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Intricacies and Stumbling Blocks of Traffic Flow in Delhi: A Case Study of Inner Ring Road

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Abstract

The population of Delhi has exploded from 17.44 lakh in 1951 to about 290 lakh in 2017. The urban built up area expanded from 195 km^2 in 1951 to 1113km^2 in 2017 which has brought incredible changes in city morphology. The road length of city has increased to more than 28500 km.whereas the number of registered vehicles also exceeded the 11 million mark. Apart from its registered vehicles large number of vehicles from neighboring states, particularly, UP and Haryana are also plying in Delhi on daily basis. Large sized mobility (inter-city and intra-city) of people and enormous exchange of goods have taken place perennially which require large transport andrelated infrastructure. Consequently, the city road finds mismatch of road availability and desired transport infrastructure. The intricate human response to city transport system further make it vulnerable to perennial traffic jam and the average speed of vehicles get minimized. It leads to wastage of precious working hours of millions of commuters and irreplaceable energy along with its severe environmental pollution hazards on daily basis.Increased travelling time on Delhi roads leads to regular violations of traffic rules and gradually it became socially accepted norm.

Since independence, the economic development coupled with unchecked urban growth resulted in the sprawling expansion of the shape and size of the city. The sui generic development multiple business centers in the city resulted in the development of more than a dozen radiating roads from the city's central business district. All these radiating roads are further connected by two concentric ring roads called inner and outer ring road. Inner ring road is one of the busiest roads in Delhi, connecting north and south Delhi. The study area is 20 km. long stretch of inner ring roads from Azadpur to Dhaula Kuan (via Punjabi Bagh). To analyze the intricacies and regular traffic jams on inner ring road, the empirical-participative study was performed based on three different perspectives. Firstly, the road related infrastructure and logistics is analyzed, wherein even after emergence of signal-free flyovers and elevated roads, the perennial bottlenecksof traffic on spatial and temporal intervals are observed. Secondly, the multiplicity of plying vehicles with different speed, structure and characteristics on same roadsare analyzed. Thirdly, the heterogenous human response of the stakeholders viz. the drivers, passengers and civic/police administration to transport system are analyzed over the time to illuminate as to how society at large accepted the traffic rule violation as social norm. The study intends to establish the inter-play of all the factors studied from three different perspectives, that are resulting in perennial traffic jams, resulting to wastage of precious material and human resources.

Keywords: Lacustrine Plain, Primate City, Senile City Stage, BPO's, Ramp Metering, Event Managers, Challans, Elevated Roads, Slip Road, Bottlenecks.

Introduction

The multi-dimensional growth of Delhi in terms of its spatial expansion, population surge, scale of economics, monetary flow and diffusion of technologyresulted in the quantum jump of flow of goods and human mobility. The lacustrine plain topography with perennial supply of water by Himalayan river Yamuna, and now by Ganges, supported the fused growth of Delhi in all the directions. The nodal location of Delhi with well-developed modes of transportation as railways and roadways network with vast hinterland further boosted the trade opportunities. Being the

capital city, Delhi developedits primate city character supported by its historical inertia. It become the magnet for perennial in-migration after independence, particularly from natural disaster-prone regions of country. The population of Delhi has increased from 4.05 lakh in 1901 to 17.44 lakh in 1951 and 167.88 lakh in 2011 census. As per moderate estimate Delhi's population size touches 290 lakh mark in 2018. Whereas, the extent of urban built up area has been increased from 43.25 km^2 in 1901 to 195 km^2 in 1951 and 1113 km^2 in 2017.

With increased urban space, population size and density of Delhi city particularly in last three decades witnessed a stupendous jump. The annual per capita income climbed at Rs.365529 in 2018-19 which is almost three times higher than the national average of Rs.125397. The higher per capita income leads to increased purchase capacity and monetary flow. Subsequently, the enhanced purchasing capacity of the people of Delhi resulted in the increased number of private vehicles especially cars and two wheelers. The larger share of urban inhabited area of Delhi is developed in illegal and unplanned colonies to accommodate the poor immigrants. The unauthorized expansion of Delhi restricted the public transport system, therefore, large number of inhabitants switched on private/individual vehicles.

As the urbanization exploded in Delhi, its population size, density and area increased vertically and horizontally. Vertical population increase leads to construction of multi-storied high rise and sky-scrapper residential buildings and a little open space left behind. The horizontal urban population increase leads to its physical expansion towards the margins of rural-urban fringe area, and hence the cropland were altered into residential and allied buildings. In both the cases of urban expansion, the number of vehicles increased exponentially, and its fixed road infrastructure could not match withits demand as plying vehicles exceeds the carrying capacity of roads in city.

