2003 International Symposium on Advanced Intelligent Systems
September 25-28, 2003, Jeju, Korea

A Study on Landscape Valuation of Bridges using Fuzzy Integral

Kazuyuki NAKANO, Seiichi KAGAYA, Kenetsu UCHIDA, Toru HAGIWARA
Graduate School of Engineering Hokkaido University
North 13 West 8, Kita-ku, Sapporo, 060-8628 Japan
E-mail: k-nakano@eng.hokudai.ac.jp

Abstract - **This study proposes a landscape valuation technique using fuzzy significance and fuzzy integral. We have two objectives. One is to clarify the relationship of infrastructure with its surrounding elements in the landscape. The other is to construct a method of selecting the most appropriate infrastructure for the landscape.**

I. INTRODUCTION

During the era of high-speed economic growth, we Japanese sought infrastructure that could be built as inexpensively and quickly as possible. These days, however, people have increased concern for amenity. Infrastructure needs to incorporate various aspects such as design and safety. "Landscape" is one of the most important aspects requiring consideration. Much research has been conducted on landscape valuation. The inclusion of landscape into infrastructure has been left to a small number of designers. However, appraisal of that landscape is carried out by large numbers of average persons. It is important to determine the difference in cognizance of landscape valuation between both the designers and non-specialists when considering the appearance of infrastructure incorporating the landscape. Moreover, it is also important to consider the most appropriate infrastructure for the landscape based upon the opinions of both groups.

2.OBJECT

Teramoto *et al.* (2001) researched the valuation techinique of bridge locations in Sapporo. They found that the citizens thought the beauty of landscape more important than the design of bridge. However, they couldn't clarify the element which the citizens pay attention to.

We have two objectives in this study. One is to clarify the relationship of infrastructure with its surrounding elements in the landscape. The other is to construct a method of selecting the most appropriate infrastructure for the landscape. This study proposes a landscape valuation technique using fuzzy significance and fuzzy integral. The fuzzy significance can faithfully express the subjectivity that maps relationships among landscape composition elements. Fuzzy integral is the technique of using the fuzzy significance to evaluate alternative plans based upon synergistic and compensatory effects. We felt that the human consciousness of a landscape could be expressed by using the fuzzy significance and fuzzy integral. Inoue *et al.* (1991) and Matsumoto *et al.* (2001) investigated the decision making problem using fuzzy measure and fuzzy integral.

We selected a bridge as an example of infrastructure. Specifically, some bridge types consisting of an arch bridge, a truss bridge, a beam bridge, a cable-stayed bridge with thin cables (1), and a cable-stayed bridge with thick cables (2) were selected. A river (including its riverbed), buildings, and a mountain were considered as the elements comprising the landscape surrounding the bridge. The combinations of these were then examined as five alternative plans.

3. FUZZY SIGNIFICANCE AND FUZZY INTEGRAL

Fuzzy significance is a measure indicating the degree of valuation effect of each element or combinations of elements. In this study, the fuzzy significance was used as fuzzy measure. When the measure of two or more sets becomes larger than the simple sum of the measures of the individual sets, we can consider that there is a synergistic effect among these sets. When the measure of two or more sets becomes smaller than the simple sum of the measures of the individual sets, we can consider that there is a compensatory effect among these sets.

Fuzzy integral is a technique for comprehensively evaluating something having two or more elements using the degree of fuzzy significance. The Choquet integral is one form of fuzzy integral and was applied in this research.

4. EXPERIMENT

A. Outline

We conducted two types of experiments by questionnaire.

The object of the first experiment was to evaluate the fuzzy significance of landscape composition elements. Eighty-two students of the Hokkaido University faculty of engineering and 7 bridge designers completed this questionnaire as subjects of the experiment. The students were chosen to representing persons not active in designing. The objective of the survey was to analyze the difference in cognizance of landscape between the students and the bridge designers.

The next experiment involved the subjects evaluating 5 landscape photomontages projected onto a screen, and giving a score to each element. Only the aforementioned students responded as subjects of this experiment. The objective of the survey was to clarify which element the students paid attention to.

