# URBAN NETWORK CONGESTION AND ROAD SAFETY ISSUES IN DELHI: A ROOT CAUSE ANALYSIS

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## ABSTRACT

In this paper, we review the traffic congestion that causes enormous loss to national economies. Delhi, the capital city of India, is highly prone to this problem for simple and known deficiencies in the network, as well as driving behavior. Road safety is also linked to the congestion. Both congestion and safety have standard solutions. The focus of this research study is on the engineering aspects of road network design and operation, traffic engineering deficiencies, and the prevailing driving behaviors.

To understand the traffic congestion and road safety issues, a detailed study or examination of the existing network has been taken up to assess the traffic (congestion) and road safety situation in New Delhi. These examples also give insight to the many engineering and behavior related issues which give rise to the congestion and safety problems. Issues related to network supply and its deficiencies are examined in this analysis.

Having examined the root causes of the engineering and behavioral issues, suitable measures to contain these underlying problems have also been suggested. These include enforcement and education, in addition to engineering measures, which have been found elsewhere to have salutary effect on behavior.

## KEYWORDS

traffic congestion; road safety; Delhi; pedestrians; non-motorized transport (NMT); root cause analysis; junctions; signal; work zone traffic control.

## INTRODUCTION

Delhi, the National Capital Region (NCR), is one of the largest urban sprawls in the world with an estimated 19 million residents spread over an area of 1484 square kms (as per the 2011 Census). In the past decade, Delhi's population has increased by 21% causing immense pressure on its infrastructures. This has led to numerous traffic and road safety problems on the roads of Delhi. In this paper, some of the symptoms of these traffic and road safety issues will be reviewed, in order to analyze the root cause of these problems and to determine the long lasting solutions.

Delhi is a major trading hub and its transport needs are met by road-based systems while the other modes like the ring rail have largely remained marginal with limited use. The main modes in road traffic are buses, private vehicles, taxis, auto rickshaws, cycle rickshaws (and now e-rickshaws too) and bicycles. The current system is clearly inadequate with peak hours lasting for more than a few hours, most major arterials operating beyond capacity and the public transport system carrying crush loads. (1)

The road network length in Delhi is approximately 34,000 kms and there are more than 800 signalized intersections and many more blinkers to control the traffic. The road network accounts for about 21% of the total area, which is much above the average of 12 to 15% for urban areas worldwide. (2) The road network in Delhi is developed and maintained by several organizations including the National Highway Authority of India (NHAI), Delhi Development Authority (DDA), Municipal Corporations of Delhi (MCD), New Delhi Municipal Council (NDMC), Public Works Department (PWD) and the Delhi Cantonment Board (DCB).

From the late 90s till the Commonwealth Games of 2010, many grade-separated/elevated structures have been built, including flyovers, Road Over-Bridges (RoB) and Road Under-Bridge (RUBs). Currently, several large-scale projects including the Eastern and Western Peripheral Expressways, MRTS Phase III and several new Interstate Bus Termini (ISBT) are being developed. All of these projects are believed to be giving significant improvement to the existing transport infrastructure of Delhi.

In this paper, the current situation of the traffic and transport problems of Delhi are analyzed and suggestions on how infrastructure can be developed in a sustainable manner are made, such that the infrastructure can cater to all segments of the population. The research focuses on engineering solutions that can contribute to relieving the traffic congestion in Delhi.

## DELHI TRANSPORT ISSUES

According to the Master Plan of Delhi (MPD) 2021, during the time period of 1981 and 2001, there has been a rise in per capita trip rate (excluding walk trips) from 0.72 to 0.87. Keeping in view the population growth, this translates into an increase from 45 lakh trips to around 118 lakh trips in 2001 and 144 lakh trips by 2008. In addition, as per the Transport Demand Forecast Study (TDFS) by GNCTD in 2011, the private motor vehicle trips have increased from 28% to 35% during 2001 to 2008, and non-motorized vehicle trips increased from 9% to 15%. However, bus trips have decreased during this period from 60% to 42% of the total number of trips. (3) Statistics indicate that from the period of 1991 to 2002, the proportion of private car trips has increased throughout Delhi and proportion of trips by Intermediate Public Transport (IPT) modes like auto rickshaws / taxis have gone down. (1) We can assume that this trend has continued for the last 15 years since 2002.

