Reducing traffic and environment problems using low cost and capital intensive measures

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ABSTRACT: Rapid growth of urbanization in Delhi Metropolitan area has resulted in substantial growth of motor vehicles amounting to 3.7 million. Due to expansion of Delhi metropolitan area, there are a number of bridges across the river Yamuna developed to facilitate the movement of high volume of passenger and goods traffic. Seven bridges as built, provide accessibility between eastern and the remaining part of Delhi. There is a phenomenal increase in traffic congestion at the approaches at most of the bridges. In this paper attempt has been made to consider a catchments area of Nizamuddin Bridge, located in the southern part of Delhi. Presently it suffers major setback in terms of its safe and efficient traffic operation, resulting in substantial vehicular delay and long queue at both approaches during the peak hour.

In order to solve these increasing traffic problems, various alternative traffic management solutions from lower order options to capital-intensive options with grade separated facility were worked out and evaluated, so as to determine feasible options. An attempt was made to analyze the traffic pattern so as to get a clear understanding about pair wise origin-destination trips. This has enabled to conceptualize the alternatives in more realistic manner. The traffic management plan evaluated includes two integrated alternative plans with combination of four options in the eastern side and two options in the western side of the bridge. Integrated scheme-II incorporating the cloverleaf in the eastern side and two one way grade separated facilities in the western side works out to be the best solution as compared to the integrated scheme-I in terms of less pollution cost, reduced vehicle operating cost and travel time.

RÉSUMÉ : La croissance rapide de l'urbanisation de la zone métropolitaine de Delhi a abouti à la croissance substantielle des véhicules automobiles s'élevant à 3,7 millions. En raison de l'expansion de la zone métropolitaine de Delhi, un certain nombre de ponts sur la rivière Yamuna se sont développés pour faciliter le déplacement d'un grand volume de voyageurs et le trafic de marchandises. Les sept ponts ainsi construits permettent d'accéder de la partie Est au reste de Delhi. Il y a une augmentation phénoménale des encombrements liés à la circulation aux approches de la plupart des ponts. Dans la communication, on a tenté d'imaginer un bassin hydrographique/une zone desservie du Pont de Nizamuddin, placé dans la partie Sud de Delhi. Actuellement, la situation est plutôt compromise en ce qui concerne l'exploitation sûre et efficace du trafic, aboutissant au retard substantiel des véhicules et la longue file d'attente dans les deux approches à l'heure de pointe.

Pour résoudre ces problèmes de trafic en augmentation, diverses solutions alternatives de gestion de trafic allant d'options d'ordre inférieur aux options onéreuses avec facilité séparée de qualité ont été mises au point et évaluées, afin de déterminer les options faisables. Une tentative a été faite pour analyser le modèle de trafic afin d'obtenir une compréhension claire des voyages origine/destination. Cela a permis de conceptualiser les alternatives d'une manière plus réaliste. Le projet de gestion du trafic évalué inclut deux projets intégrés alternatifs avec la combinaison de quatre options dans la partie Est et deux options dans la partie Ouest du pont. Le projet-II Intégré comprenant le croisement dans la partie Est et deux équipements séparés à une voie dans la partie Ouest s'avère être la meilleure solution en comparaison du projet-I en matière de coût de pollution moindre, de dépenses d'exploitation de véhicule et de temps de déplacement réduits.

1. INTRODUCTION

Rapid growth of urbanization in India bears significant impact on the existing infrastructure in the urban areas. Transportation sector is also one of the vital sectors in the economic development. If the infrastructure development of transport sector is not taken care of in a rational manner, it has a profound impact on the society resulting in traffic congestion and high rate of road accidents. This is quite evident from the fact that large-scale traffic congestion coupled with high rate of accident has become a common phenomenon in most of the cities in India.

Significant growth of urbanization in Delhi Metropolitan area has resulted in substantial growth of motor vehicles amounting to 3.7 million. Due to expansion of Delhi metropolitan area, there are a number of bridges across the river Yamuna developed to facilitate the movement of high volume of passenger and goods traffic. Seven bridges built, provide accessibility between eastern and remaining part of Delhi. There is a phenomenal increase in traffic congestion at the approaches at most of the bridges. In this paper attempt has been made to consider a catchments area of Nizamuddin Bridge, located in the southern part of Delhi. Presently it suffers major setback in terms of its safe and efficient traffic operation, resulting in substantial vehicular delay and long queue at both approaches during the peak hour.

The present study aims at appreciating the existing bridge approaches in Delhi in general and strategies of bridge approaches in particular with reference to Nizamuddin Bridge. There are a number of alternative solutions worked out keeping in view the projected traffic. An effort has been made to evaluate these alternatives. Based on the various evaluation criteria and the benefits accrued from these alternatives, a best feasible solution has been identified and recommended.

2. REVIEW OF PLANNING OF BRIDGE APPROACHES IN DELHI

The urban area of Delhi is experiencing rapid growth of population coupled with growth of high vehicle ownership. Presently there are seven bridges built across the river Yamuna over a period of time in order to improve accessibility between Trans-Yamuna area and other parts of Delhi. Figure 1 illustrates the location of seven bridges in Delhi.

I.S.B.T. Bridge (B): This Bridge is located in northern part of Delhi near inter-state bus terminal. This approach design is a quite praise worthy in a situation where there was number of constraints. The length of the bridge is 552.5 m (Gupta L.R. et al. 1991) comprising of 12 spans of 46.23 m each. It has an eight lane divided carriageway with 14.5 m width on either side. With the help of five grade separators its western approach has been made conflict free. Its eastern approach forms four arm signalised junction.

I.T.O Barrage-Cum-Bridge (D): This is the most important bridge for intra - city movements across river Yamuna. The length of this bridge is about 520 m (CRRI 1987). It has two, four lane parallel carriageway. Its western approach is having one straight flyover along with two ramps. Its eastern approach forms four arm signalised junction.

