Economic Evaluation of a Highway Project Using HDM-4: A Case Study of Widening of Ahmedabad-Bagodara National Highway

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1 Introduction

Road transport, in a developing country like India, plays an exceptional role in economic development. The construction of roads and operation of traffic on the roads leads to various advantages resulting in benefits to all other sectors of economy. Highway is an important construction of civil engineering, which requires huge amount of expenditure. Economic evaluation of highway also known as highway project appraisal is a method in which the costs and benefits from a road project are computed for a selected time horizon and analyzed by a particular point of reference [1]. Also, economic nalysis serves a number of purposes such as preparing highway plans at various levels, prioritizing various highway schemes, comparison of mutually exclusive projects, determining whether the project is worth investing, analyzing alternative strategies, standards and policies.

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1.1 Literature Review

Many 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.

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 whilst making important decisions on allocating transportation funds [2]. 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 [3]. 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 [4]. Optimum maintenance treatment for the urban road network in Chennai has been determined from the various alternatives recommended in Government of India specifications using HDM-4 [5]. 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, analyzed and used for calibration of the HDM-4 [6]. 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 [7]. 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 [8]. 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 [9].

1.2 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
2. Benefit/cost (B/C) ratio method
3. Internal rate of return (IRR) method.

1.3 Introduction to 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 to perform life cycle cost analysis. The three major applications of HDM-4 are

1. Strategy analysis: It includes planning of strategy for highways like maintenance, reconstruction, rehabilitation, etc.
2. Project analysis: It includes economic analysis for highway projects, estimation of road user costs and benefits, etc.
3. Programme analysis: It includes prioritization of a defined long list of candidate road projects into a one-year or multi-year work programme under defined budget constraints.

2 Research Objective

The main aim of this study is to carry out economic analysis of widening of Ahmedabad-Bagodara national highway using HDM-4 software. The objective of this study is to study various aspects of economic appraisal to determine necessity of widening and to check the economic feasibility of widening of Ahmedabad-Bagodara national highway using IRC SP:30-2009 and HDM-4 along with sensitivity analysis.

3 Methodology

The methodology in this study involves six stages. In the first stage, the stretches have been identified, selected, and the road inventory data have been collected. In the second stage, classified traffic volume count study has been carried out for the stretch for 7 days-24 h. Pavement condition survey has been performed for measuring the surface distresses like pothole, ravelling, patching, edge breaking and surface cracking. Pavement composition and soil CBR have also been determined. In the third stage, secondary data like topographical data and petrol-pump sales data have been collected which serve as an input to economic analysis.

Traffic has been converted from average daily traffic (ADT) to annual average daily traffic (AADT) by using seasonal correction factors. In the fourth stage, capacity

analysis has been performed to determine the necessity for widening the existing highway. In the fifth stage, economic analysis has been performed using IRC SP:30-2009 along with sensitivity analysis to find out the economic indicator results. In the sixth stage, economic analysis has been performed using HDM-4 along with sensitivity analysis, and economic viability of project has been determined based on the values of the NPV, B/C ratio and economic internal rate of return (EIRR).

4 Data Collection

4.1 Study Area Profile

The national highway under consideration is a part of NH-47 which connects Rajkot and Ahmedabad cities of India. Study area starts form the outskirts of Ahmedabad, from Changodar village and traverses and connects various cities/villages like Bavla, Bhayala and Bagodara with Ahmedabad. The highway provides connectivity to Jamnagar and Mundra ports with the rest of the nation. These centres are to become crucial given the likely high level of investments getting attracted in the SEZs therein. The total length of the study area is approximately 33.465 km. The widening of the existing project from 4 to 6 laning divided carriageway will not only result in reduced travel time and increase in speed, but will also lead to safe and efficient traffic operation and will accommodate the future growth in traffic.

4.2 Road Inventory

The existing pavement width consists of an average 7.0 m carriageway and 1.5 m shoulder on both sides including median of 2.0 m width. There are around 30 culverts, 10 minor and 1 major road over bridge along the length of highway. Also, there are 2 major junctions and 22 minor junctions which are present at the existing highway.

4.3 Traffic Survey

Classified traffic volume count survey is carried out to determine volume of different categories using roads. In this study, classified traffic volume count has been performed for 7 days, 24 h as suggested in IRC SP:19-2001 [10]. Traffic volume count has been carried for NH-47, stretch starting from Ch.0+000 to Ch.33+465, i.e., from Ahmedabad (Changodar) to Bagodara at Ch.19+465 for both sides.