Using the data of both the experiments, the Choquet integral was performed. The value of comprehensive evaluation for each landscape photomontage was computed. The most appropriate bridge for the landscape comprising a bridge, a river, buildings and a mountain can be determined by means of the score rankings.

B. Experiment 1

First the subjects were requested to imagine designing a bridge from a designer's viewpoint in a landscape including a river, buildings and a mountain. Photographs and illustrations were not used so that the subjects would not be biased. Secondly, the subjects were asked to comparatively evaluate the bridge, river, buildings, mountain, and their combinations in terms of harmony and to give a score to them. This score was treated as the fuzzy significance. Figure 1 shows the actual scoring method the subjects were required to follow. In order to fulfill monotonicity, we take the view that a landscape will become attractive if more elements harmonize. Thus, the following preconditions are set:

- The landscape where all elements harmonize well is ideal.
- Such a harmonious landscape is given 1.0 point.
- The further the arrow goes downward in Figure 1, the more the score falls.

C. Experiment 2

Five photomontages were made using Photoshop and presented as alternatives. Figure 2 shows one of the photomontages. Each photomontage had the same

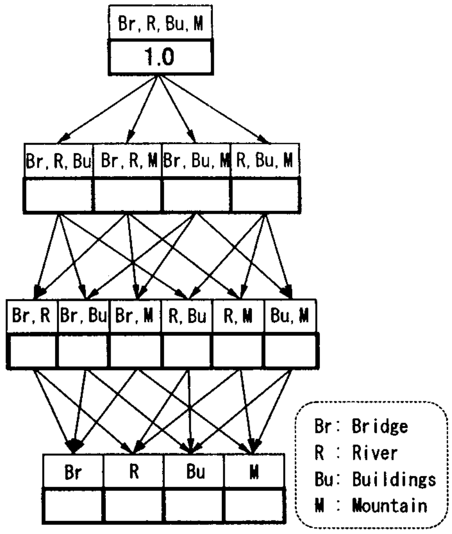

Figure 1. Method of Scoring

Figure 2. Example of Photomontage

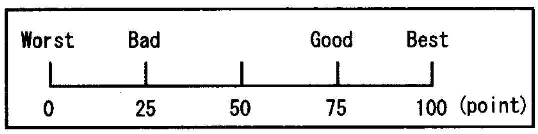

Figure 3. Scale for Rating

landscape composition elements of a bridge, a river, buildings, and a mountain. We changed only the type of the bridge, and kept other elements in the photomontages the same. The subjects evaluated the landscape composition elements and gave a score to each of the elements separately. The bridges used for the photomontages were pictures taken from the angle at which the bridges may be seen in the most comprehensible shape. The river, the buildings, and the mountain pictures were taken to be suitable for the size and the angle of the bridges. The scale shown in Figure 3 was used for rating. The subjects were asked to judge whether the harmony of each element was good or bad and to rate them.

5. RESULT

A. Result and Discussion of Experiment 1

Figure 4 shows the average of the fuzzy significance obtained from the subjects. It clarifies that the students and the bridge designers responded to the compensatory effects among all elements because the fuzzy significance of individual elements is high and that of their combinations is low. Individual elements do not increase the attractiveness of the landscape in aggregate with each other but rather reduce it compensatively. The bridge designers have the tendency to think that "River" and "Mountain" are more important than "Bridge" while the students have the tendency to think that "Bridge" is important. This is because the bridge designers think that the elements of nature are more important than the "Bridge" element.

