged in the Great East Japan Earthquake. As a result of this catastrophic disaster, seawalls of up to 400 km in length have been constructed in approximately 600 locations across these prefectures, costing a total of approximately ¥1.3 trillion. The maximum seawall height is 15.5 m, which was established assuming an L1 tsunami and is not assumed to be able to withstand an L2 tsunami.

The construction of these giant seawalls has caused significant controversy. While some people believe that seawalls of an adequate height are essential to enable residents in coastal areas to live securely, others have expressed concerns about various issues associated with seawall construction including the impact on local industry and coastal landscape, cost of construction, cost for future generations, insufficient consensus building, and negative impact on the natural environment. Although it is impossible to make improvements to the perceived problems on seawalls that have already been built, if a tsunami causes damage in the future and necessitates similar additional seawall construction, it will be important to reflect upon these problem areas and act accordingly.

Given this context, the authors of this study conducted a survey to examine the understanding and feelings of the residents in Miyagi and Iwate Prefectures concerning seawall construction. There are trade-offs in the impacts of seawall construction, for example, between increasing the height of seawalls for safety purpose and preserving coastal landscapes and the natural environment. Therefore, it is necessary to examine citizens' preferences in order to determine what should be prioritized. However, when the importance of each issue is asked in the conventional question format, there is often not much difference in the ratings among the alternatives because respondents are capable of rating any of the alternatives equally. Therefore, the study then analyzes the survey using best–worst scaling (BWS)—a

method that has recently become popular in fields such as marketing—in an attempt to capture in quantitative terms the preferences of local residents concerning seawall construction. BWS is a question format in which respondents answer under trade-offs, so there tends to be a clearer difference in evaluation among the alternatives.

24.2 Methods

The study uses BWS to examine citizens' recognition of the problems associated with seawall construction in Miyagi and Iwate Prefectures, where seawalls are being built (Fig. 24.1). BWS is an analytical method introduced by Finn and Louviere (1992) that has become widely utilized in recent years in marketing and other fields (Louviere et al. 2015; Tsuge et al. 2014). To the authors' best knowledge, there are no studies that have used BWS to understand people's preferences for disaster prevention infrastructure such as seawalls.

Using this BWS approach, the respondents were presented with multiple items and asked to choose which one they rated highest ("best") and which one they rated lowest ("worst") based on evaluation criteria such as "utility" and "importance." A

Fig. 24.1 Positions of Iwate Prefecture and Miyagi Prefecture

respondent's preferences were captured by changing the items they were shown and repeating the question (Finn and Louviere 1992; Louviere et al. 2015).

There are three classified types of the BWS method: object case (case 1), profile case (case 2), and multi-profile case (case 3), as described by Louviere et al. (2015). In the object case (case 1), respondents are shown multiple objects such as opinions and products and asked to choose the best and the worst object in the choice set. In the profile case (case 2), respondents are shown a single profile comprising the attribute levels and asked to choose the best and the worst attribute level within the profile. In the multi-profile case (case 3), respondents are presented with multiple profiles comprising the attribute levels and asked to choose the best and the worst profile in the choice set. Since the goal of this study is to capture the relative importance of problems associated with seawall construction, we have selected object case (case 1), which is appropriate to help capture a respondent's relative assessments of multiple items.

Table 24.1 summarizes the typical issues that were highlighted as seawall construction problem areas. A total of seven points with the addition of "seawall height (safety)" were used as the BWS items.

These seven items were combined to create choice sets to be presented to respondents. This study follows the precedent of numerous previous studies in using balanced incomplete block designs (BIBDs) to create choice sets. With BIBDs, each item appears the same number of times in all the choice sets created; moreover, the combinations of each item with other respective items also appear the same number of times (Louviere et al. 2015).

Seven-item BIBDs are used since this study employs seven items. Replacing BIBD numbers one to seven with each of the seven items thus creates the seven choice sets shown in Table 24.2. This table shows how each item appears three

Table 24.1 Main issues in seawall construction (problems that have been highlighted regarding such construction)

1	Impact on local industry	Seawalls divide the town from the sea and are built on sandy beaches, so will they not affect local industries like fishing and tourism?
2	Impact on coastal landscape	Will seawalls not destroy the coastal landscape or make it impossible to see the coastal landscape?
3	Cost of construction	Is the cost of construction not too high with an approximate project cost of ¥1 trillion?
4	Negative impact on the natural environment	Will seawalls not have a negative effect on the natural environment by directly impacting the flora and fauna that exist in the sea and on the beaches, or by altering the flow of sand carried by ocean currents?
5	Building consensus	Were seawalls not built without the opportunity for discussion with local residents?
6	Cost for future generations	While the construction of seawalls is covered by the special reconstruction income tax, will future generations not have to pay large sums of money for their maintenance and renewal?

