An In-Depth Study of Traffic Congestion Detection and Management in Delhi

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Abstract

The traffic in Delhi is a very important issue as the city experiences acute traffic problems in different locations. The commuters lose unpredicted and unproductive time on the road because of traffic jams. Though the roads of Delhi, by and large, are pretty wide, but still, there are traffic jams on the roads, mainly because the number of vehicles on the roads are more than the traffic load bearing capacity of the roads. In Delhi, the traffic is managed by the Delhi Traffic Police. In 1978, the Delhi Traffic Police Act was enforced and came into being. It looks into all types of traffic problems and suggests the possible solutions to the government . The traffic management plan prepared and implemented by the Delhi Police is based on four principles: regulations, road safety education, engineering solutions, and enforcement strategies. It was observed that the main focus of the Delhi Traffic Police is on removing the congestions which are experienced in prime locations to ease the flow of traffic. The objectives of this research work were to study the present traffic congestion problem in different main roads of Delhi, and to offer possible solutions to resolve the issue of traffic congestion, and also to find out the different safety measures undertaken by the Delhi Traffic Police to ensure the safe flow of traffic in Delhi.

Keywords : congestion, traffic flow, safety measures, intelligent signalling, radio frequency identification

JEL Classification : H10, H11, H19

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The traffic in Delhi is increasing day by day. The latest surveys have reported that Delhi alone has more than the total number of vehicles of the other metros, that is, Chennai, Mumbai, and Bengaluru. Despite the availability of better and wide roads in the city, Delhi experiences a traffic problem in many parts of the city everyday. The traffic in Delhi is managed by the Delhi Traffic Police, which is a part of Delhi Police. The traffic management plan prepared and implemented by Delhi Police is based upon the following principles : regulations, road safety education, engineering solution measures, and enforcement strategies.

The focus of traffic regulations is to improve traffic flow on travel corridors and reduce journey time. For this purpose, the traffic police keeps on studying the traffic flow, congestion/ bottleneck points, and ensures possible remedies to improve traffic flow patterns. In road safety education, the thrust is on training programmes for drivers, pedestrians, school children, and so forth both in the organized and un-organized sectors. Engineering solutions measure the low - cost traffic management measures and high cost traffic management measures such as implementation of the intelligent traffic system (ITS), use of modern enforcement equipments, and creative solution modules. As far as the enforcement strategies are concerned, the emphasis of the Delhi Traffic Police is on quality linked with road discipline and safety. In order to reduce congestion on Delhi roads, the Transport Department, Government of NCT of Delhi took a decision to install GPS based automatic tracking and

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monitoring system.

Traffic research still cannot fully predict under which conditions a "traffic jam" (as opposed to heavy, but smoothly flowing traffic) may suddenly occur. It has been found that individual incidents (such as accidents or even a single car braking heavily in a previously smooth flow) may cause ripple effects (a cascading failure), which then spread out and create a sustained traffic jam when, otherwise, normal flow might have continued for some time longer.

Review of Literature

Harish (2013) conducted a research on urban traffic and transport management in the city of Mysore and furnished the traffic management aspects related to time delay, congestion, parking, and framework of operations, identifying clear vision and mission statements for the future. The main focus of the framework was to identify traffic management, that is, accessibility and mobility, safety and security, & economy and environment. Kalyankar (2009) stated that traffic management consists of the amalgamation of a number of activities such as traffic measurement, traffic analysis, management techniques, result evaluation, and final results.

According to Ye, Hui, and Yang (2013), the definition of traffic congestion could differ with different organizations and purposes. The Federal Highway Administration (FHWA) defined traffic congestion as "the level at which transportation system performance is no longer acceptable due to traffic interference." They also stated that "the level of system performance may vary by type of transportation facility, geographic location (metropolitan area or sub-area, rural area), and/or time of the day." The Regional Council of Governments in Tulsa, Oklahoma, USA defined congestion as "travel time or delay in excess of that normally incurred under light or free-flow travel conditions." In Minnesota, USA, when the traffic speed is below 45 mph in peak hours, freeway congestion could be defined (as cited in Ye et al., 2013).

Roy, Bandyopadhyay, Das, Batabyal, and Pal (2013) mentioned that there are a variety of technologies that are being used to detect the congestion of traffic. The most popular technology is the inductive loop system, the simplest detectors that count the number of vehicles during a unit of time. Using airborne cameras and image processing technology, GPS devices and webcam, radar technology, and so forth, congestion can also be detected. However, these technologies have several drawbacks, such as installation problems and cost. Radio frequency identification (RFID) is an emerging technology that is still largely unexplored in the area of automatic congestion detection. Vehicle detection and counting can be done effectively using RFID technology.

Darbari, Medhavi, and Srivastava (2008) discussed about the application of Petri net as a workflow tool to model urban traffic systems. The simplest solution could be to widen the existing road network, but the authors pointed out that the widening of the road network probably is not the only solution as there are other factors too, which are to be taken into consideration before reaching a conclusion. The authors used patrient as the workflow tool to model and analyze the complex traffic control system in Lucknow.

Vadde, Sun, Sai, Faruqi, and Leelani (2012) mentioned that active traffic management (ATM) strategies are currently being used in Germany, Netherlands, Denmark, United Kingdom, Singapore, and so forth to alleviate traffic congestion problems. Several methods are being used as part of ATM to reduce congestion, travel time, accident rate, and pollution, as well as to increase traffic volume, density, speed, and so forth. Speed harmonization is one of the ATM strategies used to maintain a free flow of traffic. This method involves changing driving speed limits in real time according to traffic conditions (variable speed limit or VSL). Previous studies have shown that the use of speed harmonization decreased accident rates, improved travel time reliability, and reduced congestion and emissions. Shoulder utilization is the usage of hard shoulder during peak hours to alleviate traffic congestion. Most of the studies and implementation of this method were done in France, Germany, England, and Netherlands. Opening the hard shoulder to traffic during peak periods was found to improve travel time reliability significantly and decreased congestion levels.

Maqbool, Sabeel, Chandra, and Bhat (2013) stated that traffic signal system or traffic monitoring is a vast domain where wireless sensor network (WSN) can be applied to gather information about the traffic load on a particular road, incoming traffic flow, traffic load at particular period of time (peak hours), and in vehicle prioritization. Wireless sensor networks deployed along a road can be utilized to control the traffic load on roads and at traffic intersections. In a highly congested area, many vehicles such as personal transport, public transport, and emergency vehicles (ambulance, fire brigade, VIP cars, and other rescue vehicles) have to wait for long for the change of traffic signals at intersection points. In order to control this situation, the authors proposed a system consisting of two parts: smart traffic light control system (STLC) and smart congestion avoidance system (SCA) during emergencies.

