EVALUATION OF THE DELHI BUS CORRIDOR: LESSONS LEARNT AND RECOMMENDATIONS FOR IMPROVEMENT

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ABSTRACT

Bus rapid transit (BRT) has extensive applications in South and North America, Europe and the Far East, but it is a novel concept for South Asia. One of the initial projects in India, the Delhi Bus Corridor, has been controversial: media outlets highlighted problems for the general traffic and safety, while user surveys showed improved perception by bus users, bicyclists and pedestrians. The discussion of the benefits and problems of the corridor has been mostly based in perceptions and prejudices. The authors conducted an independent evaluation to contribute with technical arguments to this discussion and to provide suggestions for the corridor improvement. The results were also intended to contribute to the understanding of the BRT concept in the Indian context.

The authors conclude that the Delhi bus corridor has improved people mobility along the initial stretch, but requires significant performance, safety and overall quality enhancements. The project only comprised major changes in infrastructure but lacked of integrated implementation of service plans, technologies and operations. User and community education was also insufficient.

In addition to ongoing improvements, the authors identified the need to: i) establish a quality improvement program measuring the system performance, ii) focus on improving reliability and comfort; and iii) reevaluate the bus service plans to provide a better match of the supply and demand. The authors also recommend using median bus lanes with strong segregation as the preferred option for bus priority in Delhi.

The bus corridor in Delhi provides invaluable experience for the enhancement of transit facilities and services in India and beyond. The observed problems in its initial operations are partially the result of lack of understanding of the systematic nature of transit. A more holistic approach, which goes beyond bus lanes and new buses, is imperative to assure project success.

Key words: transit, bus systems, BRT, India, Delhi

INTRODUCTION

Delhi is the capital of India and one of the world megacities. The recent growth in economic activity and average incomes have resulted in increased mobility and motorization. The local government has launched several infrastructure projects to address increased need for transport infrastructure and services, including the construction of a metro system, new roads and flyovers. The city has an ambitious multimodal transit plan, which includes the implementation of bus rapid transit (BRT) system (DIMTS, 2009a) to complement and extensive metro system (DMRC, 2009).

Bus rapid transit (BRT) has extensive applications in South and North America, Europe and the Far East (Levinson et. al 2003a; Hidalgo and Graftieaux, 2008, Wright and Hook, 2007) but it is a novel concept for South Asia. An initial corridor of the proposed Delhi BRT system network was launched in April 20, 2008 along JBT Marg, between Moolchand and Ambdkar Nagar in south Delhi. The corridor ran with several difficulties during the first weeks (see for example, MSN India National News, 2008). Some of the main problems observed by the authors on a site visit in April 2008 were:

- The traffic signals did not work properly – manual operation was common;
- Queuing in the general traffic lanes was extensive;
- There were several bus breakdowns in the bus lane;
- Drivers lacked adequate training and enforcement was weak –used wrong platforms, stopped several times along the stations;
- There were several motor vehicles and two wheelers in bus lanes;
- Users were not adequately informed where to board the buses; and
- Pedestrian crossed the bus lanes and general motor vehicle lanes in unauthorized places.

Delhi Integrated Mass Transit Systems – DIMTS-, the city agency in charge of the corridor operations, rapidly responded by deploying additional wardens and reviewing the signal plans for the traffic control devices (DIMTS, 2009b; DIMTS, 2009c). Having the additional traffic wardens helped providing instructions organizing the traffic flows, and enforcing violations. Improvements in signal planning reduced, but not eliminated, the long queues in the general traffic lanes.

The initial difficulties received wide media coverage, specially focused on the problems for motor vehicle users and accidents (see for example, MSN India National News, 2008; CNN-IBN, 2008a; CNN-IBN, 2008b). As a result, the initial public perception of the project was poor. Moreover, the debate became politicized, with the opposition attacking the government on the grounds of botched implementation of the bus corridor (CNN-IBN, 2008c).

Despite the negative perception reflected in mass media outlets, the corridor users had a different opinion. A survey by the Centre for Science and Environment (CSE) in June 2008 (CSE, 2008) reflected a very positive view by bus commuters (88%), pedestrians and cyclists (85%), and a fair perception by car and two wheelers (45%) and other commuters (50%).

The discussion of the benefits and problems of the corridor was mostly based in perceptions and prejudices, rather than technical evaluations. The debate did not contribute to the improvement of the corridor operations and the definitions regarding the expansion of the concept to other corridors in Delhi. The negative image of the corridor affected the development of bus rapid transit (BRT) projects all over India (CNN-IBN, 2008c).

