RUCS-STUDY

- E V E R Y O N E W E L C O M E -

TRANSPORTATION ENGINEERING SEMINAR

Economic Appraisal of Certain Highway Projects in India

by

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Date: Wednesday, June 17, 1992

Time: 4:00-5:00 p.m.

Location: F231 Civil Engineering Conference Room

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Seminar Talk

on

"Economic Evaluation & Analysis of Highway Improvement Schemes"

by

DR. S.L. DHINGRA

at

Civil Engineering Department

I I T, POWAI Bombay

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4. Vehicle operating costs
5. Total Highway costs
6. Calculation of IRR & Marginal Analysis
7. Case Studies.
Results and Conclusions.

WIDTH OF PAVEMENT

The existing width of pavement of all the schemes considered under the study have two lanes and all the equations have been developed based on it.

ROUGHNESS OF SURFACE

The project roads have at present a black topped carriageway. The pavements in most of the reaches are deficient due to large axle load repetitions and hence roughness of the surface is of the order of 6000 mm per kilometre.

VERTICAL PROFILE OF THE ROAD

The fuel and tyre costs are dependent inter-alia on the rise and fall of the road. The average rise and fall assumed in the analysis for various terrain conditions are as follows:

Terrain	Rise & Fall (metres/km)
Plain	10
Rolling	20
Hilly	40

When the roads are improved (widening of carriageway and or strengthening), the roughness drops down from 6000 to 2000 mm/km immediately after strengthening. However, the roughness gradually increases with the passage of traffic and time till a renewal of the surface is carried out. This cycle adopted for analysis is as detailed in Table 3.

TABLE 3 10

Year	Roughness mm/km
(year of opening after improvement)	2000
1	2500
2	3000
3	4000
4 (year when renewal of surface is done)	5000
5 and so on	2000

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THE TRAFFIC FORECAST

An attempt was made to study the various economic and consumption characteristics of the regions in which the projects are located. The study encompasses the following parameters:

- Population
- Motor vehicle registration
- Diesel consumption
- GNP/GDP
- Index of industrial growth
- Index of agricultural production

Rate of growth of each of the above parameters established and are tabulated in Table 4.

Table 4 Economic Factors

TABLE 4: GROWTH RATE OF SELECTED ECONOMIC INDICATORS

Sl. No.	State	Population	Motor vehicle population	Truck population	GNP/GDP	Industrial Production	Agricultural production	Diesel consumption
1.	West Bengal	2.11	10.10	4.72	2.60	0.79	.66	10.60
2.	Gujarat	2.48	11.58	4.21	4.17	.47	2.7	NA
3.	Uttar Pradesh	2.31	11.70	4.89	2.81	4.76	2.1	NA
4.	Punjab	2.12	26.13	17.63	5.06	13.29	5.07	1.40
5.	Haryana	2.58	11.31	14.25	5.35	8.83	3.36	16.60
6.	Maharashtra	2.23	10.12	4.82	5.51	NA	7.50	NA
7.	Andhra Pradesh	2.14	12.29	10.89	3.30	7.80	2.20	NA
8.	Tamil Nadu	1.61	7.95	7.87	3.37	6.21	0.80	NA

The schemes taken up for the present study are:

(1) Construction of new four-lane access controlled expressway from Calcutta to Palsit in the State of West Bengal (Durgapur Expressway)

(2) Construction of a new four lane access controlled expressway from Ahmedabad to Vadodara in Gujarat State

(3) Construction of a new bridge and approaches across Ganga at Varanasi on National Highway (Varanasi bypass) in the State of Uttar Pradesh

(4) Widening to 4 lanes of National Highway No. 1 in the section Khanna to Jallandhar in the Punjab State

(5) Widening to 4 lanes of National Highway No 1 in the section Murtnal-Karnal in the State of Haryana

(6) Strengthening the existing two lane carriageway of National Highway No.3 in Bombay-Nasik section in the State of Maharashtra

(7) Strengthening the existing 2 lane carriageway of National Highway No.7 in Hyderabad-Kurnool (km 22 to 120) and Hyderabad-Nagpur Section (km 390-410) in Andhra Pradesh.

(8) Strengthening the existing two lane carriageway of National Highway No. 45 in Madras-Dindigul section (km 28 to 160) in Tamil Nadu

A map showing the project roads is at Fig. 4.3

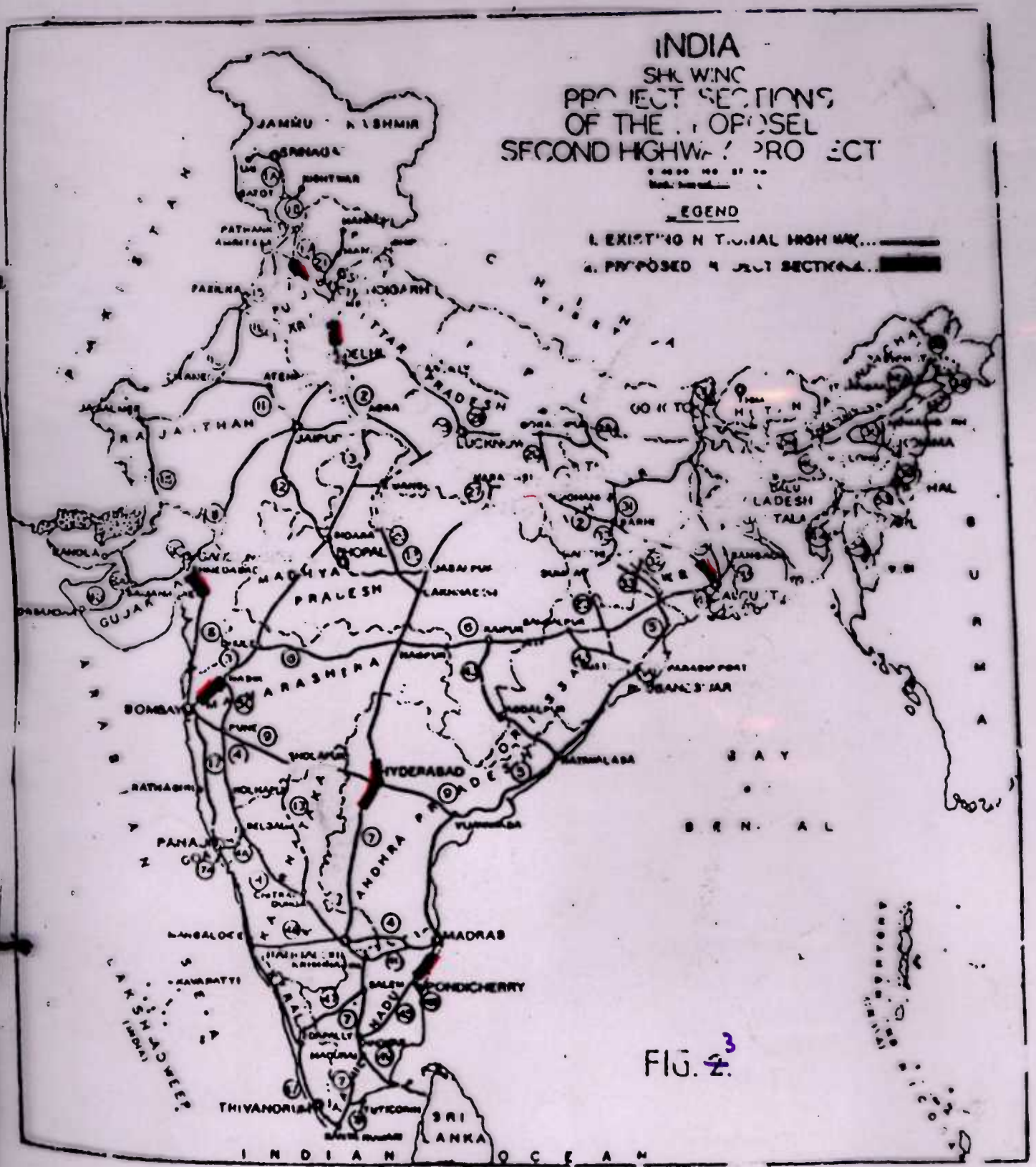
INDIA
SHOWING
PROJECT SECTIONS
OF THE PROPOSED
SECOND HIGHWAY PROJECT
LEGEND
1. EXISTING NATIONAL HIGHWAY...
2. PROPOSED PROJECT SECTIONS...
JAMMU & KASHMIR
SRINAGAR
PATHANKOT
AMRITSAR
DELHI
UTTAR PRADESH
AGRA
JAIPUR
RAJASTHAN
LUCKNOW
GUJARAT
BHOPAL
MADHYA PRADESH
NAGPUR
MAHARASHTRA
BOMBAY
PUNE
HYDERABAD
ANDHRA PRADESH
MADRAS
PONDICHERRY
THIVANDRUM
SRI LANKA
BAY OF BENGAL
INDIAN OCEAN
ARABIAN SEA

FIG. 2.3

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ENGINEERING STANDARDS

The design features and ... ign standards envisaged for all the eight projects are given in Table 5.12

The flow chart for economic evaluation & analysis model is given in Fig. 4.