Sen and Bhaskaran (2012) defined road traffic congestion as a recurring problem worldwide. In India, the problem is acutely felt in almost all major cities. This is primarily because infrastructure growth is slow as compared to growth in the number of vehicles. Secondly, Indian traffic being non-lane based and chaotic, is largely different from the western traffic. Thus, the authors felt that the intelligent transport systems (ITS) used for efficient traffic management in developed countries cannot be used as it is in India, and ITS techniques have to under go adaptation and innovation to suit the contrasting traffic characteristics of Indian roads. The researchers presented a comprehensive study of all available ITS systems, including both research prototypes and deployed systems.

Bhensadadiya and Bosamiya (2013) carried out a survey on various intelligent traffic management schemes such as simple traffic management scheme, automatic traffic management scheme, intelligent traffic management scheme based on image processing, and intelligent traffic management scheme using wireless technologies. According to them, the simplest traffic management scheme includes humans in the system. They mentioned that the automatic traffic management scheme was introduced to remove the weakest link (i.e. humans) in the above system, but this system cannot identify the emergency vehicles. The third scheme, that is, the intelligent traffic management scheme based on image processing includes cameras, which are meant to measure the length of the traffic in the system. Video footage covered by cameras is analyzed by a computer chip in order to detect objects (i.e. cars, trucks, etc.) on the roads. The last scheme described by them is the intelligent traffic management scheme using wireless technologies. In this scheme, the emergency vehicles and traffic signals are equipped with wireless antennas and receivers. As the emergency vehicle comes near an intersection, it broadcasts a signal to notify the traffic signal of its presence. As soon as the traffic signal receives a signal from the emergency vehicle, it gives a green light to that particular lane in which the emergency vehicle is traveling. After surveying the above mentioned traffic management schemes, the authors concluded that traffic management using image processing is suitable for implementation in our country.

Objectives of Study

The objectives of this present study are as follows :

(1) To find out how different road safety measures (taken by the Delhi Traffic Police to ensure the safe flow of traffic in Delhi) help the daily commuters.

(2) To find out the present traffic congestion problems faced by the daily commuters on different main roads and the solutions recommended by the Delhi Traffic Police to the government.

(3) To find out a suitable scheme for traffic congestion detection and management to facilitate smooth flow of traffic in Delhi.

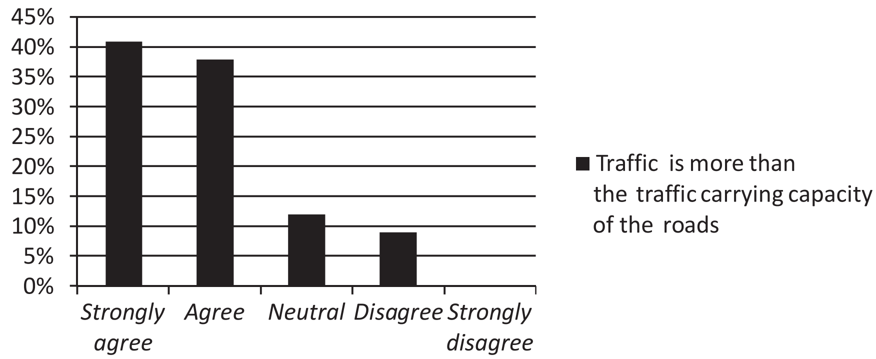
Research Methodology

The research methodology has been summarized in the Table 1.

Table 1. Research Methodology

Type of Research	Descriptive
Universe	People in Delhi
Population	Commuters on Delhi roads
Sampling Frame	Commuters of North, East, West, and South districts of Delhi
Sampling Unit	The commuters of Delhi
Sample Size	27 (From each Region of Delhi - East, West, North, and South)
Sampling Technique	Convenience Sampling
Project Instrument	Structured Questionnaire based on Likert Scale
Type of Questions	Closed Ended Questions
Statistical Tool	SPSS

Figure 1. Observations of the Respondents Towards the Traffic Carrying Capacity of Roads



Data Collection : Both primary and secondary data were collected during January to June 2014 and were used to conduct the research work. The survey was carried out by means of a self-administered, structured questionnaire. The secondary data were collected from research papers published in journals and articles.

Data Analysis : The objectives of this paper have been fulfilled by using the methods of percentage analysis and through the investigation of the collected primary and secondary data.

Analysis and Results

To collect information about how different road traffic safety measures taken by the Delhi Traffic Police work and help daily commuters, and what are the observations of commuters on reasons of the present traffic congestion on different main roads of Delhi, a questionnaire survey was conducted by interviewing 108 respondents from North, South, East, and West zones of Delhi (based upon the questionnaire given in the Appendix -1A). The data on flow of traffic in normal hours and peak hours, and the recommendations given by the Delhi Traffic Police to the Delhi government for removing the congestion were collected from the Delhi Traffic Police through interviews . The results from the survey with respect to the questions included in the questionnaire are furnished next :

Figure 2. Feedback Given by the Respondents Towards Flyovers and Underpasses

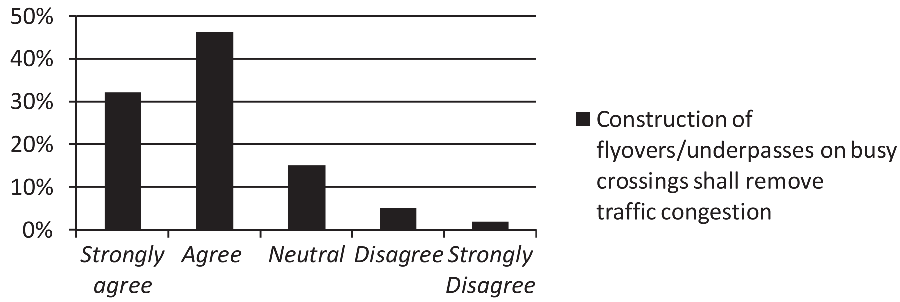
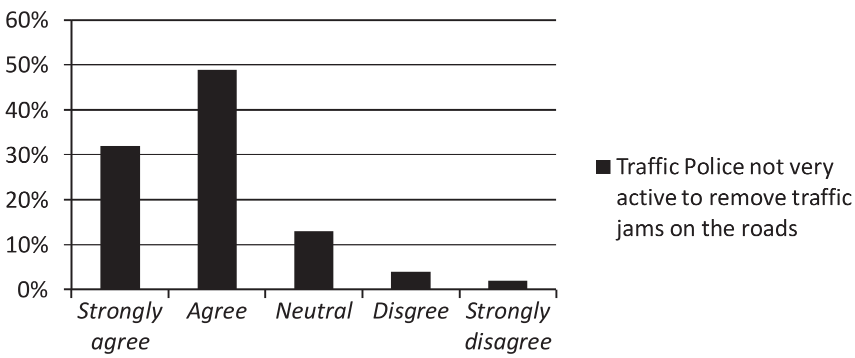


Figure 3. Activeness of Traffic Police to Remove Traffic Jams



Feedback from Commuters on Traffic Congestion Problems and Various Road Traffic Safety Measures

(1) Traffic Carrying Capacity of the Roads : The Figure 1 shows that 79% of the respondents felt that the traffic on the roads is more than the traffic carrying capacity of the roads. This creates traffic congestion on many of the roads in Delhi.

