possible through appropriate gear installation; gear with a speed of 4 mm/ min was used with the jacks in our test program.

SAMPLE TEST RESULTS

The apparatus was used for measuring direst shear strength of MSW in a closed MSW site near Islamabad, Pakistan. To avoid preparation of new specimens and to eliminate effects of sample variability, specimen were sheared repeatedly under increasing normal stresses of 6 kPa, 13 kPa, and 20 kPa at relative displacements of 2%, 3%, and 4% strains. Sample test results are shown in Figure 13 and 14.

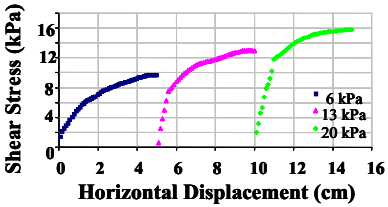

FIG. 13. Shear Stress vs. Horizontal Displacement.

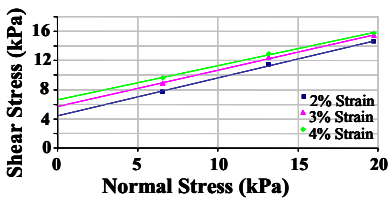

FIG. 14. Shear Stress vs. Normal Stress (C = 6.63 kPa, Φ = 25.07^{O}).

CONCLUSION

Presently construction of structures over closed MSW sites is very rare because of the lack of understanding of the geotechnical behavior of MSW sites and absence of suitable apparatus to evaluate their strength and settlement characteristics. The apparatus proposed in this paper can be manufactured with little technical skill. The results obtained from the apparatus are real representative of the shear strength of MSW at the particular site.

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Feasibility Analysis for the Ecological Sustainability of Engineering Construction of the Express

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ABSTRACT：This research is based on three different views of the industry, academic and government. Our assessment criterion goals were five dimensions of "the utility aspect", "the economic aspect", "the adoption principle", "the working-method characteristic" and "the environmental condition". Using each representative detailed item from the experts' interviews and literature reviews, and utilizing Fuzzy Delphi Method（FDM）and Fuzzy Analytic Hierarchy Process（FAHP）, we get the comprehensive performance with relative weighted index. Applying the Matrix Law of Value, we compare the comprehensive performance value of traditional method and ecological method which are applied to construct national roads. We find that the ecological method of building national roads is feasible and is better than the traditional method.

INTRODUCTION

The frequent economic development activity in Taiwan, have caused the destruction of the ecological environment. The great killer to the environmental ecology is that the road is frequently excavated and filled out. Using the ecological method on the national road, we should assess slope protection, drainage, case content, bridge, tunnel, retaining wall, bar, illumination, serving area, overpass, ecological corridor, ecological buffering area and the management of construction. The main purpose is to reduce the negative impact upon the ecological environment of the road construction, and to keep environmental sustainability. This research is from the view of road construction and environmental protection. Basing on ecological knowledge and ecological engineering, we compare the relative advantages of the traditional method and ecological method applied to the feasibility of the national road construction.

Construction of fuzzy AHP hierarchy

We approached the key dimensions of the evaluation criteria of ecological sustainability through comprehensive investigation and consultation with several experts, including two professors in civil engineering, two professors in construction engineering, three experienced ecologists and five experienced staffs in professional procurement of the government department. These individuals were asked to rate the accuracy, adequacy and relevance of the criteria and to verify their ‘‘content validity’’ in terms of ecological sustainability assessment. Synthesizing the literature review such as Chiou and Tzeng（2001）; Bergen et al.（2001）; Forman（1998）; we develop the hierarchical structure used in this study.

There are five dimensions of evaluation, including Economy, Utility, Adoption Principle, Method and Environment. From these, 20 evaluation criteria for the hierarchical structure were used in this study. (See 1,2nd column in table 1)

Table 1. Fuzzy triangular membership function of evaluation criteria

Dimensions	Criteria	Min.	Geo. mean	Max.	State
Economy	Unit building cost	6	8.51149	10	
	Maintenance cost	3	8.00825	10	
	Amount of the budget	5	8.22011	10	
	Durable service life	2	5.43613	10	Delete
Utility	Improvement of efficiency	2	6.58376	9	Delete
	Reduction of maintenance cost	1	3.56975	9	Delete
	Function of the landscape road	5	8.00792	10	
	Effect of construction method	7	8.00932	9	
Adoption	Practicability	5	7.05083	10	Delete
Principle	Security	3	6.11813	9	Delete
	Gracefulness	6	8.41042	10	
	Economy	6	8.00294	10	
Method	Concept of ecology	8	9.53102	10	
	Artistic vision	7	8.70345	10	
	Future major trend	6	8.01244	10	
	Compare with the tradition	4	6.37751	9	Delete
	Difficult degree of construction	3	6.53467	9	Delete
Environment	Geometry conditions of the road	8	9.27172	10	
	Cooperate with other environment	7	8.64017	10	
	Natural weather conditions	4	7.01487	9	Delete

Selection of evaluation criteria

This research is to investigate face-to-face interview with 6 scholars, 7 industry professionals and 7 government experts of Highway Administration Bureau.

