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PRIORITIZATION OF ROAD PROJECTS – A DISUTILITY BASED APPROACH

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Abstract. In order to boost the economic growth India has initiated a massive road infrastructure development programme. However, due to serious constrains in financial resources, non-availability of adequate technical manpower, institutional constraints etc., it is not possible to execute all the necessary road development projects within a short time span. Besides, it is essential to prioritize roads on a logical rational basis and target the development in a phased manner. In the present paper the a methodology has been proposed for the prioritization of road development. Relevant influencing factors for prioritization have been identified and their relative weights have been estimated based on an expert-opinion survey. The total disutilities on existing roads have been measured and the prioritization has been proposed on the basis of estimated total disutility. The methodology demonstrated in the paper is simple and requires data which are either available from secondary sources or may be obtained easily from simple primary surveys.

Keywords: road infrastructure; road projects; prioritization of road development.

1. Introduction

Over the last few years road sector in India has started experiencing major changes. The driving force for all these changes is the realization of the necessity for a sound transport infrastructure to push the economy forward. It has been accepted that one decade of liberalization could not bring much fruit primarily due to infrastructure bottlenecks and mainly due to the glaring deficiency in road network. Rural India does not have required connectivity for marketing agricultural produces and there is glaring deficiency in high-speed road network in the country. Therefore, the Government has appropriately realized the importance of road development and the seventeen priority areas of the Government include "Road Transport" as a mega mission [1].

India has initiated a mission to upgrade its road network with very ambitious plans for road development. It has been targeted to achieve high-speed connectivity among the four major metro cities (named as Golden Quadrilateral) as well as similar fast corridors from Kashmir to Kanyakumari; and Silchar to Saurashtra (named as North-South and East-West Corridors), together known as National Highway Development Project (NHDP). This targeted high-speed corridor under NHDP will be of about 13 500 kilometers [2]. Similarly, the rural connectivity mission of the country has been formulated as Pradhan Mantri Gram Sadak Yojana (PMGSY) to connect villages by all-weather roads, which will build about 350 000 kilometers of roads to connect about 150 000 villages in India [3]. While these two centrally sponsored road infrastructure projects themselves are highly ambitious, the State Governments and city administrations have also planned road projects of unprecedented magnitude in recent years.

It is well understood that massive targets of road development in India cannot be achieved overnight due to serious constraints of financial resources, shortfall of skilled/technical manpower, institutional constraints and many other problems [4]. Besides, it is essential to prioritize the road development on a logical rational basis and target the development in a phased manner [5]. Therefore, the broad objective of the present paper is to identify the influencing factors or variables that should be considered during prioritization and also demonstrate the methodology for the prioritization of roads.

2. Data Base and Selection of Variables for Prioritization

For the purpose of selection of appropriate variables for prioritization and demonstration of the methodology for prioritization of roads, selected portions of three National Highways (NH-1, NH-45 and NH-25) in India have been considered in the present study. All the relevant data pertaining to selected portions of these three highway stretches were made available for the present work. It was also necessary to identify appropriate influencing factors which can be considered during prioritization of road development; and accordingly, create a database for the same.

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2.1. Existing Traffic demand

For highway development and prioritization study, existing traffic demand is a key input. The existing ratio of traffic volume to capacity is often used as a measure to justify the development needs. As all the roads considered in the present paper are two lane undivided road and the widths (and thereby the capacities) are the same, the existing traffic volume has been taken as one of the major factors for prioritization. In order to obtain the traffic data on study roads, classified volume counts were made on selected mid block sections of three National Highways (NH-1, NH-45 and NH-25). The classified volume counts were carried out in both directions for 7 consecutive days with 15 minutes counting periods. The estimated Average Daily Traffic (ADT) appropriately converted into PCUs was found to be 28 186, 39 000 and 31 340 on NH-1, NH-45 and NH-25 respectively.