(2) Flyovers or Underpasses for Busy Road Crossings : The Figure 2 shows that 74% of the respondents felt that flyovers/underpasses should be constructed on busy road crossings to avoid road congestion.

(3) Action of Traffic Police to Remove Traffic Jams : It is evident from the Figure 3 that the respondents felt that the Delhi Traffic Police was not that active in removing the traffic jams from the roads. They are not properly equipped to take quick action to remove the jams.

(4) Broken - Down Vehicles on the Roads Restrict the Traffic Flow : It can be inferred from the Figure 4 that 79% of the respondents agreed that the disordered vehicles are allowed to stay on the road for long duration other than shifting these elsewhere. This causes huge traffic jams on the roads.

(5) Improper Location of Bus Stop Creates Obstruction in the Flow of Traffic : It can be inferred from the Figure 5 that 71% of the respondents felt that at many places, the traffic movement gets disturbed because of bad location of bus stops on the roads.

Figure 4.Observations Given by the Respondents Towards Broken Down Vehicles

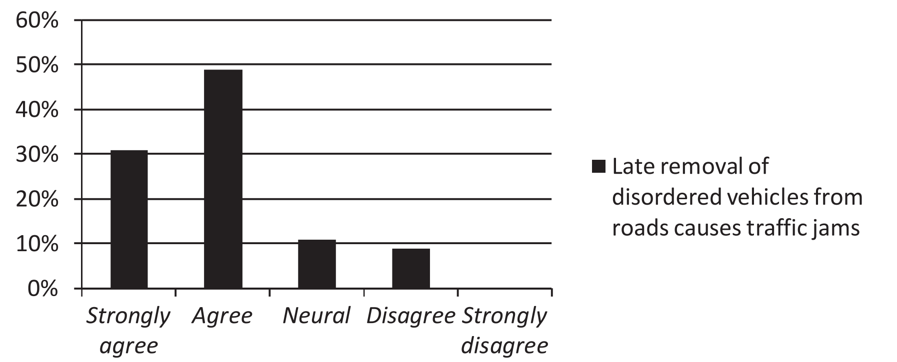


Figure 5. Feedback Given by the Respondents Towards Location of Bus Stops

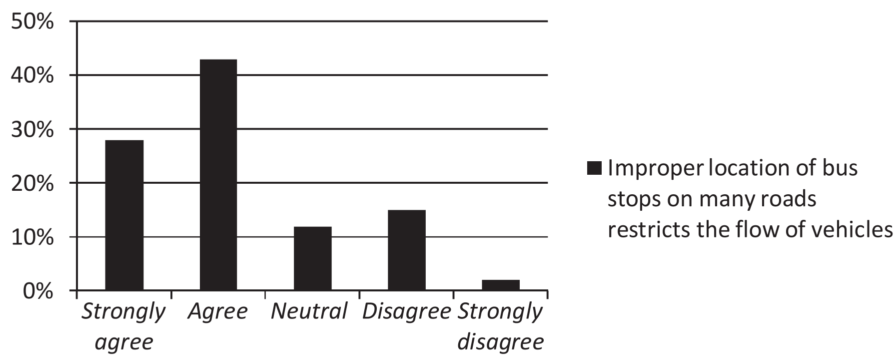
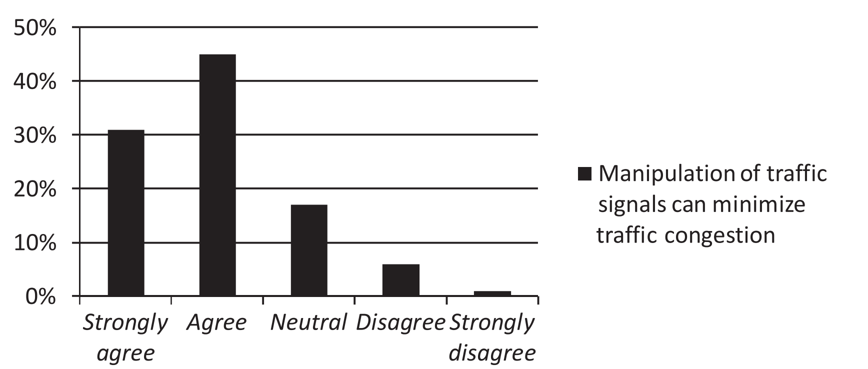


Figure 6. Feedback from Respondents Towards Manipulation of Traffic Signals



(6) Control of Traffic Signals : It can be inferred from the Figure 6 that 76% of the respondents felt that the traffic congestion can be minimized by manipulation of traffic signals.

(7) Conversion of Two Way Traffic to One Way Traffic During Peak Hours : It can be inferred from the Figure 7 that 60% of the respondents agreed that the conversion of two way traffic to one way traffic, wherever possible during peak hours, would help to remove traffic congestion.

Figure 7. Feedback of the Respondents Towards One Way Traffic

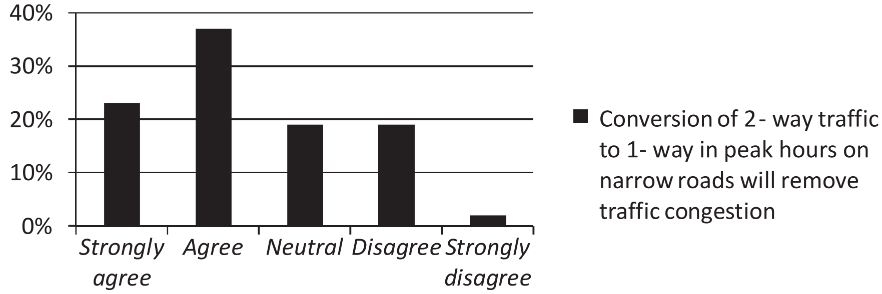


Figure 8. Feedback from the Respondents Towards Restriction of Parking on Roads

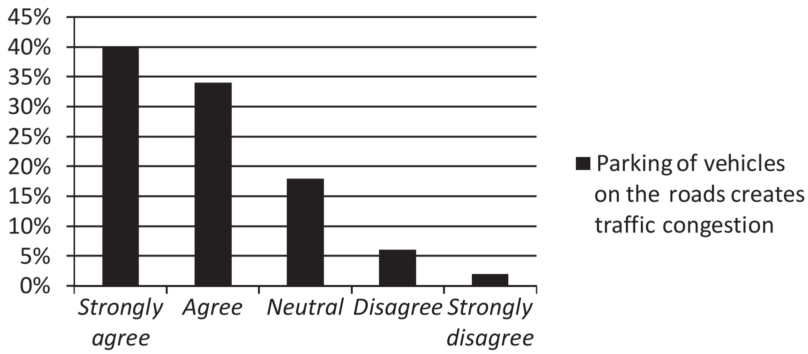


Figure 9. Feedback from the Respondents on Traffic Crossings Covering Large Circular Orbits