Table 24.2 Choice sets

Set			
1	Impact on local industry	Building consensus	Cost of construction
2	Seawall height (safety)	Cost of construction	Negative impact on the natural environment
3	Cost of construction	Cost for future generations	Impact on coastal landscape
4	Impact on coastal landscape	Impact on local industry	Seawall height (safety)
5	Cost for future generations	Negative impact on the natural environment	Impact on local industry
6	Building consensus	Seawall height (safety)	Cost for future generations
7	Negative impact on the natural environment	Impact on coastal landscape	Building consensus

Table 24.3 Examples of best–worst scaling (BWS) questions. Please select which of the following three factors you think is the most important to consider and which is the least important to consider

	Most important to consider	Least important to consider
Seawall height (safety)	X	
Cost of construction		X
Negative impact on the natural environment		

times throughout the choice sets, with each item and other items in combination appearing only once.

The BWS questions were posed as shown in the example in Table 24.3. The respondent was asked to assume that the seawall (which had actually already been built) is in the pre-construction stage and was then asked which of the three items they were shown should be considered “most important” and which should be considered “least important.” They were asked to answer on the assumption that the seawall was definitely going to be constructed.

Each individual respondent was presented with all seven choice sets to which they provided seven answers. The order in which the choice sets were shown was randomized to minimize to the extent possible the potential impacts that order may have on the way respondents answered.

There are several ways to analyze BWS, which are generally classified as counting analysis and econometric methods (Louviere et al. 2015). An advantage of counting analysis is that it does not require an advanced understanding of statistics and is easy to perform; furthermore, scores calculated using counting analysis have a strong linear relationship with the coefficients estimated through the maximum difference model (Finn and Louviere 1992), which is an econometric method (Marley and Louviere 2005; Tsuge et al. 2014). This study has therefore chosen to utilize counting analysis.

The main score calculation method used in counting analysis is shown in Eqs. (24.1), (24.2), (24.3), (24.4), and (24.5) (Cohen 2009). B_{in} and W_{in} are the number of times item i was chosen as “best” and “worst” in all the questions for respondent n . The B - W score $_{in}$, the score for each individual respondent of each item, was calculated by subtracting the latter from the former (Eq. 24.1). $\sum_n B_{in}$ is the number of times item i was chosen as “best” in all respondents’ answers. Similarly, $\sum_n W_{in}$ is the number of times it was chosen as “worst.” The B - W score $_i$ of each item was calculated by subtracting the latter from the former (Eq. 24.2). The average B - W score $_i$ was obtained by dividing B - W score $_i$ by the number of survey respondents N and the number of times each item occurs in all choice sets r , which in the case of this study is 3 (Eq. 24.3). Moreover, the value of the most highly ranked item was standardized as 1, and the relative importance $_i$ of each item was found as shown in Eq. 24.5. It should be noted that $\sqrt{B/W}_i$ was calculated using Eq. (24.4). Furthermore, $\max \sqrt{B/W}_i$ represents the maximum value of $\sqrt{B/W}_i$. Equations (24.1), (24.2), (24.3), and (24.4) are based on the descriptions from Cohen (2009).

$$B - W \text{ score}_{in} = B_{in} - W_{in} \quad (24.1)$$

$$B - W \text{ score}_i = \sum_n B_{in} - \sum_n W_{in} \quad (24.2)$$

$$\text{average } B - W \text{ score}_i = \frac{B - W \text{ score}_i}{Nr} \quad (24.3)$$

$$\sqrt{B/W}_i = \sqrt{\frac{\sum_n B_{in}}{\sum_n W_{in}}} \quad (24.4)$$

$$\text{relative importance}_i = \frac{\sqrt{B/W}_i}{\max \sqrt{B/W}_i} \quad (24.5)$$

24.3 Results and Discussion

The survey was conducted online between March 19 and 25, 2020. Survey participants were men and women between the ages of 20 and 69 in Iwate and Miyagi Prefectures who were registered contributors with the polling company. Responses were received from a total of 2099 people: 567 in Iwate Prefecture and 1532 in Miyagi Prefecture. Sample collection was coordinated to reflect as closely as possible the population compositions of the two prefectures in terms of gender and age. As a result, the respondents comprised 1053 men and 1039 women. In

terms of age, 317 respondents were in their 20s, 402 in their 30s, 476 in their 40s, 443 in their 50s, and 461 in their 60s.