The data from Census of 2011 shows (see **TABLE 1**) that the main mode of transport for households are bicycles (30%) followed by two-wheelers (39%), while personal cars are 21%. This shows that even in a city like Delhi (which has a large population of cars), the majority of the users still use NMT or two-wheelers. The Master Plan also notes that if growth of personal cars remains unchecked, “it is estimated that the total trips would rise to 280 lakhs by the year 2021” and further notes that “in a sustainable future scenario, the share of public transport and NMT should be 80%.” (3)

In general, with population increase, travel parameters such as average travel distances and trip rates increase, leading to road congestion and eventually gridlock conditions. (3) According to the 2008 urban transport study (4), Delhi has one of the highest average per capital trip rate (PCTR) of 1.55 among the major India cities, and the average trip length is one of the highest

(10.2 km) among the major cities. Almost a decade later now, chances are that these numbers have increased manifold. On the encouraging side, Delhi is ranked as the highest in the city bus supply index.

**TABLE 1 Mode share in Delhi - 2001 & 2011**

(Per cent)

| Sl. No | Mode of Transportation Facilities | 2001 | | | 2011 | | |
|---|---|---|---|---|---|---|---|
| | | Rural | Urban | Total | Rural | Urban | Total |
| I | No. of Households | 169528 | 2384621 | 2554149 | 79115 | 3261423 | 3340538 |
| 1 | Bicycle | 48.70 | 36.80 | 37.60 | 44.20 | 30.30 | 30.60 |
| 2 | Scooter/ Motor Cycles | 20.70 | 28.50 | 28.00 | 38.50 | 38.90 | 38.90 |
| 3 | Car/ Jeep/ Van | 7.30 | 13.40 | 13.00 | 10.80 | 21.00 | 20.70 |
| 4 | None of the Specified Mode of Transportation | 38.90 | 43.40 | 43.10 | 34.70 | 37.20 | 37.10 |

*(Source: Economic Survey of Delhi, Delhi Government, 2014-15 & Census of India, 2011)*

The presence of non-motorized transport modes such as walking and cycling, used by lower income groups, mixed with new and fast-moving motorized traffic cause an increasing number of road accidents and consequent fatalities. The number of fatalities is also increasing in relation to the increasing motorization and higher number of slow-moving vehicles in the traffic stream. While progress has been made towards protecting people travelling in cars, the needs of vulnerable groups of road users, primarily cyclists and pedestrians, are not being met. (3) Thus, pedestrian and other NMT fatalities constitute a significant share of total fatalities in Delhi, as in most other cities in India. This could be attributed to the "inequitable distribution of road space" and the lack of adequate pedestrian and NMT facilities in Delhi.

Peak hour congestion on most major roads of Delhi begin at around 8.30am and often continues into the evening peak hour, without a clear divide between morning, afternoon and evening peaks. The evening peaks often go on till beyond 9pm. Thus, almost the entire day the city network is clogged up with traffic, and travel at any time of the day remains a significant challenge

**FIGURE 1 Congestion at an unsignalized junction**
*(Source: The Hindustan Times)*

Signal controlled intersections suffer from indiscipline of road users, especially lane use in turning movement behavior. Vehicles wanting to make right or left turns occupy multiple lanes and as a result choke the mainline through traffic. Every signal phase sees multiple streaking and red-light running vehicles.

On minor road junctions, supposed to be unsignalized priority junctions, often traffic comes to a standstill, due to a blatant violations of the priority rules to give way. As a result, vehicles from all approaches run

into a collision course and eventually to a stop at the middle of the intersection (as shown in **FIGURE 1**). This results in queuing on all approaches and the traffic comes to a complete standstill, despite the fact that queues on the junction approaches are not more than 50 m long.
All these problems occur in Delhi, despite the city having an extensive network of roads, relatively large fleet of buses, metro rail and a suburban rail system. As in most cities of India, Delhi has seen an exponential growth in number of vehicles on the road in the last two decades. Most of these vehicles are cars and motorcycles for personal use. High growth rate of population and motor vehicles, led to this greater complexity of vehicular traffic and consequent increasing number of accidents. (5) It is to be noted that unlike in the West, the occupants of vehicles account for a very low percentage of fatalities in India. Majority of the victims are pedestrians, cyclists, motorcyclist and occupants of other slow-moving vehicles. (5)

A city like Delhi, to efficiently manage the transport demand, has to ensure usage of mass transport systems by discouraging personal/private modes. This will ensure better, cost-effective transport for majority of the users and ensure roads are free from congestion and accidents. The various issues of congestion have been categorized into two main types – Engineering and Behavioral.

