COST BENEFIT ANALYSIS FOR SIGNAL FREE TRAFFIC AT INTERSECTION: A CASE STUDY

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Abstract

Signal free junction is reducing fuel consumption, accidents and travel time. In that paper discuss the cost-benefit ratio of signal free junction at Vishrambagh Intersection, Sangli, Maharashtra, India. Here we studied the various cost as well as benefits included in signal free junction. The Results indicate that the Signal free junction may be economically viable. A benefit/cost ratio of 1.82 is generated in year 2027.

Keywords: *Vehicle Operating Cost, Accident Cost, Travel time saving cost and Cost Benefit Ratio etc…*

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1. INTRODUCTION

There are a number of variations of Cost-Benefit analysis method, but a simple procedure is to discount all costs and benefits to their present worth and calculate the ratio of the benefits to costs. Here to evaluate the cost as well as benefits available from the implementation of a signal free junction and to demonstrate the Cost and user benefits of Juntion improvement analysis. This evaluation was intended as a guide for planning and decision-making. Negative flows are considered as costs whereas positive flows as benefits. Thus the saving in the transport cost is considered as benefits. If the B/C ratio is more than 1.52, the project is worth undertaking.

The objectives of this study were to evaluate the potential benefits available from the implementation of a Signal free junction at Vishrambagh intersection and to calculate the user Benefits of Junction improvement. This evaluation was intended as a guide for planning and decision-making.here.

2. IMPROVEMENTS FOR VISHRAMBAGH JUNCTION

According to traffic analysis; in Vishrambagh junction the heavy traffic along the Sangli-Miraj and Miraj-Sangli road. Kupwad to Sangli is also having medium traffic. If the flyover will provide at Vishrambagh Junction along the Sangli-Miraj road and underpass will provide along Kupwad-Sangli, then the large amount of traffic lifted and moves on the grade separator.

If large amount of traffic will moves on the grade separator, then traffic movement at Vishrambagh junction is signal free as well as the traffic congestion problem will be solved. This flyover covered 1 major junction and 3 minor junctions. Vishrambagh is major as well as important junction. Start point location of flyover is in one side Walchand College's main gate and another side is Vishrambagh post office. End point location of flyover is in one side of road Deep enterprises and another side is Jalbhawan.

Table -1: Salient Features of Underpass

Type of Underpass	Open Cut
Length of Underpass	400m
Number of Lane	Single lane unidirectional
Carriageway Width	5.5m
Vertical Clearance	4.5m
Gradient	5% (1 in 20)
Length of Approach Ramp towards Kupwad as well as sangli	150m
Width of drainage line	0.5m
Radius of curvature	64m
Speed limit	80kmph

Table -2: Salient Features of Flyover

Total Length of Flyover	1400m
Number of Lane	4 lane- One way
Vertical Clearance	5.5m
Carriageway Width	7.5m
Total road width	18.5m
Ruling Gradient	5% (1 in 20)
Length of flyover (without Abutment)	1000m
Length of Abutment	400m (200m at entry and 200m at exit)
Width of shoulder	0.5m
Width of Parapet wall	0.25m

3. COST FOR SIGNAL FREE JUNCTION

Cost for signal free junction includes Construction cost, Maintenance cost and Road user cost. According to Survey the approximate cost per square meter of Flyover and underpass in 2015 is 59000Rs/m^2 and 35000Rs/m2 respectively.

Cost for signal free Vishrambagh junction is

Name	Cost X Area	Cost
flyover	59000 x 25900	152.81cr
Underpass	35000 x 2200	7.70cr
signal free Vishrambagh Junction		**160.51cr (Approximately)**

According to "Highway Capacity Manual 2000", to calculate yearly traffic volume in terms of PCU/day with 9% growth rate from year 2014 to 2040 and also calculate V/C Ratio.