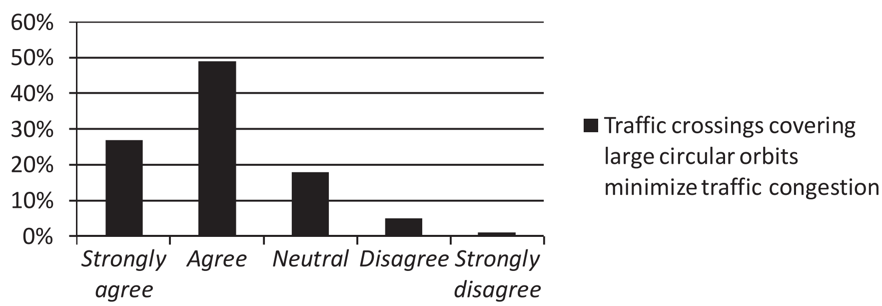


Figure 10. Feedback from the Respondents on the Movement of Heavy Goods Carriers During Business Hours

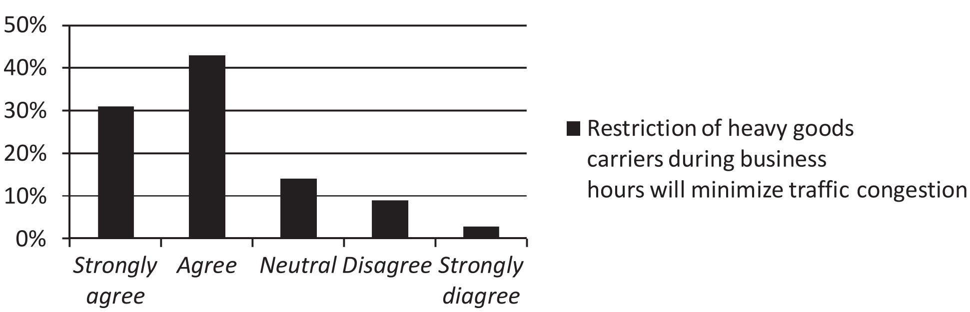


Figure 11. Feedback Given by the Respondents on Widening of Narrow Roads

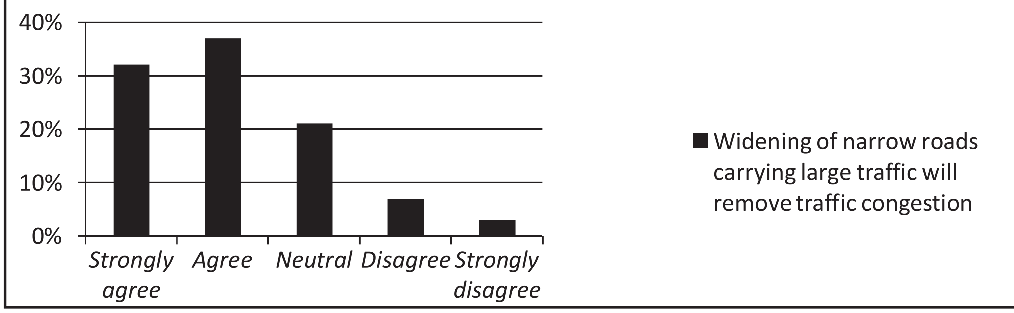


Figure 12. Feedback given by the Respondents Towards Construction of Road Dividers

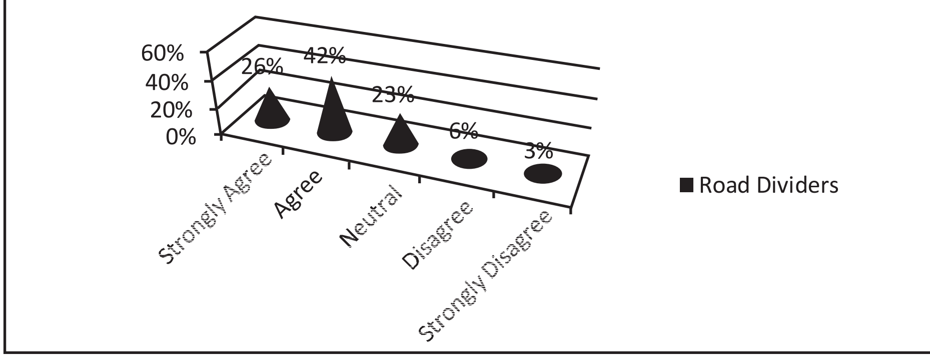
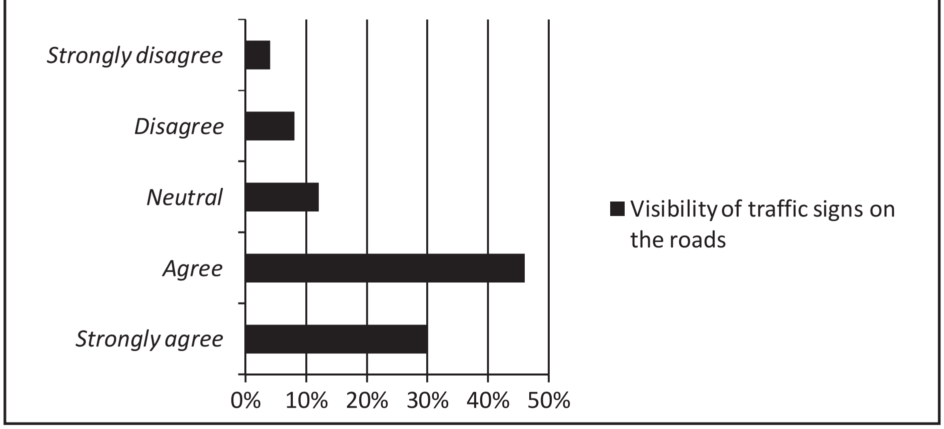


Figure 13. Feedback Given by the Respondents Towards Visibility of Traffic Signs



(8) Restriction on the Parking of Vehicles on Roads : It can be inferred from the Figure 8 that 75% of the respondents agreed that the parking of vehicles on the roads should be restricted, as this narrows the roads, which then leads to traffic congestion.

