EVALUATION METHOD OF ROAD ENVIRONMENT CONSERVATION MEASURES

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abstract: We propose a method of evaluating the environmental conservation measures for the road environment. At first, environmental evaluation functions are proposed for environmental factors. Next, we introduce a general environmental evaluation index, which integrates weighted environmental evaluation indices. Then we show some planning models for the environmental conservation measures considering cost and effect. One is an evaluation method using cost and effect ratio, and another is one using a distribution graph of the cost and effect. Finally, we examine the applicability of the models through case studies.

1. INTRODUCTION

The road traffic causes environmental problems such as noise, air pollution and so on. Mitigation measures of these problems have to be considered in the course of road construction. To conserve the road environment effectively and efficiently, it is necessary that the environmental conservation measures should be appropriately evaluated taking account of cost and effect of the measures. In this study, we propose a method of evaluating the environmental conservation measures for the road environment. The structure of the method is shown in Figure 1.

At first, environmental factors concerned with the roadside living environment are selected as follows: traffic noise, air pollution, landscape, community severance, obstruction of sunshine and so on. For these environmental factors, environmental evaluation functions are proposed taking account of these environmental quality standard.

Secondly, we review the environmental conservation measures: noise barriers, changes of road structure from a plain road to embankment, cut, and viaduct road, a buffer zone and so on. Further, conservation effects of the measures are estimated using the environmental evaluation functions above.

On the basis of these results, we indicate how to express the conservation effect of various measures introducing a general environmental evaluation index, which integrates weighted environment evaluation indices for the environment factors.

Then, we show some planning models for the environment conservation measures considering cost and benefit. One is an evaluation method using cost-benefit ratio, and

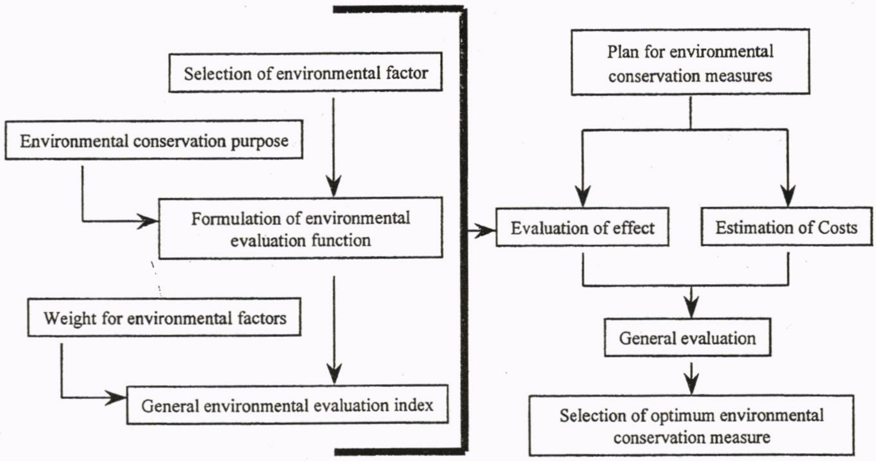

Figure 1 Structure of the method of evaluating the environmental conservation measures

another is one using a distribution graph of the cost-benefit.

Finally, we examine the applicability of the models through case studies.

2. SELECTION OF ENVIRONMENTAL FACTORS AND FORMULATION OF ENVIRONMENTAL EVALUATION FUNCTIONS

The environmental factors are selected, referring to a prediction and an evaluation method that has been already established, in these viewpoint: the effect of the factor on the roadside environment is apparent and can be weighed. In the study, eight factors are selected as environmental factors, such as air pollution, traffic noise, a vibration, a obstruction of sunshine, tree planting, landscape, community severance and oppressive feeling.

Then, let us introduce an environmental evaluation function. It is formulated for every environment factors. It converts the measured value of each environmental factor into a environmental evaluation index. In the study, it is represented in the dimensionless numerical value from 0 to 10, where 0 represents a very bad state, 10 represented a state that it does not almost have bad effects.

The environmental evaluation functions for the factors which are able to be quantified, such as air pollution, traffic noise, a vibration, the obstruction of sunshine and tree planting, can be determined in the following way, referring to the method proposed by Drenovski (1974) ; It is assumed that marginal utility of measured values increases (or decrease) at the constant rate for increase or decrease of measured values in the available range. That is, the function can be described in the quadratic function.