According to the definition of Laarhoven and Pedrycz（1983）, a triangular fuzzy number (TFN) should possess the following basic features. A fuzzy number A on R will be a TFN if its membership function, $\mu_{\tilde{A}}(x)$: R – $[0,1]$ is equal to

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-L)/(M-L), \ldots\ldots L \le x \le M \\ (U-x)/(U-M), \ldots\ldots M \le x \le U \\ 0, \ldots\ldots\ldots\ldots\ldots\ldots \ldots otherwise \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, L and U stand for the lower and upper bounds of the fuzzy number $\tilde{A}$ respectively, and M for the modal value (geometric mean).

(1) If M_A S, Accept influence factor A which is an evaluation criterion.

(2) If M_A < S, Reject influence factor A.

Where M_A is a decision group to the influence factor A, S is a threshold value whose size will influence the choice numbers of assessment criteria. General research mostly takes S =0.8, that is the most important assessment criterion.

After passing through Fuzzy Delphi Method, numbers of the overall criteria were reduced originally from 20 into 12, deleting 8 criteria which did not have the representative appraisal. The structure of the evaluation criteria after deleting is shown in Fig.1.

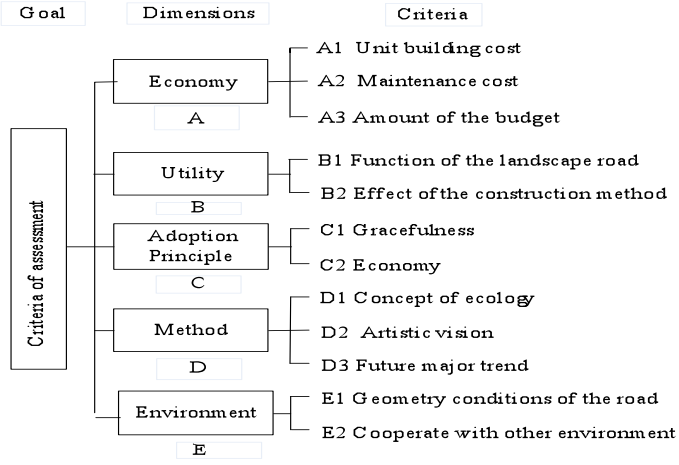

Fig. 1. The structure of AHP for ecological sustainability applied to road

ANALYSIS, FINDINGS, AND DISCUSSION

Ranking the fuzzy number

It is necessary to nonfuzzify ranking for fuzzy numbers in table 3 for comparison of each criterion（Hsieh et al. 2004）. The procedure of defuzzification (DF) is to locate the Best Nonfuzzy Performance value (BNP) by equation (1):

$$DF_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i \qquad \forall i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

According to the value of the derived DF or BNP for each criterion, the ranking of each criterion can then proceed as shown in table 2.

Table 2. Ranking fuzzy weight of assessment dimensions

Dimensions	Min.	Geo. mean	Max.	DF.	Rank
A Economy	0.0711	0.1706	0.4207	**0.2208**	2
B Utility	0.1042	0.1407	0.3107	**0.1852**	5
C Adoption Principle	0.0992	0.1774	0.3487	**0.2085**	4
D Method	0.1150	0.2317	0.4246	**0.2571**	1
E Environment	0.0785	0.1773	0.3730	**0.2096**	3

Comparing comprehensive performance

Five kinds of different facilities are the research object that enumerated respectively to the traditional method and the ecological method, as table 3 shows. Experts and scholars interviewed give subjective evaluation in 5 grades to facilities as shown in table 3. Normalizing the sample data, we carry on the calculation of performance value（Zadeh 1973）. The result is shown in table 4 and table 5.