LHS indicates direction of travel from Ahmedabad to Rajkot.

RHS indicates direction of travel from Rajkot to Ahmedabad (Table 1).

Table 1 Classified traffic volume count

Direction	2W	3W	Car	Goods pickup	BUS	LCV	Truck/HCV	MAV	Tractor	Tractor trailer	Cycle
LHS	1975	673	5717	627	793	447	1972	1017	15	142	23
RHS	2082	624	6517	675	804	748	1320	1248	25	141	24
Total	4057	1297	12,234	1302	1597	1195	3292	2264	40	282	47

4.4 Pavement Condition Survey

Pavement condition survey has been performed to determine various types of pavement distresses. This is an essential survey to be performed as it gives the amount of different distresses present on the existing pavement and it also serves as an input parameter to HDM-4 based on which vehicle operating costs and maintenance requirements are evaluated. Various types of distresses observed on the existing highway are cracking, pothole, ravelling, rutting and edge breaking.

4.5 Pavement Composition and Soil CBR

Flexible pavement comprises of different layers. These layers are granular sub-base (GSB), water bound macadam (WBM), bituminous macadam (BM), bituminous concrete (BC) and semi-dense bituminous concrete (SDBC), etc. The thickness of all these layers needs to be known because it serves as an input parameter in HDM-4 to compute the structural number of pavement (SNP). The main application of California bearing ratio (CBR) is to evaluate the stiffness modulus and shear strength of subgrade. The CBR of the subgrade layer needs to be known because it serves as an input parameter in HDM-4 to compute the structural number of pavement (SNP).

4.6 Topographical Data

Topographical parameters like altitude and rise/fall have considerable effect on the vehicle operating costs (VOC), and thus these parameters need to be given equal importance. The topographical parameters like altitude and rise/fall have been determined with the help of Google Earth.

4.7 Petrol-Pump Sales Data

For conversion of average daily traffic (ADT) to annual average daily traffic (AADT), seasonal correction factors (SCF) are required. These seasonal correction factors are based upon the round-year traffic census, and collection of such data is a relatively difficult task. Hence, petrol-pump sales data have been collected from Arth petroleum located at Ch. 16+280 km.

5 Capacity Analysis

Capacity analysis is fundamental to the planning, design and operation of roads. For the purpose of augmentation of the facilities and up gradation of the project road, the design service volume for 4 lane roads LOS B is 45,000 pcu/day, and for LOS, C is 72,000 pcu/day as per Indian highway capacity manual (2012–2017) [11]. The traffic projection has been made for total ADT by considering a growth rate of 8.00% as suggested by IRC SP:30-2009 [1]. This traffic projection has be compared with the design service volume for each year and the necessity to widen/augment the facility with year has been determined with the help of capacity analysis (Fig. 1).

From the projection and figure of capacity analysis, it can be understood that this indicates a clear necessity for widening of this highway to 6 lanes in order to keep traffic movement continuously plying on the highway with sufficient operating requirements along with safety.

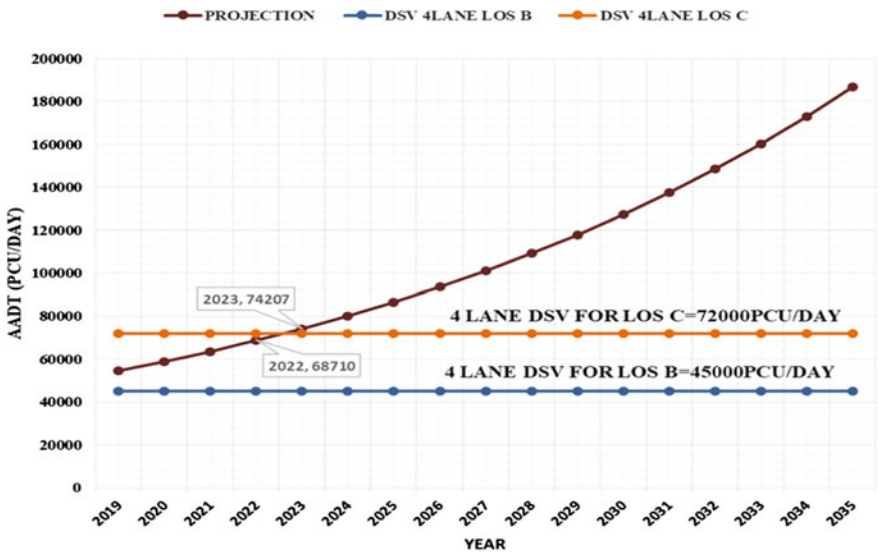


Fig. 1 Capacity analysis

Table 2 PCU values as per Indian highway capacity manual (2017)

