A REVIEW ON ECONOMIC EVALUATION OF HIGHWAY PROJECTS USING HDM-4

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Abstract: In India, being a developing country, road transport plays an exceptional role in economic development by moving people and goods from one place to another at an affordable cost and within reasonable time. The construction of roads leads to various advantages due to which all other sectors of the economy get benefits. Transportation projects are planned & designed to meet the demands placed on the system; but, not all projects are properly funded. Economic Evaluation of highway, also known as highway project appraisal or assessment is a technique in which the costs and benefits from a scheme are quantified over a selected time horizon and analyzed by a common point of reference. Construction of road requires good amount of finance and funding of roads should be properly planned so as to generate considerable returns from road projects. Economic Analysis helps in determining the benefits/returns from a particular highway project so that investments can be planned accordingly. The present study is aimed to throw light on various aspects of Economic analysis of Highway Projects. Also a brief overview and importance of HDM-4 software in Economic Analysis has been explained.

Index Terms **- HDM-4, Economic Analysis, Sensitivity Analysis, Net Present Value (NPV), Benefit/cost (B/c) ratio, Internal rate of return (IRR)**

1. INTRODUCTION

Transportation and economic development play a vital role in ensuring the efficient functioning of any state or region. A well-developed transportation network ensures a smoother, faster and more reliable movement from origin to destination. This is unavoidable because the time spent in traffic-jams results into waste and undesirable expenses of fuel and out of pocket expenses which is not good from economical view point. Moreover, time is wasted which could rather have been utilized in some other productive alternatives. For high level of economic performance, a good quality road network is much important.

Transportation projects are planned & designed to meet the demands placed on the system; but, not all projects are properly funded. The ones that are most critical and beneficial to the well-being of the transportation system and economic development of the region should be properly funded. A proposed road project is expected to have various alternatives in terms of its way of implementation. The overall expenditure incurred, and the expenditure required at various stages of project execution would be different for different alternatives. A judicious and proper selection of the best possible strategy, among various alternatives, necessitates understanding in economics of highway projects Study of highway economics and finance involves understanding of various cost components of highway project, the economic feasibility of alternative highway projects, decision on scheme of investment on a project at its various stages, funding source and policies for road projects.

1.1 Economic Evaluation of Highway Projects

Highway is an important structure of Civil Engineering, which requires huge amount of expenditure. Economic Analysis of highway, also known as highway project appraisal or assessment is a technique in which the costs and benefits from a scheme are quantified over a selected time horizon and analyzed by a common point of reference. The technique is also known as Benefit-Cost (B-C) analysis. Economic analysis of a highway serves a number of purposes which are given as under:

1. For Preparation of highway plans at the national, regional or local level within the overall development plan.

2. For prioritizing schemes within the highway sector plan competing for scarce resources.

3. For analysis of phases of the road programme over a horizon of time based upon the availability of resources.

4. For comparison of mutually exclusive schemes and selection of the most beneficial one.

5. For determining whether a scheme or a project under consideration is worth investing.

6. To assess alternative strategies such as stage-construction or full construction; alternative options such as flexible pavement or rigid pavement; alternative policies such as to opt for maintenance or for rehabilitation; alternative design standards and alternative policy options on axle loads.

2. LITERATURE REVIEW

A number of research works have been carried out in the field of Economic Evaluation of highways and other transportation projects using IRC method and HDM-4. Transportation funding must be allocated properly for constructing and maintaining a good transportation system and for providing the infrastructure required for growth and economic development of a region.

Grant G. Schultz et. al. (2007) in his study stated that transportation funding must be used efficiently for maintaining an efficient transportation system and providing the infrastructure necessary for economic development and growth. Availability of funds sometimes restricts the augmentation of capacity on the transportation network. Economic viability of the project on the region, combined with the impacts of the project to the economy, should be considered while making important decisions on allocating transportation funds

Ing. Radan Tomek et. al. (2016) explained in his research that the major deficiencies in the current investment decision process to the highway network and the major problems and ineffectiveness in realization. As Transportation plays and outstanding role in a country's economic growth and huge investments that are required, a thorough economic evaluation of these investments is unavoidable. Use of current methods of economic appraisal, their improvement and incorporation of the LCCA into the investment decision process is studied.