The authors conducted an independent evaluation to contribute with technical arguments to this discussion and to provide suggestions for the corridor improvement. The authors interviewed several stakeholders, gathered information, conducted site visits, analyzed common concerns and evaluated the corridor in terms of high-end BRT Paradigms. This report summarizes the evaluation and provides recommendations, useful for Delhi and other cities interested in improving transit corridors.

CORRIDOR DESCRIPTION

The main descriptors of the bus corridor are (DIMTS, 2009a; DIMTS, 2009b; DIMTS, 2009c):

- Length: 5.6 kms
- Stations: 9
- Total Ridership: Not available
- Peak Load: 6,500 passenger/hr/direction
- Frequency: 120 buses/hr

- Commercial Speed — In corridor: 16-19 km/hr -peak hour; Off corridor: 7-11 km/hr -peak hour
- Operational Productivity: — Not available (4.8 passengers/bus-km citywide, DTC, 2009)
- Capital Productivity: — Not available (848 passengers/bus/day citywide, DTC, 2009)
- Infrastructure Investment: — Rs. 14 crores/km (3 million/km)
- Cost per Passenger: — Not available
- Average User Fare: — Rs. ~ 1/km - Rs. 3.87 per passenger citywide (USD 0.08) Ordinary service: 1-4 Kms; Rs. 2; 4-8 Kms. Rs. 5; 8-12 Kms. Rs. 7; 12-onwards, Rs.10 (DTC, 2009)

The corridor infrastructure consist of single median lanes for buses with physical segregation and double platform bus stops located close to the intersections; two lanes for general traffic; and bikeways and sidewalks on the two sides (DIMTS, 2009b). The general traffic lanes flare at the intersection to provide an additional lane for turning movements.

Bus operations include 57 different routes operated by Delhi Transport Corporation – DTC (a public company owned by the Delhi Government), and private operators (Blue Line Buses) under permit by the Secretary of Transport STC (DIMTS, 2009c). Company and school buses are required to use the bus lanes, but school buses are allowed to go to the curb side lanes to enter colonies.

The corridor can be described as an open system, i.e. bus routes enter and leave the corridor along its way. Operations do not have centralized control.

CORRIDOR EVALUATION

The authors used a dual framework to evaluate the bus corridor in Delhi in relation to high end BRT concepts (Wright and Hook, 2007; Levinson et. al, 2003b; Diaz and Hinebaugh, 2009). In the first place the authors evaluated the bus corridor from the supply side, and then in terms of its performance. The evaluation is qualitative in nature, but provides a structure for systematic comparison across projects, cities and countries.

Supply Side Evaluation

Bus Rapid Transit "*is a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways and ITS elements into an integrated system with strong* *identity*" (Levinson et. al, 2003b). A BRT system can mix different components according to the service needs and the local constraints. The team used the common understanding of the high end characteristics of each of the components to compare with the current characteristics of the bus corridor in Delhi. The "High End" BRT characteristics are presented in Table 1.

Table 1 - High End BRT Characteristics

BRT Component	"High End" BRT
Running Ways	• Longitudinal Segregation
Traffic Engineering	• Geometric Adjustments • Left and Right Turn Controls • Traffic Signal Priorities for Buses • Modern Traffic Signal Technology
Stations	• Enclosed Facilities • Level Boarding and Prepayment • Passing Lanes (when required)
Vehicles	• Multiple doors • Easy Boarding/Alighting • Low Emissions
Services	• Mixed services (local, accelerated, express; short loops) • Design according to the service needs
ITS	• Automatic Vehicle Location/Centralized Control • Traffic Signal Priority • Electronic Fare Collection/Fare Integration

Source: Adapted from Levinson et. al, 2003

With these concepts in mind, the authors evaluated the components of the Delhi Bus Corridor (Table 2). As an evolving project, the Delhi bus corridor still requires several adjustments on the supply side to become a high-end BRT. A systematic effort to integrate these components is required if Delhi wants to upgrade the bus corridor and enhance its service and performance.

PERFORMANCE SIDE EVALUATION

BRT can also be defined as *"…a high quality public transport system, oriented to the user that offers fast, comfortable and low cost urban mobility"* (Wright and Hook, 2007). The authors used the classification presented in Table 3, to evaluate service performance. The table also includes "externalities" to see the level of achievement of impacts beyond those perceived by the bus commuters. Table 4 presents the performance side qualitative evaluation.

The corridor has achieved some advances in performance, but several elements need to be improved, especially reliability and comfort. Reliability refers to the capability of a given system to be relied on, to be dependable. A bus system is reliable if it provides consistent waiting and travel times. This is achieved through low variability of the bus intervals (consistent frequency) and low variability of the bus commercial speeds.