S. No.	Vehicle type	PCU value
1	Standard car	1.0
2	Big car	1.45
3	2-wheeler (2W)	0.4
4	3-wheeler (3W)	1.2
5	Light commercial vehicles (LCV)	3.1
6	Two/three axle trucks	4.4
7	Multi-axle vehicles (MAV)	6.6
8	Bus	5.0
9	Tractor with trailer	6.2

6 Economic Evaluation Using IRC SP:30-2009

6.1 Traffic Forecast

Initially, forecast of traffic has been carried out for the base condition, i.e., do minimum (case-1) and proposed condition, i.e., widening to 6 lanes and strengthening the existing 4 lane pavement (case-2). The traffic volume data are expressed in terms of PCUs. The conversion of vehicles into PCUs is carried out by using the conversion Table 2 of Indian highway capacity manual (2017) [11].

The construction period is taken as 2 years, i.e., from 2019 to 2021. The analysis period has been taken 15 years as suggested in IRC SP:30-2009. The traffic forecast has been carried out from the year of 2019–2035 with growth rate of 8.00% for the base case and widening. Also, 10% of total daily traffic is assumed to present the peak hour traffic. The capacity of 4 lane road for the base condition is taken as 4540 pcu/h/direction and that of 6 lane road for widening condition is considered as 6790 pcu/h/direction as suggested by Table 2 of Indian highway capacity manual (2017).

6.2 Congestion Factors

The effect of congestion on VOC can be considered separately for the distance-related and time-related components. Distance-related congestion components are fuel, lubricants, tyre, spare parts and maintenance labour. Time-related congestion components that affect the vehicle operating costs are depreciation, fixed costs, crew wages, etc. Distance-related congestion factors and time-related congestion factors for the same traffic for analysis period of 15 years have been computed.

6.3 Vehicle Operating Costs

The vehicle operating costs (VOC) for different categories of vehicles have been determined with the help of procedure specified in IRC SP:30-2009 [1]. It may be noted that vehicle operating costs are affected by roughness of the pavement surface and rise/fall of the entire highway. In this study, average rise/fall determined with the help of Google Earth is 15. Also, the roughness data obtained from the R&B department, Ahmedabad indicates that the average roughness of road can be taken as 4000 mm/km. Hence, the VOC of all the vehicles has been computed for a RF of 15 and roughness of 4000 mm/km for case-1, i.e., 'do minimum' and roughness value of 2000 mm/km has been adopted for the case-2, i.e., upgraded 6 lane road. The VOC has been corrected for present day costs by using ratio of WPI value [12] of the present year and that of 2009.

6.4 Economic Evaluation

Based on the VOC of different vehicles considering both conditions, benefits have been worked out. Construction cost of highway is Rs. 414 crores as per R&B department, Ahmedabad. As per report of the committee on norms for maintenance of roads in India, MoRTH [13], the maintenance cost for the existing 4 lane pavement is taken as Rs. 59,106,000 per year and that for 6 lane road is taken as Rs. 76,490,000 per year (converted to present day costs). These benefits are then compared to the costs involved in the construction and maintenance of the highway, and thus economic analysis has been performed (Table 3).

The economic analysis results are stated below:

1. B/C ratio for the widened 6 lane highway is 2.14, which is greater than 1.
2. NPV for the highway is Rs. 4341.88 million, which is positive.
3. EIRR value is 28.14%, which is greater than the interest rate.

6.5 Sensitivity Analysis

Sensitivity analysis has been carried out to test the economic strength of the project. The variations in the following parameters have been examined, considering them to be on the conservative side (Table 4).