Historically, transport system of Delhi evolved with technological innovation and its level of diffusion which could be observed by classifying in three different time zones as follows:

Mughal Period Road & Traffic

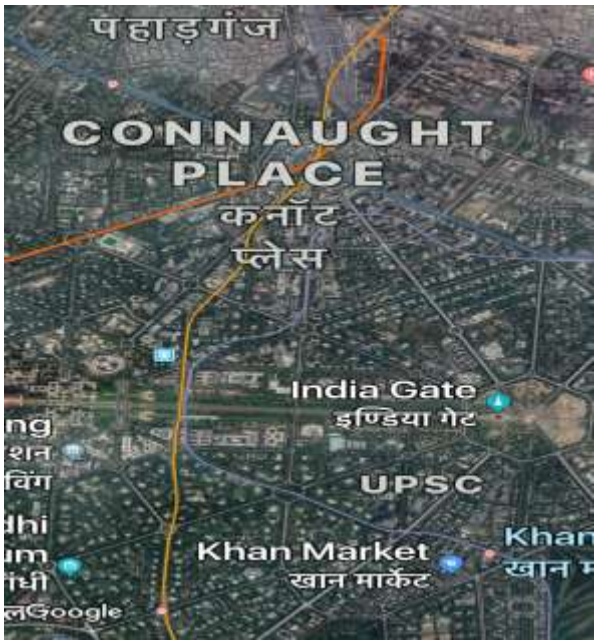
During 16th and 17th century, before the diffusion of steam engine technology the city roads were designed for bullock-carts, horse driven tonga and dominated by pedestrians. Therefore, roads were narrow, zigzag and stony with brick-works mainly for slow moving non-mechanized vehicles. The walled city (Shahazahanabad) have narrow, zigzag and non - motorized roads without side line roads.

Satellite Image of Old Delhi layout

British Period Road & Traffic

During early 20th century, for the mechanized vehicles, city and its roads were planned by the urban architect Sir Edward Lutyens. Introduction of mechanized vehicles as cars, goods vehicles and bicycles along with horse driven tonga (cart) and manually driven rickshaw/carts determined the nature of city roads. Roads become planned, wide, straight and metaled with bitumen. Subsequently, sufficient space left on both sides of road for tree plantation and pedestrian walkway.Multi-lane roads along with median, dividers and roundabouts at crossings were developed for fast moving mechanized vehicles and slow moving animate-power driven vehicles. This planned settlement developed by colonial Britisher's to administer India is known as New Delhi.

Satellite Image of New Delhi as developed by Britishers



Post-Independence Road& Traffic

After Independence, urban development authorities designed the city to accommodate the large influx of population in Delhi.Urban road infrastructure was developed to meet the need of passenger vehicle (both private and public), goods vehicles, two wheelers (mechanized and bicycles) and animal driven vehicles which are radiating in all directions from cityCentre. Roads are multi-lane with median as dividers, metaled (bitumen and cement) with fly-overs and crossings and meant for variety of private, commercial, passenger and goods vehicles.

Satellite Image of Fused Growth Layout of Post-Independence Delhi

Urban Planners Vision

Master Plan of Delhi (MPD) 2021 notes that the period between 1981 and 2001 and subsequently 2011 has seen a phenomenal increase in the growth of vehicles and traffic in Delhi. There has been a rise in per capita trip rate daily (excluding walk trips) from 0.72 in 1981 to 0.87 in 2001 and exponentially more in 2011. 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 till 2008. The Transport Demand Forecast Study (TDFS) undertaken by Govt. of NCT of Delhi and approved by the UTTIPECin 2011 haveobserved that between 2001 and 2008, the private motor vehicle trips have increased from 28% to 35% and non-motorized vehicle trips from 9% to 15%.However, bus trips have decreased from 60% to 42% of the total number of trips.

Besides, Delhi has developed as a seamless city with an urban continuum comprising of number of rapidly growing counter magnet towns in Haryana and UP. This has added to the flow and movement of traffic within Delhi. In a business-as-usual scenario, it is estimated that the total trips would rise to 280 lakh by the year 2021, including 257 lakh motorized trips and 23 lakh non-motorized trips. In this context, the roads already occupy around 21 percent of the total area of the city, which clearly limits the potential for increase in road space. In a sustainable future scenario, the share of public transport and NMT (Non-Motorised Transport) is 80%.

Aim of the Study

Favorable geographical conditions and potential of immense economic opportunities offered Delhi's urban area to grow rapidly which resulted into world's largest continental urban agglomeration in terms of both population and area. Most of the world's urban metropolitans are bestowed with coastal or insular locations whereas Delhi became the continental and second largest city in the world with 29 million persons after Tokyo, Japan (37 million persons). Subsequently, its number of registered vehicles exceeded 110 lakh (1.10 crore) mark in 2017 which ply on fixed size of roads in city. Whereas, its sub-cities, satellite towns, counter magnet towns, densely populated rural habitat with commercial farming in adjacent states of Uttar Pradesh, Haryana, Rajasthan, Punjab, Uttarakhand, Himachal Pradesh and Jammu & Kashmir from where vehicles also move and ply on diurnal and weekly basis in large number through Delhi city. Variety of passenger, goods, heavy and light vehicles transverse in Delhi simultaneously to meet the needs of the population. Exchange of agricultural and industrial goods inevitably require variety of vehicles from adjacent states to ply on Delhi roads.