The components of road user cost for different projects are presented in figure 5.

The results of economic analysis further are given in Table 14.

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5.12

TABLE 12. SERIAL NUMBER OF SCHEMES (CORRESPONDING TO PARA 5.14.5)

Design features	*Unit*	*1*	*2*		*4*	*5*	*6*	*7*	*8*
Length of Project	Km								
Terrain		Flat	Flat	Flat	Flat	Flat	Flat	Flat	Flat
Soil		Clay	Silty with fine sand and clay		Silty clay/ sandy	Silt with clay and fine sand	Rolling/ Hilly Red Stiff clay	Black cotton	Gravel
Design speed	KMPH	120	120	100	80-100	80-100	80-100	80-100	80-100
Carriageway width	metre	2×7.5	2×7.5	2×7.5	2×7.5	2×7.5	7.0	7.0	7.0
Total shoulder width	metre	2×3.5	2×3.5		2×2.5	2×2.5	2×2.5	2×2.5	2×2.5
Right of way	metre	90.0	90.0	60.0	60.0	60.0	45.0	30.0-45.0	35.0
Pavement Design					W S	W S	W S	W S	W S
Sub base	mm	250	350	175			150	150	
Granular base	mm	375	250	250	425	485	250	175	
LBM/BUSG	mm				60	50	50	75 75-150	150
Bituminous Macadam	mm	100	115	100	100 100	75 100	80 75	75 [illegible]	115 75
Asphaltic concrete	mm	40		40	40 40	40 40	40 40	40 40	40 40
Width of culverts	metres	For		Full	Formation				
Width of minor bridges		2×11.0	2×11.0		2×7.5	2×7.5	7.5	7.5	7.5
Width of major bridges		2×11.0	2×11.0		2×7.5	2×7.5	7.5	7.5	7.5

W—Widening
S—Strengthening

ECONOMIC EVALUATION MODEL

1. Road Length

Road length of each section is specified correct upto one decimal in km.

2. Terrain

Terrain of each section is specified as under:-

	Rise/fall (m/km), RF
Plain	10
Rolling	20
Hilly	40

3. Present Traffic data

The average daily traffic (ADT) for a specified year (YP) is given. ADT includes fast and slow moving vehicles. The composition of fast traffic is given as under:-

(4 types)

Cars	:	ADTC
Buses	:	ADTB
Trucks	:	ADTT
2-wheelers	:	ADTTW.

4. Roughness (RG)

The roughness of the present road is assumed as 6000 mm/km. (RG_o).

The roughness of the new road (RG_1 .....RG_5) will be as under:-

.....2/-

Year	Roughness mm/km.
Year of opening YOP	2000
YOP + 1	3000
YOP + 2	4000
YOP + 3	5000
YOP + 4	2000
YOP + 5	3000

I/

and so on repetitively.

5. Traffic growth rate (r)

for all vehicle types

1. Can be uniform growth rate/and constant for the full design period which can be varied for different analysis.

r = 0 to 25

2. Can be varying for each vehicle type, and can vary over the design period.

r = 0 to 25

6. Start of construction

1985

.....3/-

7. Alternatives to be considered

6 alternatives are possible :

Alternative No.	Specification.
N_o	Do nothing
N_1	Strengthening two lanes plus four laning later when found necessary.
N_2	Widening to four lanes.
N_3	four lane expressway
N_4	Two lane expressway
N_5	Two lane byepass.

8. Capacity norms (CAP)

	ADT
Plain terrain	7500
Rolling	5500
Hilly	2500

If projected traffic of Alt N_1 exceeds CAP, the widening of road to four lanes will be taken up in that year.

9. Period of construction (CP)

Alt N_1	3 or 4 Years (i.e. 1985,1986, 1987 and 1988) will be specified.
Alt N_2	4 Years
Alt N_3, N_4, N_5	5 Years (i.e. 1985,1986,1987, 1988 and 1989)

Year of opening to traffic (YOP) is 1985+CP.

.....4/-

10. Existing speeds

Existing speeds of four categories (cars, buses, trucks and two wheelers) will be specified in km/hr, correct up to one decimal.

11. Speed-flow Equations.

HV	=	Hourly volume.
	=	0.1 ADT.

Plain-terrain - Two lanes (Alternative No. and N, (N_1 till widening to four lanes).

Cars: V_C	=	57.88 - 0.0128 HV
Buses : V_B	=	56.93 - 0.0132 HV
Trucks: V_T	=	49.37 - 0.0097 HV.

Plain terrain - Four lane (Alt. N_2 and N_1 after widening to four lanes)

V_C	=	60.00 - 0.00345 HV
V_B	=	58.00 - 0.00212 HV
V_C	=	50.00 - 0.00152 HV.

Plain Terrain - Four lane Expressway (Alt. N_3)

V_C	=	65.00 - 0.00345 HV
V_B	=	60.00 - 0.00212 HV
V_C	=	55.00 - 0.00152 HV

Pl

.....5/-

Plain terrain - two-lane Expressway (Alt. N_4 & N_5)

V_C = 60.00 - 0.00345 HV

V_B = 58.00 - 0.00212 HV

V_T = 50.00 - 0.00152 HV.

Rolling Terrain- Two lanes

(Alt. No. and N_i (N_1 till widening to four lanes))

Cars V_C = 52.40 - 0.0098 HV

Buses V_B = 51.38 - 0.01499 HV

Trucks V_T = 48.73 - 0.01638 HV

Rolling terrain + Four lane (Alt. N_2 and N_1 after widening to four lanes)

V_C = 55.00 - 0.00345 HV

V_B = 53.00 - 0.00212 HV

V_T = 50.00 - 0.00152 HV

Hilly terrain - Two lanes.

(Alt. N_0 and N_1 (N_1 till widening to four lanes))

V_C = 35.00 - 0.01 HV

V_B = 33.00 - 0.01 HV

V_T = 30.00 - 0.01 HV

.....6/-

Hilly Terrain - Four lanes

(Alt N_2 and N_1 after widening to four lanes)

V_C = 40 - 0.005 HV

V_B = 38 - 0.005 HV

V_T = 35 - 0.005 HV

For all conditions, V_{TW} = 0.6 V_C

12. Cost of construction. (C in Lakh rupees)

C is given for Alt N_1, N_2, N_3, N_4, and N_5

C for N_0 = 0

Break-up of cost over design period is as under:

Year	Alt N_1 (CP=3)	Alt N_2	Alt. N_3, N_4 and N_5
1985	0.15 C	0.05 C	0.05 C
1986	0.40 C	0.20 C	0.15 C
1987	0.45 C	0.35 C	0.25 C
1988	--	0.40 C	0.30 C
1989	--	--	0.25 C

13. Cost of maintenance (in lakh rupees) per Km.

.....7/-

Cost of Maintenance

Year	Alt No, N_1 till widening to four lanes and N_5	Alt N_4	Alt N_1 after widening to four lanes and N_2	Alt N_3
YOP	0.1	0.15	0.2	0.3
YOP+1	0.1	0.15	0.2	0.3
YOP+2	0.1	0.15	0.2	0.3
YOP+3	0.1	0.15	0.2	0.3
YOP+4	1.25	1.25	2.5	2.6
YOP+5	0.1	0.15	0.2	0.3

and so on repetitively.

14. Design period

15 years after opening to traffic.

When comparing two alternatives, the same terminal year is considered, i.e, 2004.

All traffic, roughness, speeds, and costs are to be projected till the year 2004 and tabulated for each year.