Dr. Dipti Ranjan Mohapatra (2015) has stated that construction of new road infrastructures as well as timely maintenance of the existing one has long term economic benefits. These benefits are evaluated by carrying out benefit-cost analysis of the expenditures incurred and benefits obtained in terms of Economic Internal Rate of Return. Benefits of construction of new road infrastructures in Chandigarh city of Punjab, have been evaluated by carrying out benefit-cost analysis of the expenditures involved and returns obtained in terms of Economic Internal Rate of Return. Also, sensitivity analysis has been carried out to check the economic viability of the project.

R. Sudhakar (2009) carried out a study in which optimum maintenance treatment is determined for the urban road network among the various alternatives recommended in Government of India specifications using an appropriate and well-known tool namely HDM - 4 developed by the World bank. The study has been carried out in Chennai and optimum maintenance have been determined from the various alternatives recommended in Government of India specifications using HDM-4.

S. S. Jain et. al. (2015) in his study carried out calibration of the HDM-4 for pavement deterioration models has been conducted for a National Highway Network located in the Uttar Pradesh and Uttaranchal of India. Data for cracking, ravelling, potholing, and roughness, have been collected, analysed, and used for calibration of the HDM-4. Also in this study, the models have been checked to test their efficiency by comparing the distress predictions made by the calibrated deterioration models with those actually observed on the selected pavement sections.

Swapan Kumar Bagui et. al. (2015) carried out a study which is concerned with need for a calibration (level-1) of the HDM model according to local conditions, which is an important part of the pavement management process. HDM model Level-1 Calibration according to local conditions has been carried out for a State Highway in Uttar Pradesh. Factors viz. roughness-age environment, crack initiation and crack propagation have been computed. A well calibrated model based upon the local conditions would reduce the possibility of future funding shortages of any kind of road projects.

Snehamay Khasnabis et. al. (2012) in his research stated that the purpose of evaluating mutually exclusive highway alternatives is to choose the most beneficial one for project implementation. Different analytical techniques for evaluation of alternatives like Cost-effectiveness (C⁄E) technique, Benefit-to-cost ration (B⁄C) technique, Internal rate of return (IRR) technique, Payoff period (PP) technique have been explained. The process of economic analysis can be used for all public projects, including highways, transit, airports, and other infrastructure development involving money.

Shah Yogesh et. al. (2014) in his study stated that the HDM-4 software can be used for aiding the highway planners for allocation of funds, and also for determining priorities to increase the effectiveness of expenses incurred in the construction and maintenance of pavement. The strategic analysis of a network of selected urban roads of Noida City has been carried out using HDM-4 software for maximizing the NPV and minimizing the costs for gaining a target international roughness index.

Errampalli Madhu et. al. (2015) in his parametric study developed congestion cost relationships between Congestion Factor, a ratio of cost under congestion and steady state conditions and Volume-Capacity Ratio by considering various vehicle types plying on varying widths of multi-lane highways through the collection of exhaustive time related and fuel related data. The analysis shows that the congestion effect is more significant on fuel cost for heavy commercial vehicles whereas it is more prominent on time cost for passenger vehicles. However, the congestion effect on combined fuel and time cost is more significant on multi-axle trucks followed by cars, two wheelers and buses.

A. Talvitie (2000) in his research discusses the economic analysis of road projects. The study states that whenever there are budget issues, evaluation of roads is must. A basic principle of equity-but not the only one-is that those who receive the benefit also pay for it, thus designating the budget constraint. It also indicates that benefits and costs are considerably affected by road sector organization and management, and gives current ideas for organizing a commercialized road sector pursued in many Bank-supported projects.

3. METHODS OF ECONOMIC EVALUATION

A number of methods have been developed and the literature on them is voluminous. The various important methods are as follows:

1. Net Present Value (NPV) Method

Net present value (present worth) method is based on the Discounted Cash Flow (DCF) technique. In this method, the stream of Cost/Benefits associated with the project over an extended period of time is calculated and is discounted at a selected discount rate to give the present value. Benefits are treated as positive and costs as negative and the net present value are found. Any project with a positive net present value is treated as acceptable. In comparing more than one project, a project with the highest net present value should be accepted. The net present value is algebraically expressed as in equation:

$$NPV = \sum_{i=0}^{n} \left(\frac{B_i - C_i}{(1+r)^n} \right) \quad \text{.....[1]}$$

Where, B_i is the benefit of the i^{th} year, C_i is the cost of the i^{th} year and n is the number of years, r is the discount rate.