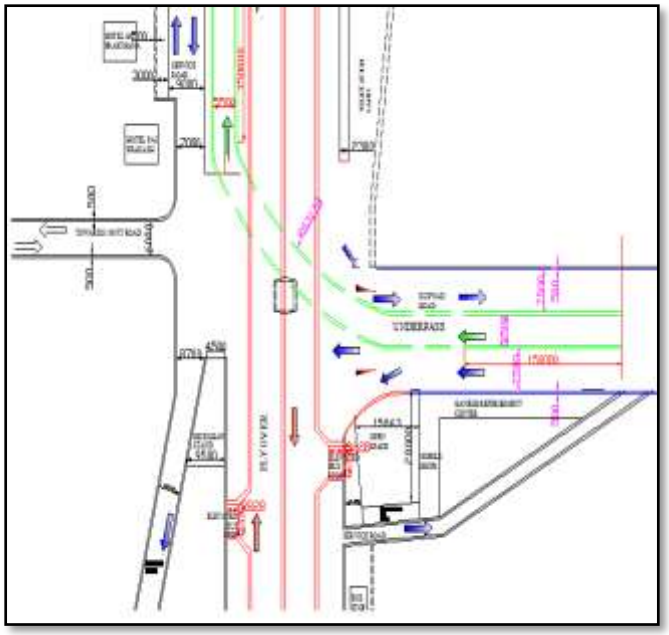

Fig -1: Improved Vishrambagh Junction

4. BENEFITS FROM SIGNAL FREE JUNCTION

Benefits from Signal free junction can be classified as Road Users Benefits and Social Benefits. Road user benefits include Vehicles operating cost saving, Value of saving in accident cost, saving in maintenance cost, Value of travel time saving. Social benefits include Improvements in Health and education, Improvements in industry, agriculture, mining and trade, Improvements in law and order, administration and defense and Improvements in environmental standards. In benefit calculation; 1st determine the Vehicle Operating Cost (VOC), according to IRC SP: 30-2009.

Benefit from signal free junction includes Vehicle operating cost saving, Value of travel time saving, Saving in maintenance cost and Value of saving in Accident cost. In benefit calculation, first determine the Vehicle Operating Cost (VOC). For determining the VOC, following road specifications values are required: Roughness of road: 2000-3000mm/Km (Bituminous concrete), Terrain: Plain, RF (Rise and Fall) per Km = 0-15, Low curvature = less than 50, Design Service value in PCU/day, Underpass (intermediate lane): 6000 PCU/day with earthen shoulder. Flyover (Four lanes): 40000 PCU/day with paved shoulder. Here to find out traffic per day at existing junction as well as traffic distribution in signal free junction. According to RTO office in Sangli, the night traffic is 30% of the morning traffic.

4.1 Vehivle Operating Cost Saving

CASE I: Traffic Volume on existing road junction; According to **"Highway Capacity Manual 2000"**, to calculate yearly traffic volume in terms of PCU/day with 9% growth rate from year 2014 to 2039 and also calculate Volume/Capacity Ratio. Formula for v/c ratio for entry lane of Signalized Intersection; **V/C Ratio= $(V_i \times C)/(S_i \times g_i)$** V_i = Actual Flow rate of lane, S_i = Saturation Flow Rate of Lane, g_i = Effective Green Time, C = Cycle Length $\mathbf{s_o}$ =base saturation flow rate, N = number of lanes in lane group, f_{HV} = factor for heavy vehicles in traffic stream, f_{bb} = factor for blocking effect of local buses that stop in intersection, f_{LT} = factor for left turn in lane group.

v/c ratio for Miraj road: $\mathbf{s_i = s_o N f_{HV} f_{bb} f_{LT}}$
= 1900 x 2 x 0.95 x 0.94 x 0.77 = 2613.

Table -3: Traffic Volume data (2014)

Type of Vehicle	No. of Vehicle per day on ExistJunct[n]	PCU/DAY at Existing Junction (Case I)	PCU per DAY at Existing Junction after Junction is Signal free Case II	PCU/DAY of Underpass and flyover after Junction is signal Free (Case III)
Motor cycle	49585	37189	15256	21933
Car/jeep	12906	12906	4628	8278
Auto Rickshaw	7921	15842	3375	12467
LCV	1567	2194	577	1617
Truck/Bus/ Tempo	2577	5669	941	4728
Tractor	85	354	182	172
MAV	259	1035	161	874

V/C ratio Calculation: V/C = (v_i x C) / (s_i x g_i) = (2284 x 105) / (2613 x 35) = 2.62

V/C ratio For Vishrambagh Junction = (2.62 + 2.67 + 2.85 + 2.5 + 0.57 + 0.35) / 6 = 1.92 **= 1** from year 2014 to 2039, the Volume -capacity ratio is **1** (Note: >1 Value is also taken as 1),for Existing Signalized Road Junction.

