IV-143 A MULTIATTRIBUTE RURAL ROADS APPRAISAL TECHNIQUE USING COMPOSITE FUZZY RELATIONS

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1. INTRODUCTION

Scoring or ranking models, based on multiattribute decision making (MADM), seem to be the most popular method for rural road projects appraisal in developing countries. Even though these models are conceptually less rigorous and make less demands on data and as such more appealing to potential users, they have many drawbacks which may become a source of contention in defending decisions based on them. For instance, these methods are criticised on the grounds that the weights applied to the different criteria are arbitrary; and that there are major difficulties in deciding a common rating scale for each attribute.

The main objective of this study is to develop a methodology based on MADM model that uses composite fuzzy relations instead of weighting and scoring, for prioritizing rural roads for investment at the district or operational level.

2. PROPOSED APPROACH AND METHODOLOGY

2.1 Attributes: Upon an extensive review of the literature, we consider four main attributes for evaluating rural road projects. These are :

1. The degree of importance of a given road link to rural development efforts.
2. The degree of hindrance to rural development due to the condition of a road link.
3. The population accessed by a given road link.
4. The cost of investment.

DEFINITION 1. Let $Y = \{y_1 y_2 \cdots y_n\}$ be a set of agencies for rural development in a district; and let $X = \{x_1, x_2, \ldots x_m\}$ be a set of rural road links in the district. We define the relation between each road link x and agency y as:

$I = \{ (x,y) \mid \text{link } x \text{ is important to agency } y\}$ for all $(x,y) \in X \times Y$; $X \times Y = \{(x,y) \mid x \in X \wedge y \in Y\}$.........(1)

DEFINITION 2: Let Z represent rural development effort in the district; let $Y = \{y_1 y_2 \cdots y_n\}$ be a set of agencies for rural development in a district. We define the relation between each agency and rural development effort in the district as:

$R = \{(y,z) \mid \text{agency } y \text{ is potentially important for rural development, } Z\}$ ....(2)

DEFINITION 3 : Let $Y = \{y_1 y_2 \cdots y_n\}$ be a set of agencies for rural development in a district; and let $X = \{x_1, x_2, \ldots x_m\}$ be a set of rural road links in the district. We define the relation between each road link x and agency y as:

$H = \{ (x,y) \mid \text{link } x \text{ hinders the performance of agency y's role in rural development}\}$ ....(3)

From definitions 1 and 2, attribute 1 can be realized as the composition of two relations , I and R. Similarly, attribute 2 becomes the composition of the two relations H and R. The relations I, R and H are essentially fuzzy relations. The composition of these fuzzy relations can be achieved.

DEFINITION 4: A binary fuzzy relation I from X to Y is a fuzzy subset of XxY , characterized by its membership function $\mu_I : X \times Y \rightarrow [0,1]$ ....(4)

DEFINITION 5: Let I be a fuzzy relation from X to Y and R be a fuzzy relation from Y to Z. The sup-min composition of R and I resulting in B = R o I, which is a fuzzy relation from X to Z is defined

$\mu_{RoI}(x,z) = \vee[\mu_I(x,y) \wedge \mu_R(y,z)]$ for all (x,z) in XxZ ....(5)

Attribute 1 can, therefore, be modeled by definition 5. The evaluation of equation 5 represents the assessment value for the road links relative to attribute 1. Smilarly, attribute 2 can be represented as:

$\mu_{RoH}(x,z) = \vee[\mu_H(x,y) \wedge \mu_R(y,z)]$ ....(6)

2.2 Assessment : The relations I, R, and H may be obtained by interviewing rural develpment agencies, rural communities and the decision maker. These relations may be considered as type 1 fuzzy sets and defined as :

I = 1.0/ IC + 0.8/C + 0.7/FC + 0.5/VI + 0.3/I + 0.2/FI + 0/U ....(7)
H = 1.0 /IC + 0.8/C + 0.7/FC + 0.5/VS + 0.3 /S + 0.2/FS + 0/NP .... (8)
R = 1.0/ IC + 0.8/C + 0.7/FC + 0.5/VI + 0.3/I + 0.2/FI + 0/U ....(9)

Where: IC = indeed critical; C= critical; FC = fairly critical; VI = very important ; I= important; FI= fairly important; U= unimportant; VS= very serious; S= serious; FS = fairly serious NP= no problem.

The assessment values for attributes 3 and 4 may also be defined by the following type 1 fuzzy set;

A = 1.0/EH + 0.9/VH + 0.8/H + 0.7/FH + 0.5/M + 0.3/FL + 0.2/L + 0.1/VL + 0.05/EL ....(10)
where: EH= extremely high; FH= fairly high; M= medium; L= low; VL= very low.

2.3 Aggregation of Attributes: We consider two cases and two different methods.

CASE 1: Attibutes have equal weights. This represents a case where the decision maker cannot determine the difference in importance or considers the attributes as being of equal importance. In that case we propose the calculation of the generalized Hamming distance given as :

$D(Q,L) = \frac{1}{n}\Sigma|\mu_Q(Xi) - \mu_L(X_1)|$ .... (11) ;

where : L is the actual assessment value and Q is the ideal for selection. A link that will make an ideal selection will have the following assessment values:

a) degree of importance = indeed critical; b) degree of hindrance = indeed critical
c) population accessed = extremely high d) cost of investment = extremely low.

The evaluation of (11) will induce an ordering; the lower the value the higher the priority for investment.

CASE 2: Attributes have unequal weights. In that case, we define the following relations:

S = { (x,t) | link x is important to attribute t } ....(12).
W = { (t,g) | attribute t is important to the goal of the rural road investment decision, g}..........(13)

We can obtain the composition of S and W, which are two fuzzy relations, as;

$\mu_{SoW}(x,g) = \vee[\mu_s(x,t) \wedge \mu_w(t,g)]$ ....(14)

The evaluation of (14) can be interpreted as the degree of importance of a link to the goals of the rural road investment decision, and can therefore be used to rank the roads.

3. CONCLUSION

The appraisal technique developed in this study is seen as a valuable tool in the project selection stage of rural roads investment planning. It enables us to handle the problems of weighting and ranking by employing the concept of fuzzy relation in fuzzy set theory. Our technique can, therefore, be considered as an advancement over traditional weighting and ranking methods popularly used in developing countries for rural roads investment appraisal. There is the need, however ,to apply the proposed technique to an actual rural road projects appraisal problem, and that will be the direction of future research.