15. Fuel costs (FC is Rs. lakhs per year)

Cars: $(ADTC + \frac{ADTTW}{5}) \times \frac{length \times 365 \times 3.40}{1000 \times 100,000}$

$\times (10.31 + \frac{1675.52}{V} + 0.0133\ V^2 + 0.0006\ RG + 0.180\ RF)$

Buses : $\frac{ADTB \times 365 \times 2.80 \times length}{1,000 \times 100,000} \times (14.49 + \frac{3904.64}{V} + 0.0207V^2$

$+ 0.0012\ RG + 0.776\ RF)$

.....8/-

Truck : ADTT x 365 x 2.37 x length

$$\times\left(32.16 + \frac{3904.64}{V} + 0.0207\ V^2 + 0.0012\ RG + 0.776\ RF\right)$$

To be calculated for each year after YOP till 2004

16. Spare parts cost (SPC) in Rs. lakhs per year

Cars : SP = -15.86 + 0.0062 RG, subject to a minimum of 3.

$$SPC = \frac{SP}{100} \times (ADTC + ADTTW) \times \frac{\text{length} \times 365 \times 0.6}{100,000}$$

Buses $(1.8753 + 0.007373\ RF + 0.0000723\ RG)$

$SP = e$

$$SPC = \frac{SP}{100} \times \frac{ADTB \times \text{length}}{100,000} \times 365 \times 1.5 \times 0.6$$

Trucks

$SP = e^{(1.7119 + 0.0001431\ RG)}$

$$SP_C = \frac{SP}{100} \times \frac{ADTT \times \text{length}}{100,000} \times 365 \times 1.5 \times 0.6$$

Calculate SPC for each year for cars buses and trucks and add using respective ADT_s, and RG_s

17. Maintenance Labour cost is R_s lakhs per year

= SPC of cars x 0.5498

+ SPC of buses x 0.4027 + SPC of trucks x 0.3692

Calculate for each year.

18. Tyre costs (TC) in Rs, lakhs per year

Cars $TC = (ADTC + \frac{ADTTW}{5}) \times 365 \times \text{length}$

$$\times \frac{4 \times 710 \times 0.727 \times 0.54}{(47340 - 2.63\ RG) \times 100,000}$$

.....9/-

Buses.

$$TC = \frac{ADTB \times 365 \times length \times 6 \times 3100 \times 0.727 \times 0.54}{100{,}000 \times (40215 - 361\ RF - 1.227\ RG)}$$

Trucks

$$TC = \frac{ADTT \times 365 \times length \times 6 \times 4200 \times 4200 \times 0.727 \times 00.54}{100{,}000\ (48113 - 367.8\ RF - 1.016\ RG)}$$

Calculate and add

TC of cars, buses and trucks for each year.

19. Fixed costs (Rs. lakhs per year)

Buses

$$\text{fixed cost} = \frac{length \times ADTB \times 18.94 \times 365}{VB \times 100{,}000}$$

Trucks

$$\text{Fixed cost} = \frac{length \times ADTT \times 40.69 \times 365}{V_T \times 100{,}000}$$

Calculate and add for each year.

20. Commodity costs (in Rs. lakhs per year)

$$\text{Commodity cost} = \frac{3.00 \times ADTT \times length \times 365}{VT \times 100{,}000}$$

Calculate for each year.

21. Crew costs

Buses.

$$\text{Crew Costs} = \frac{136 \times 1.25 \times 365 \times length \times ADTB}{(27.52 + 8.011\ V_B) \times 100{,}000}$$

Trucks

$$\text{Crew costs} = \frac{56 \times 1.25 \times 365 \times length \times ADTT}{(53.59 + 5.1637\ VT) \times 100{,}000}$$

.....10/.

22. Depreciation costs in Rs. lakhs per annum.

Buses

$$\text{Dep. cost} = \frac{0.0059 \times 3,16,250 \times 0.6 \times \text{length} \times 365 \times \text{ADTB}}{(27.52 + 8.011\ V_B) \times 365 \times 0.856 \times 100,000}$$

Trucks

$$\text{Dept. cost} = \frac{0.059 \times 2.50,000 \times 0.6 \times \text{length} \times 365 \times \text{ADTT}}{(53.39 + 5.163\ V_T) \times 365 \times 0.624 \times 100,000}$$

Add for buses and trucks and calculate for each year.

23. Travel time cost of passengers in Rs. lakhs per annum.

$$\text{Cost} = \frac{\text{Length} \times 365}{100,000} \left(\frac{8.21 \times 4.5 \times \text{ADTC}}{V_C} + \frac{4.49 \times 43 \times \text{ADTB}}{V_B} + \frac{8.21 \times 1.5 \times \text{ADTTW}}{VT_W} \right)$$

24. Congestion effect

When ADT $\geq$ 1.0 capacity, multiply fuel cost, tyre cost, spare parts cost and maintenance labour in each year by

Cars	1.54
buses	1.28
trucks	1.31

25. Calculation of IRR

Assume discount rate of 5 per cent per annum. Discount all highway costs (-Ve) and all benefits (Difference between user costs in the two alternatives) to the base year (1985).

If $B_o > C_o$

take discount rate 5 + 1 and proceed in the same way with increments of 1 % till

$B_o \leq C_o$

.....11/-

Suppose the discount rate then is d.

Take a discount rate of (d-1) + 0.1

If Bo > Co, take a discount rate of (d-1) + 0.2 and proceed in the same way with increments of 0.1 % till

Bo < Co

Let the decimal value then be d_1

(for example d_1 = 0.8)

Then I.R.R. = (d-1) + d_1 - 0.05

Calculate IRR for two cases:

1. All road user costs
2. All road user costs except bus passenger time savings.

26. Marginal analysis

Let the first set of alternatives considered be N_0 and N_1. Tabulate the stream of costs and benefits for each year. Tabulate the stream of costs and benefits of the alternatives N_0 and N_j for each year. Take the difference between the costs and benefits of the two streams for each year. Calculate I.R.R.

27. First year Rate of Return

Total the highway costs of the two alternatives N_0 and N_1 till the YOP. Find the difference in user costs (benefits) in the year YOP. The ratio of first year benefits to the costs is F.Y.R. expressed as a percentage.

28. Tabulation and print outs

(1) give print - outs of stream of discounted costs and benefits for (d-1) + d_1 and (d + 1) + (d_1 0.1) in the following forms:

.....12/-

	Costs	benefits.
1985		
1986		
.....		
2004	_____	_____
Total	_____	_____

(2) Tabulate annual benefits without discounting for each analysis as follows:-

Component	1985	1986	.....2004.
1. Fuel			
2. Spare parts			
3. Maintenance Labour			
4. Tyres			
5. Fixed costs			
6. Crew costs			
7. Commodity cost			
8. Depreciation.			
Total of 1 - 8			
9. Travel time of passenger			
Total 1-9.			

TRAFFIC FORECAST FOR TWENTY YE

YEAR	ADTC	ADTB	ADTT	ADTTH	ADTFST	ADTTL	HRVL
	LINK NUMBER = 1						
1985	2058	2104	10519	1958	16639	20266	2027
1986	2223	2272	11361	2115	17971	21888	2189
1987	2400	2454	12269	2284	19407	23637	2364
1988	2592	2650	13251	2467	20960	25529	2553
1989	2800	2862	14311	2664	22637	27571	2757
1990	3024	3091	15456	2877	24448	29777	2978
1991	3266	3338	16692	3107	26403	32158	3216
1992	3527	3605	18028	3356	28516	34732	3473
1993	3809	3894	19470	3624	30797	37510	3751
1994	4114	4205	21028	3914	33261	40511	4051
1995	4443	4542	22710	4227	35922	43752	4375
1996	4798	4905	24527	4565	38795	47252	4725
1997	5182	5298	26489	4930	41899	51032	5103
1998	5597	5722	28608	5325	45252	55116	5512
1999	6045	6179	30897	5751	48872	59526	5953
2000	6528	6674	33368	6211	52781	64287	6429
2001	7050	7208	36038	6708	57004	69430	6943
2002	7614	7784	38921	7244	61563	74983	7498
2003	8224	8407	42034	7824	66489	80983	8098
2004	8882	9079	45397	8450	71808	87462	8746
	LINK NUMBER = 2						
1985	2058	2104	10519	1958	16639	20266	2027
1986	2223	2272	11361	2115	17971	21888	2189
1987	2400	2454	12269	2284	19407	23637	2364
1988	2592	2650	13251	2467	20960	25529	2553
1989	2800	2862	14311	2664	22637	27571	2757
1990	3024	3091	15456	2877	24448	29777	2978
1991	3266	3338	16692	3107	26403	32158	3216
1992	3527	3605	18028	3356	28516	34732	3473
1993	3809	3894	19470	3624	30797	37510	3751
1994	4114	4205	21028	3914	33261	40511	4051
1995	4443	4542	22710	4227	35922	43752	4375
1996	4798	4905	24527	4565	38795	47252	4725
1997	5182	5298	26489	4930	41899	51032	5103
1998	5597	5722	28608	5325	45252	55116	5512
1999	6045	6179	30897	5751	48872	59526	5953
2000	6528	6674	33368	6211	52781	64287	6429
2001	7050	7208	36038	6708	57004	69430	6943
2002	7614	7784	38921	7244	61563	74983	7498
2003	8224	8407	42034	7824	66489	80983	8098
2004	8882	9079	45397	8450	71808	87462	8746
	LINK NUMBER = 3						
1985	972	928	4640	1012	7552	9575	958
1986	1050	1002	5011	1093	8156	10341	1034
1987	1134	1082	5412	1180	8808	11168	1117
1988	1224	1169	5845	1275	9513	12062	1206
1989	1322	1263	6313	1377	10275	13028	1303
1990	1428	1364	6818	1487	11097	14070	1407
1991	1542	1473	7363	1606	11984	15195	1520
1992	1666	1591	7953	1734	12944	16412	1641
1993	1799	1718	8589	1873	13979	17725	1773
1994	1943	1856	9276	2023	15098	19144	1914
1995	2098	2004	10018	2185	16305	20674	2067
1996	2266	2164	10819	2360	17609	22328	2233
1997	2447	2337	11685	2549	19018	24114	2411
1998	2643	2524	12620	2752	20539	26043	2604
1999	2854	2726	13629	2973	22182	28126	2813
2000	3083	2945	14720	3210	23958	30378	3038
2001	3329	3180	15897	3467	25873	32806	3281
2002	3596	3434	17169	3745	27944	35432	3543
2003	3883	3709	18543	4044	30179	38266	3827
2004	4194	4006	20026	4368	32594	41329	4133
	LINK NUMBER = 4						