CASE II : Traffic Volume on the exiting junction after providing Grade Separated intersection. According to the paper "Comparison of capacity between roundabout design and signalized junction design" in Swiss transport Research Conference in March 2001, The Formula for Capacity of junction:(Roundabout),

$$\mathbf{Q_{fcr} = 6F /\{1/\kappa + [\beta \text{ x } (R_h + 2R_L) + \alpha] \text{ x } f\}}$$

$$\mathbf{Q_{fcr}} = 6 \text{ x} 1500/\{1/1.4 + [0.6 \text{ x } (0.865) + 0.24] \text{ x } 8/9\} \mathbf{= 6480 \text{ PCU/hr}}$$

Q_{fcr} = Full Capacity of Roundabout Junction, F and f = Coefficients (For the Roundabout design, F = 1500 & f = 8/9), κ = Parameter (2 lane in the entry , k = 1.4 – 1.6), β = Parameter taking account of multilane s in the circulating carriageway (2 lanes in the circulating carriageway, β = 0.6 – 0.8), α = Parameter reflecting the degree of vehicles in the entry disturbed by the Vehicles existing at the same branch, R_h = the ratio of going ahead of roundabout, R_L = the ratio of turning left of roundabout. The construction work required approximately 5 years. Volume of traffic in 2014 = 2444 PCU/hr. V/C in 2019 =3760 /6480 = 0.58, year 2026 onwardsv/c=1

Table -4.1: Lanes and there details

Sr. No.	Lane	s_o	N	%HV	f_{HV}	N_B	f_{bb}	P_{LT}	f_{LT}	s_i
1	Traffic coming from Sangli Road	1900	2	4.9	0.95	30	0.94	6	0.77	2613
2	Traffic coming from Miraj Road	1900	2	5.1	0.95	21	0.95	6	0.77	2641
3	Traffic coming from Kupwad Road	1900	2	2.2	0.98	7	0.986	6	0.77	2827
4	Traffic coming from Vishrambagh Road	1900	1	1.1	0.99	0	1	6	0.77	1449
5	Traffic coming from Dandekar mall Road	1900	1	1	0.99	0	1	6	0.77	1449
6	Traffic coming from Sai Prathna hotel Road	1900	1	0.68	0.99	28	0.94	6	0.77	1361

Table-5.1: Lanes and there v/c ratios

Sr. No	Lane	V_i Veh/hr	S_i Veh/hr	Green Time (sec)	Clearance time (sec)	g_i sec	Red Time sec	C sec	V/C Ratio
1	Traffic from Sangli Road	2284	2613	30	5	35	70	105	2.62
2	Traffic from Miraj Road	2449	2641	30	5	35	75	110	2.67
3	Traffic from Kupwad	1469	2827	16	4	20	90	110	2.85
4	Traffic from 100ft Road	638	1449	10	5	15	70	85	2.5
5	Traffic from Dandekar mall	266	1449	30	5	35	75	110	0.57
6	Traffic from Sai Prathna Hotel	160	1361	30	5	35	70	105	0.35

Type of Junction	Existing Junction after signal free
L_{ba}	17m
α	0.24
$R_h + 2 R_L$	0.865

CASE III: V/C ratio for Underpass & Flyover after junction is Signal free.

Table-6: Volume Capacity ratio for flyover and Underpass

Year	Underpass			Flyover		
	V	C	V/C	V	C	V/C
2014	770			3709		
2019	1184	2000	0.59	5706	6000	0.95
2020	1291	2000	0.62	6220	6000	1
2025	1986	2000	0.99	9570	6000	1
2026	2165	2000	1	10432	6000	1
2030	3057	2000	1	14725	6000	1

The v/c ratio is obtained "1" immediately, but due to continuous movement of vehicles on flyover and underpass; no traffic congestion problems are occurred. As traffic volume on a road increases, the vehicles have to overtake, cross, accelerate and decelerate. These maneuvers result in drop in speeds and increase in fuel consumption along with wear and tear of vehicles. The effect of congestion on VOC can be considered separately for the distance-related and time-related components.

