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Full Length Research Paper

A techno-economic rating system for highways using discrete multi-criteria analysis

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In developing countries, like Bangladesh, priority to upgrade a national highway is mainly based on technical aspects like daily traffic demands; whereas due consideration to economic factors is generally neglected. Based on a few parameters, if highways are rated keeping in mind some social economic attributes, significant contribution to our infrastructure-based economy could be made. Socio-economic parameters are also considered as determining factors to relevant infrastructure implementation. Combination of socio-parameters, such as social viability, accident rate with technical parameters like daily demand, and amount of axle loads will offer sound retrospective of the exiting road systems. The objective of the present paper is to develop a rating system for prioritization of highways using discrete multi-criteria analysis.

Key words: Techno-economic rating, highways, Sylhet, road, priority.

INTRODUCTION

Transport is a personal activity, a social service and industry that contributes one of the most important activities of people in every aspect of advanced civilization. Economical growth of the country depends on its transport system. Nowadays, efforts have been made to explain existing regional imbalance, in terms of infrastructure; particularly according to the vital role of relevant transport activities. It should be noticed that infrastructure aids income generation and production in the rest of the economy rather than income generation and production within the infrastructure enterprises themselves. Therefore an economically viable policy should be adopted in selecting highways for up grading the income generation. For rapid economic, industrial and cultural growth of any country, a good system of road is very essential. Transportation system comprises of good network of roads, railways, well developed waterways, and airways (Alam et al., 2008). Good system of roads serves as feeder line for other modes of transport and thus helps indirectly in their development (Singh and Singh, 1991). Roads are every community's economic lifelines. Facilitating the constant movement of people and goods for travel to and from work, for services, for social and recreational purposes, and many other activities, roads are essential to modern living. In order to provide stable and even surface for the traffic, the roadway should be provided with a suitably designed and constructed pavement structure. Roads and Highways Department (RHD) is responsible to develop and maintain the major road network of Bangladesh. This road network is grouped into three categories namely National Highways, Regional Highways, Zilla Roads. Highway is the public road, street or pathway owned and maintained by the State or local authority for the use of public as per the rules regulations and restrictions made by the authorities for using the same (Banik, 2005). To evaluate the condition of highway, some parameters are essential such as International Roughness Index, pavement width, shoulder width, and annual average daily traffic (motorized and non motorized vehicle). Alam et al. (2008) used geographical information system (GIS) to evaluate the Dhaka-Sylhet national highway and to develop a digital map of Dhaka Sylhet National Highway to facilitate the highway transportation organizations. The application areas include monitoring change in land

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Table 1. Traffic volume of the study area.

Road name	Location	ADT	
		Vehicles	PCU
Sylhet-Sunamganj	Sylhet	18,178	26,000
	Dheri	18,269	28,186
Sylhet-Sherpur	Sylhet	20,272	39,000
	Sherpur	17,626	32,071
Sylhet-Comilla	Comilla	17,834	31,340
	MadhupPur	16,647	27,052

Source: Alam (2005) and Ahmed et al. (2005)

Table 2. Average percentages' composition of traffic.

Road name	Cars	CNG	Buses	Tracks	2-wheelers	Rickshaw
Sylhet-Sunamganj	23.0	3.0	22.0	35.0	11.0	6.0
Sylhet-Sherpur	32.0	4.0	7.0	28.0	22.0	7.0
Sylhet-Comilla	22.0	3.0	26.0	34.0	13.0	2.0

Source: Alam (2005) and Ahmed et al. (2005).

resources, resource management (e.g. refuse collection mapping), transport network manage (e.g. provision and maintenance of highways), public protection and within emergency services. Saarenketo and Scukion (2000) applied ground penetrating radar (GPR) for evaluation of existing highways in Scandinavia. They identified soil type, thickness of overburden, compressibility, and frost susceptibility of sub-grade soil. They also measured layer thickness, subsurface defect using GPR. Alam et al. (2010) used dynamic cone penetrometer for determining strength and thickness of pavement layers (sub-grade, sub-base, base and surface) of Sylhet-Sunamgong road in its existing condition and the impacts and effective solution of its at present and future traffic loading. Shrestha et al. (2003) used airborne laser swath mapping technology to map coastal and highway in Florida. The objective of the study is to develop a rating system for priorization of three highways (Sylhet-Sunamgong, Sylhet-Sherpur and Sylhet-Comilla) using discrete multi-criteria analysis.

