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Prioritisation of road corridors for improvement by developing Composite Index

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Abstract—Prioritising competing transport infrastructure investment schemes is an essential pre-requisite at all levels of transport decision making. 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 focused appropriately. This paper introduce 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, to identify the roads to be improved which will result in socio-economic growth of the entire region.The weight of each factors in Composite Index calculation have been formulated using Analytical Hierarchy Process (AHP). Further this prioritisation model has been used for prioritising 20 Major District Roads (MDRs) in the state of Kerala, India.

Index Terms— Analytical Hierarchy Process (AHP), Comparison Matrix, Multi Criteria, Prioritisation, Socio-Economic

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1 Introduction

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. Although the process of prioritisation could be conducted through subjective means, objective analysis guarantees fair and unbiased decision making.

The general methodology used for prioritisation is based on pavement evaluation where in the condition of the individual road was the main criteria for prioritisation. In this paper, a Multi-Criterion Decision Model based on novel set of factors like Growth centers, Road utilisation, Connectivity, Accessibility, Backwardness and the amount 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 not the same. The rating of thes indices were done by survey among experts using Analytical Hierarchy Process (AHP). AHP is one of the simplest and most useful processes which are appropriate for decision making. The AHP results have been used to develop a prioritisation methodology and used in prioritising some important roads in the state of Kerala, India.

2 Literature

Prioritisation is a decision making process, therefore statistical models is not very responsive. Analytical hierarchy process is one of the simplest and most useful processes in this field which is appropriate for decision making. In this paper, in order to prioritise alternatives, Analytical Hierarchy Process is 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. This paper gives more weightage 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 I.C and A.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 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.

First the roads to be prioritised are identified and the following secondary data are collected:

- Census classification of the towns, villages, growth centers present along the study corridors and population
- List of backward areas, tourist/pilgrim/heritage centers in the region from the relevant Govternment departments
- Industries, Public Sector Units, Certified Industrial estates growth centers.

The primary data that are collected includes classified volume count and visual road inventory. The data collected are then utilised to calculate Composite Index. The details of the factors selected for prioritisation are given in Section.3.1 and

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the process of forming Composite Index is mentioned in Section 3.2

3.1 Factors considered in the development of composite index

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 are classified based on Census classification of towns. Suitable scores are assigned for the growth centers based on the size and number of the growth centers that fall on the corridors.

Road Utilisation as Volume to capacity Ratio (V/ C Ratio):

The following parameters are considered for this analysis V/C Ratio: Traffic Volume in Passenger Car Units (PCU) per day i.e.V, and Design Service Volume (DSV), i.e.C.

C*onnectivity:*

This factor includes the following parameters: Inter district, National and State highway connectivity and access to Airport, Seaport, Railway stations.

Accessibility:

This factor measures the accessibility of the roads to Industry/ Special Economic Zone (SEZ)/Fishing, Tourist / religious / heritage places, Education Centers etc. The index is categorized into two groups based on accessibility to (1) Industry/ SEZ/Fishing and (2) Tourist/Religious / Heritage centers.

Backwardness of the area:

This factor is used to provide importance to economically backward areas. Suitable score for backward areas/Tribal areas are assigned.

***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

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. The weightage of each of the above indices in the Composite Index calculation is tabulated by survey among experts using Analytical Hierarchy Process (AHP), which is mentioned in Section 4. 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.

This methodology therefore gives a clear ranking technique for prioritising the roads.

4 Analytical Hierarchy Process (AHP)

A number of methods have been developed which use pair wise comparisons of the alternatives and criteria for solving multi-criteria decision-making (MCDM). Analytical hierarchy process (AHP), (Saaty, 1980), is one of the most effective techniques in decision making process. This technique is based on pair wise comparison and enables decision makers to investigate several different criteria in the selection of the best alternative. It provides a way of breaking down the general method into a hierarchy of sub-problems, which are easier to evaluate.

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

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	preference between the above range

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 $i,j=1, 2,..,n$). They are chosen from a given scale (1/9, 1/8,…,8, 9). The scale for comparison (Saaty & Vargas, 1991) is shown in Table 1.

Since 6 indices or criteria as mentioned in section 3.1 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 thesis project scenario. A comparison matrix A is obtained as shown in Table 2, 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:

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

Our goal is to compute a vector of Weights $\{w_1, w_2, \ldots, w_n\}$ 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. The consistency index, CI, is calculated as

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

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.

TABLE 2
TYPICAL AHP SURVEY RESULT

Indices	GI	RI	CN	AI	BI	CMI
GI	1	2	3	3	5	4
RI	1/2	1	1	1	3	2
CN	1/3	1	1	1	2	2
AI	1/3	1	1	1	2	2
BI	1/5	1/3	1/2	1/2	1	1/2
CMI	1/4	1/2	1/2	1/2	2	1

(In Table 2: GI-Growth Priority Index, RI-RoadUtilisation Index, CN-Connectivity Index, AI-Accessiblity Index, BI-Backwardness Index, CMI-Commercial Vehicle density Index)

The Eigenvector (weight) and Consistency Index (CI) of survey matrix was tabulated using Excel template as shown in Table 3. If A is a typical survey matrix as shown in Table 2 then Table 3 is matrix X. Where the columns 1 to 6 are normalised values of Table 2