(9) Designing Traffic Crossings Covering Large Circular Orbits : It can be inferred from the Figure 9 that 74% of the respondents agreed that traffic crossings covering a large circular orbit should be designed so as to avoid traffic congestion on the roads.

Figure 14. Feedback Given by the Respondents Towards Location of Traffic Signs

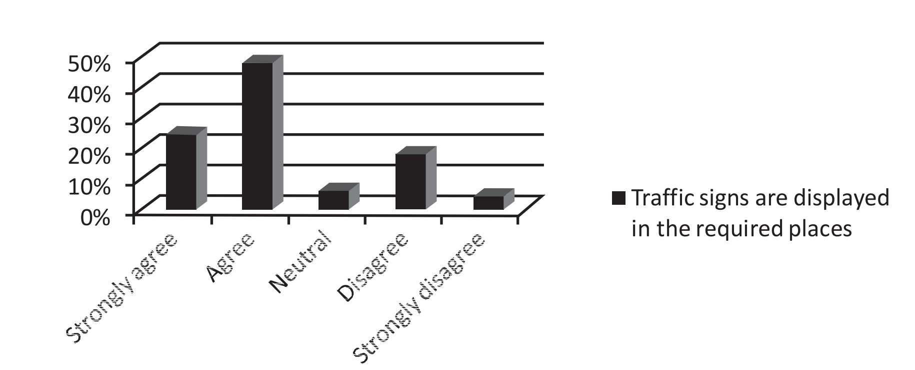


Figure 15. Feedback Given by the Respondents on Noticeability of Traffic Signs

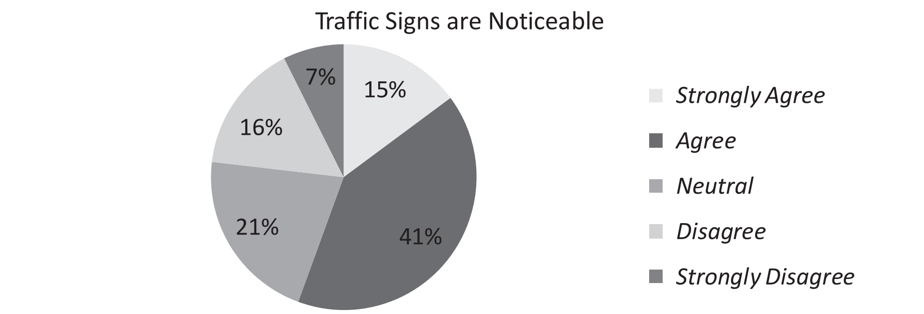
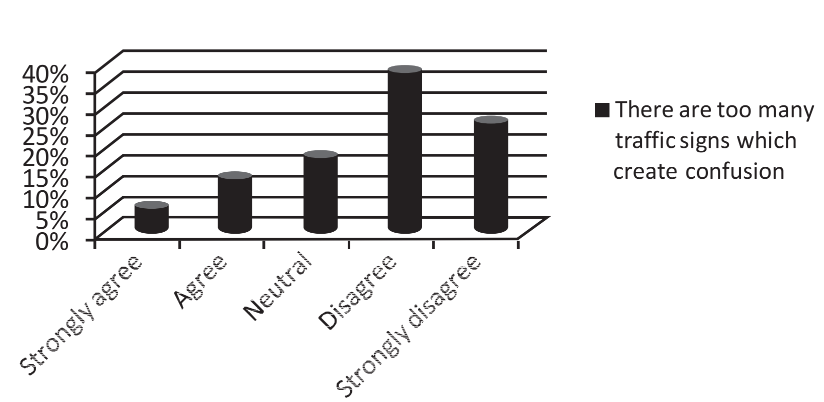


Figure 16. Feedback Given by the Respondents Towards Sign Confusion



(10) Restriction of Movement of Heavy Goods Carriers During Peak Hours : It can be inferred from the Figure 10 that 74% of the respondents agreed that there should be restriction on the movement of heavy traffic (like goods carriers) during business hours as it will minimize the problem of traffic congestion.

(11) Widening of Narrow Roads : It can be inferred from the Figure 11 that 68% of the respondents agreed that the traffic carrying capacity of narrow roads - on which high traffic movement is observed during peak hours - should be widened, wherever possible, to remove the traffic congestion problem.

(12) Constructing Road Dividers : It is evident from the Figure 12 that 68% of the respondents believed that constructing road dividers on roads where there are no dividers will make the flow of traffic smooth.

Figure 17. Feedback Given by the Respondents Towards Lane Markers

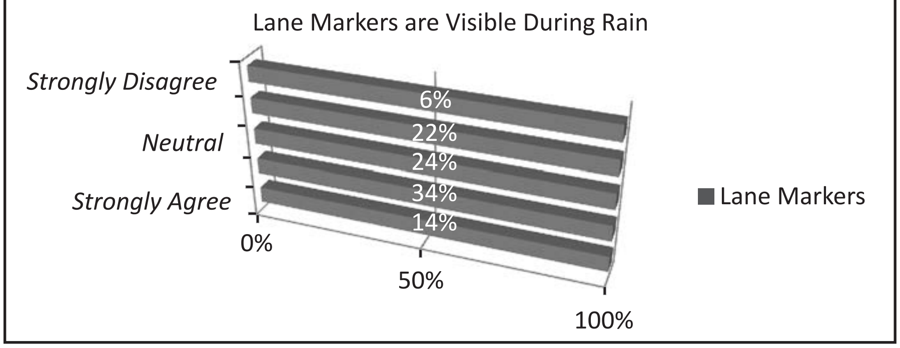


Figure 18. Feedback Given by the Respondents on Visibility of Road Dividers at Night