Wazirabad Barrage-Cum-Bridge (A): This bridge is located in the north most part of Delhi. This is 515 m long (CRRI 1987), two lane undivided carriageway. A Significant amount of inter-state traffic between U.P. and Haryana also passes through this bridge. Its Eastern approach is a six lane divided carriageway and western approach is three lane undivided carriageway. Both the approaches form signalised 'T' junction.

Rail Cum Road Over Bridge-Old Railway Bridge (C): The length of this bridge is 510 m (CRRI 1987). It consists of two parallel 5.5 m wide carriageway. Its both the approaches form at grade junctions. Tidal flow operation is used for traffic management operation in morning peak at an interval of 15 minutes.

Nizamuddin Bridge (E): The length of this bridge is 552.5 m (NATPEC et al. 1990) and it has two four lane parallel carriageways. Its both the approaches form signalized 'T' junction.

Delhi-Noida Toll Bridge (F): This bridge is located between Ashram and Sarai Kale Khan ISBT, and links between South Delhi and Noida area. It is 552 m long (ILFS 1996) and eight lane wide. Grade separated interchanges are being constructed at both the approaches. The major problem in this bridge approach is the application of poor radius of curvature provided at Delhi interchange along the Ring Road side.

Okhla Barrage-Cum-Bridge (G): Okhla Bridge is located at southern most part of Yamuna in Delhi. This bridge is 551 m. long having four lane divided carriageway. Its western approach forms unsignalized 'T' junction at the entrance of the Kalindi Kunj park. This approach has been declared as accident-prone due to poor geometry at horizontal curve and lack of sight distance.

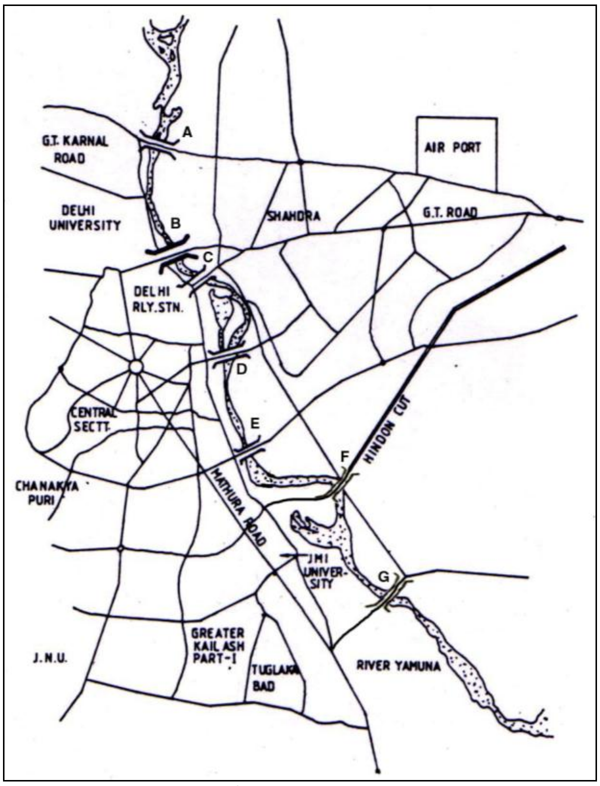


Figure 1. Location of bridges in Delhi

3. STUDY AREA PROFILE: NIZAMUDDIN BRIDGE

There are a number of transport strategies that can be evolved as a part of solution generation process for making the bridge approaches smooth and efficient. These strategies can be viewed as low cost traffic management techniques or Capital Intensive approaches. The low cost traffic management techniques include regulatory techniques, traffic control devices, traffic segregation, demand management techniques, bus pricing technology, self enforcing technology, while capital intensive solutions are generally concerned with the development of interchanges in the form of grade separated intersections.

3.1 *Network*

At present, Delhi has seven bridges and is linked by five national highways in all the directions as can be seen in Figure 2. Nizamuddin Bridge is located in South Delhi providing access to Noida, Mayur Vihar area and Ghaziabad with Delhi. It also acts as a part of NH-24 bypass. It caters to a considerable demand of passenger as well as goods traffic. The Utter Pradesh roadways buses destined to U.P. pass through this bridge. Inter state goods traffic also pass through this bridge. This bridge approach provides access to Ring Road from its western side. The length of the bridge is 552.3 m and is designed with two four-lane parallel carriageways. Cycle track and footpath are also provided on the bridge.

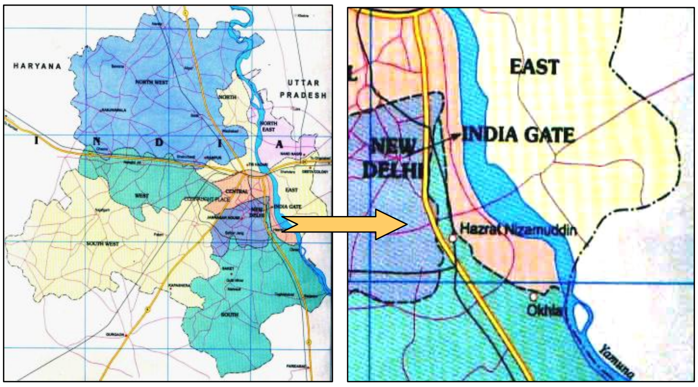


Figure 2. Key map of Nizamuddin Bridge

3.2 *Approach Roads*

As bridge is the channel for dispersal of traffic between number of origins and destinations, the traffic load on bridge is therefore extremely important to be appreciated in terms of their different types of movement pattern being generated from many zones of origin to many zones of destinations. In view of this, the approaches of the bridge are also equally important to be planned in a judicious manner, so as to cater to the different types of movement safely and efficiently. The approach of Nizamuddin Bridge at western side is not only restricted to Nizamuddin Bridge junction but also influencing the Sarai Kale Khan and Bhairon junction as shown in Figure 3. The western approach is 0.3 km long upto Nizamuddin junction. The length between Sarai Kale Khan intersection and Nizamuddin Bridge junction is 1.0 km. The distance between Nizamuddin Bridge junction and Bhairon junction is 1.7 km.