Table 2 – Delhi Bus Corridor – Supply Side Qualitative Evaluation

BRT Component	Advances	Elements to Improve
Running Ways	• Strong Longitudinal Segregation • Median Busways	• Extend Longitudinal Segregation to Delhi Gate, preferably using median lanes (expected)
Traffic Engineering	• Adequate Changes in Roadway Geometry	• Timing plan of traffic signals at intersections to maximize people throughput and minimize variability (use short cycles, eliminate manual operation) • Manage Left and Right Turn movements for buses away from the intersection to reduce the number of phases • Improve the traffic signal technology (expected)
Stations	• Protected Bus Shelters • Level Boarding for a fraction of the fleet	• Enhance the stations to provide better protection to the users • Expand the fleet with level access (expected) • Introduce pre-payment at the stations to reduce bus dwell time and increase bus commercial speeds
Vehicles	• Easy Boarding/Alighting Low Floor Buses (13% of the fleet) • Low Emissions CNG Buses	• Replace the conventional one-door buses with stairs (expected) • Introduce emissions post-treatment to reduce air pollutants beyond the current levels
Services	• Relocation of some "Blue Line" bus routes	• Introduce special service plans to increase quality of service and reduce fleet and operational costs (short cycle routes, express services) • Provide and adequate match between demand and supply
ITS	• Automatic Vehicle Location (GPS in a fraction of the fleet) • Real time user information systems (Variable message signs at stations)	• Replace manual operations with real time control and dispatch • Introduce automatic fare collection systems, preferably integrated

Table 3 - High End BRT Performance Characteristics

BRT Component	**"High End" BRT**
Quality of Service	• High User Acceptance
Travel Time	• Easily Accessible • Low waiting time • High commercial speed
Reliability	• Low variability (intervals, speeds) • Low breakdowns, incidents
Comfort	• Low Occupancy Levels (buses, platforms) • Good user information • Seamless integration with other transport modes • Perception of safety and security
Cost	• Relative low capital and operational costs • High capital and operational productivity
Externalities	• Low level of accidents (fatalities, injuries) • Low emissions • Increased physical activity • Congestion relief (attraction of automobile users) • Increased land values

Source: developed by the authors, based on Wright and Hook, 2003

Reliability is fundamental in attracting passengers to the bus system, and can be improved through:

- physical measures (segregation of the bus lanes, reduce interference with the rest of the traffic),
- the traffic operations (consistent signal cycle times at intersections), and
- the transit operations (consistent dwell times and driving practices, regular dispatch, control of the bus intervals along the route). Fleet management systems, using automatic vehicle location and on-line supervision, are able to monitor and help bus operations achieve reliable operations.

Comfort is the capacity to give physical ease and well-being. In a transit system comfort refers to several attributes of the passenger experience such as the occupancy levels in buses and station platforms, the availability of user information, the integration with other transport modes (including walking to and from stations), and the perception of safety and security, among other factors.

Comfort is probably the most important concept in making a transit system attractive for motor vehicle users. Comfort can be improved by increasing:

- the capacity and reliability of the bus system (more frequent buses, consistent arriving times and speeds, wider platforms)

Table 4 - Macrobús Calzada Independencia BRT – Performance Side Qualitative Evaluation

BRT Component	**Advances**	**Elements to Improve**
User Acceptance	• High Bus User Acceptance: 88% Weighted average total : 68% (8)	• Continuous monitoring of user perception
Travel Time	• Good accessibility through at- grade pedestrian crossings at signalized intersections; • Acceptable waiting time for bus services: 3 routes along the corridor with 5 minute interval during peak hour • Good Commercial speed: 16-19 Km/h (9); improved by 128%-27% (from 7-15 Km/h without the bus corridor)	• Reduce pedestrian wait time at pedestrian crossings, currently higher than 60 seconds at the signal. • Introduce non-grade intersections where warranted (expected) • Further increase the commercial speed for buses (beyond threshold of 20 km/hr) through improved infrastructure
Reliability	• Automatic vehicle location (GPS) for a fraction of the bus fleet may provide information to monitor this variable	• Reduce the high variability observed in bus intervals and speeds (dispatch, control, signal management) • Reduce the observed bunching of buses and wide time intervals • Reduce and manage high level of breakdowns, incidents and encroachment
Comfort	• Bus shelters provide better protection than former bus stops • Presence of guards increase the perception of safety and security • A fraction of the fleet has advanced characteristics • Variable message signs provide information on the expected interval • Integration with three wheelers provided by design	• Reduce the high occupancy of buses and platforms (match supply and demand) • Increase and maintain in adequate condition the user information systems (scarce or vandalized maps & signs) • Variable message signs need to be connected with the real information from the buses • Improve connectivity to other transport modes and introduce single payment media (Metro, Buses, Regional Buses, Trains)
Cost	• Low Costs: capital investment (Infrastructure 14 Crores/km)	• Collect data on capital and operational productivity (expected to improve as corridor is expanded)
Externalities	• Reduced emissions, particulate matter, CNG engines; 13% New Fleet (3)	• Monitor and report fatality rates (currently high 0.8/month) • Expand corridor and improve bus service to attract personal motor vehicle commuters and generate land development opportunities