7 Economic Evaluation Using HDM-4

Economic evaluation has been carried out using HDM-4 based on costs and benefits, by comparing the total net benefits in 'do minimum' situation with 'widening

Table 3 Economic analysis as per IRC SP:30-2009 (all figures in Rs. lakhs)

Year	Case-1: do min.		Case-2: widening		Costs	Benefits	Net benefits	Disc. benefits
	Maint	VOC	Const. and maint	VOC				
2019	591.06	51,710.37	20,700.00	51,710.37	– 20,108.9	0.00	– 20,108.94	– 20,108.94
2020	591.06	57,578.43	20,700.00	57,578.43	– 20,108.9	0.00	– 20,108.94	– 17,954.41
2021	591.06	64,267.62	764.90	55,576.60	– 173.84	8691.02	8517.18	6789.84
2022	591.06	71,928.83	764.90	61,453.47	– 173.84	10,475.36	10,301.52	7332.41
2023	591.06	80,752.27	764.90	68,208.05	– 173.84	12,544.22	12,370.38	7861.60
2024	591.06	90,983.08	764.90	75,969.40	– 173.84	15,013.68	14,839.84	8420.52
2025	591.06	102,945.73	764.90	84,788.10	– 173.84	18,157.63	17,983.79	9111.15
2026	591.06	117,084.86	764.90	94,835.67	– 173.84	22,249.19	22,075.35	9985.77
2027	591.06	130,929.43	764.90	106,315.79	– 173.84	24,613.63	24,439.79	9870.82
2028	591.06	141,403.78	764.90	119,471.15	– 173.84	21,932.63	21,758.79	7846.44
2029	591.06	152,716.08	764.90	134,239.51	– 173.84	18,476.57	18,302.73	5892.99
2030	591.06	164,933.37	764.90	151,123.99	– 173.84	13,809.38	13,635.54	3919.89
2031	591.06	178,128.04	764.90	170,254.50	– 173.84	7873.54	7699.70	1976.32
2032	591.06	192,378.28	764.90	189,373.96	– 173.84	3004.32	2830.48	648.67
2033	591.06	207,768.55	764.90	204,523.88	– 173.84	3244.67	3070.83	628.35
2034	591.06	224,390.03	764.90	220,885.79	– 173.84	3504.24	3330.40	608.45
2035	591.06	242,341.23	764.90	238,556.65	– 173.84	3784.58	3610.74	588.99
						EIRR	28.13	B/C 2.14
							NPV	4341.88 (million)

Table 4 Sensitivity analysis

S. No.	Conditions	EIRR (%)
1	Increase in costs by 20%	23.71
2	Decrease in benefits by 20%	22.77
3	Increase in costs by 20% and decrease in benefits by 20%	18.76

to 6 lanes and strengthening the existing 4 lane pavement' situation. The term 'do minimum' is defined as the base strategy for economic analysis, i.e., without project situation. The term 'widening to 6 lanes and strengthening the existing 4 lane pavement' is defined as widening to 6 lane dual carriageway with paved shoulder configuration of NH-47.

7.1 Sectioning of the Study Area

Taking into account the different conditions of the study area and construction of 6 lane along the length of 33.465 km, the study area has been divided into 14 sub-sections for economic analysis. Details of these sections are given in Table 5.

Table 5 Sections of the study area

Section ID	Chainage (km)		Side	Length (km)
	From	To		
1	0 + 000	5 + 000	LHS	5
2	0 + 000	5 + 000	RHS	5
3	5 + 000	10 + 000	LHS	5
4	5 + 000	10 + 000	RHS	5
5	10 + 000	15 + 000	LHS	5
6	10 + 000	15 + 000	RHS	5
7	15 + 000	20 + 000	LHS	5
8	15 + 000	20 + 000	RHS	5
9	20 + 000	25 + 000	LHS	5
10	20 + 000	25 + 000	RHS	5
11	25 + 000	30 + 000	LHS	5
12	25 + 000	30 + 000	RHS	5
13	30 + 000	33 + 465	LHS	3.465
14	30 + 000	33 + 465	RHS	3.465
Total length of the study area				33.465

7.2 Construction and Analysis Period

The construction period is selected as 2 years. The construction work is expected to be initiated by 2019, and the new facility is expected to come in operation from 2021; therefore, the construction cost phasing has been distributed as 50–50% over the stated 2 years. The analysis period is taken as 15 years.

7.3 Project Cost

In the present study, the construction cost has been taken from the R&B department, Ahmedabad. The financial cost of construction is Rs. 460 crores. Hence, this cost needs to be converted to economic cost for carrying out the analysis.