SPEED OF DIFFERENT

YEAR	VC	VB	VT	VTW
LINK NUMBER = 1				
1985	31.93	30.17	29.71	19.16
1986	29.86	28.04	28.14	17.92
1987	27.62	25.73	26.44	16.57
1988	25.20	23.23	24.61	15.12
1989	22.59	20.54	22.63	13.55
1990	19.76	17.62	20.48	11.86
1991	16.72	14.48	18.17	10.03
1992	13.43	11.09	15.68	10.00
1993	10.00	10.00	12.99	10.00
1994	10.00	10.00	10.08	10.00
1995	10.00	10.00	10.00	10.00
1996	10.00	10.00	10.00	10.00
1997	10.00	10.00	10.00	10.00
1998	10.00	10.00	10.00	10.00
1999	10.00	10.00	10.00	10.00
2000	10.00	10.00	10.00	10.00
2001	10.00	10.00	10.00	10.00
2002	10.00	10.00	10.00	10.00
2003	10.00	10.00	10.00	10.00
2004	10.00	10.00	10.00	10.00
LINK NUMBER = 2				
1985	31.93	30.17	29.71	19.16
1986	29.86	28.04	28.14	17.92
1987	27.62	25.73	26.44	16.57
1988	25.20	23.23	24.61	15.12
1989	50.49	52.16	45.81	30.29
1990	49.73	51.69	45.47	29.84
1991	48.90	51.18	45.11	29.34
1992	48.02	50.64	44.72	28.81
1993	47.06	50.05	44.30	28.24
1994	46.02	49.41	43.84	27.61
1995	44.91	48.72	43.35	26.94
1996	43.70	47.98	42.82	26.22
1997	42.39	47.18	42.24	25.44
1998	40.98	46.31	41.62	24.59
1999	39.46	45.38	40.95	23.68
2000	37.82	44.37	40.23	22.69
2001	36.05	43.28	39.45	21.63
2002	34.13	42.10	38.60	20.48
2003	32.06	40.83	37.69	19.24
2004	29.83	39.46	36.71	17.90
LINK NUMBER = 3				

T-5

(N_0 and N_1 are two alternative improvements considered for the highway)

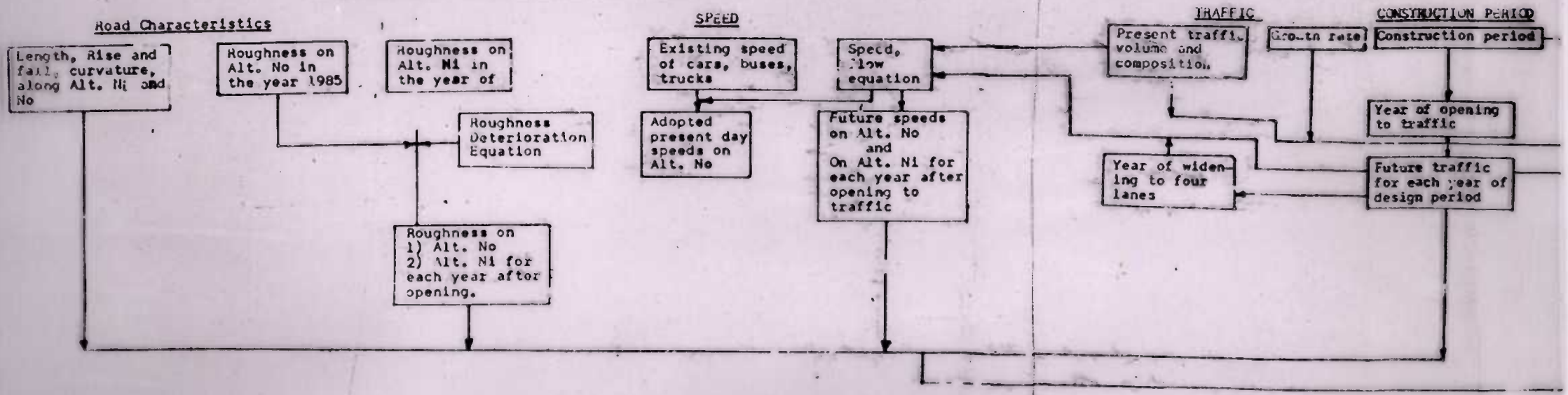
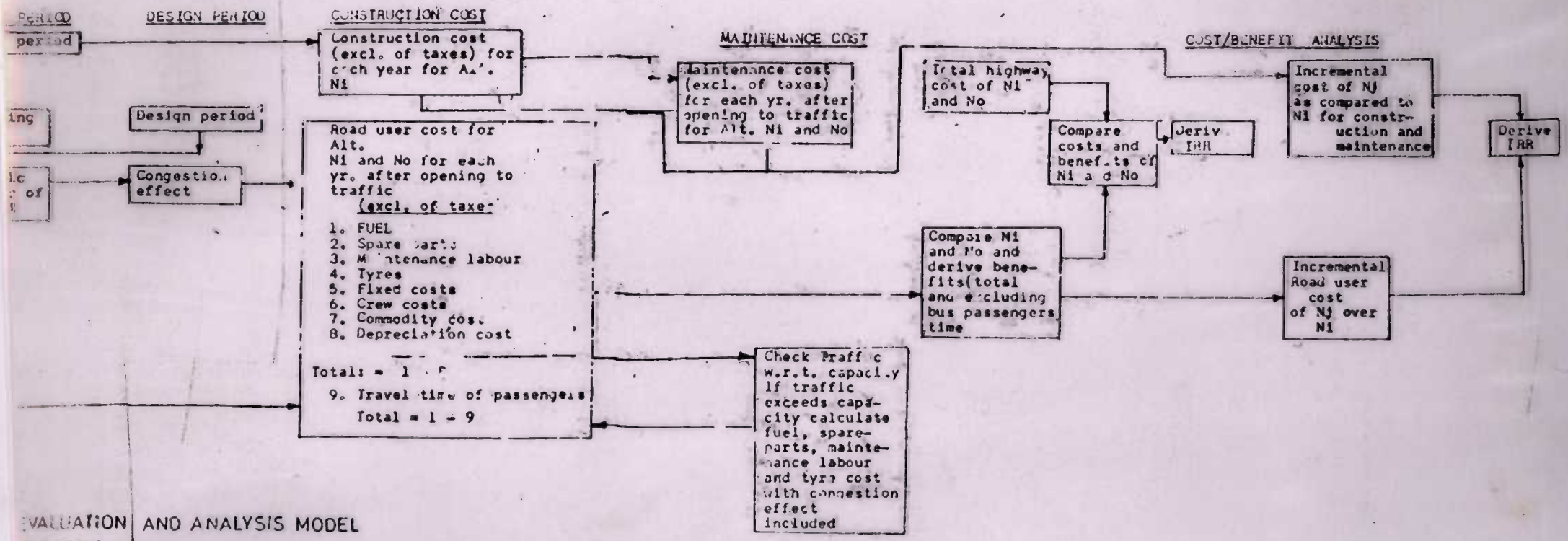


FIG. 1. FLOW CHART FOR ECONOMIC EVALUATI
(FOR HIGHWAY IMPROVEMENT PROJECT)



VALUATION AND ANALYSIS MODEL
ROJECT)