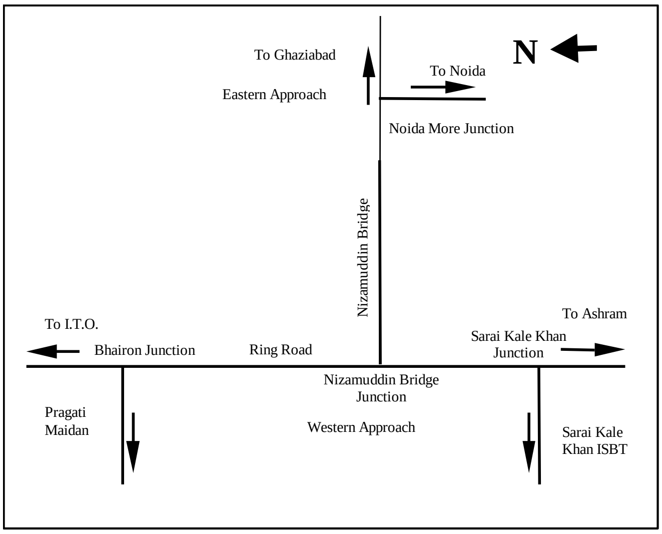


Figure 3. Approaches of Nizamuddin Bridge

The distance between junctions located in the western part and eastern part of the Bridge approaches is 2.9 km. The stretch of road on Ring Road between Sarai Kale Khan and Bhairon junction is designed as six lane divided carriageway. Eastern approach of the bridge is 2.1 km long upto Noida More junction, which is also a six lane divided carriageway. Both approaches of the bridge forms ‘T’ junction. These approaches are signalised but generally operated manually during the peak hours.

3.3 *Traffic Studies*

Three types of primary surveys (Ahmad S.A. 1999) are conducted with an objective to assess the traffic characteristics are turning movement survey, origin-destination survey and speed & delay survey.

3.3.1 Traffic Flow Characteristics

Figure 4 shows the variation of traffic flow at different hours of the day at the western approach of the bridge i.e. Ring Road-Nizamuddin Bridge junction. It can be seen in the figure that the distinct peak traffic is observed between 9:30 hr - 10:30 hr and 17:45hr - 18:45 hr in the morning and evening peak hours respectively. The peak hour traffic is 12,129 PCU and 12,801 PCU in the morning and evening respectively. Figure 5 shows the hourly variation of traffic flow at the Sarai Kale Khan junction. It can be seen in the figure that the distinct peak traffic is observed between 9:30 hr-10: 30 hr and 17:45 hr-18: 45 hr in the morning and evening peak hours respectively. The peak hour traffic is 8,156 PCU and 8,334 PCU in the morning and evening respectively. Figure 6 shows the hourly variation of traffic in a day at Bhairon junction. The peak hours are same as Sarai Kale Khan and Nizamuddin junction. The traffic in peak hour is 11,971 PCU and 11,149 PCU in the morning and evening respectively. Figure 7 shows the variation of traffic flow at different hours of the day at the eastern approach of the bridge i.e. Noida More junction. The peak hour lies between 9:45 hr-10: 45 hr and 18:00 hr-19:00 hr in the morning and evening peak hours respectively. The peak hour traffic flow is 10,309 PCU and 10,602 PCU in the morning and evening respectively.