For this, a conversion factor of 0.9 is taken as suggested by IRC SP:30-2009, and thus the economic cost of the project is taken as Rs. 414 crores.

7.4 Standard Conversion Factors

In economic analysis, the prices of all components used are in economic terms. This is because of all the distortions in prices relating to labour wages, capital market, transfer payments need to be corrected. For the purpose of economic analysis, financial prices have been converted to economic prices using a factor of 0.9, as suggested by IRC SP:30-2009.

7.5 Traffic Composition Data

For each road section, traffic level is specified in terms of average annual daily traffic (AADT) flow. Traffic data have been derived from the primary surveys like classified traffic volume count survey which was conducted for 7 days-24 h at chainage 19 + 465 km. Total AADT for LHS is taken 12,332 and that for RHS is taken 13,069. The traffic composition for the vehicle fleet data is given in Table 6.

7.6 HDM-4 Calibration Parameters

The calibration (level-1) to the road deterioration and work effects has been carried out for the sensitive parameters. The level-1 calibration parameters with their respective values for calibrating HDM-4 model are as given in Table 7.

Table 6 Traffic composition

Categories	LHS composition (%)	RHS composition (%)
2-wheeler	15.53	15.46
3-wheeler	5.30	4.63
Car	42.19	45.37
Goods pickup	4.63	4.70
Bus	5.85	5.60
LCV	3.30	5.21
Trucks/HCV	14.55	9.19
MAV	7.50	8.69
Tractor	1.21	1.15
Total MT traffic (%)	100.00	100.00

Table 7 HDM-4 level-1 calibration parameters

Parameters	Initiation	Progression
All structural cracking	0.9	1.1
Wide structural cracking	1.0	1.0
Transverse thermal cracking	1.0	1.0
Ravelling	1.0	1.0
Pothole	1.0	1.0
Edge break	1.0	
Initial densification	1.0	
Structural deterioration	1.0	
Roughness env. coefficient	1.25	
Roughness progression	1.0	

7.7 Road Network Data

The basic road network data used as input is as given Table 8.

7.8 Vehicle Fleet Data

Vehicle operating costs (VOC) is the major component of economic analysis. The primary inputs required in HDM, to estimate the VOCs, are the prices of vehicles, tyre, petrol, diesel, lubricants, crew cost, maintenance cost, vehicle utilization and other vehicle fleet characteristics. The vehicle fleet data provided as an input in HDM-4 is as given in Table 9.

Table 8 Road network data

	Section ID													
Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Existing pavement type	Asphalt mix on granular base													
Average carriageway width (m)	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Average shoulder width (m)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Number of lanes	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rise + fall (m/km)	9.5	9.5	13	13	10	10	8	8	10	10	9	9	5.2	5.2
Altitude (m)	26	26	26	26	25	25	21	21	17	17	13	13	13	13
Avg. roughness (m/km)	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total area of cracking (%)	0.0036	0.0032	0.0143	0.0047	0.0462	0.0037	0.3751	0.0139	0.2777	0.0171	0.1662	0.0147	0.0462	0.0551
Ravelled area (%)	0.0086	0.0968	0.0023	0.0837	0.1522	0.1867	0.0510	0.0475	0.0037	0.019	0.0017	0.0029	0	0
No. of potholes (no./km)	1	2	1	2	0	1	1	0	1	1	1	1	1	1
Mean rut depth (mm)	1.3	0.7	0	17	1.2	3.8	0	4	0	0.4	0	0.4	0	0

Table 9 Vehicle fleet data

Vehicle type	2-W	3-W	Car	Goods pickup	Bus	LCV	Truck/HCV	MAV	Tractor
Base type	Motor cycle	Auto	Car	Pickup vehicle	Bus	Light truck	Heavy truck	Multi-axle	Tractor
PCSE	0.5	0.70	1	1	1.5	1.3	1.4	1.6	1.9
No. of wheels	2	3	4	4	6	4	6	14	4
No. of axles	2	2	2	2	2	2	2	4	2
Tyre type	Bias-ply	Bias-ply	Radial-ply	Radial-ply	Bias-ply	Bias-ply	Bias-ply	Bias-ply	Bias-ply
Base number of recaps	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Retread cost (%)	15	15	15	15	15	15	15	25	15
Annual kilometre (km)	10,000	40,000	45,000	54,000	146,000	50,000	85,000	86,000	9000
Working hours	550	1460	730	1800	2920	1825	2200	2555	730
Average life (years)	8	6	10	15	8	8	8	10	8
Private use (%)	100	0	100	0	0	0	0	0	100
Passenger	2	5	5	6	56	2	2	2	2
Work-related passenger trips (%)	80	75	75	75	75	0	0	0	0
ESALF	0	0	0	0	1	0.27	4.25	3	1
Operating weight (tons)	0.2	0.8	1.25	1.4	10	4.5	14	18	8