2.2. Proportion of Goods Traffic

Goods traffic movement contributes significantly in the development of regional as well as national economy. In most of the National Highways in India the proportion of goods traffic is significant and a major driving force for road development is to boost the economy through faster and efficient movement of agricultural produces and other commodities. While the National Highways constitute only 2% of the road length in the country, they carry more than 40% of goods [6]. Therefore, the average composition of heavy traffic has been taken as one of the influencing factors for the prioritization of road development. The observed proportions of goods traffic were found to be 35%, 28% and 34% on NH-1, NH-45 and NH-25 respectively.

2.3. Vehicle Damage Factor

In India and many other developing countries it is frequently found that goods haulage vehicles are overloaded in spite of existing legislations and presence of enforcement agencies for avoiding overloading of vehicles [7, 8]. The vehicle damage factor (VDF) reflects the commodity type as well as the nature of overloading [9]. Therefore, the VDF has been taken into consideration during prioritization to justify the need of improvement of the existing roads, especially in terms of strengthening. The existing traffic volume and VDF together are useful for justifying the need of strengthening as well as widening of existing roads.

In order to estimate vehicle damage factors, axle load survey was carried out on all the study road stretches at strategic locations. A sample of about 15% was targeted using roadside weighing bridges for carrying out the axle load survey. The estimated vehicle damage factors as per *IRC-37* [10] were found to be 4.96, 4.53 and 5.14 on NH-1, NH-45 and NH-25 respectively.

2.4. Reduction of Average Journey Speed

Average journey speed reflects the road condition as well as the level of traffic loading on an existing roadway. As the speed reduces with an increase in traffic volume, the reduction of speed is also used as a measure of road congestion and is therefore useful for justifying road improvements [11]. In order to obtain the average journey speed a speed and delay survey using the moving car method was carried out along the project roads under study. The estimated average journey speed was found to be 38.41 kmph on NH-1, 40.29 kmph on NH-45 and 45.40 kmph on NH-25. Assuming a free speed of 80 Kmph on National Highways, the reduction of journey speed was estimated as 45.19 kmph on NH-1, 39.71 kmph on NH-45 and 34.60 kmph on NH-25.

2.5. Growth of per Capita Income

Growth in per capita income is an economic indicator, which is often related to the growth of private vehicles. The higher is the growth in per capita income, the higher is the need for transportation infrastructure. Therefore, the growth in per capita income for the influence area of a road [12] is included in the list of influencing factors during prioritization. An O-D survey on the study roads revealed that for each road, more than 90% passenger traffic had their origin and destinations within the state where the study road was located. Therefore, the average per capita growth rates of respective states were considered during prioritization. Using the data obtained from *Central Statistical Organisation, Government of India (1999)*, the average per capita growth rate for the influence area was found to be 3.20% for NH-1 and 4.76% for both NH-45 and NH-25.

2.6. Growth of Net State Domestic Product (NSDP)/ Gross Domestic Product (GDP)

The proportion of goods traffic is significant on all the highways in India. It is a common practice to derive the growth factor for goods traffic in relation to the growth of NSDP/GDP in the area of influence of project road. Therefore, in the present paper the growth of NSDP/GDP for the area of influence has been considered during prioritization. For determining appropriate growth rates of NSDP/GDP with respect to study roads, an O-D survey was conducted to identify the O-D pattern of goods traffic. Then, for the predominant states which are either origin and/or destination of majority of the O-D movements, appropriate NSDP values were used. For the remaining origins and/or destinations which were scattered to various other states, instead of state wise NSDP, GDP value was taken. Finally, based on appropriate NSDP or GDP values associated with various origins and destinations, a weighted growth factor of NSDP/GDP was estimated for the influence area using the observed O-D pattern [12]. Using the data available from *Central Statistical Organisation, Government of India (1999)*, the growth rate of NSDP/GDP for the area of influence of NH-1 was estimated to be 9.46%. The corresponding values were 11.29% for NH-45 and 12.28% for NH-25.