	CONSTRUCTION AND MAINTENANCE COST OF ALTERNATIVES IN LAKHS		ROAD ROUGHNESS MM/KM.
LINK NUMBER = 1			
1985	0.00	2.00	6000.00
1986	0.00	2.00	6000.00
1987	0.00	2.00	6000.00
1988	0.00	2.00	6000.00
1989	0.00	25.00	6000.00
1990	0.00	2.00	6000.00
1991	0.00	2.00	6000.00
1992	0.00	2.00	6000.00
1993	0.00	2.00	6000.00
1994	0.00	25.00	6000.00
1995	0.00	2.00	6000.00
1996	0.00	2.00	6000.00
1997	0.00	2.00	6000.00
1998	0.00	2.00	6000.00
1999	0.00	25.00	6000.00
2000	0.00	2.00	6000.00
2001	0.00	2.00	6000.00
2002	0.00	2.00	6000.00
2003	0.00	2.00	6000.00
2004	0.00	25.00	6000.00
LINK NUMBER = 2			
1985	14.16	2.00	6000.00
1986	56.63	2.00	6000.00
1987	99.10	2.00	6000.00
1988	113.26	2.00	6000.00
1989	0.00	4.00	2000.00
1990	0.00	4.00	2500.00
1991	0.00	4.00	3000.00
1992	0.00	4.00	4000.00
1993	0.00	50.00	5000.00
1994	0.00	4.00	2000.00
1995	0.00	4.00	2500.00
1996	0.00	4.00	3000.00
1997	0.00	4.00	4000.00
1998	0.00	50.00	5000.00
1999	0.00	4.00	2000.00
2000	0.00	4.00	2500.00
2001	0.00	4.00	3000.00
2002	0.00	4.00	4000.00
2003	0.00	50.00	5000.00
2004	0.00	4.00	2000.00
LINK NUMBER = 3			
1985	0.00	8.20	6000.00
1986	0.00	8.20	6000.00
1987	0.00	8.20	6000.00
1988	0.00	8.20	6000.00
1989	0.00	102.50	6000.00
1990	0.00	8.20	6000.00
1991	0.00	8.20	6000.00
1992	0.00	8.20	6000.00
1993	0.00	8.20	6000.00
1994	0.00	102.50	6000.00
1995	0.00	8.20	6000.00
1996	0.00	8.20	6000.00
1997	0.00	8.20	6000.00
1998	0.00	8.20	6000.00
1999	0.00	102.50	6000.00
2000	0.00	8.20	6000.00
2001	0.00	8.20	6000.00
2002	0.00	8.20	6000.00
2003	0.00	8.20	6000.00
2004	0.00	102.50	6000.00

LINK GROUP = 1 ALT NO. = 1

ANNUAL BENEFITS WITHOUT DISCOUNTING

YEAR	FUEL	SPRT	MNLBCST	TYRE	FIXED	CMDTY	CREW	DPRCN	TTCST	OC1-8	OC1-9	CNCST	MNCST	CMCST
1985	1951.9	497.6	205.6	897.6	2676.9	181.5	853.3	397.7	2831.	310495.	4 7664.1	0.0	10.2	
1986	2136.1	537.4	222.1	969.4	2993.9	202.8	948.9	441.3	3197.	411649.	1 8451.8	0.0	10.2	
1987	2343.8	580.4	239.8	1046.9	3366.1	227.7	1059.7	491.5	3638.	912994.	8 9355.9	0.0	10.2	
1988	2584.5	626.8	259.0	1130.7	3808.5	257.3	1189.4	549.7	4182.	414588.	310405.8	0.0	10.2	
1989	2865.2	676.9	279.7	1221.2	4344.7	292.8	1343.6	618.2	4872.	116518.	511646.4	0.0	127.5	
1990	3215.2	731.1	302.1	1318.9	5009.9	336.6	1530.4	699.8	5783.	318927.	313144.1	0.0	10.2	
1991	3652.6	789.6	326.3	1424.4	5863.0	392.1	1763.1	799.4	7064.	222074.	515010.4	0.0	10.2	
1992	4244.6	852.8	352.4	1538.5	7015.4	465.2	2066.4	924.5	8988.	426446.	517658.1	0.0	10.2	
1993	5069.1	921.0	380.6	1661.5	8533.9	568.1	2387.9	1069.	310694.	831211.	130518.2	0.0	10.2	
1994	5923.8	994.7	411.0	1794.5	10780.4	727.5	2752.0	1245.	011790.	936419.	724628.8	0.0	127.5	
1995	6484.1	1074.3	443.9	1938.	011918.0	804.1	3035.2	1378.	013051.	540121.	127069.5	0.0	10.2	
1996	7100.2	1160.2	479.4	2092.	913165.4	887.7	3354.1	1513.	914522.	444276.	229753.8	0.0	10.2	
1997	7806.1	1253.0	517.8	2260.	414605.2	983.9	3721.2	1676.	216268.	149091.	832823.7	0.0	10.2	
1998	8631.5	1353.2	559.2	2441.	316297.4	1096.5	4150.4	1864.	318397.	954790.	636392.7	0.0	10.2	
1999	9716.1	1461.5	603.9	2636.	518328.3	1230.8	4661.5	2085.	721090.	261714.	540624.3	0.0	127.5	
2000	10833.9	1578.5	652.3	2847.	620634.1	1394.9	5285.4	2351.	124671.	070448.	845777.8	0.0	10.2	
2001	12414.1	1704.7	704.4	3075.	324059.7	1602.8	6075.3	2678.	529750.	082064.	652314.7	0.0	10.2	
2002	14634.2	1841.1	760.8	3321.	328489.6	1879.9	7136.2	3099.	937756.	098918.	961163.0	0.0	10.2	
2003	17248.5	1988.3	821.6	3587.	034188.2	2279.9	8089.1	3552.	741987.	2113742.	671755.4	0.0	10.2	
2004	20181.4	2147.4	887.4	3874.	041399.4	2792.3	9132.4	4056.	845347.	7129818.	8844 71.1	0.0	127.5	

LINK GROUP = 1 ALT NO. = 4

ANNUAL BENEFITS WITHOUT DISCOUNTING

YEAR	FUEL	SPRT	MNLBCST	TYRE	FIXED	CMDTY	CREW	DPRCN	TTCST	OC1-8	OC1-9	CNCST	MNCST	CMCST
1985	1951.9	497.6	205.6	897.6	2676.9	181.5	853.3	397.7	2831.	310495.	4 7664.1	469.1	10.2	
1986	2136.1	537.4	222.1	969.4	2993.9	202.8	948.9	441.3	3197.	411649.	1 8451.8	1407.2	10.2	
1987	2343.8	580.4	239.8	1046.9	3366.1	227.7	1059.7	491.5	3638.	912994.	8 9355.9	2345.4	10.2	
1988	2584.5	626.8	259.0	1130.7	3808.5	257.3	1189.4	549.7	4182.	414588.	310405.8	2814.5	10.2	
1989	2865.2	676.9	279.7	1221.2	4344.7	292.8	1343.6	618.2	4872.	116518.	511646.4	2345.4	127.5	
1990	3236.0	424.8	169.1	1062.4	3233.5	219.6	1077.8	506.2	3342.	812397.	2 9054.4	0.0	38.1	
1991	3652.6	525.7	210.8	1242.4	3531.3	239.8	1175.1	551.6	3661.	513888.	310226.8	0.0	38.1	
1992	4244.6	582.9	233.2	1351.9	3861.6	262.1	1282.4	601.5	4017.	115173.	711156.6	0.0	38.1	
1993	5069.1	689.8	278.6	1483.0	4230.0	287.0	1401.4	656.8	4415.	916682.	412266.5	0.0	38.1	
1994	5924.5	816.8	332.4	1628.2	4641.9	314.9	1533.7	718.1	4868.	618379.	013510.4	0.0	368.9	
1995	6779.2	697.4	280.1	1677.7	5105.3	346.1	1681.4	786.4	5384.	319737.	714353.4	0.0	38.1	
1996	7115.3	772.4	309.6	1825.4	5631.6	381.6	1847.6	862.8	5981.	821728.	215746.4	0.0	38.1	
1997	7491.9	856.4	342.7	1986.3	6233.7	422.0	2035.3	947.8	6680.	723996.	917316.2	0.0	38.1	
1998	7925.4	1013.4	409.2	2179.0	6932.6	468.8	2250.1	1046.4	7519.	726744.	519224.8	0.0	38.1	
1999	8425.6	1200.1	488.3	2392.1	7757.3	523.6	2499.0	1158.4	8562.	530006.	921444.4	0.0	368.9	
2000	9031.5	1024.7	411.5	2465.1	8758.6	589.6	2793.5	1288.8	9924.	833187.	023262.2	0.0	38.1	
2001	9641.7	1134.9	455.0	2682.0	10021.9	671.4	3152.8	1444.	011817.	938021.	626203.7	0.0	38.1	
2002	10504.9	1258.5	503.5	2918.	511610.1	778.7	3541.0	1620.	313633.	943369.	329735.4	0.0	38.1	
2003	11537.6	1489.0	601.3	3201.	713794.8	932.1	3974.1	1826.	614996.	249353.	334357.1	0.0	38.1	
2004	12325.9	1763.3	717.5	3514.	815216.6	1028.2	4363.1	2003.	916545.	354482.	637937.3	0.0	368.9	