Delhi administrative region is bestowed with about 1750 km. roads per 100 km^2 area which is one of the highest road-density in India. The absolute length of roads in Delhi is 28508 km. including 388 km. length of national highways. With growing population and number of vehicles in Delhi, its road infrastructure could not meet its demand. Therefore, the aim of the study is to identify the genesis of intricacies and regular traffic jams in Delhi in spatio-temporal perspective. Traffic jams become the perennial problem of Delhi where precious working hours of millions of people are wasted apart from fuel wastage leaving behind carbon footprints. Broadly, there are varied complex factors for scanning the stumbling traffic problem in terms of composition of road and related infrastructure, quantum of vehicles in spatio-temporal perspective and arduous human response to it.

Urban Planning and Transport System

The urban transport system got strenuous after 1990 with the increasing number of illegal colonies in the outer margins of Delhi, though, Delhi city is bestowed with maximum number of flyovers, underpasses, foot-over bridges, elevated roads, bridges and signaled crossings in the country. The urban development authority in the city is called as Delhi development Authority (DDA) with its formation in 1962, mainly emphasized on the development of residential housing colonies (plotted and flats),

industrial complexes, recreational grounds and desired institutional nucleus.

In the absence ofdesired number of houses and allied infrastructure in Delhi, the adjacent part of neighboring states developed well planned, low cost residential-institutional-industrial complexes in all sides of Delhi especially in Gurgaon, Faridabad, Noida and Ghaziabad. These sub-cities of Delhi provided ultra-modern institutional infrastructure such as business provider organizations (BPO's) and cyber space centres to meet the demand of global market. Subsequently, large number of multi–national companies established their corporate offices in these sub-cities up to the distance of around 50 km. from Delhi urban limit. After the development of alternate, low cost, user friendly, planned and employment generating urban infrastructure, millions of youths started commuting from Delhi, (as their residential base) to these sub-cities for employment on daily basis. The carrying capacity of feeder roads to these sub-cities could not sustain the number of plying vehicles and ultimately created chaos on roads. The absence of mass-rapid public transport system forced the commuters to switch on to private vehicles like cars and two wheelers. Single feeder road connectivity from Delhi to employment generating sub cities created regular traffic jams. The rapid growth of sub-cities in all directions is the result of non-construction of institutional infrastructure near the residential areas in Delhi by its urban planners and development agencies.

Even through there was a development of multiples growth nuclei in the city, the Central Business Districts of Chandni Chowk, Connaught Place and Karol Bagh, possibly due to historical inertia, continue to govern the economics of the city and the hence, the newer business districts need to be more connected to the older districts. Therefore, all the roads radiating from central part of Delhi (CBD's) are always flooded with public and private vehicles and reduced the traffic flow up to the speed of 5-7 km. per hour. Narrow, zigzag and encroached road with multiplicity of vehicles leads to perennial traffic jams on city roads. Moreover, residential areas along main roads are altered into institutional and commercial markets under the mixed land-use policy of Delhi. Such market space in residential buildings without parking space and civic amenities completely stumbled the traffic flow and led the city towards its senile stage.

It's the irony to observe that municipal planners never consider the parking space while approving the layout plan of residential buildings. Therefore, entire covered area of building is utilized for residential purpose and all the vehicles of each household are parked on road sides. Both the sides of roads are parked with the cars/passenger vehicles in residential colonies and only one lane left for the mobility of vehicles. The outer peripheral roads of the residential colonies are parked with commercial vehicles and almost half of the space on road is illegally encroached all the time. The urban development authority which developed the commercial complex and where mass-movement of vehicles takes place as commercial malls, shopping complexes, cinema halls, public institutions as municipal offices, hospital, police station, courts, educational institutes and all other variety of institutional buildings. The development agencies in Delhi failed to provide the desired parking space for private vehicles in its planning. Therefore, almost half of the road sides are always occupied by non-plying vehicles as parking space, which ultimately reduced the speed of traffic flow due to reduced capacity of roads.

The residential colonies which are developed by urban-planners almost a decade ago as Dwarka, Rohini and Narela are exclusively meant for residential space. These residential colonies are developed without the institutional infrastructure which could not generate the employment near the residential space so the road ramp-meter could be reduced. Youth from these residential colonies are commuting to sub cities like Gurgaon or NOIDA on daily basis for employment which is more than 50 km far on one side. It seems that technological innovations andits diffusion is much faster than the vision of urban planners, resulting into traffic chaos.

