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PRIORITISATION OF ROAD CORRIDORS BY DEVELOPING COMPOSITE INDEX

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ABSTRACT

All countries face the basic economic problem of allocating scarce resources among competing uses in a way that maximises the social welfare. Therefore it is very essential to prioritise the projects to ensure that resources are spend judiciously. This paper demonstrates the use a Multi Criteria Prioritisation model based on novel set of factors like Growth Centers, Road Utilisation, Connectivity, Accessibility, Backwardness and the amount of Commercial Vehicles using the road in order to rank roads to be selected for improvement. Using Analytical Hierarchy Process (AHP) the weight of each factors in Composite Index calculation have been formulated. This prioritisation model has been used for prioritising 20 Major District Roads (MDRs) in the Kottayam district of Kerala, India.

NOMENCLATURE

n	Number of Indices
w	Weight of Indices
V	Design Service Volume
λ	Eigenvalue

1. INTRODUCTION

It is very essential to prioritise infrastructure projects to ensure that resources of the country are allocated appropriately. With pressure on resources and the growing awareness about the impacts of infrastructure projects among public, the pressure on decision making bodies to develop a reliable and transparent appraisal methods for ranking process has increased. In order to have unbiased means of prioritsation we need to formulate a methodology without subjective means. The general methodology used for prioritisation is based on pavement evaluation where in the condition of the individual road was the main criteria. In this paper, a Multi-Criterion Decision Model based on novel set of factors like Growth centers, Road utilisation, Connectivity, Accessibility, Backwardness and the number of Commercial vehicles using the road is developed. Screening is based on the role of the selected stretch in the socio-economic growth of the region and traffic demand on the corridor. The advantage of Multi Criteria Analysis (MCA) is that it can accommodate quantitative as well as qualitative aspects of projects. The influence of each of the factors or the weights of each index in the total Composite Index (CI) calculation is derived by survey among experts using Analytical Hierarchy Process (AHP). The AHP results have been used to develop a prioritisation methodology. This methodology is used in prioritising some important roads in the state of Kerala, India.

2. LITERATURE

Analytical Hierarchy Process is one of the simplest and most useful processes in this field which is appropriate for decision making (Schutte and Brits, 2012). Since prioritisation is a decision making process, statistical models is not very responsive for that. In this research, in order to prioritize alternatives, Analytical Hierarchy Process was employed for finding relative weights. The AHP method of decision making was introduced by Thomas L. Saaty (2008). Moazami et al. (2011) demonstrated an AHP methodology for evaluation and prioritisation of road corridors based on pavement condition, where each road is considered as single entity. Thus more weightage is given to overall development of the Road Network than the rehabilitation of individual roads.

3. METHODOLOGY

The methodology to prioritise the corridors for improvement based on Multi–Criteria Analysis (MCA) have been evolved from literature review of Moazami et al. (2011), Schutte and Brits (2012) and similar studies. The methodology considers the role of the selected stretch in the socio-economic growth of the region and traffic demand on the corridor. The screening is conducted with the objective of identifying specific stretches of roads which are likely to lead to the overall economic development, by connecting growth centers and backward areas and exploiting locally available natural and human resources to the maximum extent. The methodology followed is explained in this section.

The roads which are to be prioritized are first identified and the following secondary data are collected:

- Census classification of the towns, villages along with their population
- Backward areas, tourist/pilgrim/heritage centers in the region
- Industries, Public Sector Units, Certified Industrial estates and growth centers.

The primary data that are collected includes classified volume count and visual road inventory.

3.1 Factors Considered in the Development of Composite Index

3.1.1 Growth Centers: It relates to the number and importance of Growth Centers connected by the selected road. Growth centers are central places that transmit growth impulses to the hinterland. The growth centers will be classified based on areas ranked by Census classification of towns. Suitable scores will be assigned for the growth centers based on the size and number of the growth centers that fall on the corridors.

3.1.2 Road Utilisation as Volume to Capacity Ratio (V/C Ratio): The following parameters will be considered for this analysis: Traffic Volume in Passenger Car Units (PCU) per day i.e.,V , and Design Service Volume (DSV), i.e.; C.

3.1.3 Connectivity to Other Network: This factor will include the following parameters: Inter district, NH/SH connectivity and access to Airport, Seaport, Railway stations.