LINK PAIR 6 9 ALT. PAIR 1 4

CR UC
450.26 [illegible] 40

LINK ALTERNATIVE PATH

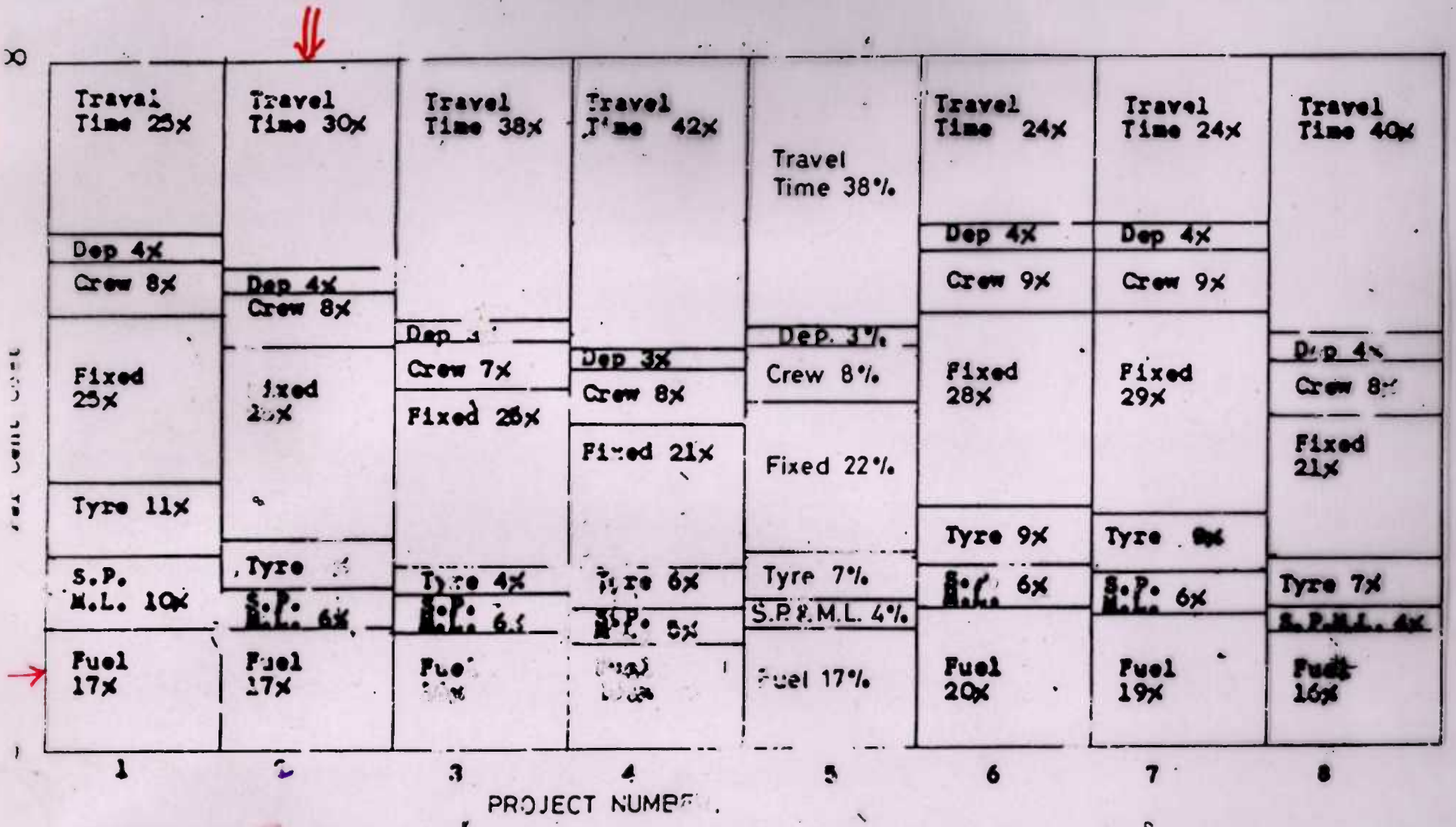


FIG. 5. BROAD COMPOSITION OF ROAD USER COST FOR DIFFERENT PROJECTS

Table 7 Components of Road User Cost

		Fuel	Spare	Mce. Lab.	Tyre	Fixed	Commodity	Crew	Dep.	Travel time
1. Durgapur Expressway	85	19.2	4.9	2.0	9.5	26.2	1.8	8.5	4.0	[illegible]
	2004	16.7	5.9	2.3	11.9	24.5	1.7	7.8	3.6	25.6
		17	6	2	11	25	2	8	4	25
2. Ahmedabad-Vadodara 4 lane Expressway	85	18.6	4.7	2.0	8.6	25.5	1.7	8.1	3.8	27.0
	90	19.0	3.4	1.4	8.6	26.1	1.8	8.7	4.1	27.0
	2004	17.1	3.2	1.3	6.5	27.9	1.9	8.0	3.7	30.4
		17	3	1	7	28	2	8	4	30
3. Varanasi bypass	85	19.3	5.0	2.2	7.9	22.5	1.5	7.2	3.4	31.0
	90	19.4	4.6	2.0	7.3	22.7	1.5	7.3	3.4	31.4
	2004	16.4	2.5	1.1	3.8	25.8	1.7	6.4	2.9	39.3
		16	3	1	4	26	[illegible]	7	3	8
4. Punjab	85	18.8	5.6	2.5	7.9	19.2	1.2	6.8	3.0	34.9
	89	18.0	2.2	0.9	7.0	21.4	1.4	7.	3.4	38.0
LK 1,3	2004	14.2	1.8	0.7	5.5	21.4	1.4	7.5	3.3	44.2
		15	2.	1	6	21	2	8	3	42
5. Haryana LK 1	1985	18.5	5.1	2.2	8.2	19.8	1.3	7.3	3.1	34.5
	89	16.7	4.6	2.0	7.3	21.0	1.3	7.6	3.2	37.6
	2004	13.8	1.6	0.7	2.5	24.6	1.5	6.4	2.5	46.2
	Say	16	4	1	6	21	1	7	3	41
LK 3	1985	18.5	5.1	2.2	8.2	19.8	1.3	7.3	3.1	34.5
	89	17.5	2.2	0.9	7.4	22.0	1.4	8.2	3.5	37.0
	2004	14.3	1.8	0.7	6.6	22.2	1.4	8.2	3.5	41.6
	Say	17	3	1	7	22	1	8	3	38

(Contd.)

TABLE 14 (Contd.)

		Fuel	Spar.	Mce. Lab.	Tyre	Fixed	Commodity	Crew	Dep.	Travel time
6. Maharashtra	1985	18.8	5.2	2.2	8.6	27.2	1.9	[illegible]	[illegible]	23.5
LK 28,30	89	21.1	2.7	1.0	8.6	27.9	2.0	8.7	.3	23.6
	2004	20.1	2.6	1.0	8.4	28.3	2.0	8.8		24.5
	Say	20	3	1	9	28	2	9		24
7. Andhra Prade l	1985	18.5	4.7	.9	9.0	27.5	1.8	8.9	4.3	23.2
LK [illegible]	89	19.9	2.6	1.0	8.9	28.4	2.0	9.2	4.5	23.5
	2004	19.4	2.6	1.0	8.7	28.6	[illegible]	9.3	4.5	24.0
	Say	19	3	1	9	[illegible]9	[illegible]	9	4	24
8. Tamil Nadu	1985	15.0	3.[illegible]	.6	7.3	20.[illegible]	1.3	[illegible].1	3.5	39 1
LK 4,6	1989	16.7	[illegible].3	.9	7.2	20.8	[illegible]	[illegible].3	3.[illegible]	39.2
	2004	15.9	2.2		7.0	21.0	1.3	[illegible]	3.4	40 0
	Say	16	2	1	7	21	1		4	40
LK 1,3	1985	16.6	4.5	1.9	7.8	18.[illegible]	1.	7.	2.9	39.5
	89	15.9	2.2	0.8	6.9	19.8	1.2	[illegible]	3.3	41.7
	2004	14.5	2.0	0.8	6.4	20.1	1.2	[illegible]	3.3	43.5
	Say	15	2	1	7	20	1	3		41