Methodology and Study Areas

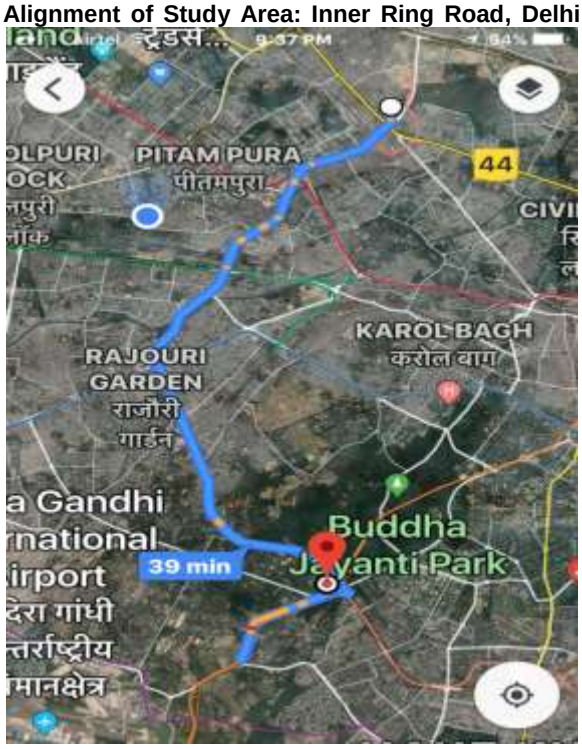
The study is based on the enquiry of transport system of Delhi which developed stumbling blocks and traffic jams on regular basis. Certain corridors during peak hour finds vehicles on the roads more than their carrying capacity. To analyze the intricacies of traffic flow on roads of Delhi, the research work remained concentrated on nature of road infrastructure, quantum and multiplicity of vehicles and human response to transport system. The study is based on empirical method with participatory observations. Informal interaction with traffic managers, road planners, engineers and drivers of public and private vehicles is performed to pin-point the genesis of traffic problems and its suggestive solutions. To find out the real-time problem, field visits are performed at various locations and different time schedules. Comparison of nature of traffic flow in different types of inhabited colonies (planned and illegal) was also done like traffic of New Delhi and Old Delhi.

To observe the real time traffic and related problems, google map which is showing the long queue of stumbled vehicles was analyzed through artificial intelligence. Further, to obtain the human response to public transport system, informal discussions were performed with the drivers of public transport system, private vehicle riders and two-wheeler riders. Apart from field visits, the secondary data was procured from Census of India, Statistical Handbook of Delhi and traffic police. Literature review of related research work has been done. Choudhury and Gupta (2015) worked in-depth study on the detection and management of traffic problem of Delhi. D. N. Singh (1992) was the pioneer of transport analysis and published a paper on Geography of Transportation System in India. Apula Singh (2016) studied the Delhi's Urban Transportation System-Challenges Galore which discussed the institutional, human and infrastructure related aspects to address

the traffic problem in Delhi. Jaiswal, A. (2012) worked on Sustainable Transit Oriented Development for solving the road traffic congestion problem in Delhi. Report of the High Powered Committee on Decongesting Traffic in Delhi, Ministry of Urban Development, Government of India has been consulted at appropriate places for authentic data for analysis. Further, reports of the reputed think-tanks in private and public consultancy domains like Mckinsey Global Insights were also considered in the study.

The study area is identified as Ring Road (clockwise and anticlockwise flow on both sides) covering the areas of North, West and Central-South Delhi. Delhi city have two functional ring roads and two semi-functional ring roads. Out of the two functional ring roads, the older and first tier ring road is called Inner Ring Road while second tier of ring road is called outer Ring Road. The inner ring road is completely signal free with flyovers, slip roads and elevated roads as it is proved to be the lifeline of Delhi. Study area identified the extent of 20 km. long stretch of inner ring road in western part of Delhi from Azadpur (crossing of erstwhile G.T. Road, NH.1.) to Punjabi Bagh, Raja Garden and Dhaula Kuan (crossing of NH. 8, heading towards airport and Gurgaon) with 8 main crossings. Series of measures takenby civic administration to stream line the traffic flow without any obstructionas lengthening and widening the road network, construction of number of flyovers/grade separators and launching of the Metro Rail network. Even after planning, the traffic congestion on ring roadis continued to increase unabated. The stretch of the Ring Road under study is the one of the worst affected areas in the city, and hence represents aoptimal sample area for study to identify the constraints as well as its possible solutions.

Alignment of Study Area: Inner Ring Road, Delhi



The traffic police fixed the specific plying hours for medium and heavy commercial goods vehicles from 9 pm to 6 am. Therefore, during day time passenger vehicles could move with ease and commercial vehicles movement takes place at night only. The entry of all inter-state commercial vehicles which are non-bound to Delhi is not allowed to Delhi as eastern and western peripheral express way is constructed around Delhi in neighboring states.

Table 1.: Road infrastructure of Inner Ring Road, Azadpur to Dhaula Kuan.