2.7. Accident Cost

The rate of road accidents in India is very high. The vehicle population in the country has increased from 22 700 000 in 1994 to 38 100 000 in 1997, while the fatalities of road accident has increased from 64 000 to 78 000 during this period. In India the rate of road accidents is as high as one accident per minute and one death in every 7.5 minutes [6]. As most of the existing national highways are two lane roads, the number of accidents, especially head on collision is very significant. The high rate of accidents on the existing two lane roads and the increased awareness to improve road safety [13–15] justify the need of considering accident cost as one of the influencing factors during the prioritization of roads for improvement. In the present paper, the total accident cost has been taken as the summation of the cost of injuries and the cost of damage of vehicles [6]. The accident data and the cost of various types of accidents as well as damages of different vehicle types as reported in [16] have been used to estimate the accident cost on all the study roads under consideration. The total cost of accidents, thus estimated, is found to be Rs. 1 160 398 on NH-1, Rs. 1 050 996 NH-45 and Rs. 814 519 on NH-25.

2.8. Road Users' Cost

Road users cost reflects the pavement condition as well as the overall travel condition on a road stretch. Therefore, road users cost is also an important consideration during the prioritization of roads for improvement. Based on road geometry (e.g. gradient, curvature, width of pavement), surface characteristics (e.g. surface type, roughness), vehicle characteristics (e.g. age of vehicles, type, model, horse power etc.) and traffic factors (e.g. volume, composition, load carried etc.), [17] estimated the road users cost considering the cost of fuel, lubricants, spare parts, maintenance, labor, depreciation costs, etc. The road users cost used in the present paper is based on the recommendations of [5]. The estimated road users cost per vehicle Km of travel was found to be Rs. 2.17, Rs. 2.86 and Rs. 3.17 on NH-1, NH-45 and NH-25 respectively.

3. Methodologies and Application

The influencing factors or variables to be considered for prioritization have been identified as described in Section 2.1 to 2.8. The estimated or observed variables on all the study roads are also summarized in Table-1. The list of influencing factors or variables presented in this paper is not unique and therefore, may be modified depending on motivation, characteristics and nature of development considered for prioritization. However, once the variables are identified, it will be required to prioritize the roads using identified variables. In the present paper, the variables identified in the process of prioritization, have been used to estimate the total disutilities of existing roads; and the development has been proposed in the descending order of total disutility (i.e. the one with highest disutility to be taken first for improvement). For estimating the total disutility, a linear function has been assumed as follows.

$$U_j = -\sum_i a_i^n X_{ij}^n , \qquad (1)$$

where, U_j = total disutility for existing road 'j', X_{ij}^n = observed/estimated normalized variable 'i' on road 'j' a_i^n = normalized coefficient or weight attached to variable X_{ij}^n.

The variables shown in Table-1 have been selected in such a way that higher value of a variable, will need the higher improvement of the existing road. The negative sign in Equation (1) has been incorporated as U_j is a measure of disutility.

In order to estimate the total disutility, it will be required to estimate the weights to be assigned to variables considered during prioritization and then to normalize the weights. Similarly, it will be required to normalize the variables shown in Table 1. In the present paper, 3 roads (i.e. j = 1, 2 and 3) and 8 variables (i.e. i = 1, 2, … 8) have been considered during prioritization.

Table 1. Summary of variables considered during prioritization

Name of variable	Observed/estimated value on		
	NH-1	NH-45	NH-25
Existing traffic demand (PCU/day)	28 186	39 000	31 340
Composition of goods traffic (in %)	28	35	34
Vehicle damage factor	4.96	4.53	5.14
Reduction of average journey speed (Kmph)	45.19	39.71	34.60
Growth of per capita income	3.20	4.76	4.76
Growth of NSDP/ GDP	9.46	11.29	12.28
Accident Cost (Rs.)	1 160 398	1 050 996	814 519
Road users cost (Rs per Vehicle Km)	2.17	2.86	3.17

3.1. Estimation of Weights

In order to estimate the weights of different variables, a questionnaire was prepared and distributed among eighteen experts to rank variables in order of priority. The following pre-assigned weights to various priorities were also communicated to the experts.