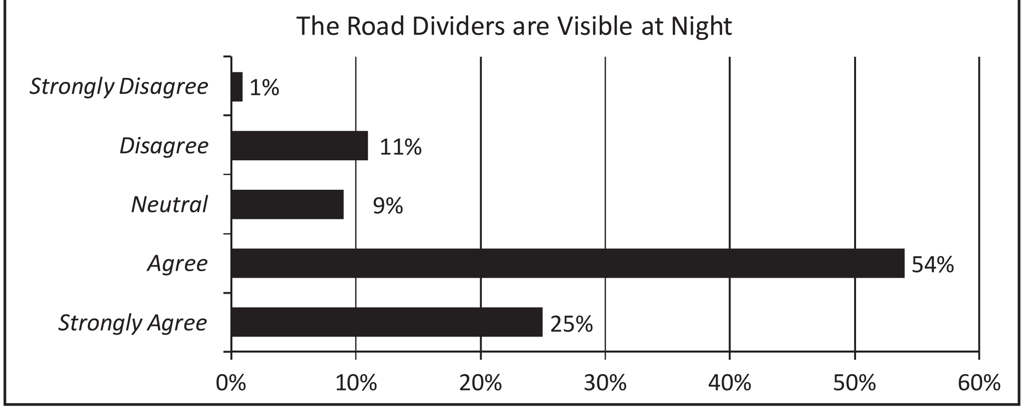
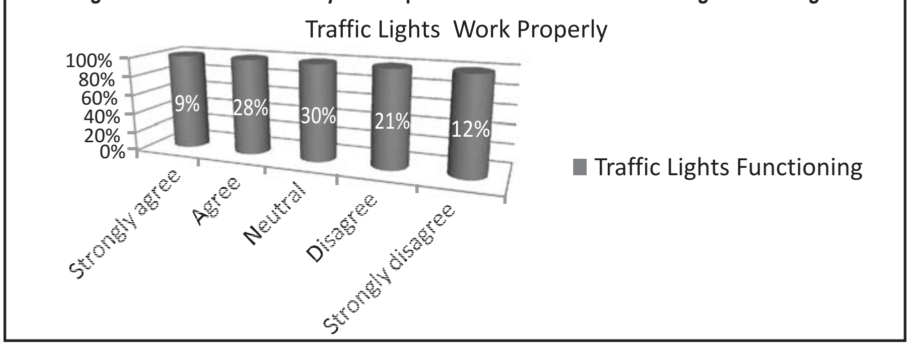


Figure 19. Feedback Given by the Respondents Towards the Functioning of Traffic Lights



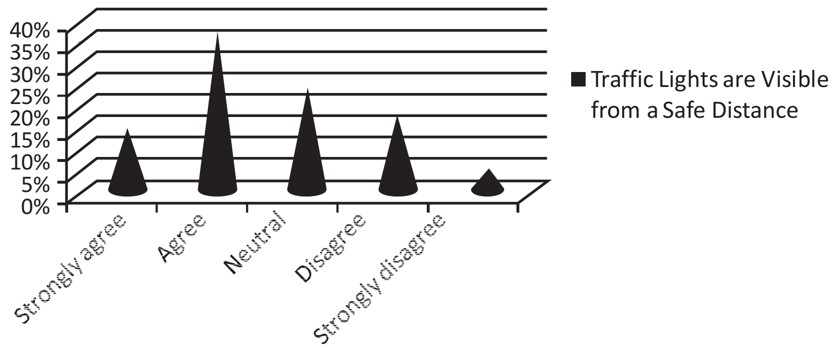
(13) Visibility of Traffic Signs on the Roads : The Figure 13 shows that 76% of the respondents agreed that traffic signs on the roads need to be easily visible to facilitate smooth traffic movement on the roads.

(14) Display of Traffic Signs at the Required Places : The Figure 14 reveals that 72% of the respondents agreed that traffic signs need to be displayed properly at the required places on the roads.

(15)Traffic Signs are Noticeable : The Figure 15 shows that 41% of the respondents agreed that traffic signs were large enough to notice ; whereas, 16% of the respondents disagreed with the same.

(16) There are Too Many Traffic Signs, which Creates Confusion : It can be inferred from the Figure 16 that 18%

Figure 20. Feedback Given by the Respondents Towards Visibility of Traffic Lights



of the respondents agreed that there are too many traffic signs displayed on the board, which creates confusion and diverts them from their routes to the wrong direction ; whereas, 64% of the respondents disagreed and felt that the signs displayed on the roads did not create confusion.

(17) Visibility of Lane Markers During Rain : It is apparent from the Figure 17 that 34% of the respondents agreed that they were able to see the lane markers during rain ; whereas, 22% of the respondents disagreed with the same.

(18) The Road Dividers are Easily Visible at Night : It is evident from the Figure 18 that majority of the respondents agreed that the road dividers were visible at night.

(19) Proper Functioning of Traffic Lights : It is evident from the Figure 19 that 37% of the respondents agreed that traffic lights on their routes worked properly, 33% of the respondents disagreed, while 30% of the respondents preferred to be neutral.

(20) Traffic Lights Visibility from a Safe Distance : It is observed from the Figure 20 that 53% of the respondents agreed that they were able to see the traffic lights from a safe distance, 23% of the respondents disagreed to that, while 24% of the respondents preferred to be neutral.

Traffic Congestion at Different Locations and the Solutions Recommended by the Delhi Traffic Police

From the questionnaire survey, some portions of the roads which were badly affected because of traffic congestion during business hours were noted, and the data regarding the flow of traffic was collected from the records of the Delhi Traffic Police. The flow of traffic in peak hours and in normal hours in different locations where the traffic congestions were observed, and the solutions offered by the Delhi Traffic Police to the Delhi government are furnished in the Table 2 with respect to the model shown in the Figure 21, where Point A indicates the entry from one side of the road crossing, and Point B indicates the exit to the other end.

Scheme for Traffic Congestion Detection & Management

As discussed in the Review of Literature, Roy et al. (2013) developed a scheme for detecting and managing traffic congestion, which may be effectively applied in real time in Delhi as well. The scheme basically consists

Table 2. Observed Traffic Flow in Different Locations and Recommendations of the Delhi Traffic Police to Remove Congestion

Location	Flow (Movement) of traffic in 5 minutes between A & B in busy hours	Flow (Movement) of traffic in 5 minutes between A & B in normal hours	Recommendations made by the Delhi Traffic Police to the Government
1.Burari-Mukundpur Traffic Point (Near Nirankari Samagam Ground)	150 vehicles	320 vehicles	To construct an elevated road over the stretch.
2.Wazirabad - Nanaksar Road Crossing (Near Yamuna Bridge)	40 vehicles	135 vehicles	To double the bridge lane .
3.Seelampur - ShyamLal College Road Crossing	150 vehicles	312 vehicles	To construct another flyover after Seelampur.
4.New Rohtak Road - Sarai Rohilla Road Crossing	70 vehicles	235 vehicles	To construct an elevated road above the existing road.
5. Netaji Subhaash Palace - Prembari Point	36 vehicles	123 vehicles	To install intelligent traffic signal to remove traffic congestion.
6. Ashram - New Friends Colony Crossing	55 vehicles	165 vehicles	To implement intelligent signalling system to facilitate smooth flow of traffic .
7.Navada - Uttam Nagar Metro Station	30 vehicles	181 vehicles	To refrain the "Gramin Sewa" from haphazard parking on the road which obstructs the traffic flow.
8.Rajouri Garden Flyover - Punjabi Bagh Road Crossing	56 vehicles	213 vehicles	To construct flyover on both sides as the existing flyover is only one side.
9.Rajouri Garden - Subhash Nagar Metro	80 vehicles	290 vehicles	To reduce the number of traffic red lights on this portion of the road & allow continuous flow of traffic on a longer stretch for removing traffic congestion.
10. The DhaulaKuan - Airport road	30 vehicles	105 vehicles	Not to allow any bus stop in close vicinity of Dhaula Kuan flyover and to implement intelligent signalling system to facilitate smooth traffic flow.
11. AIIMS - Yusuf Sarai road crossing	25 vehicles	90 vehicles	To remove all fruit vendors occupying spaces on the road.
12.Lado Sarai - Mehrauli road crossing	35 vehicles	110 vehicles	To install intelligent signalling system .
13.Laxmi Nagar Metro - NirmanVihar road crossing	59 vehicles	160 vehicles	To implement intelligent signalling system.
14.Jhilmil Traffic Rd Light - Apsara Border	43 vehicles	103 vehicles	To manage the traffic by Traffic Police using manual control.
15.BhikajiCama Place - MotiBagh road	70 vehicles	210 vehicles	To construct a cross-flyover over the existing flyover at Bhikaji Cama Place.
16.Paharganj-Ajmeri Gate road	62 vehicles	150 vehicles	To install intelligent signalling system.
17. The Kashmiri Gate - Novelty Cinema road	25 vehicles	55 vehicles	To allow only one way traffic during business hours (from 10.30 AM to 8.00 PM).
18.Pulbangash - Azad Market Gurudwara road	40 vehicles	82 vehicles	To construct a flyover at the crossing (which is already under construction) to solve the traffic problem.
19. Hanuman Mandir - ISBT road	35 vehicles	78 vehicles	To shift the ISBT else where.