The scores obtained through counting analysis are shown in Table 24.4. Figure 24.2 is a graph of *relative importance_i*. Both “negative impact on the natural environment” and “seawall height (safety)” received particularly high scores. The negative impact on the natural environment received the highest score, although only by a small amount. These two items were followed in order by “impact on local industry,” “cost for future generations,” “building consensus,” “cost of construction,” and “impact on coastal landscape.” It thus follows expectations that seawall height was highly ranked, given that the point of constructing the seawalls is to reduce tsunami damage, so it is noteworthy that the negative impact on the natural environment received an even higher score. This finding shows that people feel strongly that the issue of a seawall’s impact on the natural environment should be given very careful consideration during seawall construction.

It is worth analyzing the preferences for the negative impact on the natural environment and seawall height in more detail, given how highly both of these two items were valued. The authors conducted regression analysis to understand the characteristics of the individuals scoring these items highly; in this analysis, the B-W scores of respondents to the two items (Eq. 24.1) were used as the explained variable, while the explanatory variables were each respondent’s gender, age, address, knowledge of seawalls, recognition of the need for seawalls, and harm suffered in the tsunami from the Great East Japan Earthquake. A male dummy (*d_male*), taking the value of 1 for male and 0 for others (females and others, including those who do not wish to disclose their gender), was used for gender as variable. For age, values ranging from 25 to 65 were used as variables for people in their 20s to their 60s, respectively. A Miyagi Prefecture dummy (*d_miyagi*) was used for the address as a variable, taking the value of 1 for Miyagi Prefecture and 0 for Iwate Prefecture. Dummy variables were set for knowledge of seawalls based on responses to the question “Do you know about seawalls?” with the responses “I know about seawalls and have seen one,” “I know about seawalls but have not seen one,” “I have heard about seawalls,” and “I don’t know anything about seawalls” (in order, *d_knowledge1*, *d_knowledge2*, *d_knowledge3*, and *d_knowledge4*), with the three dummy variables excluding *d_knowledge4* used as variables. For recognition of the need for seawalls, respondents were asked the question, “Do you think the seawalls need to be constructed?” with answers on a seven-point Likert scale (Jamieson 2004), with seven being “very necessary” and one “not necessary.” Responses choosing one or two—meaning essentially there was no need for a seawall—were set to a dummy variable (*d_need12*) with a value of 1. Responses choosing three, four, or five—meaning there was no significant need for a seawall—were set to a dummy variable (*d_need345*) with a value of 1. Responses choosing six or seven—meaning there was a significant need for a seawall—were set to a dummy variable (*d_need67*) with a value of 1. The dummies *d_need12* and *d_need67* were used as variables. For harm suffered in the Great East Japan Earthquake tsunami, the authors constructed four dummy variables for responses to the question “Did you suffer harm in the Great East Japan Earthquake tsunami?” The responses

Table 24.4 Calculation results of scores

	Impact on local industry	Building consensus	Cost of construction	Seawall height (safety)	Negative impact on the natural environment	Cost for future generations	Impact on coastal landscape
$\sum_n B_{in}$	2165	1595	1663	3134	2881	1950	1305
$\sum_n W_{in}$	1486	2549	2656	1451	1180	2138	3233
B-W score _i	679	-954	-993	1683	1701	-188	-1928
Average B-W score _i	0.107829	-0.1515	-0.15769	0.26727	0.270129	-0.02986	-0.30618
Sqrt(B/W) _i	1.207034	0.791035	0.791283	1.469656	1.562538	0.955022	0.635334
Relative importance _i	0.772483	0.50625	0.506409	0.940557	1	0.611199	0.406604

Fig. 24.2 Relative importance

of “I suffered harm,” “My family and relatives were harmed,” “My friends and acquaintances were harmed,” and “No harm was suffered” were assigned respective dummy variables (in order, *d_damage1*, *d_damage2*, *d_damage3*, *d_damage4*) with a value of 1, and the first three dummy variables (with the exclusion of *d_damage4*) were used as variables. The descriptive statistics of the variables used in the regression analysis are shown in Table 24.5.

The model where the B-W scores of “negative impact on the natural environment” is taken as the explained variable is referred to as Model 1, and the model where the B-W scores of “seawall height (safety)” is taken as the explained variable is referred to as Model 2. Table 24.6 shows the estimation results through the least-squares method, using the data of the 2099 people.