**Engineering and Infrastructure Issues**

Some common engineering and infrastructure issues that are widely seen and experienced throughout Delhi are:

- Traffic signal related issues including long cycle time, poor maintenance, lack of engineering to signal timings and lack of signal coordination on corridors. Signals are the responsibility of the Traffic Police who have no knowledge of traffic engineering, and signal cycles are not designed with Webster's method of optimal signal cycle to minimize delays. In addition, lack of proper direction and destination signs causes confusion among driver about turning movements. As a result, signal delays in Delhi are extremely high.
- Junctions in the urban/city road network in Delhi are badly designed in terms of geometry without any concern for smooth flow of traffic. The junctions do not have adequate channelization and turning radii for heavy vehicles, and therefore, lane usage is erratic. In addition, lack of pedestrian/cyclists/NMT facilities at junctions make it even more chaotic in operation and make the junctions highly unsafe for all road users.

**FIGURE 2 Encroachment due to construction on both sides of a road**

- Construction activities of urban utilities or even the road side properties cause materials to be dumped on the road side, in both residential as well as busy roads/streets (as shown in **FIGURE 2**), occupying footpaths and even the carriageways. Traffic shies off from those areas, and pedestrian are forced to use carriageway space causing continual congestion at these locations. Lack of use of work zone traffic control standards (see **FIGURE 3**) means that the traffic does not get enough transition and buffer space, and this

results in further congestion of traffic, that could have been properly transitioned and diverted to alternative routes.

- The system of flyovers and other grade-separated structures throughout the city built with the belief that these will relieve congestion, has been proven to be an illusion, and these have become the root cause of many of the ills of the network. Flyover construction also leads to access management issues for both vehicles and pedestrians on all the approaches of the previously at-grade intersections. This has resulted in several types of traffic violations including contra-flow movement at restricted junctions and service roads.


**FIGURE 3 Work zone in Delhi**

*(Source: Sunday Guardian)*

- Footpaths are encroached or in poor condition and rendered unusable, causing pedestrians to use the roadway. Systematic encroachments of footpaths by the commercial establishments located along the road, is a common feature all over Delhi without any control by the responsible agencies. In residential areas, the house property owners make ramps of their entrance gate outside the gate on to the road (not inside) and use the footpath space/strip alongside the property to make gardens with plantations etc dislocating pedestrians to the carriageway, which is a root cause of safety concern as well as congestion.
- Bus stops are without bus bays, causing buses to stop on the carriageway lane and blocking other traffic. Even on multi-lanes divided road, the behavior of buses to stop away from the actual bus stop, encroaching to the adjacent lane, makes it worse. Buses, never dock at the actual stop aligning with the curb (and mostly stopped between the lanes), and all other traffic has to slog behind the bus. Thus the 7 to 7.5m carriageway in one direction is not completely utilized for serving the traffic due to ill-behaved bus operations.

The Indian Roads Congress (IRC) is the nodal agency that compiles design guidelines and standards for construction of roads and bridges, for rural and intercity roads, but urban roads or street design is not handled by IRC. It also has some standards for urban roads.

In Delhi, the Unified Traffic and Transportation Infrastructure. (Planning & Engineering) Centre (UTTIPEC) under the DDA has been compiling guidelines suited for Delhi. These standards are voluntarily followed by all road construction agencies, including Public Works Departments of cities. Similar is the case with standards on signing, marking, lighting and specifications of other road side furniture. Institute of Urban Transport (IUT) has attempted to develop some guidelines for urban roads, which are also incomplete. This results in inconsistency in the design and sub-standard implementation of most urban roads and junctions.