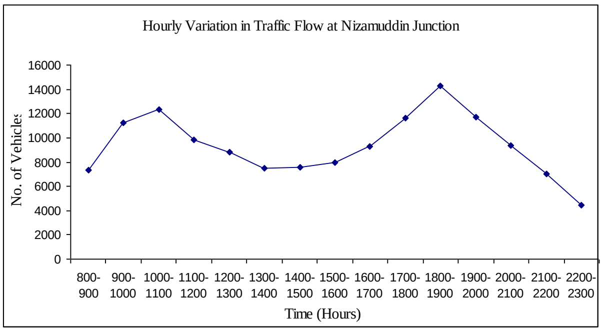


Figure 4. Hourly variation of traffic at Nizamuddin junction

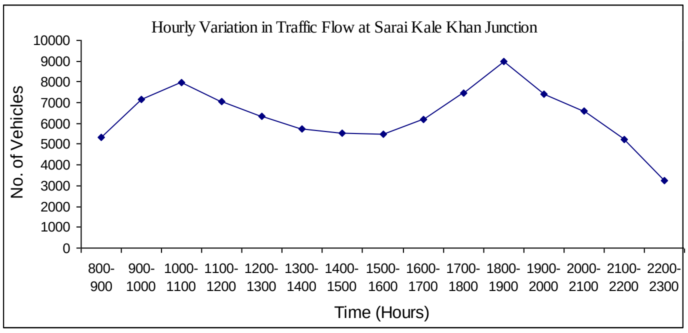


Figure 5. Hourly variation of traffic at Sarai Kale Khan junction

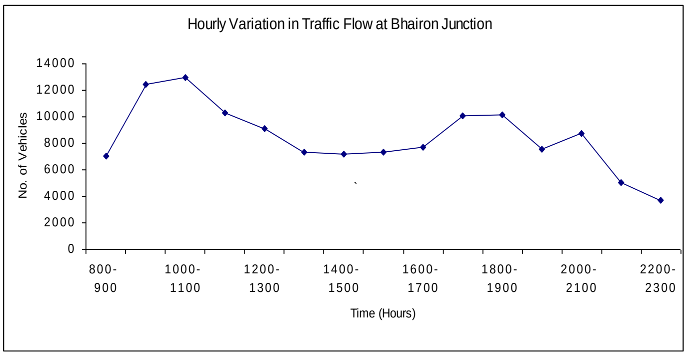


Figure 6. Hourly variation of traffic at Bhairon junction

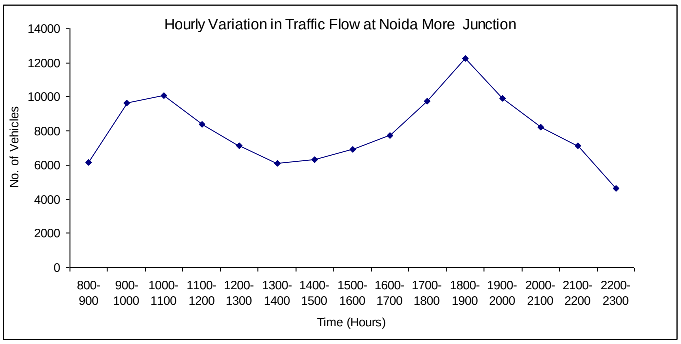


Figure 7. Hourly variation of traffic at Noida Mode junction

3.3.2 Travel Characteristics

3.3.2.1 Passenger Movement

In order to appreciate major corridor of travel by different modes in the study area, origin-destination (O-D) survey was conducted at each four station (junction). The O-D survey was carried out in the morning and evening peak hours with respect to car, two-wheeler, auto rickshaw, bus, LCV, truck and cycle. In order to organise the study in more rational manner, the study corridor was delineated in such a way so as to closely record the movement of traffic entering / leaving at each entry / exit point. There are six entry points / exit (cordon) points in the study corridor which are shown in Figure 8 and tabulated in following Table 1.

Table 1. Entry / Exit (cordon) points in the study corridor

Entry / Exit points (cordons)	Direction
1.	from Ashram
2.	from Sarai Kale Khan
3.	from Pragati Maidan
4.	from ITO
5.	from Ghaziabad
6.	from Noida

The O-D matrix of all modes is shown in Table 2 and Table 3 for morning and evening peak hour respectively. In the morning peak hour, the major direction of travel is established from ITO side to Pragati Maidan side, Noida side to Pragati Maidan side and Ashram side, Ghaziabad side to Ashram side and Ashram side to ITO side. In the evening peak hour, the major direction of travel is Pragati Maidan side to Ghaziabad side, Ashram side to Ghaziabad side, Pragati Maidan side to ITO side and Noida side.

Table 2. Origin-destination of total trips- morning peak hour

O \ D	Destination 1	2	3	4	5	6	Total
1	0	159	449	1121	816	682	3227
2	141	0	78	79	86	42	426
3	513	78	0	982	414	308	2295
4	868	106	4161	0	247	171	5553
5	1329	132	957	442	0	672	3532
6	1470	121	1483	747	817	0	4638
Total	4321	596	7128	3371	2380	1875	19671

Table 3. Origin-destination of total trips- evening peak hour

O \ D	Destination 1	2	3	4	5	6	Total
1	0	169	657	1242	1653	1097	4818
2	165	0	49	68	87	49	418
3	625	77	0	1334	1664	1320	5020
4	1277	134	984	0	505	643	3543
5	957	93	259	480	0	664	2453
6	725	99	350	604	1162	0	2940
Total	3749	572	2299	3728	5071	3373	19192

It can be seen from the Figure 8 that the busiest corridor forming with the links between the cordon points 5 and 1. Apart from that the corridor forming the links between cordon no. 3 and 4 also carries substantial volume of trips. The busiest corridor in the study area is identified by considering O-D matrix of both the peak hours.

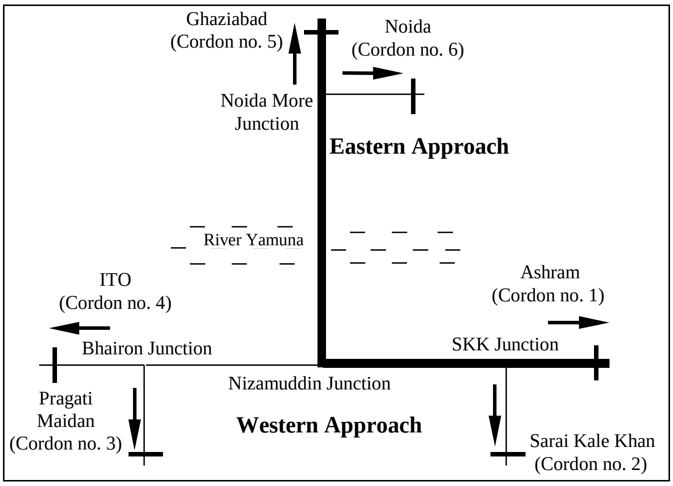


Figure 8. Busiest corridor in the study area

In order to workout the passenger movements, the occupancy of different modes was determined during the period of origin-destination survey. The occupancy of passengers for different modes of transport is shown in Table 4.

Table 4. Occupancy of passenger in peak hour

Sl. No.	Mode	Occupancy	No. of Passengers	%
1	Car	2.45	16300	13.1
2	Two-Wheeler	1.6	14286	11.5
3	Auto	1.8	2693	2.2
4	Bus	71.8	90037	72.6
5	Cycle	1.2	768	0.6

Total passenger movement by all modes in the morning peak hour are of the order of 1,24,000 passengers and a maximum 72.6% passenger movement is catered by buses followed by car and two-wheelers.

3.3.2.2 Turning movement pairs

Analysis of turning pairs is an important component of the study and needs to be investigated in detail, so as to get a clear understanding of nature of traffic flow in the study area.

In any traffic circulation system, the movement of uninterrupted flow of traffic is most desirable one. When traffic is to negotiate different types of movement in terms of left, straight and right turning then it experiences different degree of freedom in terms of smooth travel. The left turning movement in most of the cities is considered to be uninterrupted as compared to straight and right turning traffic. Right turning traffic is comparatively more inconvenient than straight moving traffic.

The degree of delays therefore varies according to the type of movement. Keeping this in view, the number of formation of turning pairs such as straight to straight, straight to right, straight to left, right to left etc. have been considered for detail analysis with respect to turning movement pairs.