CASE I: Traffic Volume on existing road junction
Sample Calculation: Two Wheeler
Distance Related Congestion Factor $\mathbf{CF_D}$ **=** {0.917+0.112 x (V/C)} x 0.8 **=** {0.917 + 0.112 x (1)} x 0.8 = 0.82 = **1**
Time Related Congestion Factor $\mathbf{CF_T}$ = {0.804 + 0.865 x (V/C)} x 0.8 = {0.804 + 0.865 x (1)} x 0.8 = **1.33**

Table-7.1: Distance & Time Related Corrected Congestion Factor (Case I)

Year	Motor Cycle		Jeep/car		Auto\ 6 seater		LCV (pick up)	
	CF_D	CF_T	CF_D	CF_T	CF_D	CF_T	CF_D	CF_T
2014	1	1.33	1	1.26	1.52	1.2	1.52	1.2
2015	1	1.33	1	1.26	1.52	1.2	1.52	1.2
2027	1	1.33	1	1.26	1.52	1.2	1.52	1.2

Table-7.2: Distance & Time Related Corrected Congestion Factor (Case I)

Year	Truck\Bus\ Tempo		Tractor		Trailer (MAV)		Truck\Bus\ Tempo	
	CF_D	CF_T	CF_D	CF_T	CF_D	CF_T	CF_D	CF_T
2014	1	1.33	1	1.26	1.52	1.2	1.52	1.2
2015	1	1.33	1	1.26	1.52	1.2	1.52	1.2
2027	1	1.33	1	1.26	1.52	1.2	1.52	1.2

Distance-Related and Time-Related Vehicle Operation Costs are calculated by referring the economic cost data available from Table VOC CARS 26 in Annex D (IRC SP:30- 2009), for uncongested conditions and the WPI data in India is maintained and published by the economic advisory board, Ministry of Commerce and Industry, Government of India (Year 2014). Compare the WPI of Year 2009 and Year 2014, the WPI of year 2014 more than 27%.

Distance-related VOC costs	***Rs/Km***
Fuel Cost	1.36
Spare Parts	0.16
Maintenance Cost	0.09
Tyre Cost	0.18
Engine Oil	0.14
Other Oil	0.04
Grease	0.013
Total	**1.98**

Time-Related economic costs	***Rs/Km***
Fixed cost	1.08
Depreciation Cost	0.11
Total	**1.19**

Distance-Related Vehicle Operation Cost for congested conditions = VOC for uncongested condition x CF_D=1.98 x 1= 1.98. Time-Related Vehicle Operation Cost for congested condition = VOC for uncongested condition x CF_T = 1.19 x 1.33 = **1.58** Total of Distance-Related and Time-Related VOC per Kilometer is = 1.98 + 1.58 = **3.56The Vehicle Operating cost (case I) for Two Wheeler** = Total of Distance-Related and Time-Related VOC per Kilometer x Vehicles/day x 365 x length of road in Km = **3.56 x49585 x 365 x 1.4 =902 Laces**.

Table-8.1: Total Vehicle operating cost for Case I

Year	**Motor Cycle**	**Car/ jeep**	**Auto**	**LCV**
2014	90203048	22950481	17931005	3547264
2015	98321322	25016025	19544795	3866518
2016	107170242	27267467	21303827	4214505
2017	116815563	29721539	23221171	4593810
2027	276544922	70361692	54972958	10875221

Table-8.2: Total Vehicle operating cost for Case I

Year	**Bus/ Truck**	**Tractor**	**MAV**	**TOTAL VOC (Rs)**
2014	4582627	156800	663068	140034296
2015	4995064	170912	722744	152637383
2016	5444619	186294	787791	166374748
2017	5934635	203061	858692	181348475
2027	14049440	480719	2032838	429317793

Table-9: Cost Saving in Vehicle Operation in Vishrambagh Junction

Year	**TOTAL VOC (Rs) Case I (A)**	**TOTAL VOC (Rs) Case II (B)**	**TOTAL VOC (Rs) Flyover Case III (C)**	**TOTAL VOC (Rs) Underpass Case III (D)**	**Cost Saving in VOC/yr (Rs) (A+B+C+D)**
2019	215460123	65283244	109222126	6257892	34696861
2020	234851534	72220459	120361445	6848675	35420955
2027	429317793	147507683	220025430	13935980	47848700
2030	555978992	191026727	284939313	18047498	61965454

4.2 Cost Saving in Accident

According to reference paper "Social Cost of Road traffic crashes in India" and Evaluation of Road Accident cost by TCS in IRC SP: 30–2009.