The function can be decided univocally, because evaluation index becomes 0 when measured

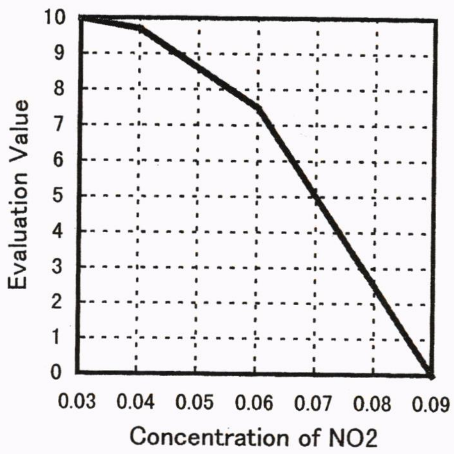

Figure 2 Environmental evaluation function as for air pollution

Table 1 Example of environmental evaluation index for unmeasurable factors

	plain	embankment	cut	viaduct	semi-underground
Landscape	5.5	2.0	6.0	3.0	6.5
Community Severance	4.0	2.0	5.0	3.0	6.0
Oppressive feeling	7.0	4.0	7.0	2.0	7.0

value becomes minimum(or maximum), 10 when maximum(or minimum), furthermore an increase of utility becomes 0 when evaluation index becomes 0. Then, the point that corresponds to an environment standard, etc. is dropped on the curve of the function. This point is joined to maximum (and minimum) value mentioned above in the straight line. (Marginal utility is made conveniently constant for increase or decrease of a measure value in each straight line section.)

An measured value for the environmental factors is used as follows: Nitrogen dioxide concentration(ppm) as for the air pollution, the noise and vibration level (dB) as for the noise and vibration, the hours of sunlight as for obstruction of sunshine, and the road width that can be planted with the trees is used as for the tree planting. The function for air pollution is shown in Figure 2 as an example of these functions. And, as for landscape, community severance and an oppressive feeling, that are unmeasurable item, an evaluation index are set discretely by road structure as Table 1.

3. FORMULATION OF GENERAL ENVIRONMENT EVALUATION FUNCTION

A general environmental evaluation index is obtained by totaling the environmental evaluation index of every factor, which is determined by an environmental evaluation function, multiplying each weight (Keeney and Raiffa 1976).

$$\text{General environment evaluation index} = \Sigma Xk \cdot Dk$$

Where Xk is a weight of factor k and Dk is the environmental evaluation index of factor k.

Table 2 Weight of environmental factors

	Questionnaire to inhabitants	Questionnaire to learned and experienced persons
Noise	0.282	0.237
Air pollution	0.261	0.168
Vibration	0.162	0.122
Oppressive feeling	0.113	0.090
Community Severance	0.098	0.114
Landscape	0.043	0.078
Tree planting	0.033	0.082
Obstruction of Sunshine	0.008	0.109

The methods deciding a weight of factor are arranged by Fishburn(1967), Hobbs and Voelker(1977). In the study, a weight of the environment evaluation item is obtained from the questionnaire to inhabitants in 1992 shown in Table 2. In the Table, the result of similar questionnaire to men of learning and experience carried out by another institute is shown. The weight values of each factor have the similar tendency between the questionnaires. However, the weight value of questionnaire to inhabitants is larger than to men of learning and experience as for the obstruction of sunshine and tree planting, and it is opposite as for air pollution.

4. EFFECT AND COST OF ENVIRONMENTAL CONSERVATION MEASURES

We arrange effects of various environmental conservation measures on each factors as shown in Table 3. The effects on the environmental factors can be evaluated quantitatively in consideration of a road structure and a traffic condition by using these relations. Then, the environmental evaluation index and the general evaluation index can be calculated by the

Table 3 Effects of Environmental Conservation Measures on Environmental factors

		Environmental factor*							
		A	N	V	S	T	L	C	O
Vehicle-related measures	structual improvement	O	O	-	-	-	-	-	-
	tire cover	-	O	-	-	-	-	-	-
Road structure measures	structual improvement	O	O	O	x	O	x	x	x
	noise barrier	O	O	-	x	-	x	-	x
	low noise pavement	-	O	-	-	-	-	-	-
	buffer zone	O	O	O	O	O	O	x	O
	noise absorption panel	-	O	-	-	-	-	-	-
Roadside measures	buffer building	-	O	-	-	-	-	-	-
	soundproof works for residences	-	O	-	-	-	-	-	-
	noise absorption panel	-	O	-	-	-	-	-	-
Traffic flow measures	speed regulation	#	O	O	-	-	-	-	-
	traffic regulation	O	O	-	-	-	-	-	-

*) A:Air pollution, N:Noise, V:Vibration, S:Obstruction of Sunshine,
T:Tree planting, L:Landscape, C:Community Severance, O:Oppressive feeling
O:Good Effect, x:Bad Effect, #:depend on occasion, -:no (little) effect

method shown in sections 2 and 3.

And, the cost of environment conservation measures can be calculated based on the following steps:

(a) Strengthening of regulation on noise and gas emission: the reconstructive cost of the vehicle that runs a certain length of road section.

(b) A change of road structure: construction cost and land acquisition cost when the plain road is reconstructed to other road structure.

(c) The low noise pavement: difference of the construction costs between the ordinary dense asphalt pavement (twice /20 years) and the low noise pavement (10 times /20 years).