7.9 HDM-4 Configuration

It is essential to configure the model to local conditions in HDM-4. The configuration of the model, therefore, includes traffic flow pattern, speed-flow type and Currency. Inter-urban traffic pattern has been selected for the study area. Speed-flow type for the project has been defined for 4 lane having ultimate capacity of 2000 PCSE/lane/h and 6 lane having ultimate capacity of 2400 PCSE/lane/h.

7.10 Unit Costs for Vehicles

A unit cost database has been prepared for new vehicle price, replacement of tyre, petrol/diesel/engine oil, body-building costs of vehicles, etc., by referring certain guidelines given by HDM-4 itself (Table 10).

7.11 Maintenance Strategy and Cost

Maintenance strategy adopted for the analysis has been given in Table 11.

7.12 Results of Economic Evaluation

Economic analysis conducted using HDM-4 has stated the below mentioned results:

1. NPV for the highway is Rs. 7394.63 million which is positive.
2. EIRR value is 32.1% which is greater than the interest rate (Fig. 2).

7.13 Sensitivity Analysis

Sensitivity analysis has been carried out using HDM-4, considering the following scenarios (Table 12).

8 Conclusions

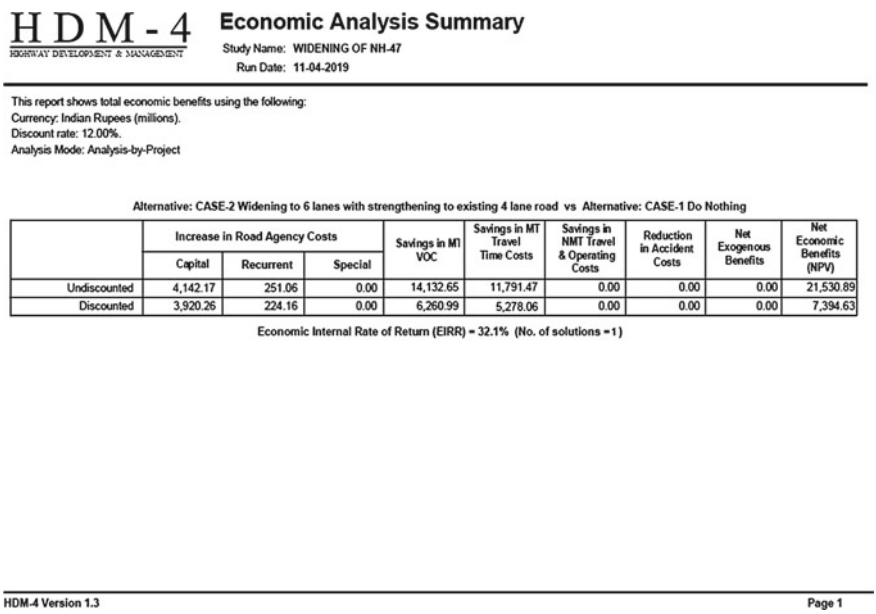
Traffic volume on Ahmedabad-Bagodara national highway NH-47 is 59,726 pcu/day for both directions which is more than the design service volume for LOS B for 4 lane roads. Also, as discussed in capacity analysis, the traffic volume will cross the

Table 10 Unit costs for vehicles

Vehicle type	2-W	3-W	Car	Bus	LCV	Truck/HCV	MAV	Tractor
New vehicle (Rs.)	54,090	230,260	763,220	1,102,520	652,750	1,141,900	1,287,960	616,000
Replacement tyre (Rs.)	990	1675	2950	9980	4620	9360	9360	11,400
Fuel (Rs./l)	28	28	28	28	28	28	28	28
lubricating oil (Rs./l)	87	87	87	180	87	180	180	87
Maintenance labour (Rs./h)	6	3	6	6	2	4	4	3
Crew wages (Rs./h)	0	50	0	80	20	52	52	30
Annual over head	5000	10,000	20,000	200,000	120,000	400,000	400,000	120,000
Annual interest (%)	12	12	12	12	12	12	12	12
Passenger working time (Rs./psngr. h)	40	30	65	40	0	0	0	0
Passenger non-working time (Rs./psngr. h)	2	3	4.5	5	0	0	0	0
Cargo (Rs./veh. h)	0	0	0	2	1	3	5	0

