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USING FUZZY LINEAR OPTIMIZATION TECHNIQUE AS AN AID TO RURAL ROADS INVESTMENT PLANNING

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1. INTRODUCTION

Owing largely to the constraints of limited budget, vis-a-vis massive road rehabilitation needs, road planning agencies, particularly those of developing countries, are under obligation both nationally and internationally to spend their budgets effectively.

The development and implementation of tools for road investment planning is, however, beset with difficulties. The major problems include, i). Uncertainties about future conditions, ii). Data-related issues, particularly in developing countries, such as insufficient, inexact and vague data and, iii). Trade-off between complexity of analytical techniques and comprehensibility.

The objectives of this study are:

1. To present the rural roads investment planning problem as a resource allocation problem (budget optimization).

2. To explore the use of Fuzzy Linear Optimization techniques to handle the uncertainties and data related problems.

3. To apply the techniques to Offinso District in Ghana.

2. APPROACH

2.1 The budget allocation Problem

The main objective of rural roads investment (rehabilitation and maintenance in this study) is considered to be to increase rural accessibility. Considering the accessibility situations "with" and "without" road investment, the increase in accessibility may be measured via savings in travel time. The investment decision can be expressed as a budget allocation problem, namely:

$$\text{Max } Z = \Sigma P_i [k_1 X_i (V_{iom})^{-1} + k_2 X_i (V_w)^{-1} - 365 X_i (V_{iam})^{-1}] \quad (1)$$

$$\text{S.T.} \quad \Sigma a_i X_i \leq b \quad .....(2)$$

$$0 \leq X_i \leq U \quad .....(3)$$

Where: k_1, k_2 = number of passable and impassable days, respectively, in a year

V_{iom} = average vehicle speed, without road improvement(km/hr)

V_{iam} = average vehicle speed, with road improvement

V_w = average walking speed (km/hr)

a_i = average cost of improving 1 kilometer of road

X_i = the length of link to be improved

U = upper limit of X_i

2.2. **Limitations** : Application of the model in (1) - (3) is limited. Let us consider three practical situations in developing countries.

Case I : Violations of budget and/or aspiration level are tolerated to some limit. **Case II** : The exact values of the parameters of the problem are not known. **Case III** : The exact relationship between road investment and the objective function value (accessibility increase in our case) is not known.

2.3. **The Fuzzy Sets Approach:** Fuzzy Sets Theory allows us to cope with all these situations in an efficient way. The modeling aproaches and solution methods adopted in this study are summarized in Table 1.

Table 1: Modeling Approach and Solution

CASE	MODELLING APPROACH	SOLUTION METHOD
1	Flexible Programming	Zimmermann's Approach
2	FLP With Fuzzy numbers	WKT Approach
3	Fuzzy Relation	Wierzchon's Approach

3. RESULTS OF APPLICATION TO OFFINSO DISTRICT IN GHANA AND CONCLUSION

3.1 **Crisp LP:** Results indicated the optimal selection of roads, given a budget of 120 Million Cedis, and a maximum time savings of 2,154,800 man-hours.

3.2 **Case I:** Results are summarized in Table 2

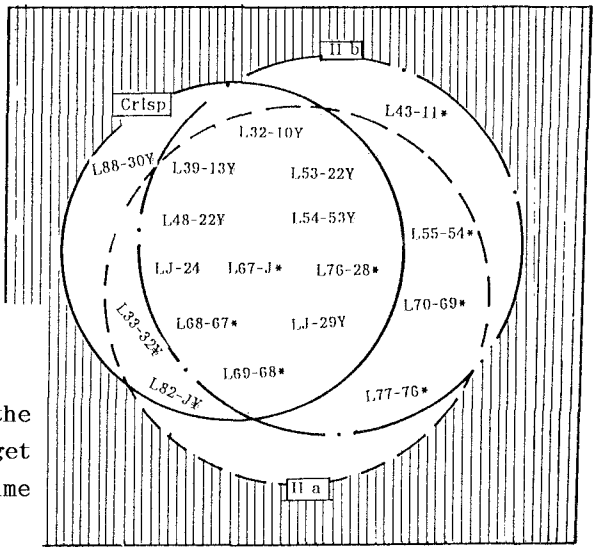

Figure 1 Selection of Roads in Case II Relative to Selection in Crisp LP Case

Table 2: Results of Case I

CASE	ASPIRATION LEVEL	VIOLATION TOLERABLE	BUDGET	VIOLATION TOLERABLE	CHANGE IN ROADS	SATISFACTION INDEX
1 a	2,154,800	No	120 m	Yes	No	1.0
1 b	2,154,800	No	Reduced	Yes	No	<1.0
1 c	2,154,800	No	Increase	Yes	Yes	1.0
1 d	2,154,800	Yes	120 m	No	No	<1.0
1 e	Reduced	Yes	120 m	No	Yes	1.0

3.3 **Case II:** It was further divided into

IIa: Assuming accessibility increase will certainly be greater than 2,154,800, and budget available will be possibly not less than 120 Million Cedis.

II: Assuming accessibility increase will be possibly not less than 2,154,800 and the available budget possibly greater than 120 Million Cedis.

In the pessimistic case, there is no feasible solution. The results of the optimistic case are indicated in Figure 1.

3.4 **Case III:** The results are summarized in Table 3.

The significance of Fuzzy Linear Optimization techniques to rural roads investment planning , as illustrated in this study, cannot be gainsaid. It has enabled us to handle uncertainties and data-related problems inherent in road investment planning. Multiple criteria situations can also be handled by this approach and this will be the direction of future research.

Table 3: Results of Case III

Degree of Satisfaction	Objective Function Value (Accessibility increase)		Remarks
	a	b	Change in Road Selection
1.0	2154.734	2154.734	No
0.8	2176.288	2133.098	〃
0.6	2197.876	2111.650	〃
0.4	2220.706	2090.105	〃
0.2	2240.924	2068.560	〃
0.0	2262.476	2047.005	〃

a= α -Inter-Nondominated Alternative
b= α -Inter-Dominating Alternative