MATERIALS AND METHODS

Selection of variables

Rating is implemented through the following variables:

1. Present day traffic demand in terms of PCU.
2. Average percentage composition of heavy traffic.
3. Vehicle damage factor.
4. Average journey speed in the desired stretch.
5. Growth in per capita income.
6. Net district domestic product.
7. Accident cost.
8. Road users cost.

Required data for rating

With the following strings, the most important issue is the allocation of weight-age to the selected parameters. The basis of providing weight-age to different parameters may differ from place to place, but broadly the sequence will not alert to a greater extent. After selecting the weight-age direction, vectors for individual attribute are allocated depending on the nature of effect contributed by this specific parameter. Depiction of the methodology used is presented in Table 1, according to the case study of Sylhet- Sunamganj, Sylhet-Sherpur and Sylhet–Camilla.

For safe ranking implementation, the maximum values of PCU among the stations were considered (Azmi and Ibrahim, 2001). Therefore, the values 28,186 for Sylhet-Sunamganj; 39,000 for Sylhet-Sherpur, and 31,340 for Sylhet-Camilla were considered.

The average percentages' compositions of traffic on different roads have been shown in Table 2. These data are required for ranking of highways. Vehicle damage factors are essential elements for rating of national highways (Azmi and Pandey, 1999). As in Bangladesh, vehicle damage data is not available and the characteristics of traffic in Bangladesh are considered identical with those of India. Vehicle damage factor was collected from the study of Azmi and Pandey (1999). The vehicle damage factors are depicted in Table 3. Average journey speed was calculated using face to face interviews of the drivers at the control points. These outcomes were found to be 38.41 km/h for Sylhet-Sunamganj; 40.30 km/h for Sylhet-Sherpur, and 45.40 km/h for Sylhet-Camilla. The inferences that can be concluded from the statistics for net district domestic Product, per capita income of the study area is presented in the Table 4. Gross domestic product of Bangladesh for the last decade was taken (3.87%) (BBS, 2000).

The total loss due to accidents is accounted in two broad

Table 3. Vehicle damage factor.

Road name	2 axle truck	3 axle truck	Multi axle vehicles	Average
Sylhet-Sherpur	5.90	4.50	4.40	4.96
Sylhet-Sunamganj	4.60	4.10	4.90	4.53
Sylhet-Comilla	6.20	4.10	5.10	5.14

Table 4. Net district domestic product and per capita income.

Various growth rates	Sylhet-Sunamganj (%)	Sylhet-Sherpur (%)	Sylhet-Comilla (%)
Per capita income growth	2.20	3.76	3.76
Growth in net district domestic product	3.87	4.14	4.14

Table 5. Cost of injuries in Taka (Bangladeshi national currency).

Road name	Cost of injuries (in Tk)			
	Fatal	Serious	Major	Minor
Sylhet-Sunamganj	8278404	3366643	1469412	94052
Sylhet-Sherpur	660776.4	287692	1274323	17443
Sylhet-Comilla	4527383	2573555	1333344	64364

Table 6. Cost of vehicle damage in Taka.

Road name	Cost of vehicle damage (in Tk)			
	Truck	Bus	Car	3 W and 2 W
Sylhet-Sunamganj	471343	577832	36715	0
Sylhet-Sherpur	471013	750635	25769	0
Sylhet-Comilla	391503	210583	10465	0

categories: Firstly loss to human life and secondly to property. This is a fundamental parameter because of loss to human life significance over loss in terms of money. Since these data are not available in Bangladesh, costs of different types of injuries and vehicle damages in Taka were collected, based on the study of Highway Research Records of India (HRR, 2000) and Local Transport Authority, Sylhet, Medical College and Police records. Tables 5 and 6 show the costs of injuries and vehicle damage in Taka, respectively. The total cost will be the summation of the costs of vehicle damage and that of injuries. Depending on the amount of congestion, wear and tear of the vehicles road users' costs have been estimated for all the highways. This cost is generally in the range of Rs. 2 to 4 per vehicle per km (Kadiyaki, 2000). In the present study, the road users' costs are taken on the basis of importance of the road. The costs due to use at Sylhet-Sunamganj is 2.53; at Sylhet-Sherpur is 2.78; at Sylhet-Comilla is 2.65.

Methodology used for rating

Using a face-to-face technique, empirical data were collected for the study by sample survey method, where the universe contains 36 experts' opinions. Based on the information and the data, collected from the first visit, several meetings of the team members were held and an interim test information-checklist was prepared. The information-checklist was pre-tested in the non-sampled area, through a pilot survey before finalization. The final information-checklist contained both pre-coded and open-ended questions. To value the relative importance of one criterion over others, initial weight-age is given to the number of parameters under consideration.