**Behavior Issues**

As stated earlier, a large part of the traffic congestion and safety issues in Delhi are caused by driving behavior that is not based on scientific principles of lane following, yielding and gap acceptance. Some of the common behavioral issues are:

- Speed differentials between high-speed and low-speed/NMT/2-3 wheelers vehicles: Speeding between junctions is a common scene in Delhi. Drivers frustrated with long wait at a junction, suddenly find free space between junctions and indulge in rash driving. This act of motor vehicles on roads with slow moving vehicles (NMT and IPT) and pedestrians, leads to dangerous conflicts and often violations (as shown in **FIGURE 4**) and accidents. This situation is further aggravated by aggressive driving by the taxi drivers and drivers of larger vehicles. Lack of enforcement, of late, has resulted in excessive and rampant use of mobile phones while driving;
- Several behavioral issues at junction including
    - Turning movement violations and inconsistency in lane usage at intersections
    - Signal violations by red-light jumping
    - Lane usage issues including poor lane following behavior by all motorists and bus stop violations by buses
    - Not following the priority rules about the right-of-way at the uncontrolled/stop-controlled junctions
- Lack of adequate pedestrian facilities, encroachment and construction of elevated/grade-separated structures, cause pedestrians to forcibly stop traffic at will to cross the road;
- Two-wheelers displaying unruly/unsafe driving behavior, including red-light running, contra-flow violations at junctions. This behavior often results evasive action from other vehicles and often leads to conflicts and accidents
- Parking along the road side is a menace in Delhi, in commercial as well as along the residential streets. It is a serious problem of enforcement by the Municipal Corporation of Delhi (MCD). It causes havoc in commercial places, where there are no separate parking areas and road side is outsourced by MCD to third-party parking management agency. The situation is made worse by a complete lack or absence of a uniform policy for organized citywide taxi/bus/Intermediate Public Transport (IPT) parking system.

**FIGURE 4 Violation of NMV separation in Sadiq Nagar, Delhi**

A large part of the driving behavior arises from the fact that most of the drivers in India for taxi, truck and other commercial vehicles are not well educated. Proper driver training and effective and stringent licensing system are two of the basic prerequisites of required driving skill, but most drivers in India hardly had any formal training. (5)

## ROOT CAUSE ANALYSIS FRAMEWORK

The problem of traffic congestion and safety in Delhi is extremely complicated with a myriad of political, policy, engineering and behavioral elements, which are the root causes for it. Governments of Delhi, at different times, have tried their hand in reducing these problems and instituted what have turned out to be short-lived measures. Panaceas that have been looked at include even the “odd-even” license plate restriction of cars, efforts for transit-oriented development (TOD) along corridors, developing automated parking garages, and a few other infrastructure strategies including elevated roads and rails. Some of these have been tried with

varying degrees of success, while many others are yet to be seen by political masters as beneficial. Therefore, traffic congestion in Delhi continues unabated, and the safety problems aggravate every year.

Looking at the root cause of these problems was thought to be a way to develop genuine engineering measures that can be implemented for relief. If successful, these measures could be replicated throughout the city and cause some degree of relief to all modes of transport including the pedestrians, cyclists and other NMT users, who makes a significant share of the city's transport demand.

Root cause analysis (RCA) is a method of problem solving used for identifying the root causes of faults or problems. A factor is considered a root cause, if removal thereof from the problem-fault-sequence prevents recurrence of the undesirable events, whereas a causal factor is one that affects an event's outcome, but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence with certainty. (6) "5 Whys" is an iterative system of interrogation to explore the relationship between cause and effect underlying a particular problem.

The 5 why's technique has been used in this approach to determine major causes of traffic and transport problems in Delhi and gain better insights into traffic and road safety dynamics to enable better design and operation of the transport system.

**Framework Methodology**

A brief schematic depicting the RCA framework has been shown in **FIGURE 5** and **FIGURE 6**. The basis of using the RCA framework were using three common symptoms of Delhi road transport issues:

- Congestion and chaotic traffic behavior at junctions
- Congestion and bottleneck of traffic on road stretches between junctions
- High accident and resultant fatalities on roads

Using these three issues as the basis, the first tier of Why's were several symptoms of the three basic issues – for example, "Pedestrians forcibly stopping traffic at will to cross the road". These visible symptoms were then examined in greater details with further layers of Whys which resulted in zooming to the root cause of the visible symptoms.