2. Benefit / Cost (B/C) Ratio Method

The benefit/cost ratio method is one of the widely used one for evaluation of highway projects. In this method, ratio of net annual benefits to the net annual costs is determined. The benefits are evaluated for a single reference year, which for convenience can be the first of operation after construction or the median year of the analysis period. The costs are the equivalent annual charge representing equal amortization and interest payment (at a specified discount rate) spread over the economic life of project. The benefit cost ratio for a particular project would be given in equation:

$$\frac{B}{C} = \frac{Benefits\ in\ the\ reference\ year}{Annual\ costs} \quad \text{.....[2]}$$

The numerator of the B/C ratio represents the benefits, which are the reduction in user cost. The denominator represents the difference in annual highway costs between the new facility and the existing facility, including maintenance. If the number of the projects are being considered, B/C ratio for each of these is determined in the same manner, comparing conditions for the existing road with those for the improvement is less than the benefits that are likely to occur and the project is economically justified.

If several projects are being considered, the ratio would enable them to be ranked in order of attractiveness, the one having the highest B/C ratio being the most attractive. When several major alternatives are under evaluation, a second analysis is made, using the proffered alternatives as the base to determine whether an added increment of investment might yield a proportionately larger increase in road user savings when compared with another alternative.

3. Internal Rate of Return (IRR) Method

The internal rate of return is the discount rate which makes the discounted future benefits equal to the initial outlay. In other words, it is the discount rate which makes the stream of the cash flow to zero. The following equation can thus be modified as in equation, if B_o is zero

$$Co = \sum_{i=0}^{n} \left(\frac{B_i - C_i}{(1+r)^n} \right) \quad \text{.....[3]}$$

where, C_o = Capital cost of the investment in the year o
B_i= Value of the benefits which occur in the i^{th} year
C_i= Cost which occur in the i^{th} year
r = Internal rate of return
N = Number of the years for which the analysis is done

The solution to be above equation is tedious and is possible only by trial and error. With a computer program the work can be simplified. If the rate of return calculated from the above equation is greater than the rate of interest obtainable by investing capital in the open market, the scheme is considered acceptable.

3.1 Comparison of Various Methods of Economic Evaluation

The various methods of economic evaluation described earlier have their own advantages. Each one of them may be more appropriate than the other one for a given situation. The benefit/cost ratio method, through widely used by highway engineers, suffers from the following drawbacks:

1. It requires an assumption of the rate of interest, which should be somewhat related to the opportunity cost of capital is very often not known or can be estimated only approximately

2. The significance of B/C ratio is ambiguous and its relative value is difficult to understand and interpret. For example, if there are two proposals, one with a B/C ratio of 1.05 and the other one with a ratio of 1.10, the difference is very difficult to appreciate.

3. It is times difficult to decide which items should be treated as costs and placed in the denominator and which ones as negative benefits and placed in the numerator.

The net present value method also suffers from the disadvantage since a discount rate has to be assumed initially. It is much simpler computationally when compared to the internal rate of return method. The internal rate of return avoids the necessity for selecting a discount rate initially. The rate which is derived as a result of the computation can be easily compared with the market rate of interest, with which economists and financial experts are familiar. Thus, the method is considered to be more meaningful than the others. Its disadvantages are that the calculation s are tedious and a solution can only be found by trial and error and it may sometimes be misleading in comparing projects having different lives and different streams of benefits. The first-year rate of return method is quick to use but has obvious shortcomings. More importantly, many projects may have attractive benefits initially but whose benefits taper off abruptly thereafter and this factor will be lost sight of in this method.

4. OVERVIEW OF HDM-4

Economic Analysis is important parameter in making decisions related to highway investments. World Bank's HDM-4 software is an important tool to which not only performs economic analysis but is also helpful in planning maintenance strategies for highways, and also for performing Life cycle cost analysis.