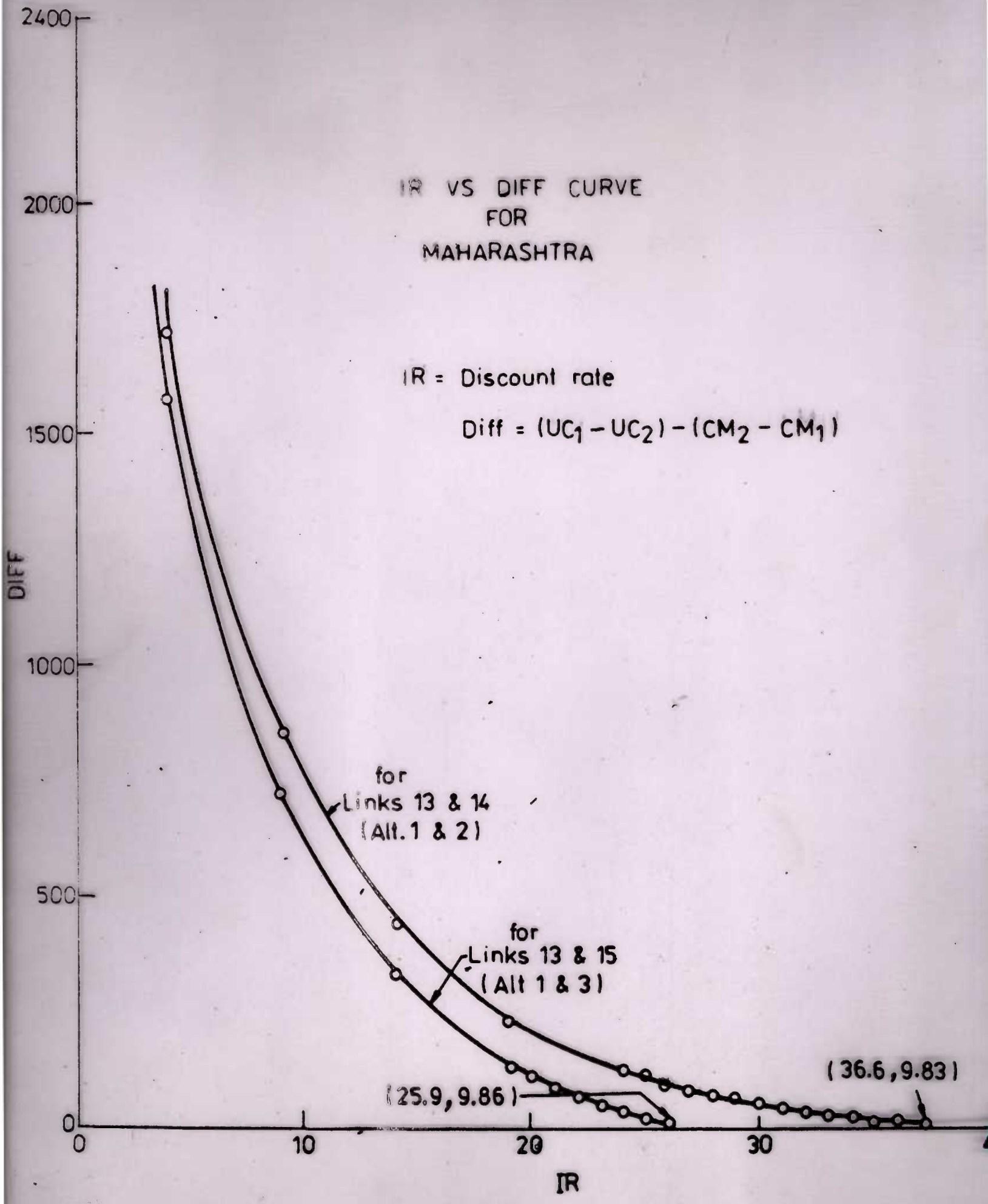

IR VS DIFF CURVE
FOR
MAHARASHTRA
IR = Discount rate
Diff = (UC1 – UC2) – (CM2 – CM1)
DIFF
2400
2000
1500
1000
500
0
0
10
20
30
IR
for
Links 13 & 14
(Alt. 1 & 2)
for
Links 13 & 15
(Alt 1 & 3)
(25.9, 9.86)
(36.6, 9.83)

TABLE 13. RESULTS OF ECONOMIC ANALYSIS

Project Section	Compared Alternatives															
	IRR (%) Excluding Travel Time Savings								IRR (%) Travel Time Savings included							
	1-2	1-3	1-4	2-3	3-4 & 1-5	4-5	5-6	1-6	1-2	1-3	1-4	2-3	3-4 & 1-5	4-5	5-6	1-6
1. Durgapur Expressway			20.7		29.0	9.0	43.0	19.9			28.3		35.2	13.0	52.0	24.8
2. Ahmedabad-Vadodara Expressway			43.2		45.7	29.6	51.7	43.9			55.0			29.		
4 laning existing road km 20-102		40.1								48.6						
3. Varanasi bypass								22.0[a]								27.6[a]
								21.8[b]								27.4[b]
4. Widening road to 4 lanes Karnal-Jallandhar section		67.1								87.1						
5. Widening road to 4 lanes Murthal-Karnal section																
km 50-87		[illegible]								3						
km 87-130		[illegible]								72.7						
6. Bombay-Nasik section																
km 414-426	22.4	20.1	—						25.8	23.6	—					
km 426-431	22.1	19.5	—						25.[illegible]	23.0	—					
km 431-457		26.6								29.6						

(Contd.)

TABLE 13 (Contd.)

Project Section	Compared Alternatives															
	IRR (%) Excluding Travel Time Savings								IRR (%) Travel Time Savings included							
	1-2	1-3	1-4	2-3	3-4 & 1-5	4-5	5-6	1-6	1-2	1-3	1-4	2-3	3-4 & 1-5	4-5	5-6	1-6
km 457-464	22.6	20.0	—						26.9	23.5	—					
km 464-480		22.9								26.6						
km 480-493		24.0								26.6						
km 493-508	21.2	19.5	—						25.7	23.0	—					
km 508-512		28.2								30.3						
km 512-517	19.4	17.0	—						22.7	20.3	—					
km 517-520		27.2								30.2						
km 520-539/5	25.0	22.1	—						28.5	25.8	1.2					
km 539/5-559/5	20.2	15.5	—						24.1	18.8	0.8					
7. Hyderabad-Bangalore section	15.4	11.2	2.7						18.1	14.5	2.2					
Hyderabad-Nagpur section	14.9	11.1	2.5						17.3	13.9	0.5					
8. Madras-Dindigul section																
km 27/2-67		40.4								55.7						
km 67-152		27.7								36.2						
km 152-160		41.2								54.2						

a. 4 lane bridge (without cycle tracks) & 4 lane bypass
b. 4 lane bridge (with cycle tracks) & 4 lane bypass