3.1.4 Accessibility: This factor measures the accessibility of the roads to Industry/SEZ/Fishing, Tourist / religious / heritage places, Education Centers etc. The index is categorized into two groups they are; (1) Industry/SEZ/Fishing and (2) Tourist/Religious / Heritage centers.

3.1.5 Backwardness of the Area: This factor is used to provide importance to economically backward areas. Suitable score for Areas of backward areas/Tribal areas will be assigned.

3.1.6 Commercial Vehicle Density: The share of commercial vehicles in the traffic is considered as the commercial vehicle index. If the CVD is high; the road will be more beneficial in terms of economy and finance

3.2 Composite Index

Prioritisation of roads is done on the basis of above multiple criteria. This requires the assessment of various criteria and the evaluation of alternatives on the basis of each criteria and the aggregation of each evaluations to achieve a composite index and then give a relative ranking of the roads.

The method used for finding the composite index is the Weighted Sum Method. In this method all the indices are given a specific weight. After which for each of the project alternative a score is given for all indices based on the sub criteria (Fulop, 2001). The weightage of each of the above indices in the Composite Index calculation is tabulated by survey among experts using Analytical Hierarchy Process (AHP). The scores set for each criterion are multiplied with the corresponding weightages and then added up to get composite score for each road. The roads are ranked based on the final total score or the composite index calculated.

4. ANALYTICAL HIERARCHY PROCESS (AHP)

Analytical Hierarchy Process (AHP), is one of the most effective techniques in Multi Criteria Decision Making (MCDM). This technique is based on pair wise comparison and enables decision makers to investigate several different criteria to find the relative importance of alternatives. Structuring the decision problem as a hierarchy is fundamental to the process of the AHP. Hierarchy indicates a relationship between elements of one level with those of the level immediately below. This relationship percolates down to the lowest levels of the hierarchy and in this manner every element is connected to every other one, at least in an indirect manner.

In AHP, criteria are evaluated in pairs by one or more referees (e.g. experts or decision makers). It provides a way of breaking down the general method into a hierarchy of sub-problems, which are easier to evaluate (Bhushan and Rai, 2004). In this paper AHP has been used to find relative weights of indices.

Let $\{A_1, A_2.........A_n\}$ denote the alternatives (n is the number of compared alternatives) then a *n x n* Decision Matrix of pair wise comparisons is formulated.

The matrix $A=[a_{ij}]$ represents the intensities of the expert's preference between individual pairs of alternatives (a_i versus a_j, for all i,j=1, 2,..,n). The scale for comparison (Saaty, 2008) is adopted. Preferences are chosen from a given scale (1/9, 1/8,…,8, 9).

TABLE 1
THE SCALE USED FOR COMPARISON

Scale	Degree of Preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6, 8	Preferences between the above ranges

TABLE 2 INDICES WEIGHT CALCULATION

INDICES		GI	RI	CN	AI	BI	CMI	TOTAL	AVG	CI
		1	2	3	4	5	6	7	8	9
1	Growth Priority Index	0.38	0.34	0.43	0.43	0.33	0.35	2.26	0.38	6.08
2	Road Utilisation Index	0.19	0.17	0.14	0.14	0.20	0.17	1.02	0.17	6.05
3	Connectivity Index	0.13	0.17	0.14	0.14	0.13	0.17	0.89	0.15	6.08
4	Accessibility Index	0.13	0.17	0.14	0.14	0.13	0.17	0.89	0.15	6.08
5	Backwardness Index	0.08	0.06	0.07	0.07	0.07	0.04	0.39	0.06	6.06
6	Commercial vehicle Density Index	0.10	0.09	0.07	0.07	0.13	0.09	0.54	0.09	6.04
Average Consistency Index										0.01

(GI-Growth Priority Index, RI-Road Utilisation Index, CN-Connectivity Index, AI-Accessibility Index, BI-Backwardness Index, CMI-Commercial Vehicle density Index)

Since six criteria as mentioned in earlier section are considered in this study, a 6X6 decision matrix was formulated and was send to transportation planning experts for pair wise comparison and rating of indices based on the policy directions of the project scenario. A comparison matrix A is obtained where the element a_{ij} shows the preference weight of a_i obtained by comparison with a_j. Each entry in the matrix A is positive ($a_{ij} > 0$) and reciprocal as:

$$a_{ij} = \frac{1}{a_{ji}} \qquad (\forall\ i,j=1,2,..,6) \qquad (1)$$

The goal is to compute a vector of weights $\{w_1, w_2, ...,w_n\}$ associated with A. The principal normalised eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalised eigenvector are termed weights with respect to the criteria or sub-criteria.