Figure 21. A Road Crossing(Typical) Marking Entry and Exit Points for Measuring Traffic Flow

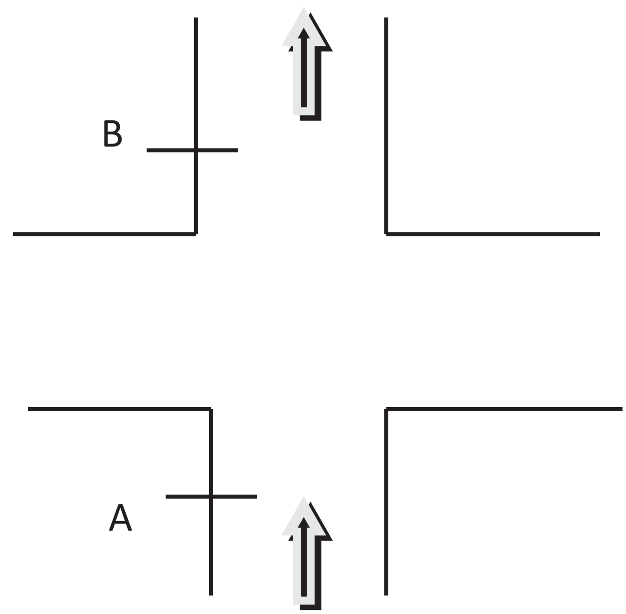
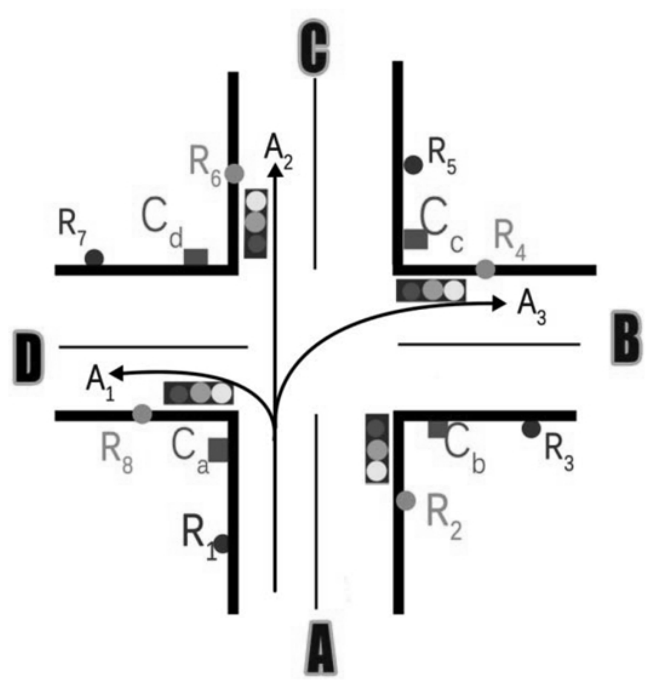


Figure 22. Typical 4-way Crossing



of two parts: (a) detection of congestion at any road leading to a junction and, (b) effective management to control that congestion, thereby ensuring smooth traffic flow. This scheme was suggested by Roy et al. (2013) in their paper.

At present, the traffic lights are passively controlled. At the time of setting up the traffic lights at a particular junction, the concerned officials study the traffic flow pattern through that junction at different times of the day on different days of the week. From this observed flow pattern, the corresponding timers of traffic lights are programmed to operate for a predefined time-duration. However, the pre-programmed scheme for traffic lights can be overridden to control them manually, if such a need arises. That is, the traffic lights should change automatically so as to ensure smooth traffic flow through the junction at all times, regardless of the occurrence of any incident.

➷ **System Overview :** Consider a four point crossing as shown in the Figure 22, and for convenience, the four stretches leading to the junction are named as A, B, C, and D. The left, straight, and right turn from any stretch has been denoted by 1, 2, and 3 (in subscript). Thus, for example, all vehicle movement from stretch A towards stretch D (i.e. left turn) has been denoted by A_1 and so on. The salient features of the scheme are as follows :

The average speed of vehicles on stretches A, B, C, and D are checked as they approach the junction. If the average speed of the vehicles falls below a threshold at any particular stretch, the system will detect that as congestion and will also measure the intensity of congestion by comparing the detected data with the normal traffic speed data already recorded for that stretch. In such a situation, a message is sent to the junction prior to the current junction on that stretch, asking to stop all inflow of traffic on that stretch. Since the system offers real-time congestion detection, therefore, as the congestion is released, automatically, the system will send another message to the previous junction, notifying to resume the flow of vehicles on that stretch. Since this system is fully automatic, there should not be any need of any manual intervention.

➷ **Device Description :** The system requires active RFID devices (tags, routers and gateway/ coordinators). Tags emit radio signals that can be captured by devices like routers or coordinators. Routers are capable of capturing tag data and relay the captured data to either another router or coordinator in its range. Coordinators have a serial interface through which external GSM/ GPRS devices can be interfaced with it to make it a dual-radio device; one is radio interface, and the other is GSM/GPRS interface. The coordinator receives data from either router or tag using its RF interface and can communicate with a remote server using its GSM/GPRS interface. The GSM/GPRS modem is used for testing.