The above analysis leads to detail appreciation of turning pair movements with respect to four 'T' legged junctions located in the study area as can be seen in the Figure 9. For example when a vehicle enters from the entry point of any link of the study area and leaves from any exit point of the link of the study area, then different combination of turning pairs can be formed leading to left to left, left to straight, left to right, right to right, right to straight pairs etc.

From the Table 5 it is clear that the total number of pairs form in the entire corridor are 48, out of which number of turning pair causing delay are 35 as it do not count left turning movements. The numbers of turning pairs causing delay on Ring Road are 25.

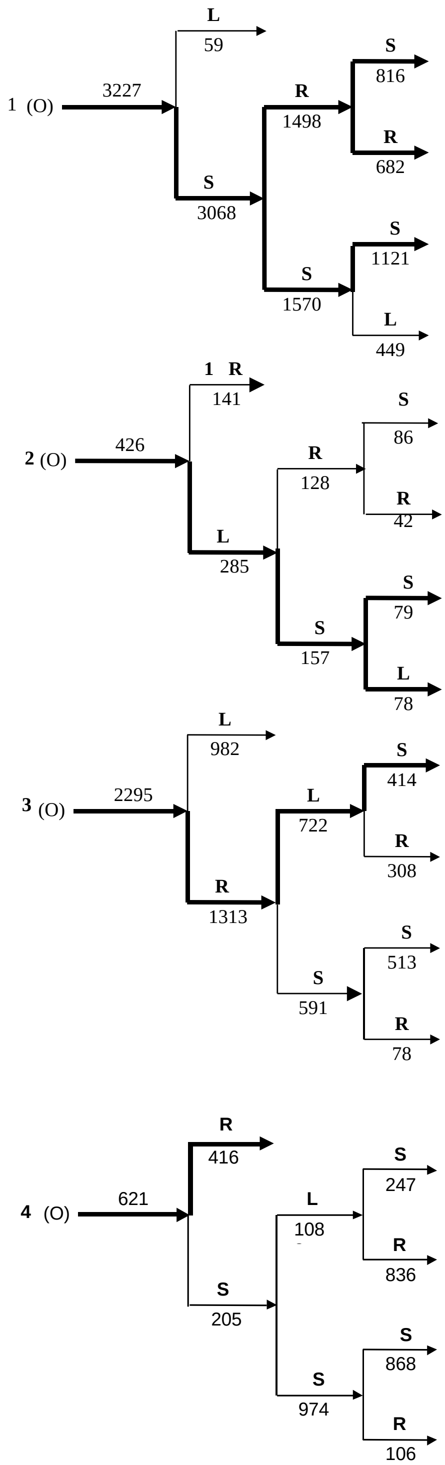
Table 5. Pair wise movement from each entry point in the corridor

Pair \ Origin	1	2	3	4	5	6	Total
O-L	1	1	1	0	1	1	5
O-R*	0	1	1	1	0	1	4
O-S*	1	0	0	1	1	0	3
L-L	0	0	0	0	0	1	1
L-S*	0	1	1	1	1	1	5
L-R*	0	1	1	1	1	2	6
R-R*	1	1	0	0	0	0	2
R-L	0	0	1	0	1	1	3
R-S*	1	1	1	0	1	1	5
S-S*	2	1	1	2	0	0	6
S-L	1	1	0	1	1	0	4
S-R*	1	0	1	1	1	0	4
Total	8	8	8	8	8	8	48

*Turning pairs causing delay

Note- O-L: origin to left, L-L: left to left, R-R: right to right, S-S: straight to straight, R-L: right to left, L-R: left to right etc. O: origin/cordon, L: left turning, S-straight movement, R: right turning

Figure 9 shows the vehicular movement in each pair from all entry points in morning peak hour. It has been found that, there is a heavy straight moving traffic from entry point no. 1 then this straight traffic further divides into right turn and straight. This straight traffic is more than the right turning traffic and further go more towards straight direction i.e. ITO side. Left turning traffic is more towards Bhairon junction side from entry point no. 2 i.e**.** Sarai Kale Khan ISBT and almost divides equally in straight and right direction. Right turning traffic is large from entry point no. 3 i.e. Pragati Maidan side, then it diverts more towards Nizamuddin Bridge side. There is large number of right turning traffic for Pragati Maidan side from entry point no. 4 i.e. ITO side. The traffic flow pattern is same from Ghaziabad side i.e. entry point no. 5. Straight traffic is more than the left turning traffic, which further divides in almost equal manner towards left and right direction and move towards Ashram side, Pragati Maidan side and ITO side. Distribution of traffic is almost same from entry point no. 6 i.e**.** Noida side. Left turning traffic is more which further moves more towards right direction than left direction. The right turned traffic almost divides equally for straight and left turning. This kind of pair-wise turning analysis has provided an insight in appreciating the detailed traffic movement pattern. This would enable to formulate a rational approach towards providing better traffic management measures in tackling the congestion problem.



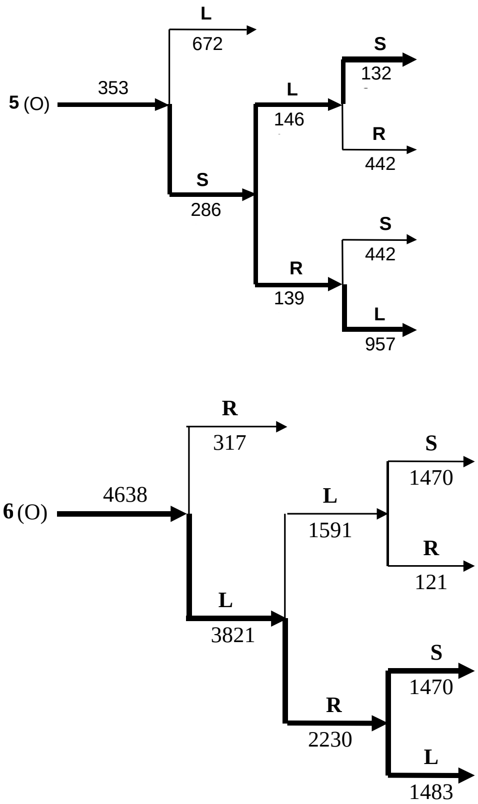


Figure 9. Pair wise traffic flow distribution (vehicles) in morning peak hour
Note-O-origin/cordon, R-right turning, S-straight movement, L-left turning

Table 6 presents the delay for each type of mode at junction where the vehicular traffic is observed to be interrupted in one or more times during its journey in the study area. The table depicts that the car is observed to experience a maximum delay of the order of 64 sec. followed by LCV with 63 sec. in respect of single straight movement. As regard to single right turning movement, two-wheeler experiences a maximum delay of the order of 93 sec.