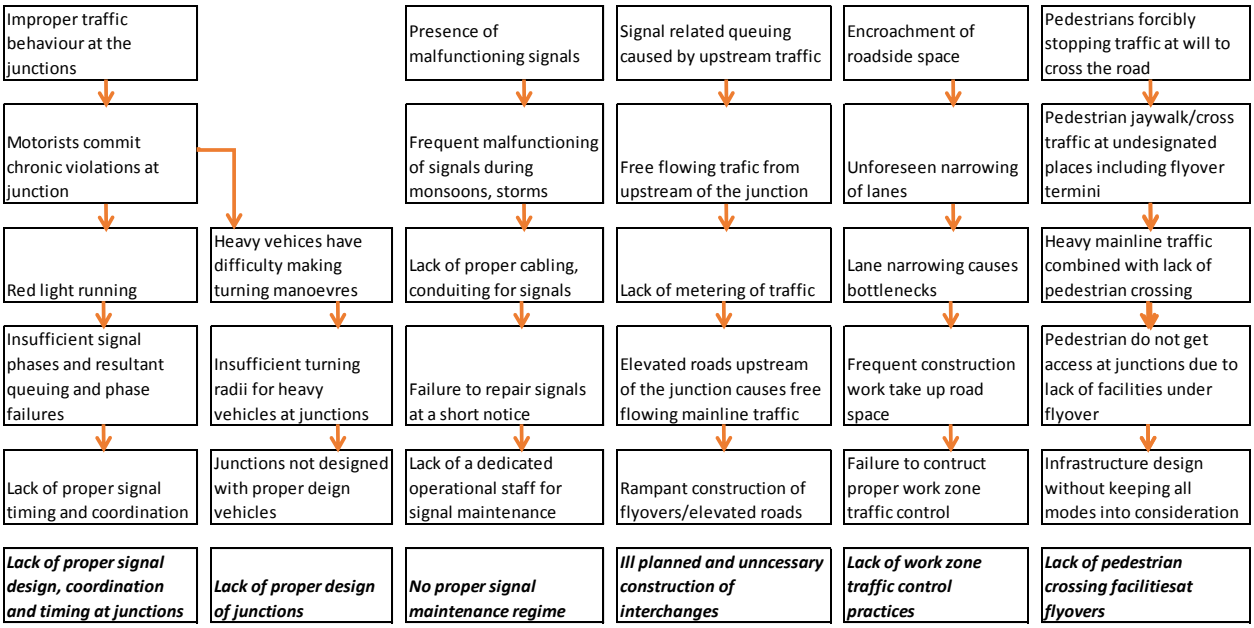


**FIGURE 5 RCA methodology for congestion**

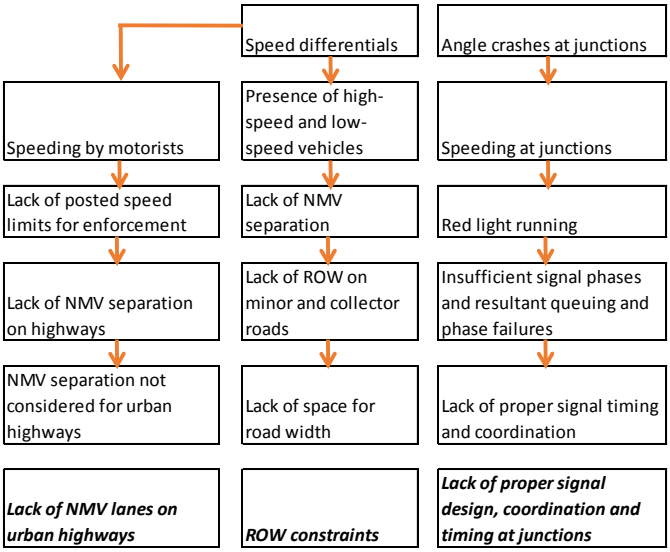


**FIGURE 6 RCA methodology for safety**

Having identified the root cause, suitable engineering countermeasures were then suggested to alleviate these problems, keeping in mind the complexity of land-use, Right-of-way (ROW), functioning of traffic police enforcement and other factors.