Priority	I	II	III	IV	V	VI	VII	VIII
Preassigned weight	8	7	6	5	4	3	2	1

On the basis of the opinion of experts and pre-assigned weights to different priorities, the weights for different variables were estimated. For example, from the opinion of experts, it was found that the distribution of priorities for "Traffic Volume" was as follows.

Priority on "Traffic Volume"	I	II	III	IV	V	VI	VII	VIII
Distribution of Priorities from opinion of 18 experts	11	3	2	2	0	0	0	0

Therefore, the weight for "Traffic Volume" was estimated as (11x8+3x7+2x6+2x5) or 131. Similarly, the weights for other variables were also estimated.

3.2. Normalization of Variables and Weights

As the magnitudes of variables considered during prioritization vary widely, all the variables (X_{ij}) shown in Table 1, have been normalized as follows.

$$X_{ij}^{n} = \frac{X_{ij}}{\sum_{j} X_{ij}} \tag{2}$$

where, X_{ij}^{n} = Normalized variable.

Similarly, the estimated weights associated with different variables have also been normalized as follows

$$a_i^n = \frac{a_i}{\sum_i a_i}. \tag{3}$$

While the normalized variables used during prioritization are shown in Table 2, the estimated weights associated with different variables are shown in Table 3.

Table 2. Summary of normalized variables considered during prioritization

Name of variable	Estimated normalized value on		
Existing traffic demand (PCU/day)	NH-1	NH-45	NH-25
Existing traffic demand (PCU/day)	0.29	0.39	0.32
Composition of goods traffic (in %)	0.28	0.37	0.35
Vehicle damage factor	0.33	0.33	0.34
Reduction of average journey speed (Kmph)	0.38	0.33	0.29
Growth of per capita income	0.26	0.37	0.37
Growth of NSDP/GDP	0.29	0.34	0.37
Accident cost (Rs.)	0.38	0.35	0.27
Road users cost (Rs per Vehicle Km)	0.27	0.34	0.39

Table 3. Summary of estimated weights

Name of variable	Estimated weights	Normalized weights
Existing traffic demand (PCU/day)	131	0.23
Composition of goods traffic (in %)	64	0.09
Vehicle damage factor	117	0.17
Reduction of average journey speed (Kmph)	95	0.15
Growth of per capita income	72	0.11
Growth of NSDP/ GDP	24	0.03
Accident cost (Rs.)	55	0.08
Road users cost (Rs per Vehicle Km)	94	0.14

3.3. Prioritization

Using the normalized variables $\left(X_{ij}^{\ n}\right)$ and estimated normalized weights $\left(a_i^n\right)$, the total disutilities were estimated for all the study roads as per Equation (1). The estimated disutilities are shown in Table 4.

It is clear from Table 4 that among the three roads under study, NH-45 with the highest disutility should be taken first for improvement. Then, NH-25 and NH-1 may be taken in sequence based on the level of disutility.

Table 4. Estimated disutilities and priorities for different roads

NAME OF THE ROAD	TOTAL DISUTILITIES	PRIORITY
NH-1	-0.3105	III
NH-45	-0.3551	I
NH-25	-0.3344	II

4. Conclusions

Prioritization of roads is a crucial step in the process of road infrastructure development. For the purpose of prioritization it is necessary to identify appropriate influencing factors or variables and estimate their relative weights. In the present paper eight variables have been logically identified and their relative weights have been estimated based on an expert-opinion survey. Incorporating all the variables, a linear function has been proposed for the estimation of the total disutilities of study roads and the prioritization has been done on the basis of estimated total disutility. The methodology demonstrated in the paper is simple and based the data which are either easily available from secondary sources or may be obtained from simple primary surveys. Therefore, the methodology proposed in the paper is useful for the policy makers involved in road infrastructure development.

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