In Model 1, *d_male*, age, and *d_need67* were significant; *d_male* was negatively significant, meaning that males had significantly lower B-W scores than others. Age was positively significant, meaning that older respondents had higher B-W scores. On the other hand, *d_need67* was negatively significant, meaning that people who think there is a strong need for seawalls had lower B-W scores than did people who think otherwise. It is possible to interpret these various findings to conclude that people who think there is a strong need for seawalls want greater safety and are thus willing to tolerate some negative impact on the natural environment with that end in mind. However, since there are few significant variables and the adjusted coefficient of determination (*adj.R*²) is relatively low in Model 1, other factors not included in the model may have influenced the explained variable. Further research is needed in this regard.

Table 24.5 Descriptive statistics of the variables used in the regression analysis

		Min	Max	Mean	Std. Dev.
B-W score	negative impact on the natural environment	-3	3	0.8104	1.5859
B-W score	seawall height (safety)	-3	3	0.8018	1.9796
d_male	Each respondents' B-W score for seawall height (safety) = 1 for male and = 0 for other	0	1	0.5017	0.5001
Age	=25 for 20s, =35 for 30s, =45 for 40s, =55 for 50s, and = 65 for 60s	25	65	46.5674	13.6437
d_miyagi	= 1 for Miyagi prefecture and = 0 for Iwate prefecture	0	1	0.7299	0.4441
d_knowledge1	= 1 for the response "I know about seawalls and have seen one" to the question "do you know about seawalls?"	0	1	0.4326	0.4956
d_knowledge2	= 1 for the response "I know about seawalls but have not seen one" to the question "do you know about seawalls?"	0	1	0.3492	0.4768
d_knowledge3	= 1 for the response "I have heard about seawalls" to the question "do you know about seawalls?"	0	1	0.1258	0.3317
d_need12	= 1 for the responses choosing one or two to the question "do you think the seawalls need to be constructed?" with answers on a seven-point Likert scale, with seven being "very necessary" and one "not necessary."	0	1	0.0853	0.2794
d_need67	= 1 for the responses choosing six or seven to the question "do you think the seawalls need to be constructed?"	0	1	0.4640	0.4988
d_damage1	= 1 for the response "I suffered harm" to the question "did you suffer harm in the Great East Japan Earthquake tsunami?"	0	1	0.1501	0.3572
d_damage2	= 1 for the response "my family and relatives were harmed" to the question "did you suffer harm in the Great East Japan Earthquake tsunami?"	0	1	0.2573	0.4372
d_damage3	= 1 for the response "my friends and acquaintances were harmed" to the question "did you suffer harm in the Great East Japan Earthquake tsunami?"	0	1	0.4307	0.4953

Table 24.6 Estimation results

	Model 1		Model 2	
Explained variable	B-W score negative impact on the natural environment		B-W score seawall height (safety)	
	Coefficient	Standard error	Coefficient	Standard error
Constant	0.7095	0.1790***	0.7199	0.1963***
d_male	−0.3257	0.0691***	−0.1137	0.0758
Age	0.0086	0.0026***	−0.0048	0.0028*
d_miyagi	−0.1107	0.0780	0.1010	0.0855
d_knowledge1	0.0843	0.1263	−0.4487	0.1384***
d_knowledge2	0.0298	0.1275	−0.2425	0.1398*
d_knowledge3	−0.1422	0.1491	−0.0508	0.1634
d_need12	0.1441	0.1294	−1.5853	0.1419***
d_need67	−0.2656	0.0724***	1.4917	0.0794***
d_damage1	−0.0865	0.0995	0.2332	0.1091**
d_damage2	0.0094	0.0811	−0.1227	0.0889
d_damage3	0.0850	0.0700	0.0348	0.0767
Adjusted coefficient of determination (<i>adj.R</i> ²)	0.02527		0.24797	
Number of respondents	2099		2099	

NB: ***significant at 1% level; **significant at 5% level; *significant at 10% level