S. No.	Parameters	Dimensions
1	Length of Road	20 km
2	Railway crossings/bridges	3 nos.
3	Foot-over bridges	6 nos.
4	Underpasses for pedestrians	3 nos.
5	Road Lanes	3 to 4
6	Flyovers (with different width, height and length)	5 nos.
7	Perpendicular flyovers (metro + roads)	9 nos.
8	Signals for pedestrians crossing	3 nos.
9	Bridge over the fluvial drainage (Western Yamuna Canal and Najafgarh Drain or erstwhile Sahibi river)	2 nos.
10	Elevated Road	1 (2km)
11	Major crossing (perpendicular roads)	10.
12	One-way flyover (single leaf)	2.
13	Number of bus-stops/waiting stands	19.
14	Metro rail overhead crossings	8
15	Metro-station parallel to road	11

Source: Based on field study.

Road Infrastrucrural Issues

The entire stretch of 20 km long ring road is connected to almost one dozen perpendicular feeder roads, therefore, slip-roads, exit roads and converging roads are interrupting the traffic flow as lane changing zone is very limited. Subsequently, all the flyovers are three-lane/line while main roads are 4 to 5 lane, therefore, the starting point of every flyover become the bottleneck and stumbling block of traffic flow. The public transport buses are halting on main roads for the passengers to board in the absence of bus-bays. All the public transport bus-stops on both the sides of road are prone to traffic jams as unorganized halting and halting the buses in second and sometimes third lane on the road used to takes place. Alienated attitude of public transport-bus drivers forced the passengers to encroach the road for boarding/ de-boarding the bus as the buses usually halt at the middle of the road. Therefore, all the 40 bus stops on both the sides of road are prone to intermittent traffic jams. Service roads along main road have great significance in sustaining the traffic flow. However, in the study area throughout the 20 km stretch of inner ring road on both the sides, service roads are either encroached, unavailable or out of road plan. Practically, throughout the main road, service lane roads are non-existent. Therefore, the absence of

service roads is another significant factor for stumbling/obstructing the smooth traffic flow on the main road.

Single leaf fly-overs for one side traffic flow creates traffic nuisance due to lane changing zone and the presence of traffic signal for pedestrians on the busy main road. The single leaf flyovers where only one side of traffic crosses the perpendicular or turning traffic of feeder roads while the opposite side flow of traffic remains on same floor with slip-roads. Moreover, public transport bus-stands are constructed next to slip-roads and such areas become the dark-spots of traffic jam. Simultaneously, slip roads have a little space to accommodate the traffic whereas traffic-signal under the single leaf flyover stumbles the traffic of main road. The violation of lane driving norms, particularly at exit points of main road and the starting points of fly-overs leads to perennial obstruction of traffic flow.The service stations, gas-station, market areas, public offices, schools and commercial institutes located on main road without sideline roads and parking space of vehicles always leads to traffic jam particularly in busy traffic hours.

The location of electric poles, trees and religious structures (may be before the expansion of road) onthe roads, narrow-width of flyovers, absence of signage boards, absence of foot-over bridges, broken median fence, narrow slip roads and poor engineering of roads are the main infrastructure related factors responsible for bottlenecks and traffic jam. During rainy season, storm water got stored along the roads and bad weather became a perennial phenomenon of traffic jam in Delhi round the year. The capacity of road is fixed while the number and frequency of vehicles are increasing continuously.Therefore, even a minor engineering lacuna leads to traffic jams up to tens of kilometers. The regular digging/repair of road by water-supply, electric-transmission and various other underground pipes, supplying gas and petroleum by-products departments which display the lack of coordination with road maintenance agencies are the other important causes of traffic jam.

There are 11 metro rail stations which runs parallel to ring road in 20 km. long stretch of study area and out of which, 4 stations are underground whereas 7 metro stations are located on overhead pillars. Further, out of those 7 overhead metro stations, 5 stations are constructed on parallel lane to Ring Road while 2 metro stations are constructed on the pillars covering the Ring Road. Such stations were constructed with the passage of 3 lane/line road on both sides whereas on both the sides of stations, there are 4 to 5 functional lanes which are acting as the bottleneck on the ring road. Subsequently, for halting or parking of all types of commercial vehicles, there are no such areas or earmarked locations, therefore, in the absence of parking lot, the halted commercial vehicles always occupy one lane of the ring road, resulting in traffic congestion. Further, 5 metro rail lines intersect the ring road but the poor connectivity on the inter-sections of all metro lines is the lacunae of visionary architectural planning of metro rail. There is very poorly designed connectivity of inter connecting metro stations. Out of 5 inter connecting metro station 4 are poorly designed andhave no passenger friendly connectivity, therefore, large number of commuters prefer private vehicles and increase the ramp metering particularly during peak hours.

Table 2: Nature of metro-rail inter connectivity at intersections.

S.No.	Metro junction/inter-section.	Location of metro-station.	Distance between stations at inter-section.
1.	Azadpur (yellow line and pink line).	Both underground and connected.	100 m.
2.	Netaji Subhas Place (Redline & Pink line).	One overhead Another underground and connected.	500 m.
3.	Punjabi Bagh (Green line & Pink line).	Both elevated station No connectivity	1000 m.
4.	Rajauri Garden (Blue line & Pink line).	Both elevated stations and connected.	900 m.
5.	Dhaula kuan (Orange line & Pink line).	Both elevated/overhead stations and connected.	1200 m.

