Cite this article
Modinpuroju A and Prasad CSRK
Network evaluation and prioritisation of rural roads using vulnerability analysis.
Proceedings of the Institution of Civil Engineers – Transport,
https://doi.org/10.1680/jtran.20.00022

Research Article
Paper 2000022
Received 12/02/2020;
Accepted 19/03/2021

Keywords: roads & highways/transport management/transport planning

Transport

ice Publishing

Network evaluation and prioritisation of rural roads using vulnerability analysis

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The extent of a country's rural road network (RRN) is a major determinant of its economic activity and level of poverty. Connectivity to the rural population and the rest of the network are major tasks in the development of RRNs. This study envisages the consolidation of an existing RRN to improve its overall efficiency as a provider of transportation services for people, goods and services. Funding for rural road construction/upgrade is usually a major constraint in developing countries. Hence, the available resources should be effectively used and, for this, a prioritisation method is necessary. Different RRN models for the prioritisation of links for new construction and upgrading works were explored in this study. It is proposed that prioritisation can be achieved, using realistic and practical criteria, by considering two parameters – the population and the vulnerability of a link. Different patterns of road investment were investigated and compared in order to keep total transportation costs to a minimum while keeping within an investment budget constraint.

Notation

A_i	accessibility index of location i
B	fund available to improve road condition
B_j	attractiveness of location j
C_{ij}^S	cost per unit flow
c_{ij}^S	operating cost per unit flow
d_{ij}	distance
$f(c_{ij})$	impedance function
I_{ij}^S	total cost for road upgrading work
L	set of village nodes
O_{ij}^S	operating cost on link
S	surface type
W_{ij}	weight of road link
x_{ij}^S	travel time
z	total transportation cost

1. Introduction

The growth and development of economic activity and major sectors such as health and education depend on the availability of good transport infrastructure. Rural roads are the lifeline of India, with 68.8% of the population living in rural areas, according to the 2011 census. Proper infrastructure planning helps to mitigate poverty, create more employment opportunities and improve people's quality of living. The primary objective of a rural road network (RRN) is to open up access to land, meet individual transport requirements and connect to growth points.

To improve rural road connectivity in India, in 2000 the government of India, under the Ministry of Rural Development, launched a nationwide programme – the *Pradhan Mantri Gram Sadak Yojna-I* (PMGSY-I). The primary objective of PMGSY-I was to provide connectivity, by all-weather roads, to unconnected habitations. In May 2013, with the aim of consolidating the entire RRN, PMGSY-II was launched for the upgrading of existing selected through routes and main rural links. The selection of roads was based on their economic potential and their role in facilitating the growth of rural market centres and rural hubs.

In developing countries, a limited budget is allocated for the construction and maintenance of rural roads, which is usually a major constraint. Hence, a prioritisation method is necessary for effective utilisation of the available resources. Rural road construction is an intervention that raises living standards in deprived rural areas (Gannon and Liu, 1997). The development of infrastructure such as public facilities and road networks has been extensively studied in the past, mostly independently of each other.

Models developed for urban regions are often not suitable for rural areas (Shrestha, 2003) as the socio-economic characteristics, availability of facilities, traffic and other parameters differ. A study on the planning of rural roads and public facility locations in an integrated manner, targeting optimised budget allocation, was thus the main objective of this study.

The vulnerability of a transportation network, a performance measure of a system or component, plays an essential role in the evaluation of a transport network and efficient allocation of resources. Disconnection after a natural disaster is the most severe problem, which has been relatively less addressed in the literature. With a failure in connectivity, many villages, cities or towns can become isolated. There then arise difficulties in rescue, evacuation and post-disaster support. In addition, transportation costs are increased, with economic loss. The severity of weakness in a network will differ from location to location. Identification of the weakest position and critical links in a system in order to prioritise them for improvement projects was the aim of this evaluation.