- the quality, adequacy and quantity of user information elements (fixed signs, maps, variable message signs)
- the connections and systems to integrate the bus corridor with other transport systems, including seamless pedestrian crossings and integrated fare collection systems, and
- the design features of the stations and buses, illumination, tidiness and presence of security personnel and personal protection systems (closed circuit TV, alarm and communication elements).

STAKEHOLDER INTERVIEWS

Interviews included representatives of Delhi Integrated Multimodal Transport Services (DIMTS); the Traffic and Injury Prevention Program (TRIPP) of the Indian Institute of Technology (IIT) Delhi; Delhi Transport Corporation (DTC) and the Delhi Traffic Police. The purpose of the meetings was to understand the background of the project from the point of view of the stakeholders, identify the various difficulties/issues encountered and understand the approach chosen to mitigate these difficulties.

Interviewed individuals coincided that the objective of the corridor was to improve mobility and security, through priority measures for public transportation and assignment of dedicated space for bicycles, cycle-rickshaws and pedestrians. It was also clear that Delhi Government introduced several initiatives to improve operations since the inception of the corridor (DIMTS, 2009b; DIMTS, 2009c):

- There was a reorganization of bus services, moving several traditional routes, known as “Blue Line Buses”, to other routes and improving the fleet of DTC buses with new low floor and air conditioned vehicles.
- DIMTS commissioned studies to improve traffic management activities and implemented recommendations, and introduced continuous measurements of travel speeds for buses and general traffic.
- DIMTS retained staff and assigned it to the corridor management, with special focus on mitigating queuing at Chirag Delhi junction.

Based on the interviews the authors selected a set of common concerns about the bus corridor:

- Have the project improved the mobility in the corridor?
- Were the strategies to mitigate delays to motor vehicles effective?
- Would curbside bus lanes work better than median bus lanes?
- Had the corridor reduced or increased accidents?

SITE VISITS

The authors visited the corridor to experience the operations at different times of the day and days of the week. Aspects of special attention were the operation of each of the components of the corridor: pedestrian and bicycle facilities, bus lanes and stations, motor vehicle lanes. Some of the interviews were conducted on the facility itself (operational personnel of DIMTS and Delhi Police).

The main observations resulting from these visits were:

- Traffic signal cycles were long (4 minutes in the peak hour)
- General traffic lanes experienced long queuing
- Bus queues were longer than the station platform length, with some passengers alighting and boarding outside the platforms
- There were bus breakdowns that affected the operation of the bus lanes and the stations
- Pedestrian jaywalking was common
- Some motor vehicles encroached the bus lanes
- Bus occupancy levels were high, specially in the peak period
- Bus operation displayed high variability in intervals and commercial speeds
- Bike tracks catered for a large number of bicycles
- Two wheelers encroached the bicycle tracks to jump the motor vehicle queues
- Space for bicycles was reduced to create an additional turning lane for general traffic in Chirag Delhi junction.

Figure 1 - Chirag Delhi Junction, South to North, Feb 5 2009, 9:00 AM

KEY QUESTIONS ABOUT THE BUS CORRIDOR – ANALYSIS

Has the project improved mobility in the corridor?

From the data collected (DIMTS, 2009d) it was evident that the pilot corridor has improved mobility on the corridor. The average travel time for motorized travel along the corridor reduced 19% (Figure 2). This is the combined effect of a 35% reduction in travel time for bus users and a 14% increase in travel time for personal motor vehicles users.