Table 11 Maintenance strategy and cost

Year		Type of maintenance		Cost of maintenance (Rs.)			
Do min.	Widening	Do min.	Widening	Do min.		Widening	
				Economic (m^2)	Financial (m^2)	Economic (m^2)	Financial (m^2)
Periodic maintenance (scheduled for every 5th year)							
2019 2024 2029 2034	2026 2031	Overlay 25 mm BC	Overlay 40 mm BC	334	367	534	588
Routine maintenance (scheduled for every year)							
All years other than stated above		Patching	Patching	104	114	104	114
		Crack sealing	Crack sealing	82	90	82	90



HDM - 4
HIGHWAY DEVELOPMENT & MANAGEMENT

Economic Analysis Summary

Study Name: WIDENING OF NH-47
Run Date: 11-04-2019

This report shows total economic benefits using the following:
Currency: Indian Rupees (millions).
Discount rate: 12.00%.
Analysis Mode: Analysis-by-Project

Alternative: CASE-2 Widening to 6 lanes with strengthening to existing 4 lane road vs Alternative: CASE-1 Do Nothing

	Increase in Road Agency Costs			Savings in MT VOC	Savings in MT Travel Time Costs	Savings in NMT Travel & Operating Costs	Reduction in Accident Costs	Net Exogenous Benefits	Net Economic Benefits (NPV)
	Capital	Recurrent	Special						
Undiscounted	4,142.17	251.06	0.00	14,132.65	11,791.47	0.00	0.00	0.00	21,530.89
Discounted	3,920.26	224.16	0.00	6,260.99	5,278.06	0.00	0.00	0.00	7,394.63

Economic Internal Rate of Return (EIRR) = 32.1% (No. of solutions = 1)

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Fig. 2 HDM-4 economic analysis summary

Table 12 Sensitivity analysis as per HDM-4

S. No.	Conditions	EIRR (%)
1	Increase in capital cost by 20%	28.3
2	Decrease in traffic growth by 20%	26.7
3	Increase in capital cost by 20% and decrease in traffic growth by 20%	23.3

design service volume for LOS C for 4 lane roads, there is necessity to widen it to 6 lane highway in order to keep traffic movement continuously plying on the highway with sufficient operating requirements along with safety. The results of economic analysis of widening of highway carried out using IRC SP:30-2009 are stated below:

1. B/C ratio for the upgraded 6 lane highway is 2.14, which is greater than 1.
2. NPV for the highway is Rs. 4341.88 million, which is positive.
3. EIRR value is 28.14%, which is greater than the interest rate.

Economic analysis conducted using HDM-4 has stated the below mentioned results:

1. NPV for the highway is Rs. 7394.63 million, which is positive.
2. EIRR value is 32.1%, which is greater than the interest rate.

Also the results of sensitivity analysis in each and every case indicate that the EIRR is favourable. The variation in the results obtained by using IRC SP:30-2009 and

HDM-4 is substantial. 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. The certain limitations of method of economic analysis using IRC SP:30-2009 are equations of calculating distance-related congestion factor and time-related congestion factor, and vehicle operating costs are given only up to 4 lane highways and not for 6 lane/8 lane highways. Also, the class of vehicles for which DRCF and TRCF equations are given are only limited to 2-wheeler, car, bus, truck/HCV and MAV. There is no provision in the code for other vehicles like 3-wheeler, goods pickup vehicle, tractor. This leads to variation in the results.

Thus, due to above mentioned limitations of IRC SP:30-2009, it cannot be used for multilane highways and other important highway constructions in which large amount of investments is involved and for which there is no any clearly specified provision in the code. HDM-4 covers the above-mentioned limitations of IRC SP:30-2009, given that entire data set required for performing economic analysis is available with the analyst. Thus, from the results of economic evaluation of Ahmedabad-Bagodara national highway, it is concluded that the 6 lane highway is more economical as compared to existing 4 lane highway.

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