In Model 2, age, d_knowledge1, d_knowledge2, d_need12, d_need67, and d_damage1 were significant (noting that age and d_knowledge2 were significant at the 10% level). Age was negatively significant, meaning that B-W scores increased as age decreased. In addition, d_knowledge1 and d_knowledge2 were negatively significant, meaning that people with knowledge of seawalls had lower B-W scores than did people who lacked such knowledge. The fact that the absolute value of the coefficient of d_knowledge1 was greater than the coefficient of d_knowledge2 shows that people who have seen a seawall in person had lower B-W scores. This finding may be interpreted to mean that people with knowledge of seawalls are aware of both their magnitude and their associated problems and therefore do not want the structure to be as high as do people without that direct knowledge. People who have seen seawalls in person immediately have a clear sense of their magnitude and thus have a particularly strong tendency toward this reaction. Additionally, d_need12 was negatively significant, whereas d_need67 was positively significant, meaning that in comparison to people who think there is no significant need for a seawall, those who think there is basically no need for a seawall had lower B-W scores, while people who think there is a strong need for a seawall had higher B-W scores. A reasonable interpretation of these findings suggests that people who think there is basically no need for a seawall have a comparatively lower interest in focusing on safety and people who think there is a strong need for a seawall have a comparatively higher interest in focusing on safety than do people who think there is no significant need for a seawall, respectively; thus, the former are less desirous of

high seawalls than are people with other opinions and the latter are more desirous of high seawalls than are people with other opinions, respectively. Finally, *d_damage1* was positively significant, meaning that people who suffered harm in the Great East Japan Earthquake tsunami had higher B-W scores than did those who experienced no harm. A reasonable conclusion is that people who personally suffered harm in the Great East Japan Earthquake tsunami now understandably want high seawalls to provide greater safety.

24.4 Conclusions

In this study, the authors used the best–worst scaling method to examine the preferences of citizens in Miyagi and Iwate Prefectures (areas stricken by the Great East Japan Earthquake) regarding the construction of seawalls. The main issues were presented in the form of seven items: impact on local industry, impact on coastal landscape, cost of construction, negative impact on the natural environment, building consensus, cost for future generations, and seawall height (safety). The results demonstrated that citizens believe that the negative impact on the natural environment and seawall height in particular should be taken into consideration during seawall construction.

The authors then conducted regression analysis. Respondents' B-W scores for the negative impact on the natural environment and seawall height (safety) were set as the explained variable, and respondents' gender, age, address, knowledge of seawalls, recognition of the need for seawalls, and harm suffered in the Great East Japan Earthquake tsunami were set as explanatory variables. The results showed that people who did not identify as male were more likely to feel that the negative impact on the natural environment should be taken into consideration more than did those who identified as male; older people were also more likely to feel that the negative impact on the natural environment should be taken into consideration. Additionally, people who felt there was a strong need for seawalls were less likely to think that the negative impact on the natural environment should be taken into consideration than did those who felt otherwise. Furthermore, younger people were more likely to think seawall height should be taken into account, while people who did not know about seawalls were more likely to think seawall height should be taken into account than did people with seawall knowledge. Among people with knowledge of seawalls, those who had not seen a seawall in person were more likely to think seawall height should be a consideration than did people who had seen a seawall in person. People who feel more strongly that there is a need to build seawalls are more likely to think seawall height should be taken into consideration, whereas those who suffered personal harm in the Great East Japan Earthquake tsunami are more likely to think seawall height should be taken into consideration than did people who did not suffer personal harm.

This study has shown that local residents place particular importance on the negative impact on the natural environment and seawall height (safety). However,

since there is a trade-off between the two, it is difficult to achieve both with gray infrastructure such as seawalls. Therefore, in order to achieve both, it is necessary to utilize hybrid infrastructures that combine gray and green infrastructures.

As described above, this study successfully clarified what specific issues citizens feel should be thoughtfully addressed during seawall construction. If there is a need to build future seawalls, these findings should be considered and acted upon.

There are, however, unresolved issues in this study. First, the authors chose to use BWS to conduct their analysis, but other analytical methods, including choice experiments (Holmes et al. 2017), are also possible. Comparing the results of this study with the results of analysis by other methods would also help to verify the robustness of these results. Second, this study focused on Iwate and Miyagi Prefectures, but it would be beneficial to conduct similar surveys in other regions of Japan, given that the development of coastal seawalls is planned as part of the National Resilience (Onuma 2015; National Resilience Promotion Office, Cabinet Secretariat, 2020). It would be worthwhile to capture the preferences of people in other regions, rather than just in the areas stricken by the Great East Japan Earthquake, and then use these findings for discussions and consensus building around seawall construction. Third, while this study examined the issues that most matter to citizens during seawall construction, it is also important to investigate which disaster prevention measures they specifically want. In addition to gray and green infrastructure, various hybrids of the two also exist. An important future topic will be to capture citizens' preferences in this regard to assistance with regional consensus building.

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