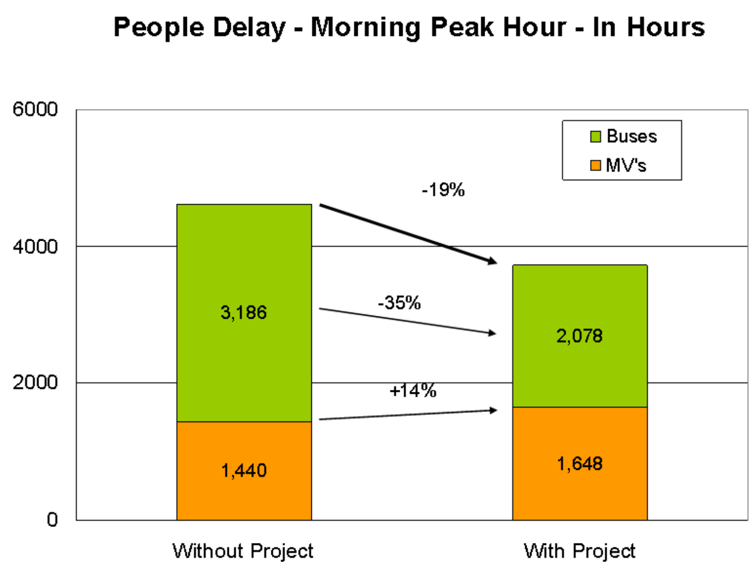

Figure 2 -Travel time savings in the without and with project

This comparison was made with the traffic counts and vehicle occupancies reported after the corridor was implemented: 3,675 motor vehicles per hour, with 3,841 people (1.045 persons per vehicle), and 112 buses per hour with 6,371 people (57 passengers per bus), as reported to the authors by DIMTS (2009d). The situation without project, which cannot be observed, assumed the same volumes and vehicle occupancies and changes in average speed: from 16 km/h to 14 km/h in motor vehicles, and from 12 km/hr to 18 km/hr in buses. The speed figures were reported by DIMTS (2009d) from data collected using probe vehicles as well as GPS data from the buses in the corridor and outside the corridor.

As most of the users of the corridor were bus commuters, the decrease in travel time for bus users offsets the increased travel time for cars. The data from DIMTS (2009d) indicated that buses comprise just 2 per cent of all vehicles at the Chirag Delhi Junction during the morning peak hour, but they move 55 per cent of the people (Figure 3). Cars and two-wheelers make up 75 per cent of the vehicles, but move 33 per cent of the people. Vehicle wait time for buses is 4 per cent of the total vehicle wait time at the Chirag Delhi junction, but 68 per cent than the total people wait time (Figure 4). Wait time for vehicles is 96 percent of the total vehicle wait time, but 32 per cent of the total people wait time. These calculations are based on Webster's delay formula for signalized intersections (Webster, 1958) and the data provided by DIMTS (2009d).

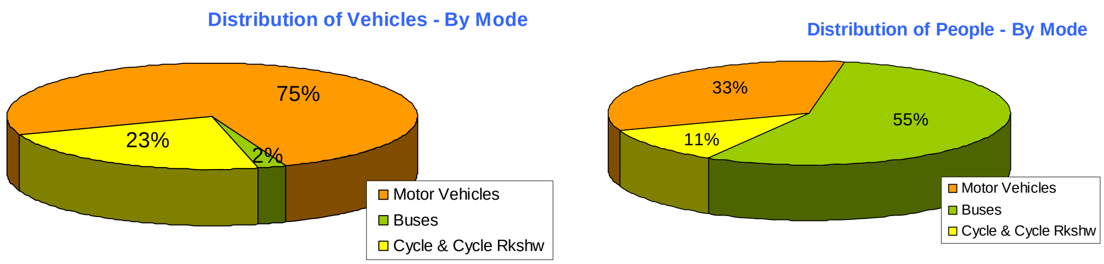

Figure 3 - Mode shares at the Chirag Delhi junction in the peak hour, in terms of vehicles and people

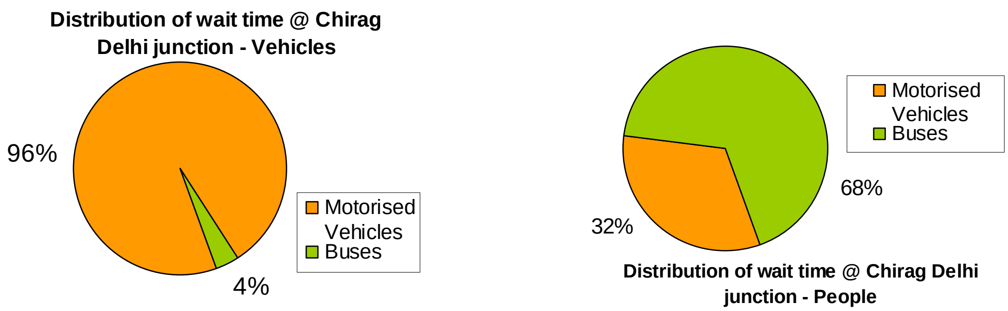

Figure 4 - Wait times (average delay peak hour) Chirag Delhi junction, by vehicles and by people

Were the strategies to mitigate delays to general traffic effective?