Table 3. The sample data of the third stage questionnaire

Facilities \ Criteria	Economy	Utility	Adoption Principle	Method	Environ.
:Pavement of traditional method (T1)	2	2	3	2	2
●:Pavement of permeability (E1)	(4)	(4)	(4)	(4)	(4)
:Retaining wall of anchor (T2)	1	2	1	1	2
●:Retaining wall of frame (E2)	(5)	(4)	(5)	(4)	(3)
:Slope protection of spray (T3)	3	2	2	2	2
●:Slope protection of grille (E3)	(4)	(4)	(4)	(5)	(3)
:Cutting of excavation (T4)	2	2	3	3	2
●:Tunnel (E4)	(3)	(4)	(4)	(4)	(4)
:Pavement of asphalt concrete (T5)	2	1	2	1	2
●:Pavement of chain brick (E5)	(4)	(5)	(5)	(5)	(4)

Note: : Traditional method; ●: Ecological method

Retracing the data to an expert's questionnaire, we calculate:

$$Scoring.value = X_i \times 100 \Big/ \sum_{i=1}^{n} X_i = Q_i \quad (2)$$

1. Traditional method: Pavement of traditional method

$$2\times100/(2+1+3+2+2+4+5+4+3+4)=6.67$$

2. Ecological method: Pavement of permeability

$$4\times100/(2+1+3+2+2+4+5+4+3+4)=13.33$$

Table 4. Scoring value of satisfying degree in selection samples

Facilities \ Criteria	Economy	Utility	Adoption Principle	Method	Environ.
:Pavement of traditional (T1)	6.67	3.45	9.38	6.45	7.14
●:Pavement of permeability (E1)	(13.33)	(13.79)	(12.50)	(12.90)	(14.29)
:Retaining wall of anchor (T2)	3.33	6.90	3.13	3.23	7.14
●:Retaining wall of frame (E2)	(16.67)	(13.79)	(15.63)	(12.90)	(10.71)
:Slope protection of spray (T3)	10.00	6.90	6.25	6.45	7.14
●:Slope protection of grille (E3)	(13.33)	(13.79)	(12.50)	(16.13)	(10.71)
:Cutting of excavation (T4)	6.67	6.90	9.38	9.68	7.14
●:Tunnel (E4)	(10.00)	(13.79)	(9.38)	(12.90)	(14.29)
:Pavement of asphalt concrete (T5)	6.67	3.45	6.25	3.23	7.14
●:Pavement of chain brick (E5)	(13.33)	(13.79)	(15.63)	(16.13)	(14.29)

$$Performance.value = \sum_{i=1}^{5} DF_i \times Q_i \quad (3)$$

Pavement of traditional method:

$$(0.2208\times6.67)+(0.1852\times3.45)+(0.2085\times9.38)+\cdots+(0.2096\times7.14)=7.22$$

Pavement of permeability:

$$(0.2208\times13.33)+(0.1852\times13.79)+(0.2085\times12.50)+\cdots+(0.2096\times14.29)=14.22$$

Table 5 Comprehensive performance value of different methods

Traditional method	Pavement of traditional	Retaining wall of anchor	Slope protection of spray	Cutting of excavation	Pavement of asphalt concrete	Average
Ecological method	Pavement of permeability	Retaining wall of frame	Slope protection of grille	Tunnel	Pavement of chain brick	
Performance Value	7.22 (14.42)	4.99 (15.05)	7.94 (14.50)	8.69 (13.03)	5.74 (16.57)	6.92 (14.71)

Feasibility analysis of ecological method

Fig. 2 shows the comprehensive performance value that the traditional method and ecological method are used to assess five kinds of different project facilities of national road. We find the superiority of ecological method basing on the following:

1. Three kinds of experts such as government department, scholar and industry reflect that the ecological method maps to the higher performance value of engineering construction of national road unanimously.
2. The average performance value shows that “pavement of permeability” is higher than “pavement of traditional method”, “retaining wall of frame” is higher than “retaining wall of anchor”, “slope protection of grille” is higher than “slope protection of spray”, “tunnel” is higher than “cutting of excavation” and “pavement of chain brick” is higher than “pavement of asphalt concrete”. This shows the ecological method is superior to the traditional method in the engineering construction of national road.

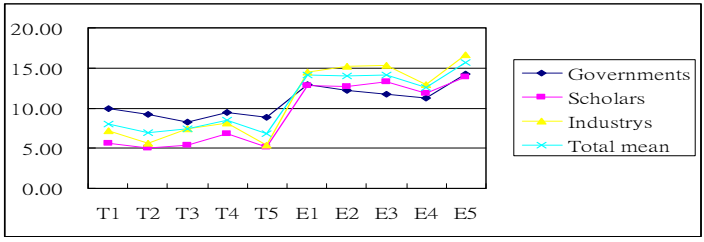

Fig. 2 Performance value of different experts’ group

CONCLUSIONS

In recent years, advanced countries advocate that the ecological method, could maintain the structure and function of the natural ecosystem to ensure the human security and to reach the ideal sustainability at the same time. We find that the ecological method of “the slope protection”, “retaining wall “, “drainage facilities”, ”tunnel “and “serving area” of national road can offer better satisfaction than the traditional method . The comprehensive performance value of the ecological method is 14.71 which is superior to the traditional method of 6.92. This implies that the ecological method on the road construction deserves extensive adoption.