It is important to note that there are several issues that plague the traffic and safety situation in most cities of India, including Delhi. Many of these issues have underlying enforcement and policy level implications and causes. While developing the RCA framework, many such policy and enforcement issues came up including curbing behavioral issues and disorderly parking with enforcement and policy implementations. These were considered to be beyond the scope of the paper, since the focus of the paper was on engineering and behavioral issues.

The exception were enforcement mechanisms which could be implemented with technology. It should also be noted that while focusing on engineering and behavioral issues and moving along the 5 Why analysis, there is the possibility of several causes at every point in the analysis. In order to keep to the scope of the research work, only a few of these were investigated.

**Results of RCA Framework Analyses**

The results of the RCA framework analyses yielded the following root causes of the traffic and safety ills that plague the roads of Delhi as given in **TABLE *2***.

**TABLE 2 Root Cause Analysis results**

| ISSUES | ROOT CAUSE IDENTIFICATION | POSSIBLE CORRECTIVE ACTION |
|---|---|---|
| **Congestion and delays at junctions** | Lack of proper signal design, coordination and timing at junctions | Implement common signal design, coordination and timing practices for signalized junctions in coordination with Delhi police |
| | Lack of a proper signal maintenance regime | The Delhi traffic police in conjunction with DDA should institute a signal maintenance regime that involves periodic checks at all signalized junctions. |
| | Lack of use of proper design principles of junctions | Implement common urban street and junction design guidelines for the entire NCR area |
| **Congestion on road sections between junctions** | Flyovers prevent equitable use of road space and cause difficulty for pedestrians and NMT at flyover junctions | Curb on rampant construction of flyovers with every construction preceded by detailed traffic operations and safety study that details impacts on every mode. |
| | Lack of speed limit posting and enforcement causes unnecessary congestion at road sections and accidents | Assessment of the road network for correct placement of speed limit signage and enforcement of traffic police personnel for regular radar gun enforcement. |
| | Lack of pedestrian crossing facilities | Include pedestrians and NMT into consideration in traffic and safety impact studies of any infrastructure development |
| | Lack of work zone traffic control practices | Develop Work Zone traffic control typical template suited for Delhi road and make it mandatory to design work zone phases to prevent undue and recurrent congestion on roads |
| **Road Safety on Roads and Junctions** | Lack of proper signal design, coordination and timing at junctions | Implement common signal design, coordination and timing at signalized junction in coordination with Delhi police |
| | Lack of NMV lanes on urban highways | Develop NMV separation on urban high-speed corridors |

## ROOT CAUSE IDENTIFICATION AND SOLUTIONS

As a result of the RCA analysis, the main root engineering causes identified can be grouped as follows:

- Speed differentials of various modes along a road link
- Inequitable use of flyovers
- Improper junction design and work zone traffic management/control
- Lack of pedestrian and NMT amenities
- Lack of maintenance of signals, signing and marking

From the RCA framework in the previous section, it can be seen that a few engineering countermeasures have been developed to mitigate the problems that arise on the roads of Delhi.

- Remove speed differentials on high-speed arterials with NMV separation: Speed differentials are a known cause in congestion and road accidents. Removal of speed differentials has a high potential of crash reduction, if implemented with proper study and review of locations. The so-called high-speed corridors of Delhi like Ring Road and Outer Ring Road are good candidates, with their numerous flyovers to test such an engineering measure. An effective way would be to eliminate slow-moving and NMT vehicles from accessing the grade separation and devise better pedestrian, cyclist and NMT access in the signalized junction under the flyovers. Effectively, the signalized junctions under the flyovers would be used by slow moving traffic for all movements (including the through movements) and high-speed traffic for turning movements. On high-speed corridors of significant length, NMV separation should be done to separate two/three-wheelers and other slow-moving vehicles, with the help of signage (as shown in **FIGURE 7**).