DIMTS introduced traffic management strategies to reduce the queue length at Chirag Delhi Junction based on increasing the cycle time of the signal when the queue length in the motor vehicle lanes exceed a given threshold -about 700-750 meters (DIMTS, 2009c). The analysis of this strategy showed that increasing the signal cycle increased the waiting time for all users; hence the strategy has not been effective. Moreover, the biggest negative impact is accrued by the majority of the people traveling in buses (55%).

Figure 5 compares the wait times at the Chirag Delhi junction in the peak hour/ peak leg for two signal cycle settings. The cumulative delay (wait at the junction) is computed in terms of people hours. Computations using Webster's delay formula for signalized intersections (Webster, 1958) show that augmenting the signal cycles increases wait time for all users.

The automatic cycle of 148 seconds (2 minutes 28 seconds) results in delays of 53 hours for users of motorised vehicles and 111 hours for bus commuters during the peak hour and in the peak direction. The manual cycle of 240 seconds increases the delay to 105 hours for motorised vehicles (98 per cent increase) and 179 hours for bus commuters (61 per cent increase).

Moreover, longer signal cycles result in longer wait times for pedestrians at the signalized intersections. This contradicts the general principles of safe pedestrian intersections (ITE, 1998), as many pedestrians stop watching for lights and instead look for gaps to cross streets when their delay exceeds 30 seconds; as a result long cycles greatly increase the likelihood of jaywalking.

In addition to the queue reduction strategy through cycle time expansion, there is an effort to create additional capacity for motor vehicles. For instance, a left turn lane has been created by encroaching into the bicycle lane at the Chirag Delhi Junction. This temporary solution for motor vehicle congestion relief compromised the concept of segregated facilities for bicycles and pedestrians not only at the current location, but across the whole corridor, with negative impacts in safety and performance.

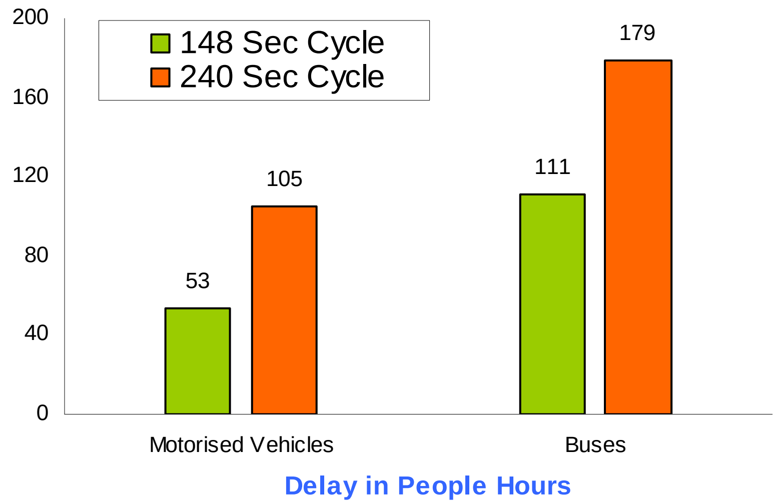

Figure 5. Wait times at the Chirag Delhi junction in the peak hour peak leg (in people hours).

Would curb side bus lanes work better than median bus lanes?

International experience with bus priority measures indicates that curbside lanes result in lower travel speed for buses and, hence, longer travel times for bus commuters (Wright and Hook, 2007; Levinson et. al, 2003; Diaz and Hinebaugh, 2009). The main reasons are:

- Curbside lanes are usually encroached by hawkers, taxis, auto-rickshaws
- Curbside lanes provide direct accessibility to the properties, so flow is interrupted by vehicles going out or coming in.
- Vehicles with mechanical failures are left in curbside lanes
- Continuous enforcement is more difficult

In addition, the type of segregation is also important. Physical segregation, as opposed to horizontal and vertical signage significantly reduces encroachment.

The authors analyzed the quantitative impact of the location of the bus lane in terms of travel time and fleet requirements for the expansion of the bus corridor to Delhi Gate. According to this analysis the required fleet with segregated median lanes is 110 buses, while the required fleet with curbside lanes is 220 buses. At the same time, the reliability of the service drops as a result of higher friction with other vehicles, pedestrians, and even hawkers, making it more difficult to comply with scheduled service and reducing the quality of the service provided.