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Ant Colony Optimization Algorithm for Vertical Alignment of Highways

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ABSTRACT: Based on discrete theory, this article tries to develop an optimization methodology to produce an optimum vertical highway profile for a pre-selected horizontal alignment. The aim of the program was to establish an initial vertical alignment according to discreet ground elevation of station. Considering the discreet characteristic of the ground elevation and the intersection point of grade line, a discrete model is presented. The automatic design problem is set to select the number, location and elevation of the intersection point of the grade line after considering several designing constraints. To solve the constrained nonlinear problem, an ant colony optimization algorithm is adopted to select the roadway grades that minimize the earthwork cost and satisfy the geometric specification. A numerical example is presented to illustrate the application of the program.

1. INTRODUCTION

The alignment design of roadway normally involves the vicissitudinary applications of two elements: the horizontal design and the vertical design. The two parts would be employed by turn for many times before the final alignment of the roadway could be established. Usually, the vertical alignment design is based on a pre-selected horizontal alignment. The horizontal alignment could provide the related data of road centerline and some necessary parameters to the automatic design of vertical alignment. Following a certain algorithm we could turn to the vertical alignment automatically with the help of computer by using the ground data and parameter provided by the horizontal alignment. To realize this idea, many scholars devoted to researches involving the following algorithm: enumeration, dynamic programming, linear programming, and genetic algorithms.

Enumeration has been employed by Easa (1988). The searching process is exhaustive. the dynamic programming (Goh et al., 1988; Fwa, 1989) is more effective and better than before. The method makes it possible to optimize the grade change point and the position of the elevation, obtaining the best railroad vertical section design. However, when it comes to three-or-more-dimension cases, the model could not cope with problems caused by the advanced time and space complexity. For the

two-dimensional problem, the memory requirement for it is approximately of O(n·m), while the computational times is of O(n ·m^2). If applying it in a higher dimension situation, computation is not able to be carried out

Another alternative approach for the problem is to regard the road profile as a continuous function, such as a spline function to simulate alignments and turn it into a constrained nonlinear programming problem. After all, the function curve is quite different from the alignment of roadway.

The linear programming approaches (ReVelle et al., 1997; Chapra and Canale, 1988; Fwa, 1989) were used for vertical alignment optimization. The approaches employed much more simplified assumptions to establish a model which was adapted to linear programming approaches. However the computing ability was limited.

Numerical Search (Goh et al., 1988; Fwa, 1989)is effective ,but there exist some local optimal in the search space.

Genetic Algorithms: Jong (1998) employed genetic algorithms for vertical alignment optimization. Only in the condition that the preliminary design is given and the number of intersection points (grade change points) is determined, the algorithm could carry on. But actually, the computer, not given by an engineer, should calculate the number of intersection point out.

Ant colony optimization algorithm is a kind of important intellectual colony optimization algorithm, ant colony optimization algorithm was established initially by Dorigo (1997, 1999), an Italian scholar. Its basic idea is that ant individuals deliver the information by the pheromone. When an ant is crawling, it will not only release its own pheromone which would gradually disappear at a certain velocity on its route, but also detect the circumstance nearby to figure out whether the pheromone exists or not. An ant adopts a kind of positive feedback mechanism, if more ants had chosen this route, there will be more pheromone left on the route, and this route also will lead more ants to select it, creating a higher pheromone. So the final result is that ants form an optimum route.

Ant colony optimization algorithm can provide solution to many intractable NP-hard optimization problems. It has its own advantage in solving the complicate combination optimization, with huge parallelism, positive feedback and robustness. A great deal of literature shows that the ant colony optimization algorithm had successfully worked out the following combination optimization problem: Traveling salesman (TSP), Vehicle routing (VRP), Job shop scheduling (JSP) and so on.

If the vertical alignment automatic optimization is built into a model with discrete idea, it could be seen as the problem of combinational optimization essentially. Thus, we could use the ant colony optimization algorithm to seek a route effectively. This paper is set to solve the problem of vertical alignment automatic optimization with the help and development of ant colony optimization algorithm.