RESULT AND DISCUSSION

Estimation of weights

The ranking and the respective initial weight-age is presented in Table 7 and final weight age of different parameters are cited in Table 8; consequently, 36 experts were asked to rank one criterion such as present day traffic demand according to their importance. By multiplying the initial weight-age of the criteria by the number of respondents, gross weight-age is calculated.

Table 7. Ranking and corresponding initial weight age.

Rank	I	II	III	IV	V	VI	VII	VIII
Initial weight-age	8	7	6	5	4	3	2	1

Table 8. Final weight age of different parameters.

Criteria	Gross weight-age	Final weight-age
Traffic volume	262	5.40
Vehicle damage factor	234	4.85
Average journey speed	190	3.95
Road user cost	188	3.91
Growth in per capita income	144	3.00
Percentage of commercial vehicle	128	2.66
Accident cost	110	2.29
Growth in net district domestic product	48	1.00

Source: Papacostas, 1989 and Rostow, 1960.

Table 9. Criteria of different parameters.

Name of criteria	Direction of vectors
Traffic volume	Negative
Vehicle damage factor	Positive
Average journey speed	Negative
Accident rate	Negative
Growth in per capita income	Positive
Road users cost	Negative
Percentage of commercial vehicle	Positive
Growth in NDDP	Positive

Similarly, the weight-age for all the criteria was estimated on the basis of expert survey, and the corresponding final weight-age were calculated.

Fixation of direction vectors

Direction vectors depict the reflection of the type of effect incurred by each particular parameter. Depictions made by this particular statement may differ with the type of study being taken and the impact of the parameter on the outcomes. Indicatively, direction vector for growth in GDP is taken as positive in this study, since higher trends reflect development and taking such areas on priority may fasten the pace. Nevertheless, in cases that the study is materialized for identifying most rural area director they may have been reversed. The direction vectors considered for analysis are depicted in Table 9.

Development of concordance matrix and analysis of the highways

Basis of concordance matrix

Population in Sylhet-Sherpur Road is higher and our direction vector is valued as a negative factor, so it is not considered as an advantage; therefore the weight-age will not be taken into account. Numbers of commercial vehicles plying on Sylhet-Sherpur Road are higher, comparing that of Sylhet-Shunamganj road and positive vector indicates its accountability. It is apparent that Sylhet-Sherpur road is more advantageous than Sylhet-Shunamganj road, particularly at about 2.66 times. Similarly, vehicle damage factor at Sylhet-Sherpur Road isles than Sylhet-Shunamganj road; the direction vector is also negative. The above outcome indicates that weight-age of this factor should be considered. Moreover,

Table 10. Final concordance matrix for evaluation.

Road name	Sylhet-Sunamganj	Sylhet-Sherpur	Sylhet-Comilla
Sylhet-Sunamganj	-	16.775	11.410
Sylhet-Sherpur	9.310	-	14.185
Sylhet-Comilla	15.550	9.900	-

average journey speeds, growth in per capita income, growth in NDDP; accident costs are considerable because of their data significance. Nevertheless, road user cost is not significant. This makes Sylhet-Sherpur road on Sylhet-Shunamganj road have been advantageous by 16.775 times. The final concordance matrix is cited in Table 10. According to these outcomes, it is obvious that Sylhet-Sherpur road on Sylhet-Sunamganj road has 16.775 necessities to prioritize. Again, Sylhet-Sunamganj road on Sylhet-Sherpur road has 9.31 necessities to prioritize. Thus, Sylhet-Sherpur road should be given priority on Sylhet-Sunamganj road. Similarly, Sylhet-Comilla road on Sylhet-Sunamganj road has 9.90 necessities to prioritize. Again, Sylhet-Sunamganj road on Sylhet-Comilla road has 14.185 necessities to prioritize; therefore, Sylhet-Sunamganj road should be given priority on Sylhet-Comilla road.

Conclusion

This method presented in the study offers a concrete logic to decide the priority in terms of technical and economical factors. This study also provides an effective technical support to planner decision maker for up gradation in the viewpoint of limited fund. From the study, it was found that Sylhet-Sherpur Road is more advantageous than Sylhet-Sunamgong Road due to more commercial vehicles plying on the road. Similarly vehicle damage factor at Sylhet-Sherpur Road isles than Sylhet-Sunamgong Road. On the other hand, Sylhet-Sunamgong Road has more advantage than Sylhet-Comilla Road. Finally, analysis of the study provides information about the roads' priority; particularly valuing them under the following ranking (a) Sylhet-Sherpur, (b) Sylhet-Sunamganj, and (c) Sylhet-Comilla.

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