Had the corridor reduced or increased accidents?

The most important indicator of traffic safety is the number of fatalities. According to the reports received from the Delhi Police (2009), there have been 8 fatalities in 10 months since the corridor started operations.

The comparison of this figure with data before the corridor started construction does not suggest any statistically significant change in the fatalities per month (Figure 6). Data from 2001 to 2005 shows an average of 0.73 fatalities per month, but a very high variation from one year to another (Delhi Police, 2009). One of the reasons for the very high variation is that the corridor is very short. In addition, comparing one point with a short series may not result in meaningful evidence.

Representatives from DIMTS (2009c) indicated that the number of fatalities per month has been decreasing since the start of operations. This is important and needs to be part of the standard reporting the agency collects and publish. The reported decrease may be a natural effect of the commuters getting used to the characteristics of the corridor, the strong presence of wardens, the speed reduction devices implemented in the bus lanes, and better driver and pedestrian behaviour, among other causes.

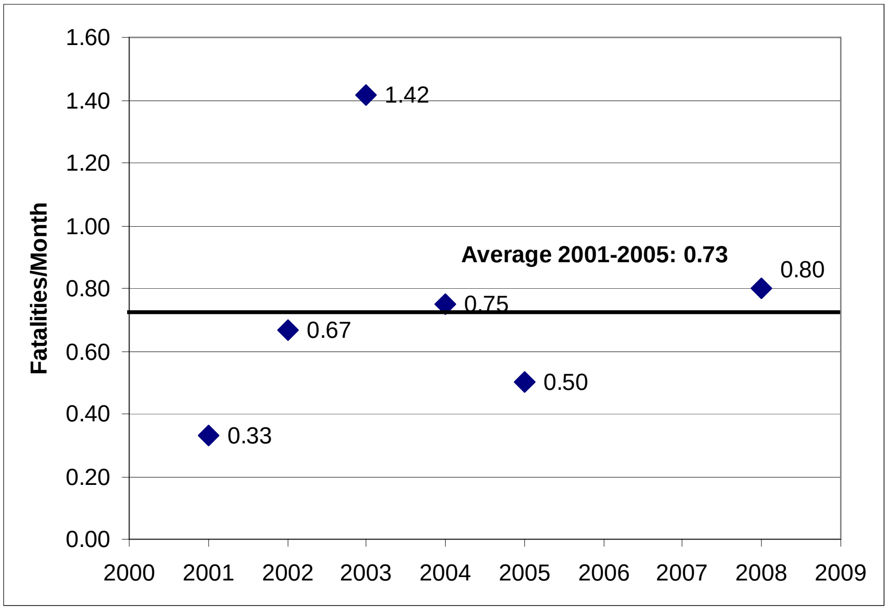

Figure 6 - Comparison of Monthly Fatality Rates Before and After Corridor Implementation (Delhi Police, 2009)

Nonetheless, the authors still observed a significant number of pedestrians crossing at non-designated places due to bus queues spilling beyond the platforms at the stations, lack of safe access/exit in the back of the station, long pedestrian waiting times at the zebra crossings, and lack of education and enforcement.

CONCLUSIONS AND RECOMMENDATIONS

The Delhi bus corridor has improved the mobility of the people along the initial pilot stretch. Bus travel speeds are 150% faster than buses outside the corridor resulting in a travel time reduction along the corridor of 19% for all commuters. The corridor has also received high ratings from the users. In addition, the facilities for bicycles and pedestrians have improved the travel experience and the perception of safety for these important users of the corridor.

Despite the initial advances, the bus corridor shows several problems which need to be addressed. In general, the project was not a systematic implementation of bus rapid transit concepts. It only comprised major changes in infrastructure but lacked of integrated implementation of service plans, technologies and operations. It also lacks of mechanisms to gradually improve the service delivery in a methodical way.

The bus corridor in Delhi provides invaluable experience for the enhancement of transit facilities and services in India and abroad. The observed problems in its initial operations are partially the result of incomplete implementation of the project plans and lack of understanding the systematic nature of transit improvements. A more holistic approach, which goes beyond bus lanes and new buses, is imperative to assure project success. Recommendations for Delhi can be extended to other transit systems being implemented in India and abroad.

The following sections summarize conclusions and recommendations specific to the Delhi bus corridor.

Delhi Bus Corridor Evaluation in contrast to BRT Paradigms

The Delhi bus corridor is a project in evolution. It has been a step in the right direction to improve mobility to the majority of the population, and should be improved gradually from the current incomplete condition.