Table 6. Mode-wise delay for single and double movements at bridge approaches

Direction	Mode	Delay (Sec)		
		Single	Double	More than double
Straight	Car	64.5	129.0	193.5
	T/W	51.7	103.0	155.0
	Auto	45.0	90.0	135.5
	Bus	46.0	92.0	138.5
	LCV	63.0	126.0	189.0
	Cycle	20.0	41.0	61.0
Right	Car	87.0	136.0	-
	T/W	93.0	151.0	-
	Auto	81.0	165.0	-
	Bus	76.4	123.5	-
	LCV	90.0	137.5	-
	Cycle	93.4	185.0	-

Note- Single straight or single right indicates the desire of travel negotiating only one straight or one right turning during the journey within the study area.

Distance travelled during the above delay time is determined on the basis of average running speed of each mode and presented in following Table 7. Distance travelled during the delay time by each mode is dependent on the amount of observed delay and their respective speeds. In the single straight movement delay time, car can travel maximum distance as 0.84 km followed by LCV, two-wheeler and bus of the order of 0.76 km, 0.61 km and 0.43 km respectively.

Table 7. Distance travelled during the delay time in single and double movements by each mode at bridge approaches

Direction	Mode	Distance travelled (km)		
		Single	Double	More than double
Straight	Car	0.84	1.68	2.52
	T/W	0.61	1.20	1.84
	Auto	0.48	0.97	1.45
	Bus	0.43	0.86	1.29
	LCV	0.76	1.53	2.30
	Cycle	0.06	0.12	0.18
Right	Car	1.14	1.78	-
	T/W	1.10	1.80	-
	Auto	0.86	1.76	-
	Bus	0.71	1.15	-
	LCV	1.10	1.67	-
	Cycle	0.27	0.54	-

3.3.3 Capacity Analysis

At Bridge Section:

Nizamuddin Bridge is eight lane wide with four lane for each direction. According to Indian Road Congress capacity standards, lane capacity in urban roads is 1,200 PCU/hour/lane. Specifically at bridge section with access control and good road condition, capacity of road may be increased to 50%. For calculating capacity at bridge section per lane, capacity has been taken as 1,800 PCU/hour/lane. Table 8 shows the v/c ratio as 0.83 in morning peak hour from eastern approach to western approach side and 0.78 in the evening peak hour from western side to eastern side direction. So, the bridge section is not over-utilized.

Table 8. Capacity of Nizamuddin Bridge section

Peak Hour	Direction		Traffic flow (PCU/ hr)	Capacity (PCU/hr)	V/C
	From	To			
Morning	W. Approach	E. Approach	2633	7200	0.4
	E. Approach	W. Approach	5956	7200	0.8
Evening	W. Approach	E. Approach	5588	7200	0.8
	E. Approach	W. Approach	3287	7200	0.5

At Junctions:

Capacity at all four junctions are found to be greater than 1.0. Maximum v/c is at Bhairon junction (1.8) followed by Nizamuddin junction, Noida More junction and Sarai Kale Khan junction of the order of 1.7, 1.3 and 1.2 respectively as can be seen in Table 9.

Table 9. Capacity of Intersections at Peak Hours

Name of Junction	Peak Hour	V/C
Sarai Kale Khan	Morning Peak Hour	1.2
	Evening Peak Hour	1.2
Nizamuddin Bridge	Morning Peak Hour	1.4
	Evening Peak Hour	1.7
Bhairon junction	Morning Peak Hour	1.8
	Evening Peak Hour	1.3
Noida More	Morning Peak Hour	0.8
	Evening Peak Hour	1.2

It can be revealed from the above table that most of the junctions are saturated during the peak hour in terms of v/c ratio.

3.3.4 Traffic Projection

The traffic projection for future years of peak hours have been determined upto horizon year 2005 by taking growth rate of 5% per annum (LASA 1999). The projected peak hour traffic at Niamuddin junction for the year 2005 is 18,815 PCU and 19,859 PCU in the morning and evening respectively. At Sarai Kale Khan junction, projected peak hour traffic is 12,653 PCU and 12,930 PCU in the morning and evening peak hours respectively. Projected traffic in peak hour for Bhairon junction is 18,570 PCU and 17,295 PCU in the morning and evening peak hours respectively. The projected peak hour traffic at eastern approach of the bridge i.e. Noida More junction is 15,999 PCU and 16,447 PCU in the morning and evening peak hours respectively.

4. POSSIBLE SOLUTIONS: SITE SPECIFIC

There are two alternative proposals envisaged to minimise the problems at the western approach of Nizamuddin Bridge. These alternative proposals presented below, were evaluated separately. Besides this, the feasible alternative proposals developed in the eastern approach of Nizamuddin Bridge were also evolved.

4.1 *Western approach (Ring Road side) of the Nizamuddin Bridge*

4.1.1 Proposal I

It may be worth mentioning that the proposal at the western part of the study area along the Ring Road envisaged to be developed in the form of loops to facilitate incessant movement of traffic as shown in the Figure 10. This proposal is a low cost solution, which is a at grade facility. Through this solution all the 25 delay pairs at Ring Road would become non-delay pairs as discussed in previous analysis indicated in sub section 3.3.2.2. The detail evaluation of this proposal is presented in Table 10.