TABLE 3
INDICES WEIGHT CALCULATION

Indices	GI	RI	CN	AI	BI	CMI	TOTAL	AVG
	1	2	3	4	5	6	7	8
GI	0.38	0.34	0.43	0.43	0.33	0.35	2.26	0.38
RI	0.19	0.17	0.14	0.14	0.2	0.17	1.02	0.17
CN	0.13	0.17	0.14	0.14	0.13	0.17	0.89	0.15
AI	0.13	0.17	0.14	0.14	0.13	0.17	0.89	0.15
BI	0.08	0.06	0.07	0.07	0.07	0.04	0.39	0.06
CMI	0.1	0.09	0.07	0.07	0.13	0.09	0.54	0.09
CM	**6.08**	**6.05**	**6.08**	**6.08**	**6.06**	**6.04**		
Avg CI=0.01								

The Indices abbrevations are same as in Table 2. 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 pairwise comparisons. The CM and CI are calculated using Equation 3 and 4 respectively.

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

$$Avg = \frac{\sum_{j=1}^{n} X_{ij}}{n} \tag{3}$$

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

$$CI = \frac{\frac{\sum CM}{n} - n}{n-1} \tag{4}$$

(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 4.

TABLE 4
RANDOM INDICES (SAATY, 1980)

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 (Table 3) and RI= 1.24 (Table 4) Thus, Consistency Ratio (CR) =CI/RI =0.01/1.24=0.01. In practice, a consistency Ratio CR 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 expert opinion are tabulated and the average value is taken as the proportional weights of each of the indices.

TABLE 5
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%

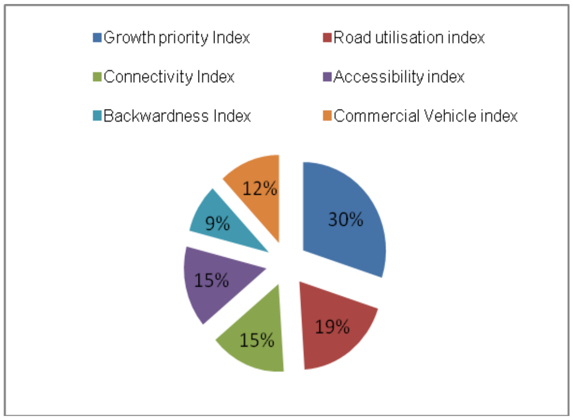

Fig 1 The Weights of Indices in Composite Index

Those matrices with RI value greater than 0.1 are re examined before the average tabulation. The average weights that were calculated by openion survey for thesis case study are shown in Table 5 and are represent in Fig 1.

5 Case Study Using Composite Index Methodology

The developed methodology was used to prioritise 20 Major District Roads in the state of Kerala, India. 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 in section 3.1. These score were multiplied by tabulated weights (Table 5) and were added up to give composite score. The Composite Index tabulated for the selected roads are shown in Fig 2. This score was then used to rank the 20 roads.

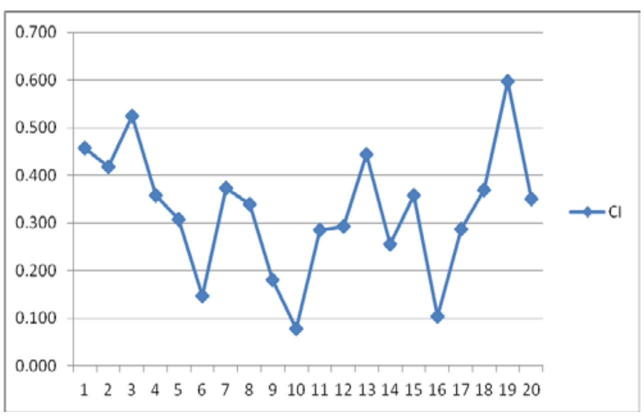

Fig 2 The Composite Index (CI) of the Selected Roads

Composite Index was calculated using equation (5)

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

Where R_i is the rank of the i^{th} alternative, a_{ij} is the score of the i^{th} alternative in terms of the j^{th} criterion, and w_i is the weight or importance of the j^{th} criterion. The Composite Index calculated ranges from (0.598-0.078) and as seen from Fig 2 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. This methodology therefore gives a clear protocol for ranking roads. Moreover the stake holder confidence in the outcome of any infrastructure can also be enhanced by an understanding of the robustness of the ranking to variations in key inputs.

6 Conclusion

Prioritisation is an efficient tool used by all road administrations to ensure that the projects undertaken are significant and that the most effective utilisation of resources takes place. This paper applies a novel approach of using multi- criteria analysis (MCA) using Indices like Growth centers, Road Utilisation, Connectivity, Accessibility, Backwardness and the amount of Commercial Vehicles using the road. Methodology tries to identify the roads to be improved which will result in better road network system as a whole and helps in the socio-economic growth of the region. Prioritisation is a decision making so it is better to use decision making process than static models. AHP is one of the simplest and most useful processes which are appropriate for decision making. The weightage of each of these factors in Composite Index calculation has been therefore formulated by survey among experts by using Analytical Hierarchy Process (AHP). Further this AHP results have been used to develop a prioritisation methodology and this model has been used in prioritising some important roads in the state of Kerala. The result shows a variation from (0.598-0.078) in Composite Index. Therefore this methodology gives a clear and robust Multi Criteria ranking technique for the prioritisation of roads.

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