The authors observed several difficulties associated with the bus operations and the interaction of pedestrians and general motor vehicles with the facilities. The Delhi government, through DIMTS, indicated that several actions are underway to improve the project: DTC bus fleet is being replaced, new contracts for private providers are under preparation, traffic signals will be replaced by advanced technologies, and the corridor will be expanded 9 km to reach Delhi Gate.

These measures may not be enough. The authors identified the need to:

- Establish a Quality Improvement Program with the participation of external stakeholders in measurement and oversight
- Define Indicators: User Acceptance, Travel Time, Reliability, Comfort, Productivity, Externalities
- Define goals and time based milestones
- Set up a monitoring mechanism: plan, perform, report, including periodic user surveys to define commuter’s acceptance and specific studies for the other categories (e.g. every 4-6 months)
- Take improvement actions and evaluate the impact in the set of indicators
- Focus on Improving Reliability and Comfort, which are key components in making the system attractive:
    - Reliability refers to consistent arrivals of the buses at the stations, to minimize waiting time uncertainty, and consistent travel speeds. Reliability can be improved through steady signal cycle times at intersections and improved transit operations, to achieve regular dwell

times and driving practices, steady dispatch and control of the bus intervals along the route. Fleet management systems, using automatic vehicle location and on-line supervision, are able to monitor and help bus operations achieve reliable operations.

  - Comfort refers to several aspects of the passenger experience such as the occupancy levels in buses and station platforms, the availability of user information, the integration with other transport modes, and the perception of safety and security. Comfort can be mainly achieved by increasing the capacity and reliability of the bus system (more frequent buses, consistent arriving times and speeds, wider platforms), and by enhancing other user convenience elements, such as the user information systems, the integration with other transport systems, the maintenance and illumination of the stations and buses and the presence of security personnel.

- Reevaluate the bus service plans to provide a better match of the supply and demand, while minimizing the fleet and the bus-km, through mechanisms like:
- Data collection on the load profile along the routes, occupancy at peak location, and variation along the day for each route;
- Definition of the required supply (buses/hour, fleet) according to the data collected regarding the use patterns; and
- Introduction of flexible route planning (e.g. short loop routes as opposed to routes from terminal to terminal only, as well as express services where possible)

Common concerns

Most of the attention of the media and the authorities was given to the queues in the motor vehicle lanes. While this is a visible difficulty, focusing on this problem misses the goal of improving mobility to the overall population. Data available for this evaluation showed that cars and two-wheelers make up 75 per cent of the vehicles, but move only 33 per cent of the people, while buses are just 2 per cent of all vehicles but they move 55 per cent of the people at the Chirag Delhi Junction during the morning peak hour. If special attention is given to the vehicles, as has been the case, any improvement measure will result in benefiting a fraction of the people only.

The authors recommend shifting the management focus to improve the performance of the corridor in terms of people delay, not vehicle delay. This is also applicable to the design of extensions and new corridors.

As a consequence of the special media attention to the difficulties in the motor vehicle lanes, DIMTS and the Traffic Police had introduced traffic management strategies to reduce the queue length at Chirag Delhi Junction. These strategies are based on increasing the cycle time of the signal when the queue length exceeds a given threshold, and have not been effective.

The analysis of this strategy shows that the signal cycle increase results in more delays for all users, and increased likelihood of conflicts between pedestrians and vehicles. The authors recommend using short cycle times and avoiding manual operation of the traffic controllers.

The initial difficulties, especially for motor vehicles, had sparked a discussion on whether the bus lanes should be located in the median or the curb side, and whether to use simple road markings as opposed to strong segregation. Based on extensive international experience, and the observed performance of painted curb side lanes in several Delhi arterial roads, the authors recommend using median bus lanes with strong segregation as the preferred option for bus priority in Delhi. This reduces the time for most users and reduces the bus fleet required.

The bus corridor has been also portrayed as a very dangerous facility. Data available indicated that there were 8 traffic related fatalities in 10 months of operation. The comparison of this figure with data before the corridor started construction does not suggest any statistically significant change in the fatalities per month. Nevertheless, the authors observed a significant number of pedestrians crossing at non-designated places due to bus queues spilling beyond the platforms at the stations, lack of safe access/exit in the back of the station, long pedestrian waiting times at the zebra crossings, and lack of education and enforcement.

The authors recommend addressing the outstanding traffic safety needs of the corridor through a combination of measures such as: safe crossings at the other end of the stations (preferably at grade); better management of the bus operations to reduce spill-over at the stations; review of the infrastructure devices that prevent jaywalking; and increased education and enforcement . The goal should be to reduce fatalities to zero.

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