(d) Buffer zone: the construction cost and the land acquisition cost that are needed for establishment of the buffer zone of 20 m in width.

(e) Soundproof works for the residence: the cost of the soundproof works for ten existing wooden houses in 100 m of road section.

5. EXAMINATION OF GENERAL EVALUATION TECHNIQUE

We should choose the optimum conservation measure by evaluating the measures using a general environment evaluation index and its cost. The followings are the general evaluation models:

(a) Environmental conservation measures with high general environmental evaluation indices are chosen, and the optimum conservation measure is selected from viewpoints of cost, applicability, etc.

(b) Method by cost and benefit rate

The environmental conservation measures that have high cost and benefit (i.e. general environment evaluation index) rate are chosen, and the optimum measure is selected from viewpoints of applicability, etc.

(c) Method by a distribution graph of cost and benefit.

a. Evaluation by the mean values of cost and benefit

A distribution graph in which cost and benefit are variables about various environmental conservation measures is created, and the mean values of cost and benefit are obtained individually. The optimum conservation measure is selected in consideration of the applicability, etc. from the several measures that are in the quadrant of the graph in which cost is less than the average and benefit is more than the average.

b. Evaluation by a recursive straight line

A recursive straight line determined from several environmental conservation measures is drawn in a distribution graph, and the optimum measure is selected in consideration of the applicability, etc. from the measures that are positioned in a part upper than the recursive straight line.

(d) Paying attention to individual environmental factors

The measures that satisfy the criteria in terms of individual environmental factors, such as environment quality standards, are selected from several environmental conservation measures that are chosen by the above methods.

6. CASE STUDY

A case study was carried out for applicability of the general evaluation models mentioned above to several roads with different characteristics, such as road function, land use along the road. A result of the case study using the distribution graph for the bypass of National Route 17 (a plain road with commercial, industrial and residential district in its roadside area) is shown in Figure 3. In the figure, where the origin shows the situation of the road at present, and a change of the general environmental evaluation index and the cost of conservation measures are plotted. Seeing the graph, installation of noise barrier (3m or 5m in height) and construction of buffer building are considered to be the optimum measures from viewpoints of the change of general environmental evaluation index(higher than the average), and the cost(lower than the average). Especially, the cost and benefit rate of the installation of noise barrier (3 m in height) is the highest.

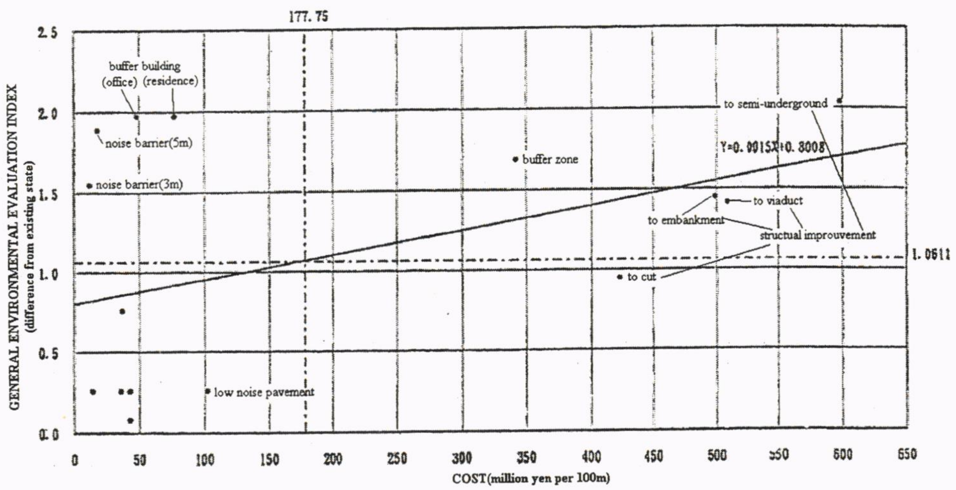

Figure 3 Result of Case Study

7. REMAINING ISSUES

Cost is expressed in the amount of money and benefit is evaluated as a general evaluation index of dimensionlessness respectively in the general evaluation model. However, if we refine the general evaluation model further, it is necessary to convert the environmental evaluation index into the cost as a general evaluation model or to convert the cost into the environmental evaluation index. Furthermore, it is necessary to weigh degree of realization considering the situation of a construction site.

REFERENCES

Dorenovski (1974) On Meaning and Planning the Quality of Life, Vitgeverig Monton & Co.B.V.

Fishburn (1967) Methods of estimating additive utilities, **Manage. Sci., 13(7)**, 435-453

Hobbs and Voelker (1977) Analytical Multiobjective Decision-Making Techniques and Power Plant Silting: A Survey and Critique, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Keeney and Raiffa (1976) Decision with Multiple Objectives: Preferences and Value Tradeoffs, John Wiley & Sons, New York.