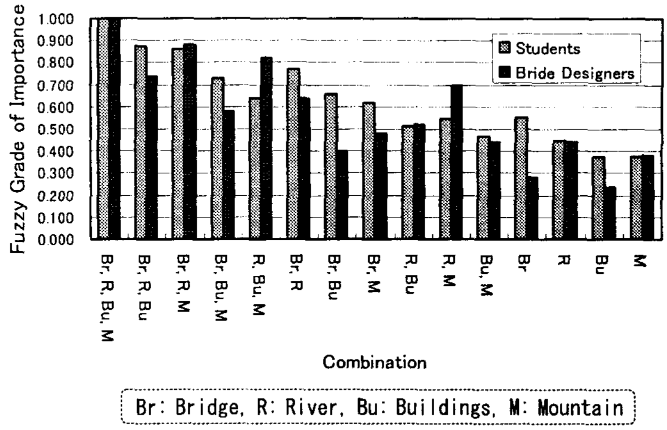

Figure 4. Comparison of Average of Fuzzy Grade of Importance

B. Experiment to Confirm the Reliability

To confirm the reliability of the data obtained from Experiment 1, another experiment was conducted. Forty-six students of the Hokkaido University faculty of engineering, different from those of Experiment 1, responded to this questionnaire as subjects of the experiment. The fuzzy significance obtained from Experiment 1 was evaluated by the method where the score of the upper bound is assumed to be 1.0. There is a possibility that the fuzzy significance will not decrease in a desirable fashion and the fuzzy significance of individual elements will be high. Figure 5 shows the method where the score of the upper bound is not decided. A T-test was conducted to compare the fuzzy significance obtained from this experiment with that from Experiment 1. As a result, no significant difference was seen between them. Moreover, Figure 6 clarifies that the students also responded to the compensatory effects among all elements in this experiment, also. Therefore, it can be said that a person's subjectivity may be expressed accurately to some degree by the method of Experiment 1.

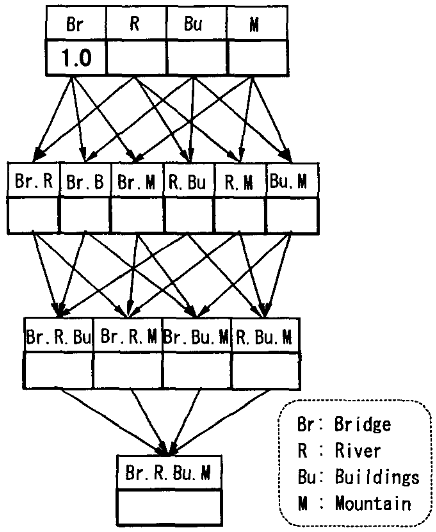

Figure 5. Method of Not Deciding Score of Upper Bound

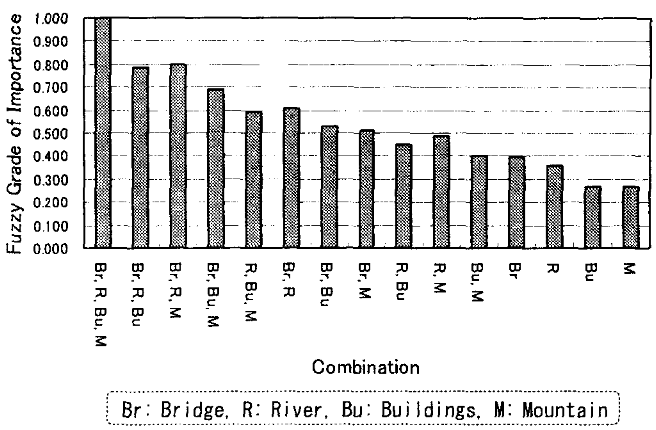

Figure 6. Average of Fuzzy Grade of Importance in Experiment to Confirm Reliability

C. Result and Discussion of Experiment 2

Figure 7 shows the average score for each of the elements obtained from the students. The score for "Bridge" changes greatly with each type. Change in the score for the background elements is smaller than that for "Bridge". "Buildings" shows low scores in all photomontages. This element is not paid so much attention in the landscape which includes a bridge. Conversely, the scores for "River" and "Mountain" are high. These elements are paid more attention.

Using the score and the fuzzy significance obtained from Experiment 1, the Choquet integral was analyzed using the following combinations.