Table 10. Evaluation of proposal I at western approach of Nizamuddin Bridge

Parameter	Year	Sarai Kale Khan Junction	Nizamuddin Bridge Junction	Bhairon Junction
Peak hour traffic flow (PCU)	Base year (1998)	8156	12129	11971
	Horizon year (2005)	12653	18815	18570
Capacity utilisation (V/C)	Base year (1998)	1.2	1.4	1.8
	Horizon year (2005)	> 1	> 1	> 1
Average vehicular delay (sec)	Base year (1998)	47.92	56.02	71.13
	Horizon year (2005)	Nil	Nil	Nil

4.1.2 Proposal II

In order to ensure the smooth flow of straight movement traffic in an uninterrupted manner on Ring Road, a proposal of grade separated junction without interchange facility catering one directional movement of traffic at Nizamuddin bridge junction and Sarai Kale Khan junction were evolved as shown in Figure 11 In addition to the above facilities, at grade slip lanes are also envisaged to be provided to enhance greater degree of freedom for straight moving traffic on Ring Road. Through this solution 12 delay pairs at Ring Road would become non-delay pairs. The detail evaluation of this proposal is presented in Table 11. It can be seen from the table that the magnitude of delay at Bhairon junction is estimated to be 118 sec. on an average. Presently there are two rail-under-bridges at Ring Road at north and south ends of the junction. Hence grade separation is not possible. Keeping in view extra capacity is presently being created that would bring down the above delay to a greater extent.

Table 11. Evaluation of proposal II at western approach of Nizamuddin Bridge

Parameter	Year	Sarai Kale Khan Jn.	Nizamuddin Bridge Jn.	Bhairon Junction
Peak hour traffic flow (PCU)	Base year (1998)	8156	12129	11971
	Horizon year (2005)	12653	18815	18570
Capacity utilisation (V/C)	Base year (1998)	1.2	1.4	1.8
	Horizon year (2005)	< 1	< 1	> 1
Average vehicular delay (sec)	Base year (1998)	47.92	56.02	71.13
	Horizon year (2005)	18.94	22.68	118

4.1 Eastern approach (Noida mode side) of the Nizamuddin Bridge

Due to space constraint at the eastern approach of the Nizamuddin Bridge the concept of loops cannot be applied and other possible alternatives have been tried. The details of the alternatives adopted for eastern approach of the Nizamuddin Bridge (at Noida More junction) are evaluated and presented below.

*Proposal I:*Optimisation of cycle time by evaluating various combinations of signal phases.

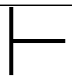
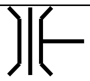
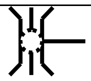
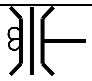
Proposal II: Grade separated junction with a grade separated facility along NH-24 bypass alignment. The signalisation would continue to regulate the right turning movements at the junction.

Proposal III: Grade separated junction with a grade separated facility along NH-24 bypass and design of round about at grade to facilitate the turning movements. Through this proposal all 10 delay causing pairs at eastern approach will become non-delay pairs.

Proposal IV: A development of partial cloverleaf to ensure uninterrupted movement of traffic from all directions at the junction. Through this proposal also, all 10 delay-causing pairs at eastern approach will become non-delay pairs.

All the above proposals have been examined and evaluated. The IV proposal of partial cloverleaf has been found to be feasible for eastern approach side (Noida More junction). The detail analysis of the above-discussed proposals is presented in Table 12.

Table 12. Evaluation of proposals at eastern approach of Nizamuddin Bridge

Options		I	II	III	IV
Eastern Approach (Noida More junction)					
Schemes		Signalized 'T' junction	Straight flyover with signalized junction	Straight flyover with rotary	Partial cloverleaf
Traffic flows (PCU)	Base year (1998)	10,313	10,313	10,313	10,313
	Horizon year (2005)	16,447	16,447	16,447	16,447
Performance indicator	Delay (avg. delay), sec.	92.2	76.1	-	-
	Capacity utilization	Saturated	Saturated	Saturated	Not Sat.
Remarks		Not feasible	Not feasible	Not feasible	Feasible

5. EVALUATION AND SELECTION OF BEST ALTERNATIVE

Keeping in view the performance of different alternatives as discussed earlier with respect to western approach and eastern approaches of Nizamuddin Bridge. Two integrated traffic schemes were evolved by considering feasible alternative from both sides (eastern as well as western side). Out of four alternatives developed at the eastern side of the Nizamuddin Bridge, alternative IV was found feasible and had been evaluated with two alternative proposals of western side. It is an attempt towards developing integrated schemes. The details of the schemes are presented below.

5.1 *Integrated Schemes*

5.1.1 Scheme I

Partial cloverleaf at Eastern approach and Loops at western approach of Nizamuddin Bridge. The scheme is presented in Figure 10.

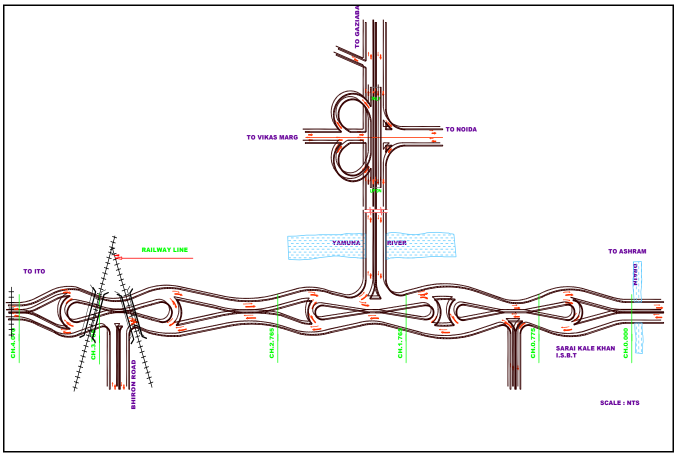


Figure 10. Integrated scheme I (loops at western approach and partial cloverleaf at eastern approach)

5.1.2 Scheme II

Partial cloverleaf at eastern approach and half flyovers on Nizamuddin Bridge and Sarai Kale Khan junction at western approach of Nizamuddin Bridge. The scheme is presented in Figure 11.