Source: Based on field survey.

Nature of Vehicles and Traffic Flow

The multiplicity and quantum of vehicles on road exceeds beyond carrying capacity and the major reasons for regular traffic jam on inner Ring Road. The proportionate increase in the number of private vehicles (two wheelers and cars) than the public transport vehicles on roads leads to traffic congestions in Delhi. With increasing number of vehicles, the average speed of traffic is also decreasing simultaneously as the average gap between two plying vehicles is getting minimized. CSE (Centre for Science and Environment) in its report has identified that the area under consideration has been designed to achieve a driving speed of 50-70 km/hour as per UTTIPEC's (Unified Traffic and Transportation Infrastructure (Planning & Engineering) Centre street design guidelines as well as Indian Road Congress guidelines for urban roads. However, the regulated speed on the stretch under consideration is 40-60 km/hour, but the actual observed average peak speed on these roads is 26 km/hour and off-peak is 27 km/hour, which is 50-60 percent lower than the designed speed. During the 12 hours (from 8.00 am to 8.00 pm) of the day, around 75 percent of the time, the average speed remained a 25-30 km/hr. About 17 percent of time, the average speed remained between 20-25 km/hr. Only during 8 percent of the days light time (6 am to 6 pm) speed remain more than 30 km/hour. This amply highlights the crippling problem of traffic jams on the stretch. In

fact, CSE pointed out that stretches of road, like the one taken in the present study, remain chocked throughout the day i.e. non-peak hours are vanishing. It is conventionally assumed that there is a sharp dip in vehicle numbers during off-peak hours (12 noon to 4.00 pm) compared to peak hours. It is typically assumed that peak hour average speed is about 40 percent lower than the peak hour speed. But in the stretch under study, non-peak hours have nearly disappeared. As the empirical data indicates, there is negligible variation between peak and non-peak hours.

Congestion may be defined as reduction of average travel speed to below 10 km/hr or Traffic Volume/ Road Capacity (V/C) ratio greater than 1. The empirical data highlights that the stretch is always congested, no matter what time of day the traffic flow is measured. The economic and social costs of this congestion on the national capital is mammoth. As per the study of IIT Madras, in 2013 traffic congestion cost the city close to Rs 54,000 crores, which is a whopping 14% of Delhi's GDP. Further, the cost of traffic congestion shall increase to Rs 90,000 crore by 2030. Mckinsey Global insights have calculated that Economic costs of congestion for any city of developed or developing country is as much as 2 to 4% of city GDP.

This is in backdrop of the fact that Delhi is bestowed with longest and one of widest flyovers/freeways in the country. National and International Studies have amply highlighted that building 8-12 lane roads do not address the congestion issues, on the contrary, the problem usually worsens, and has ultimately leads to reduction of average travel speed on major corridors even in the developed cities and countries.

Table 3: Trends of Different Types of Registered Vehicles in Delhi

S. No.	Types of vehicles	Number 2007-08	Percentage	Number 2016-17	Percentage.
1	Cars and Jeeps	1729695	30.73%	3152710	30.07%
2	Moter Cycles and Scooters	3578199	63.58%	6707891	63.98%
3	Autorickshaws	75297	1.33%	174000	1.6%
4	Taxis	30704	0.54%	148434	1.41%
5	Buses	52763	0.93%	38265	0.36%
6	Goods vehicles etc.	160726	2.84%	161821	2.21%
7	E-rickshaw	-----	----	29690	0.28%
	Total	5627384	100%	10482757	100%

Source: Delhi Statistical Handbook, 2015 & 2017.

Multiplicity of vehicles plying simultaneously appeared as one of the significant factors for stumbling traffic on inner ring road. Even after dedicated corridors forheavy and commercial vehicles and no-entry time rule for commercial medium and heavy vehicles during peak hoursthe volume of vehicles (particularly private vehicles) exceeds the carrying capacity of existing roads which reduced the speed of normal traffic flow. Subsequently, a separate express-way called KMP (Kundli-Manesar-Palwal) 135.6 km long expressway around Delhi to divert non-Delhi bound vehicles is also constructed and being functional to bypass Delhi city. Multiplicity of vehicles may be classified on different parameters as speed, utility, capacity and use of energy etc.