-The score and the fuzzy significance of the students

-The score and the fuzzy significance of the bridge designers

Figure 8 shows comparisons of the values of comprehensive evaluation. The value of comprehensive evaluation for each of the photomontages was computed. It can be said that the value of the comprehensive evaluation represents the harmony in the photomontages. The landscapes including the arch bridge, the beam bridge, and the cable-stayed bridge (1) obtained relatively high values of comprehensive evaluation. Change in the value of comprehensive evaluation by the students in Figure 8 and that of "Bridge" in Figure 7 are almost the same. This is because the fuzzy significance of "Bridge" for the students is high. Change in the value of comprehensive evaluation by the bridge designers is smaller than that of the students. This is because the fuzzy significance of "Bridge" for the bridge designers is low, whereas those of "River" and "Mountain" are high.

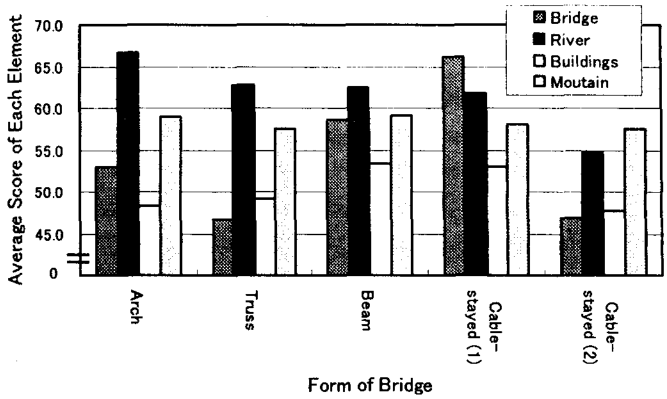

Figure 7. Average Score of Each Element According to Bridge

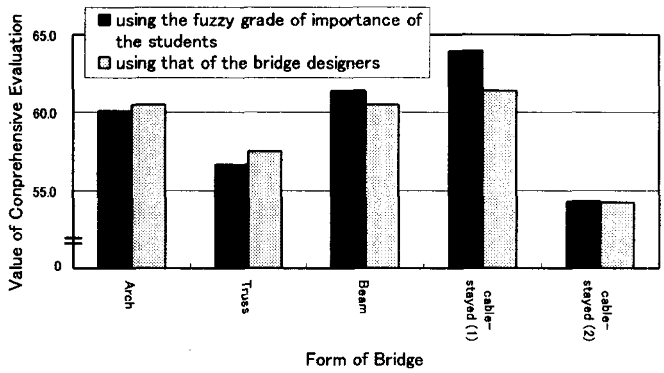

Figure 8. Comparison of Value of Comprehensive Evaluation

6. Summary

The results of Experiment 1 clarified that there were compensatory effects within all of the combinations of the elements. Comprehensive evaluation scores were not as high as the summed scores of individual elements. For example, the score for the combined evaluation of "Bridge" and "River" is lower than the sum of individual scores for "Bridge" and "River".

The results of Experiment 2 showed that the landscapes including the arch bridge, the beam bridge, and the cable-stayed bridge (1) acquired relatively high values of evaluation. The beam bridge and the cable-stayed bridge (1), which obtained high scores in Experiment 2, have simple forms and do not interfere with the other landscape composition elements in this case. The compensatory effect, due to the different natures of the elements, greatly affects the relation between the structure and the background. It was clarified that the cable-stayed bridge (1) and the beam bridge may be considered to be good structures under the given conditions.

Only the compensatory effect was measured among the structure and other landscape elements in this study. In our future research, we have to conduct investigation that confirms the existence of structures with synergistic effect.

References

[1] Teramoto, T., Kagaya, S., Uchida, K. and Hagiwara, T., A Study on the Evaluation Techniques for Landscape of Bridge Locations, Proceedings of the Annual Conference of the Japan Society of Civil Engineers, vol. 56th, pp. 42-43, 2001

[2] Inoue, K. and Anzai, T., A Study on the Industrial Design Evaluation based upon Non-addite Measures, Proceedings of 7th Fuzzy System Symposium, pp. 521-524, 1991

[3] Matsumoto, M., Wada, T., Takahagi, E. and Shingu, K., Beauty Evaluation of Houses Using Fuzzy Theory -Introducing of Evaluation Using Transactional Analysis-, Proceedings of 17th Fuzzy System Symposium, 2001