The accident cost increases by 5% per year, it is kept in mind for calculating the future accident cost. In Vishrambagh Junction, no accident Rate pattern is available. So, the Average no. of accident increases by 1 no. per 3 year (e.g. in year 2014 to 2016, the average accident is 3. The average accident is 4 for year 2017 to 2019) and the No. of people die is 1 per 3 year. (E.g. in year 2014 to 2016, the

average No. of people die is 1. The average No. of people die is 2 for year 2017 to 2019)

Average No. of Accident = 3 (Serious Accident), Total Accident Cost = Accident Cost + Vehicle Damage Cost.

According to Accident data and Accident Cost, the total Accident cost in 2014 is = {(No. of Accident x Accident Cost) + (No. of Vehicle Damage x Vehicle Damage Cost)}={ (3 x 498181) + (3 x [42227+ 8414])} =**16.47Lac.**

Table-10.1: Accident Cost Saving (Rs) from Signal free Vishrambagh Junction

Year	Cost of Serious Accident		Cost of Fatal Accident		Avg Accident / year		No. of people die	Total Accident Cost saving per year
	Accident Cost	*Vehicle Damage Cost*	*Accident Cost*	*Vehicle Damage Cost*	*Serious Accident*	*Fatal Accident*		
2019	633099	53663	1396652	127017	2	2	2	4420862
2020	664184	56298			5		0	3602410
2021	696795	59062.04			5		0	3779285
2027	928981	78742.6			7		0	7054068

4.3 Revenue Obtained from Advertisement

In benefit calculation the next Value is added that is the Revenue coming from Advertisement. The Municipal Corporation can apply charges on the advertisements located on the flyover and underpass and generate money from it. The Charges like permission fee, license fee and tax on advertisement decided by Municipal Commissioner or the Municipal Corporation publish the tender notice for Advertising.

Advertisement Cost per year = Type and size of advertisement x (Permission fee + License Fee + Tax + Land utilization Charges). Land Utilization charges are considered only for flex or banner. Assume that, the advertisement rates increases by 10% per 5 year.

Total Revenue = (Revenue from Advertisement) + (Revenue from land utilization) = (Size of hording x No. of hordings x charges/ sq. ft. / year) + (area of land used per hording x No. of hordings on ground x charges/ sq. ft. / year) = (120 x 30 x 170) + (15 x 20 x 1870) = 1173000.
Total Revenue Coming from Advertisement in year 2014 is = Advertisement on hoardings/post/kiosk/Structure + Advertisement hoarding on Street light + Posters + Advertisement flex banner on outer side of flyover parapet wall + Advertisement flex cross over the flyover= 1173000+ 285600 + 12000 + 499200 + 332800 **= 2302600 Rs.**

Table-11: Total Revenue from Advertisement per year

Year	Total Revenue From Advertisement
2019	2532860
2020	2786146
2027	3064761
2030	3371237

4.4 Travel Time Saving

Generally, **savings in travel time** are enjoyed by bus passengers, car passenger and two-wheeler riders. In travel time saving, time saving for passenger and saving the commodity holding time. In the case of commodities, lesser travel time signifies smaller inventory cost. Speedier travel means that for transporting the same quantity of goods in a certain period, lesser number of commercial vehicles can be used. Speedier travel leads to reduction in the fixed charges per km which every operator has to pay. Quicker travel also results in time savings to the vehicle crew. The savings in travel time are an important component of the benefits from highway improvements. The Average income of population in Sangli-Miraj-Kupwad area is approximately 30000Rs/Month that means 0.012 Rs / Second/ person. Now, to pass the distance from Jalbhavan-Sangli to Walchand College, Sangli require 238 second according to survey (168 sec for traveling and 70 sec for stopping at signal). Total Cost of travel time saving (Rs/day) = (Total No. of Person in Vehicles x Travel Time Saving (Sec) x Cost/Sec per passenger)

Motor Cycle: Peak hour Cost of travel time saving (Rs/day) = ((7224 x 2) x 154 x 0.012) = 26700.
Total Cost of travel time saving (Rs/day) = ∑ (Cost of travel time Saving (Rs)) = 147698.