Table 4: The different types of vehicles may be classified as follows

S.No.	Basis of Classifications	Types of Vehicles
A	**Utility**	1. Passenger vehicles (Public and Private both) 2. Goods vehicles (Industrial and agricultural goods) 3. Multipurpose vehicles (Goods and passengers both) 4. Agro-based vehicles (Tractors and combined harvesters) 5. Tankers for liquid products vehicles (Oil and Milk etc.)
B	**Number/Size of wheels**	1. Two wheelers (Bicycle, Scooters/Bikes etc.) 2. Three wheelers (Manual rickshaw, auto rickshaw, e-rickshaw for passenger and goods both) 3. Four wheelers (Cars, Tempo, Mini-buses etc.) 4. Six wheelers (Buses, trucks, JCB Machines etc.) 5. Eight+ wheelers (Heavy duty trucks and specialized vehicles)
C	**Use of energy**	1. Petrol driven vehicles. 2. Diesel driven vehicles. 3. CNG/Gas driven vehicles. 4. Electric vehicles. 5. Manually pulled vehicles with muscle power. 6. Cattle pulled vehicles.
D	**Speed**	1. Fast running vehicles. 2. Slow running vehicles. 3. Rural oriented vehicles.
E	**Natureof passengers**	1. Private- 1 to 7 passenger vehicles: Cars/Jeeps. 2. Public-Mass passenger's vehicles: Buses. 3. Public-Individual vehicles: Taxis/Auto rickshaw.

		4. Private-1 to 2 passenger vehicles: Bikes/Scooters.
F	**Travelling Distance vehicles**	1. Short distance vehicles- Bicycles, Scooters, Auto rickshaw (Intra-City) 2. Medium distance vehicles (Inter-City) – Cars, Jeeps, Mini-Buses. 3. Long distance vehicles (Cross-country) – Trucks, Buses and Tempos.
G	**Landscape/ Terrains**	1. Urban-oriented vehicles – Cars. 2. Rural-oriented vehicles – Tractors, Jeeps. 3. Military vehicles (General purpose vehicles – GPV) 4. Mountain-oriented vehicles.

Inner ring road of Delhi is one of the busiest roads as it connects densely populated north and western part of Delhi to commercialized and institutional South Delhi, Gurgaon and Noida. Therefore, the commuters of different economic strata use different modes of transport as bicycles, bikes, cars, buses and auto-rickshaw etc. to reach their respective work places. The distance of work-place from residence also determines the modes of vehicle used. Though, the wide network (approximately 453.58 km length) of Delhi Metro rail (length of 453.58 km.) offered great relief to the commuters in which around 25 lakh passenger travel per day, public transport is still more popular with the travelling of approximately 44 lakh passengers daily.

Apart from passenger vehicles, the goods vehicles with different capacity, size and speed also ply simultaneously on ring road. Therefore, the vehicles plying with different speed and size without dedicated corridors for all types of vehicles create perfect traffic nuisance on ring road particularly during peak-hours. It becomes the risky and hazardous driving when a slow moving 2-wheelers/3-wheelers or bicycle move with heavy trucks and buses simultaneously in same lane in the absence of lane driving.

On the inner ring road during day time almost a dozen types of vehicles ply together with bumper to bumper driving. It not only reduces the speed of traffic flow but is also prone to traffic jams, bottlenecks and high risk of accidents. During the late-night hours, when entry for commercial vehicles is opened, majority of heavy vehicles ply at different speed. Therefore, the inner ring road is always (day and night hours) prone to stumbling traffic flow mainly due to multi-variety mobility on same road and at same time.

Table 5: Zonal Nature of Road Accidents on Inner Ring Road in Delhi: 2017.

S. No.	Location	No. of Non- Fatal Accidents	No. of Fatal Accidents	Total Accidents
1.	Prem Bari Bridge	3	7	10
2.	Punjabi Bagh Crossing	15	5	20
3.	Naraina Flyover Zone	9	5	14
4.	Rajauri Garden	7	4	11
5.	Mayapuri Crossing	7	4	11
6.	Brar Square Zone	4	4	8
7.	Wazirpur/NSP Crossing	4	4	8
8.	Club Road (Punjabi Bagh) X-ing.	2	4	6
9	Brittania Chowk	6	3	9
10	Dhaula Kuan Crossings	10	0	10

Source: Delhi Traffic Police Report: Road Accidents in Delhi, 2017.

Human Perspectives of Traffic Flow

With increasing size of population in Delhi, the number of registered vehicles has also been increasing in high proportion, whereas the length and width (capacity) of roads has not been increasing in the desired ratio. Subsequently, the traffic jams became a regular phenomenon. Commuters become habitual of stumbling traffic at any point of time and location on Delhi roads. The delayed and tiresome travelling time on roads in Delhi, changed the perception of drivers and commuters both. Broadly, there are four types of drivers with different perception and background, which are plying vehicles on same road and time. Firstly, the drivers of public passenger transport system (buses, taxi and auto rickshaw etc.), secondly, the drivers of private passenger vehicles (different types of cars), thirdly, the drivers of goods/commercial vehicles (tempo and trucks etc.) and fourthly, the drivers of two-wheelers and other light vehicles. All these different types of drivers are responding differently to traffic byelaws in Delhi as some of them are owners of vehicles while others are salaried.