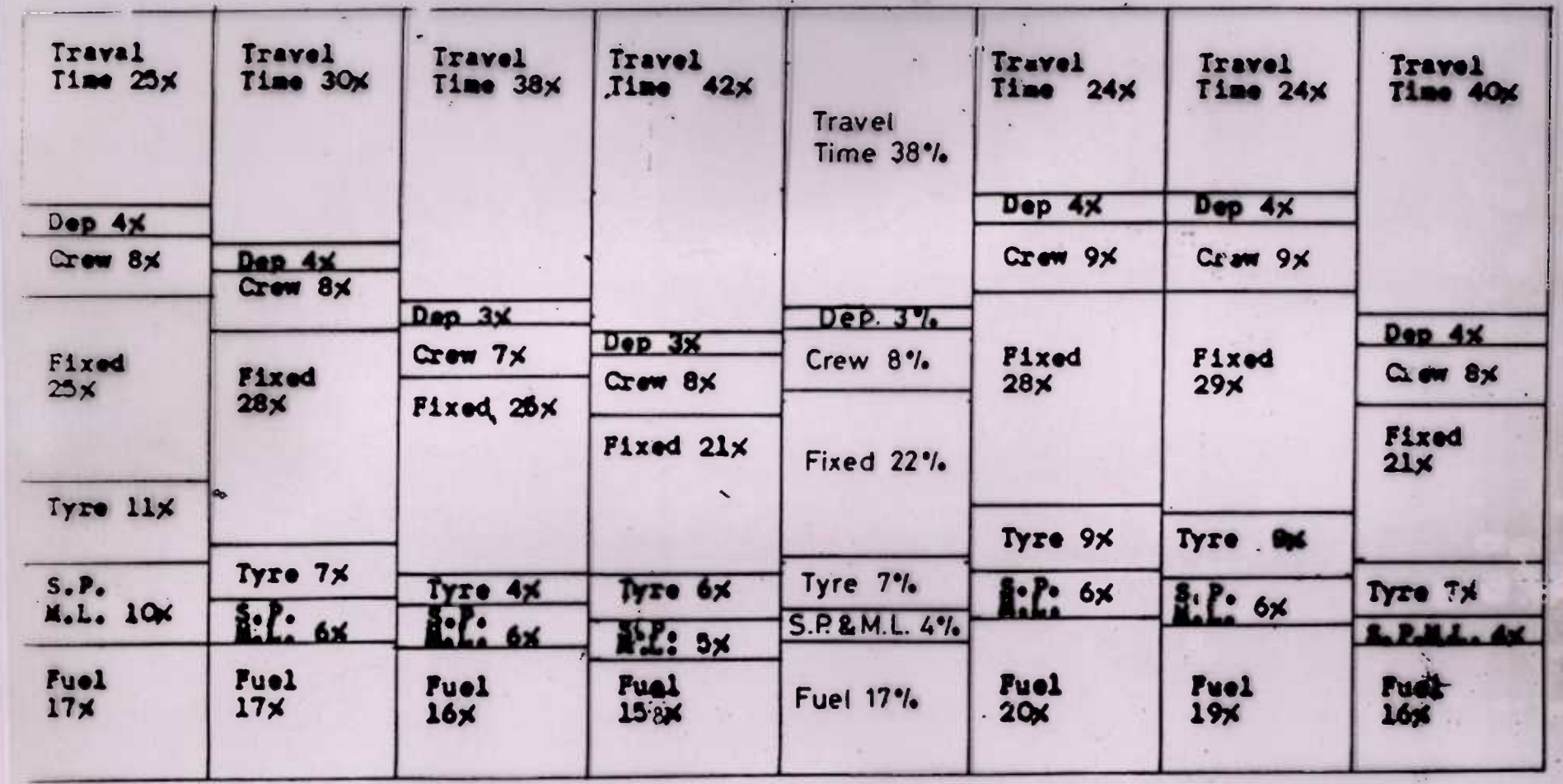


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FIG. 3. BROAD COMPOSITION OF ROAD USER COST FOR DIFFERENT PROJECTS

Table 4.4 (Contd.)

1	2	3	4	5	6	7	8	9	10	11
6. Bombay - Nasik Section										
KM 414-426	22.4	20.1				25.8	23.6			
KM 426-431	22.1	19.5				25.5	23.0			
KM 431-457		26.6					29.6			
KM 457-464	22.6	20.0				26.9	23.5			
KM 464-480		22.9					26.6			
KM 480-493		24.0					26.8			
KM 493-508	22.2	19.5				25.7	23.0			
KM 508-512		28.2					30.3			
KM 512-517	19.4	17.0				22.7	20.3			
KM 517-520		27.2					30.2			
KM 520-539/5	25.0	22.1				28.5	25.8			
KM 539/5-559/5	20.2	15.5				24.1	18.8			
7. Hyderabad-Bangalore Section	15.4	11.2				18.1	14.5			
Hyderabad-Nagpur Section	14.9	11.1				17.3	13.9			
8. Madras-Dindugul Section										
KM 27/8-67		40.4					55.7			
KM 67-152		27.7					36.2			
KM 152-160		41.2					54.2			

Alternative 1 - Do nothing
Alternative 2 - Strengthening 2 lane pavement now and widerning to 4 lanes when traffic demands.
Alternative 3 - 4 laning now
Alternative 4 - 4 lane express way
Alternative 5 - 2 lane express way
Alternative 6 - 4 lane bye-pass.

Table 4.4

RESULTS OF ECONOMIC ANALYSIS FOR PROJECTS PROPOSED FOR WORLD BANK AID

PROJECT SECTION	COMPARED ALTERNATIVES										
	IRR EXCLUDING TRAVEL TIME SAVINGS					IRR INCLUDING TRAVEL TIME SAVINGS					
	1 & 2	1 & 3	1 & 4	1 & 5	1 & 6	1 & 2	1 & 3	1 & 4	1 & 5	1 & 6
1	2	3	4	5	6	7	8	9	10	11
1. Durgapur Express way			20.7	29.0	19.9			28.3	35.2	24.8
2. Ahmedabad - Vadodara Express way			43.2					55.0		
4 laning existing road Km. 20 - 102		40.1					48.6			
3. Varanasi bye-pass					22.0[a]					27.6[a]
					21.8[b]					27.4[b]
4. Widening to 4 lanes Khanna-Jullundur Section.		67.1					87.1			
5. Widening to 4 lane Murthal - Karnal Section KM 50 - 87		76.5					96.3			
KM 87-130		56.5					72.7			

a - 4 lane bridge (without cycle track) and 4 lane bye-pass

b - 4 lane bridge (with cycle track) and 4 lane bye-pass.

Contd....

```
LINK PAIR
   6   9
     CM          UC
    450.26  375572.60
   9587.28  217914.60

DIFF = 148520.90

                IRR =   43.20


LNKGP NO.  LINKS PAIR
     1       6   9
LINK      ALTERNATIVE PAIR


   1            1   4
     CM          UC
    67.21   34998.91
  4204.25   30867.15

0        ANNUAL DISCOUNTED COST AND BENEFITS

         YEAR      COSTS          BENEFITS

         1985      469.08           0.00
         1986      982.71           0.00
         1987     1143.75           0.00
         1988      958.45           0.00
         1989      557.76           0.00
         1990        4.63         679.17
         1991        3.23         554.74
         1992        2.26         510.32
         1993        1.58         466.55
         1994        9.53         439.09
         1995        0.77         350.69
         1996        0.54         269.77
         1997        0.37         208.56
         1998        0.26         161.24
         1999        1.58         125.79
         2000        0.13         103.12
         2001        0.09          83.51
         2002        0.06          70.19
         2003        0.04          58.33
         2004        0.26          50.68

                IRR =   43.10


LNKGP NO.  LINKS PAIR
     1       6   9
LINK      ALTERNATIVE PAIR



   1            1   4
     CM          UC
    67.38   35086.53
  4210.44   30928.91

0        ANNUAL DISCOUNTED COST AND BENEFITS

         YEAR      COSTS          BENEFITS

         1985      469.08           0.00
         1986      983.40           0.00
         1987     1145.35           0.00
         1988      960.46           0.00
         1989      559.32           0.00
         1990        4.64         681.55
         1991        3.24         557.07
         1992        2.27         512.82
         1993        1.58         469.17
         1994        9.59         441.86
         1995        0.77         353.15
         1996        0.54         271.85
         1997        0.38         210.31
         1998        0.26         162.71
         1999        1.60         127.03
         2000        0.13         104.21
         2001        0.09          84.45
         2002        0.06          71.03
         2003        0.04          59.07
         2004        0.27          51.36
LINK PAIR      ALT. PAIR
   6   9         1   4
     CM          UC
    450.26  568847.80
   9587.28  305641.30
```

```
1038
1039
1040     DIIF = 254069.40
1041
1042                          IRR =    55.00
1043
1044
1045                LNKGP NO.   LINKS PAIR
1046                     1        6   9
1047                LINK       ALTERNATIVE PAIR
1048
1049
1050                  1              1   4
1051                    CM              UC
1052                 51.62        38513.83
1053               3580.38        34987.67
1054
1055   0            ANNUAL DISCOUNTED COST AND BENEFITS
1056
1057                YEAR       COSTS              BENEFITS
1058
1059                1985        469.08               0.00
1060                1986        907.90               0.00
1061                1987        976.24               0.00
1062                1988        755.80               0.00
1063                1989        406.34               0.00
1064                1990          3.11             729.91
1065                1991          2.01             590.33
1066                1992          1.30             524.46
1067                1993          0.84             436.09
1068                1994          4.67             349.36
1069                1995          0.35             254.66
1070                1996          0.22             181.75
1071                1997          0.14             130.50
1072                1998          0.09              94.10
1073                1999          0.52              68.63
1074                2000          0.04              52.04
1075                2001          0.03              39.68
1076                2002          0.02              32.29
1077                2003          0.01              24.15
1078                2004          0.06              18.23
1079
1080                          IRR =    54.90
1081
1082
1083                LNKGP NO.   LINKS PAIR
1084                     1        6   9
1085                LINK       ALTERNATIVE PAIR
1086
1087
1088                  1              1   4
1089                    CM              UC
1090                 51.72        38581.95
1091               3584.91        35037.32
1092
1093   0            ANNUAL DISCOUNTED COST AND BENEFITS
1094

1095                YEAR       COSTS              BENEFITS
1096
1097                1985        469.08               0.00
1098                1986        908.48               0.00
1099                1987        977.50               0.00
1100                1988        757.26               0.00
1101                1989        407.39               0.00
1102                1990          3.12             752.26
1103                1991          2.02             592.62
1104                1992          1.30             526.84
1105                1993          0.84             438.35
1106                1994          4.70             351.39
1107                1995          0.35             256.31
1108                1996          0.22             183.04
1109                1997          0.15             131.51
1110                1998          0.09              94.89
1111                1999          0.53              69.25
1112                2000          0.04              52.54
1113                2001          0.03              40.09
1114                2002          0.02              32.64
1115                2003          0.01              24.43
1116                2004          0.06              18.45

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