In order to examine the feasibility of the above traffic-integrated schemes; a number of parameters were considered for evaluation. These include pollution, vehicle operating cost and vehicle operating time. Cost estimates were also worked out for integrated traffic schemes and evaluated against the do nothing scenarios.

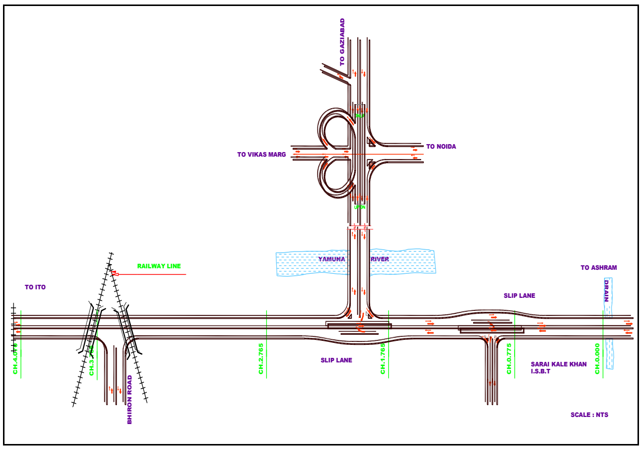


Figure 11. Integrated scheme II (half flyovers at western approach and partial cloverleaf at eastern approach)

5.1.3 *Scheme III*

In order to evaluate the above proposals against do-nothing alternative, it is considered that do-nothing alternative can be treated as scheme III for analysis purpose.

5.2 *Benefits*

It is necessary to estimate future benefits to be accrued under different traffic alternative scenarios. An attempt has been made to estimate the future benefits with respect to saving in pollution cost, saving in vehicle operating cost and saving in vehicular travel time among three schemes including do-nothing situation, as presented in the Table 13. It can be seen from the table that three scenarios have been developed in terms of above parameters. The first scenario is related to comparison between do-nothing situation as against alternative scheme I, while second scenario is related to the comparison between do-nothing situation as against alternative scheme II. Third scenario is concerned with the comparison between alternative scheme I and alternative scheme II.

Table 13. Evaluation Among Various Alternative Schemes

Year	Scenario I			Scenario II			Scenario III		
	Do nothing situation - alternative scheme I			Do nothing situation - alternative scheme II			Alternative scheme I - alternative scheme II		
	Pollution (Tonnes)	VOC * (US$ Million)	VTT* (US$ Million)	Pollution (Tonnes)	VOC (US$ Million)	VTT (US$ Million)	Pollution (Tonnes)	VOC (US$ Million)	VTT (US$ Million)
1998	30	-0.54	2.00	165	0.32	2.96	135	0.86	0.97
1999	72	-0.49	2.78	202	0.40	3.61	131	0.88	0.83
2000	91	-0.48	3.18	223	0.44	3.98	132	0.92	0.80
2001	113	-0.47	3.63	246	0.48	4.38	133	0.95	0.76
2002	137	-0.46	4.13	271	0.53	4.83	134	0.99	0.70
2003	165	-0.44	4.69	299	0.59	5.33	134	1.03	0.64
2004	196	-0.42	5.31	330	0.65	5.88	134	1.06	0.57
2005	230	-0.39	6.00	363	0.71	6.48	133	1.10	0.47

*VOC-Vehicle operating cost, VTT- Vehicular travel time
Note - Estimates of pollution, VOC and VOT have been carried out from the data (CRRI 1996, IIPD 1994, IRC 1993 & Sharma V. 1992) available.

After having studied various integrated traffic schemes and comparative evaluation among them, the alternative scheme II is found to be most feasible and impressive. It can be seen from the Table 14, that alternative scheme II is most favorable against alternative scheme I in terms of cost and benefit. The proposed alternative scheme II is comparatively better than alternative scheme I primarily because of significant savings in pollution of the order of 133 tonnes, substantial saving in vehicle operating cost of the order of US$ 0.71 Million coupled with considerable saving in vehicle operating time of the order of US$ 6.48 Million to be achieved in the horizon year 2005. Table 14 presents a cost benefit analysis for a period of 10 years, taking into the components of only savings in vehicle operating cost and vehicular travel time. A discount rate of 10% has been considered as per the prevailing situation. It can be seen from the table that the net present value (NPV) for scheme II is substantially higher than scheme I. As monitory cost with respect to pollution is not available, therefore it has not been considered in cost benefit analysis. Accident cost has also not been taken into consideration. Net present value for scheme II would have been much more higher, had saving in pollution and accident cost been taken into account. Details for projected traffic estimated has been indicated in the earlier sections.

Table 14. Cost benefit* analysis

Schemes	Benefits in different years due to saving in VOC and VTT											NPV (US$ M)
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Scheme I	-8.9	-8.1	2.23	2.37	2.5	2.64	2.76	2.88	2.77	2.67	2.6	7.8
Scheme II	-6.3	-5.7	3.65	3.65	3.66	3.68	3.69	3.68	3.42	3.18	2.9	19.6

*Note – Benefits accrued due to improvement in schemes I and scheme II have been estimated w. r. t. existing situation

In view of the above, the proposed integrated transport alternative scheme II has been considered for recommendation and implementation.

6. CONCLUSIONS

In the light of the detailed study undertaken as demonstrated above, integrated scheme II has been found to be most suitable. It is felt that wherever a programme for bridge planning is required to be carried out, it would be imperative to look into pros and cons of various studies such as cost benefit analysis and environment impact assessment. Most important component of bridge planning is to identify the proper approaches and linking the bridges with its approaches in most comprehensive manner, so as to ensure most economic, safe and uninterrupted movement of traffic. This study has provided a correct framework with respect to problem identification, analytical approach and conceptualisation of various measures. This can be considered as a demonstrative example for the conduct of this kind of study.

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