The traffic police which manage the smooth flow of traffic is considered as incredible event-managers. On Delhi, roads traffic may get stumble at any point for varied reasons and it gets piled up to kilometers within a few minutes. But, once the traffic police reached at site, traffic get diffused quickly, therefore traffic police in uniform are pronounced as precise event managers. The increased number of vehicles on road leads to decreased traffic speed and increased travelling time, therefore, violation of traffic rules becomes a socially accepted phenomenon. Violating the traffic signals, wrong lane driving, over-speeding and illegal parking are the common traffic violations which are embedded in the social behavior of all sections of drivers. Education is not the determining criteria of violating the traffic rules as all section of drivers (illiterate, partially literate or highly literate) are equally involved in the violation of traffic rules on road. The drivers of two wheelers are the most impatient and involved in violating the traffic

signals and changing the lanes. Ironically, large number of commuters shifted to two wheelers from public transport as it takes lesser travelling time due to their unique capacity of bypassing the traffic through narrow lanes, footpaths and streets.

There seems to be two basic reasons behind the social acceptance of traffic rule violations. Firstly, the number of traffic police personnel are quite less than their desired strength. Secondly, very low conviction rate on traffic rules violations. Though, traffic rule violation and traffic jams are the two different issues, but traffic police have more priority on traffic rule violations. The break-down of vehicles on the road is another important reason for traffic jams as one line is completely stumbled for the following traffic and it created the temporal bottleneck. Traffic police is ill-equipped with the crane facility to remove the halted vehicle from the busy road. Simultaneously, parking of vehicles on roads for various purposes and time duration generally near the market areas and cremation-ground is also the reason for minimizing the speed of traffic flow. Traffic police failed to remove those halted/parked vehicles from the busy roads due to its limitations of available logistics. Traffic police working is more concentrated on plying vehicles and not for unauthorized and illegal parking of vehicles. Subsequently, there is no clear-cut policy of municipality, civil administration and Delhi Traffic Policeregarding the allocation of parking lots in Delhi. Unauthorized road side parking of vehicles is the major reason for traffic snarls in Delhi.

Table: 6. Comparative chart of Nature of Accidents in Four Major Cities in India: 2017.

S. No.	Nature of Accident	Delhi	Mumbai	Kolkata	Chennai
1.	Fatal	1565	467	318	1264
2.	Injury	5017	2603	2215	5670
3.	Total	6673	3160	3131	7252
4.	No. of Persons Killed	1584	490	329	1299
5.	No. of Persons Injured	6604	3287	2559	6975

Source: Ministry of Road Transport and Highways: Transport Research Wing, New Delhi. Road Accidents in India, 2016

To maintain the smooth flow of traffic, Delhi traffic police is selectively using smart signal system, electronic surveillance with CCTV camera and GPS and GIS system. Demarcation of dedicated corridors for vehicles with different speed limit along with ramp-metering are the other essential requirements formaintaining the uninterrupted flow of vehicles on roads in Delhi. Traffic challans and penalty for rule violating vehicles required to be implemented rigorously. It was further observed that roads are used for various other individual and social events as occasionalreligious activities, installation of tents on road sides, stray cattle, weakly markets, building material storage, encroachments on roads and unauthorized vendors on road side are the other reasons for slow traffic flow in the absence and poor implementation of rules in Delhi.

Conclusion

The rapidly increasing population size of Delhi leads to surge in economic and commercial activities, particularly in last three decades. Inter-city and intra-city mobility of people and exchange of goods increased tremendously, so the demand of variety of transport vehicles also surged. The road infrastructure remained almost constant over the decades with some locational-surgical improvements. Whereas, the number of plying vehicles on roads exceeded beyond capacity and traffic jams become a perennial phenomenon in Delhi. The horizontal expansion of city in all directions and radiating roads from its central part are connected by two ring roads i.e. inner and outer ring roads in Delhi. The inner ring road is traffic signal free road with 3 to 4 functional lanes, more than a dozen feeder roads and series of flyovers.

To analyze the intricacies and stumbling blocks of traffic of inner ring road, the study is divided into three major parts. Firstly, the nature of road infrastructure and related logistics, where missing link of planners and stakeholders was observed as the width of road is not uniform. It ranges from 2 to 5 lanes and entry points of all the flyovers resulted into bottleneck for traffic jams. Secondly, the multiplicity of vehicles plying on same time and same road leads to stumbling of the traffic flow. Two wheelers, cars, trucks, and public transport buses ply together with varying speeds and created complete traffic nuisance particularly during peak hours. Thirdly, human perception towards obeying traffic rules and byelaws is depleting rapidly. Illegal parking on road sides, wrong lane driving and violating the traffic signals become the part of social-acceptance. Scarcity of police personal and meagre punishment to traffic violations are the other human parameters for traffic violations which ultimately resulted into traffic jams. Encroachment of roads and side lanes by public, road side vendors, tents, religious activities and absence of integrated transport system are the factors for making the traffic flow slow and complex.

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