The 3 major applications of HDM-4 are:

1. Strategy analysis: Includes planning of strategy for highways like maintenance, reconstruction, rehabilitation, etc.

2. Project Analysis: Includes Economic Analysis for highway projects, estimation of road user costs and benefits, etc.

3. Programme Analysis: Includes prioritization of a defined long list of candidate road projects into a one-year or multi-year work programme under defined budget constraints.

Other applications of this software are:

- Road sector policy studies
- Strategic planning of road network development, improvement & maintenance
- Determination of funding requirements
- Preparation of multi-year road work programmes
- Economic appraisal of individual road projects
- Research studies
  - Road pricing
  - Vehicle regulations
  - Pavement design standards

5. CONCLUSIONS

From this study, it can be concluded that due to the number of purposes it serves, the Economic Analysis of Highways plays a vital role in proper planning of allocation of funds for highway construction. Different Parametric researches carried out in the field of Economic Analysis of Highway projects explain the various aspects of the same and its importance in determining the benefits and returns from a particular project. This study explains various methods of Economic Evaluation of highways. According to various studies mentioned above, the most used method is Benefit Cost (B/c) ratio method due to ease of its computation compared to IRR method which is based on trial & error process. The study also gives the overview and explains the importance of HDM-4 software in Economic Evaluation of Highways. Various applications of HDM-4 Software indicate its outstanding role in evaluation of World Bank funded Highway Projects. In India, mostly IRC SP:30-2009 is used for performing Economic Evaluation of highways. There may be variation in the results obtained by using IRC SP:30-2009 and HDM-4. This is due to the fact that the equations given in IRC SP:30-2009 are developed for Indian conditions, whereas the equations in HDM-4 model are calibrated for the same. For full calibration, enormous data is required, which is difficult to be made available in the course of the study of this nature. Thus, Economic Evaluation of highways plays a vital role in planning for investments in highway projects and is helpful in determining benefits/returns from the same.

REFERENCES

[1] Bagui, S., & Ghosh, A. (2015). Level 1 Calibration of HDM-4 Analysis with a Case Study. Malaysian Journal of Civil Engineering, 27(1), 121-143.
[2] Dr. Mohapatra, D. R. (2015). An Economic Analysis of Improvement of Road Infrastructure: A Case Study. European Academic Research, 2(11), 14636-14651.
[3] Errampalli, M., Senathipathi, V., & Thamban, D. (2015). Effect Of Congestion On Fuel Cost And Travel Time Cost On Multi-Lane Highways In India. International Journal For Traffic And Transport Engineering, 5(4), 458-472.
[4] Jain, S. S., Aggarwal, S., & Parida, M. (2005). HDM-4 Pavement Deterioration Models for Indian National Highway Network. Journal of Transportation Engineering, 131(8), 623-631.
[5] Khasnabis, S., Mishra, S., & Safi, C. (2012). Evaluation Procedure for Mutually Exclusive Highway Safety Alternatives under Different Policy Objectives. Journal of Transportation Engineering, 138(7), 940-948.
[6] Schultz, G. G., & Stewart, A. L. (2007). Evaluating Economic Analysis Alternatives in the Transportation Decision Making Process. International Conference on Transportation Engineering, 3133-3139.
[7] Shah, Y. U., Jain, S. S., & Tiwari, D. (2016). Adaptation of HDM-4 Tool for Strategic Analysis of Urban Roads Network. Transportation Research Procedia, 17, 71-80.
[8] Sudhakar, R. (2009). Pavement Maintenance Management System for Urban Roads Using HDM-4. Indian Geotechnical Society Chennai Chapter, 31-37.
[9] Talvitie, A. (2000). Evaluation of Road Projects and Programs in Developing Countries. Transport Policy, 7, 61-72.
[10] Tomek, R., & Vitasek, S. (2016). Improvement of Economic Effectiveness of Road Highway Projects. Procedia Engineering 164, 164, 395-401.
[11] IRC: SP:30-2009. "Manual of Economical Evaluation of Highway Projects in India", Indian Roads Congress.
[12] Kerali Henry G. R., Odoki J. B., 2000, HDM-4 Highway Development & Management, Volume 1 to 5, The Highway Development and Management Series
[13] Ministry of Road Transport and Highways (MoRTH) Annual Report 2017-18.
[14] National Highways Authority of India (NHAI) Annual Report 2016-17.