The consistency of the matrix should be evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level then answers to comparisons are re-examined examined. The consistency index, CI, is calculated as

$$CI = \frac{\lambda - n}{n - 1} \qquad (2)$$

Where λ is the Eigenvalue of the judgment matrix.

A project specific AHP comparison matrix of a subject expert, obtained as a result of survey to determine weight of all the indices in Composite Index calculation is shown in Table 2.

The Eigenvector (weight) and Consistency Index (CI) of survey matrix was tabulated using excel template Khwanruthai (2012). If A is a typical survey matrix is used to formulate a 6X8 matrix X for weight calculation of indices, where the columns 1 to 6 are normalised values as shown in Table 2. The seventh column gives the row totals (Total), and eighth column gives the row averages (Avg) as shown in Equation 3.

The average column gives the eigenvectors or the weights of each of the indices. CM is the consistency measure of matrix. If the matrix is perfect the CM value will be equal to n (the number of Indices). In AHP, the quotient of this difference divided by (n-1) is defined as the Consistency Index (CI), which is the index of the consistency of judgements across all pair wise comparisons. The CM and CI are calculated using Equation 3 and 4 respectively.

$$Total = \sum_{j=1}^{n} X_{ij}$$

$$Avg = \frac{\sum_{j=1}^{n} X_{ij}}{n} \qquad (3)$$

$$CM = \frac{\sum_{j=1}^{n} X_{ij}}{n} [A_{ij}][X_{i8}]$$

$$CI = \frac{\frac{\sum CM}{n} - n}{n-1} \qquad (4)$$

(Here n=6, i=1 to 6, j=1 to 6)

To check the consistency of matrix this CI is compared with that of a random index, RI. The ratio derived, CI/RI, is termed the consistency ratio, CR. The random Indices are shown in Table 3.

TABLE 3 RANDOM INDICES

n	**1 &2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0.58	0.9	1.12	1.24	1.32	1.4	1.46	1.49

The value of Avg CI=0.01 and RI= 1.24 (Table 2 and Table 3). Thus, Consistency Ratio (CR) =CI/RI =0.01/1.24=0.01. In practice, a Consistency Ratio of 0.1 or below is considered acceptable, since the CR value of decision Matrix is 0.01 the matrix can be considered consistent. Similarly eigenvectors of the decision matrix of each of the expert opinion are tabulated and the average value is taken as the proportional weights of each of the indices.

Those matrices with RI value greater than 0.1 are re examined before the average tabulation. The average weights that were calculated by opinion survey are represented are tabulated are shown in Table 4. It is observed that since the paper gives importance to socio economic growth of the region, Growth Priority Index had the maximum weightage and the least weight is found for Backwardness Index.

TABLE 4 THE WEIGHT OF INDICES

No	**Factors**	**Weights**
1	Growth priority Index	30%
2	Road utilisation index	19%
3	Connectivity Index	15%
4	Accessibility index	15%
5	Backwardness Index	9%
6	Commercial Vehicle density	12%
Composite Index		100%

5. CASE STUDY USING COMPOSITE INDEX METHODOLOGY

Availability of a good infrastructure facility is an essential pre-requisite for the development of a state. Major share of roads i.e., 82% of roads that fall under Kerala PWD are Major District Roads (MDRs). Therefore it is important to develop a strategy to improve, including upgrading the existing MDRs in a prioritized manner, depending upon the condition and infrastructural needs for economic growth. The Kerala State Government has recently taken over about 8,500 km of important roads from the Panchayats and classified them as MDRs. Though these roads are classified as MDRs, many of them are of single lane and some with intermediate lane standards. The developed methodology was used to prioritise 20 Major District Roads in Kottayam district of Kerala. Kottayam is a major district of Kerala which has the highest percentage of MDR roads.

The aim of the case study is to prioritise the selected set of roads by developing a composite index relating to the Socio Economic data which include (such as Demographic and Economic trends, Growth centers and Backwardness), Engineering data (like traffic parameters, distribution of road network, mobility and the network connectivity).