Commodity Cost saving = (Total No. of Vehicles x Travel Time Saving (Sec) x Commodity holding cost (Rs/sec) x Total commodity holding cost saving (Rs/day) = ∑ (Total commodity holding cost saving (Rs))= 528.

Total Cost saving in travel (Rs/day) = Total Cost of travel time saving (Rs/day) + Total Commodity holding cost saving (Rs/day) = 147698 + 528 = 148226 Rs/day.

The traffic density increases 9% per year. Assume that, the Average income of Sangli-Miraj-Kupwad Area increases by approximately 3% per year. The WPI increases 8.5% per year (approximately) on the basis of study of WPI from 2009 to 2013.

Total Cost of travel time saving (Rs/day) for yr 2020 = Total Cost of travel time saving (Rs/day) for year 2019 x 1.09 x 1.03 = 264388 x 1.09 x 1.03 = 296829.

Total Commodity holding cost saving (Rs/day) for yr 2020 = Total Commodity holding cost saving (Rs/day) for yr 2019 x 1.09 x 1.085 = 1221 x 1.09 x 1.085 = 1444.

Total Cost saving in travel time (Rs/day) = Total Cost of travel time saving (Rs/day) for yr 2020 + Total Commodity holding cost saving (Rs/day) for yr 2020 = 296829 + 1444 = 298273.

Total Cost saving in travel time (Rs/Year) = Total Cost saving in travel time (Rs/day) x 365 = 298273x 365 = 108869992.

Table-12: Total travel time cost saving

Year	Total Cost of travel time saving (Rs/day)	Total Commodity holding cost saving (Rs/day)	Total Cost saving in travel time (Rs/day)	Day	Total Cost saving in travel time (Rs/Yr)
2014	148226	528	148226	365	52400860
2019	264388	1221	265610	365	96947770
2020	296829	1444	298273	365	108869992
2027	667348	4674	672023	365	245288565
2029	841163	6538	847701	365	309411092
2030	944373	7732	952106	365	347518906

Table-13.1: Total Benefit from Signal Free Vishrambagh Junction

Year	Vehicle operating cost saving (VOC) in Rs	Accident Cost Saving (Rs)	Revenue from Advertisement (Rs)
2019	34696861	4420862	2532860
2020	35420955	3602410	2786146
2026	43897890	6723920	3064761
2027	47848700	7054068	3064761
2028	52155083	13842101	3064761
2029	56849041	8872888	3064761

Table-13.2: Total Benefit from Signal Free Vishrambagh Junction

Year	Travel Time Saving (Rs)	Total Benefit (Rs)	Cumulative Benefit
2019	96947770	138598353	138598353
2020	108869992	150679503	289277856
2026	218403911	272090482	1585347674
2027	245288565	303256094	**1888603768**
2028	275487766	344549711	2233153479
2029	309411092	378197782	2611351261

Table-14: Benefit-Cost ratio for Signal Free Vishrambagh Junction

Year	Cost (Rs) { Cost of Construction + Maintenance Cost}	Benefits (Rs) {VOC saving + Accident Cost saving + Revenue from Advertisement + Travel Time Saving (Rs)}	Benefit/Cost Ratio
2019	1605100000	138598353	0.086
2020	1605100000	289277856	0.18
2021	1605100000	455086488	0.28
2025	1605100000	1313257192	0.82
2026	1605100000	1585347674	0.99
2027	**1605100000**	**1888603768**	**1.18**

5. CONCLUSION

1) In junction improvement, it is feasible to provide flyover, underpass and the available area permits its construction.
2) According to Benefit-Cost ratio analysis, the cost forSignal (Congestion) Free Vishrambagh junction is recovered within 9 years

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