**FIGURE 7 Example of vehicle separation in Ho Chi Minh City, Vietnam**

- Pedestrian and NMT accommodation at flyover junctions: Currently, the situation at all flyovers is that the signalized junctions below suffer from extreme congestion, vehicle queuing and innumerable difficulties for pedestrians and NMT in moving from one point to another. Construction of flyovers causes plenty of access management issues to pedestrians and NMT transport. It is recommended that these signalized junctions be given better pedestrian and NMT facilities including accommodation them in signal phases. The area below the bridge can be utilized as pedestrian refuge and if needed, pedestrian phases could be split to accommodate the different turning movements.
- Curb on construction of elevated roads and flyovers: At some point, grade separation became the panacea for working the way out of the trouble of land acquisition and developing better at-grade intersections. Construction of innumerable flyovers all over the city in the past twenty years has produced pockets of improvement and done nothing to improve the overall traffic situation. In fact, the grade separation has given rise to higher private vehicle ownership and resulted in slow moving vehicles and NMT getting penalized with restrictions and hazards. Grade separation should be performed only after detailed traffic studies are undertaken, taking

into consideration the modal share of the city and adequate consideration for pedestrians and NMT at the specific location;

- Work zone traffic control: Delhi has seen continuous construction activities for the past two decades. With metro expansion and other works of Corporation/DDA, the constructions show no signs of abating. Each day commuters face nightmarish rides due to road constrictions, sudden diversions and restrictions to movement. These hassles can be avoided with the following strategies:
    - Following proper work zone control measures including signing and marking, advance warning signs, buffer zones and pedestrian control measures with the use of traffic control devices like DMS (Dynamic Message Signs). Although there are existing guidelines including IRC:SP-55, they are completely ignored at ground level implementations;
    - Prior information about diversion through all mediums of communication should be developed and standardized, including using the internet and social media. Currently, news of major diversions (like Delhi metro work) are broadcast on newspapers, but many others are completely unknown to the pubic till they reach the work site.
- Speed Limit posting and enforcement: Except for pockets of areas like the Diplomatic Enclave, currently Delhi (like most other Indian cities) has almost no posted speed limits. In addition, the roads which do have speed limits are not strictly enforced. Installation of speed limit signs on all major roads is not enough, and it is to be supplemented by regular enforcement on violations for speeding, which can easily be done by use of appropriate technology. This will bring an immediate improvement to both road safety and congestion. These measures are implemented on rare occasions and need to be institutionalized, in order to bring a radical change in driving behavior. Historically, it has been seen that regular enforcement brings a radical change in the driving speeds and behavior. For 24x7 enforcement adoption of technology through a PPP arrangement is the most attractive;
- Standardization and NMT consideration in Junction and Signal design: Standardization of junction design by type, and signal design for cycle time is a must for improving the current situation in Delhi. The intersections should have pedestrian and other NMT facilities and their accommodation in the signal cycle time for alleviating traffic congestion and resultant safety concerns at the junctions caused due to improper lane use, and violations;
- Signal Operation and Maintenance System: Currently, signal maintenance is outsourced to companies and often malfunctioning signals are unchecked and unresolved for days and weeks. This situation becomes worse during monsoon. Under such a situation. congestion and accidents are common, resulting in huge delays. It is imperative that the maintenance of signals (preventive or otherwise) be undertaken by the Delhi Police or alternatively by the Department of Transport, working in tandem with the Delhi Police. This is a common practice in developed countries, where maintenance of signals is done by the Departments of Transport, who take help from outside consultants on an as-need basis.

## CONCLUSIONS

The city of Delhi suffers from numerous issues in traffic and road safety with a variety of causes attached to them. This paper has investigated some of those issues and suggested a method to identify root underlying causes to these problems. During the analysis, it was found that numerous issues which cause congestion and safety problems on the roads of Delhi, have roots in policy and enforcement related measures. These are very important means for long-term improvement of the system. However, they were not considered for further analysis, since the paper focused on engineering measures as a means of improvement.

Determination of the root causes led to a further investigation on counter-measures to mitigate the effects of these causes. Many of these suggested measures aim to preserve or improve the modal share prevalent in Delhi, instead of thoughtless construction of roads and elevated structures which give preference to private motorized transport only, which are inequitable solutions. Implementation of suggested measures is expected to play a part in reducing speeds, segregation of vehicles, encouraging NMTs and pedestrians, and therefore, bring down the burgeoning congestion and accident rates. Many of these measures can be successfully implemented only with political will, and will be successful only by enforcement.

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