The individual score for each index namely Growth centers, Road utilisation, Connectivity, Accessibility, Backwardness and the amount of Commercial vehicle were tabulated for all the 20 roads based on the sub criteria mentioned earlier section. These score were multiplied by tabulated weights given in Table 4 and were added up to give composite score. This score was then used to rank the 20 roads. Composite Index is calculated as:

$$R_i = \sum_{j=1}^{N} a_{ij} w_j \qquad (5)$$

The Growth Priority Score was determined by the number and importance of Census Towns connected by the selected road. The importance of Census Towns were estimated based on class to which town belongs based on the population as per 2011 Census. Connectivity index score of each road were calculated based on the immediate connectivity of the road to NH/SH, and rail terminals and Inter district connectivity. Accessibility Index Score was calculated based on two factors accessibly of the road to Industry/SEZ/Fishing areas and Tourist/Religious/Heritage/Educational centers. The list of major tourist centers were collected from Kerala Tourism Development Corporation. The accessibility to other tourist and religious areas were identified during road inventory and from detail map study. The Backward areas associated with all the roads were identified based on data from Scheduled Tribes Development Department of Kerala. Road Utilisation Score was determined by V/C ratio based on traffic volume count. The case study deals with important MDRs in Kottayam district which belong to rural roads category. The Indian Roads Congress (IRC) specifies LOS B for rural highways design and the same was used for case study. A classified volume count of all the selected roads was conducted and Commercial Vehicle Density Score was given based on the commercial vehicle in PCU expressed as a percentage of total vehicles PCU. Composite Index is calculated using Equation 5.

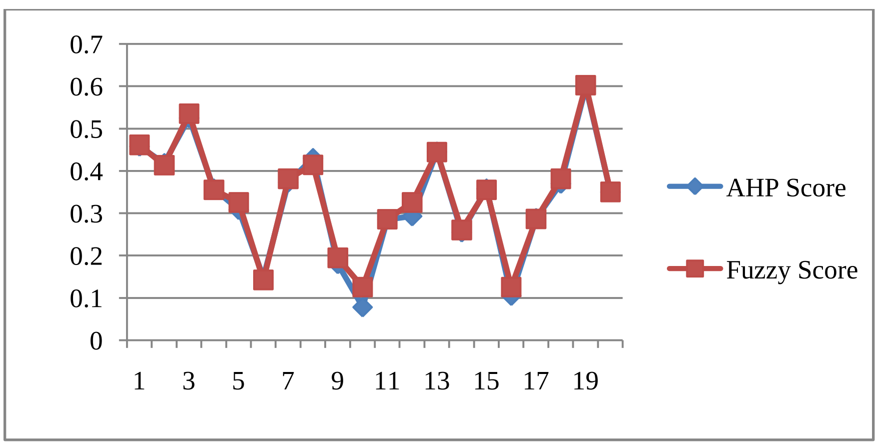

FIGURE 1 THE COMPOSITE INDEX OF ROADS USING AHP AND FUZZY MODEL

Defining a multi criteria model is difficult; therefore a more advanced model using fuzzy If Then Rules is referred for verifying prioritization methodology. The comparisons by both methods are shown in Figure 1.

The Composite Index calculated ranges from (0.598-0.078) and as seen from Figure 1, Road No. 19 had the highest composite score (0.598) and was ranked first, similarly Road No 10 had the lowest composite score (0.078) and was ranked as the road with least priority.

The same sets of roads were ranked using the Fuzzy Model. Fuzzy set based model Rank and composite Index Rank calculated by AHP weights showed 98% Correlation. Therefore this methodology gives a clear protocol for ranking roads and can be used practically in prioritisation of road corridors for improvement.

6. CONCLUSION

This study has developed a new approach of multi-criteria analysis (MCA), using Indices like Growth Centers, Road Utilisation, Connectivity, Accessibility, Backwardness and the amount of Commercial Vehicles using the road, to identify roads for improvement. Prioritisation is based on the contribution of the roads in the socio-Economic growth of the region. The weightage of each of the Index in Composite Index calculation was formulated by survey among experts by using Analytical Hierarchy process (AHP). This AHP results was used in ranking some important roads in Kottayam district of Kerala. Composite Index was calculated based on Weighted Sum Method and the roads were ranked. This methodology gives a clear and robust Multi Criteria Ranking Technique for the prioritization of roads.

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