➷ **Placement of Devices :** It is assumed that all the vehicles have a unique active RFID tag attached to them. Furthermore, it is considered that all the four roads leading to the junction are 2-way and traffic can flow along three different directions from a crossing.

C_a, C_b, C_c , and C_d are coordinators and R_1 to R_8 are routers that are capable of reading active RFID tags. Routers and coordinators are placed 100 mts apart on each stretch of the road leading to the crossing (Figure 22). Furthermore, it is ensured that all the four coordinators placed near a particular junction are not in each other's range of communication through RF. Also, R_2 and R_3 are in the range of C_b ; R_4, and R_5 are in range of C_c , and so on. All the coordinators are connected to GSM modems, and are capable of receiving and sending SMS texts to coordinators in other neighboring junctions, and also to the local traffic kiosk and central control room. The traffic lights at the junction are controlled by the coordinators nearest to them. All coordinators have a physical clock integrated with them, and they are capable of recording time stamps (the absolute time of occurrence) of events.

➷ **Congestion Detection Phase :** When a vehicle passes the router, the active RFID tag of that vehicle sends a beacon to the nearest router. The router then forwards it to the coordinator. As soon as the coordinator gets the router's message, immediately it saves the message and waits for getting another message from the same tag when it passes by the coordinator. When that tag passes by that coordinator, it sends another beacon to the coordinator. After receiving the beacon, from its time stamp, the coordinator calculates the speed of the vehicle and sends it to the control station using a GSM network.

It was proposed by the scheme designer (refer to Roy et al., 2013) that all the stretches leading to the junction get the green signal in a cycle, for a time duration that is proportional to the population of the vehicles on each stretch. This population is calculated from the number of tags that are in the range of each coordinator. For example, the population of vehicles on stretch A that are bound towards the junction can be determined from the number of active tags read by coordinator C_a at the beginning of the light cycle. It was assumed that C_a only reads those tags that have already been read by router R_1, and it rejects signals from all other tagged vehicles that are moving through other stretches and might be in its RF range.

After obtaining the count and the average speed of all vehicles, the coordinator determines the level of congestion depending upon some predefined condition.

➪ **Congestion Management Phase :** When a coordinator detects a high level of congestion, it cannot take further load since further traffic volume can create a stand-still situation. It sends an SMS to the coordinators in its preceding junction, notifying them to temporarily stop traffic along that stretch. After receiving the SMS from its successor's crossing point, the coordinator will switch on the red signal for that stretch towards that congested crossing point for a set period of time. As soon as the congestion is released at the crossing, the corresponding coordinator will send another SMS to its earlier coordinator, indicating to resume the traffic flow again in that direction. Accepting this message, the coordinator of the preceding junctions will put the red light off and will switch on the green signal and restart the signal cycle as before.

Discussion

The findings of the study are as follows :

(1) The survey results indicate that the commuters in Delhi found that the road traffic safety measures taken by Delhi Traffic Police are in order and help the commuters.

(2) It has been observed from the study that the locations which are badly affected by traffic congestion are Rajouri Garden - Subhash Nagar Metro Station, New Rohtak Road - Sarai Rohilla Road Crossing, Seelampur - Shyamlal College Road Crossing, Bhikaiji Cama Place - Moti Bagh, Rajouri Garden Flyover - Punjabi Bagh Road Crossing, and Navda - Uttam Nagar.

(3) Since there is no proper facility on Delhi roads for the movement of emergency vehicles like ambulance, fire brigade, and so forth, the Delhi government should think of a suitable solution to this problem.

(4) In Delhi and other metros, there is no provision of air lifting of the broken -down vehicles from the road to clear the traffic. As a result, many times, the commuters loose even more than an hour on the road when a vehicle breaks down and the situation becomes such that it is difficult to push it to a safe place to clear the traffic.

(5) The outcome of the study has suggested a scheme for detecting and managing traffic congestion which may be applied in real life situations in Delhi. The scheme consists of two parts - (a) detection of congestion at any road leading to a junction, and (b) effective management to control that congestion, thereby ensuring smooth flow of traffic.

Implications and Suggestions

Delhi has the highest number of vehicles as compared to any other metro city in the country. The timely planning of metro rail services in Delhi and its continuous expansion programme has helped the Delhi residents and visitors for visiting prime office complexes and commercial places in Delhi. But the arrangements and facilities developed so far are not enough to solve all the traffic related problems. The traffic problems still exist and will continue to exist unless many flyovers and underpasses - as air marked by the Delhi Traffic Police and mentioned above - are immediately constructed. In the city of London, the streets are not as wide as they are in Delhi. However, still, the traffic is managed well with the use of RFID tags in the vehicles. In Delhi, it has become a must to go in for the "intelligent signalling system" on all critical crossings. Furthermore, the government may implement the rule of withdrawing 15-year-old vehicles from the roads of Delhi, which will ease the traffic congestion to a great extent. The government may also think in terms of shifting the inter state bus terminals from the city to a suitable location so that the buses from Punjab, Haryana, Rajasthan, Uttar Pradesh, and Himachal Pradesh do not come much inside the city and restrict the flow of traffic.

Conclusion

Different researchers have carried out extensive research work in the recent past for traffic management in different cities. While conducting a study on traffic management in Mysore city, Harish (2013) provided a reasonable solution - to shift the public and private bus stands out of the centre of the city and building them on the city outskirts from where the people can take town buses or private vehicles into the city. It is possible to build more than one central bus station on the city outskirts and stopping the bus inflows at the entrances to the city. A similar method has been suggested in this paper for managing traffic in Delhi .

Traffic congestion on city road networks was one of the main issues duly addressed by Bhensadadiya and Bosamiya (2013). The researchers used several techniques such as embedded systems, wireless sensors network, intelligent ambulance, and image processing for traffic management. In earlier studies, the researchers suggested either a method to detect traffic congestion or suggested a plan for managing traffic. However, this present study has suggested a comprehensive system that automatically detects as well as controls traffic congestion based on the detected level of congestion using active RFID and GSM technology.

The current study also focused upon the road traffic safety measures taken by Delhi Traffic Police vis-à-vis the observations of daily commuters on Delhi roads. The study also identified the problems related to traffic congestion on various roads of Delhi, and the solutions recommended by the traffic controlling agency (Delhi Traffic Police) . Like USA and other developed countries, it is very essential for our government to develop free lanes for the movement of emergency vehicles on all the wide roads of Delhi. In this study, we have presented the method for intelligent signalling, and the government and policy makers may look into this to facilitate the smooth flow of traffic on many roads of Delhi.

Limitations of the Study and Scope for Further Research

The scope of the present research work is limited to the study of traffic management in Delhi. The study focused on the East, North, West, and South zones of Delhi. In future studies, the scope may be extended to cover the regions of Noida, Gurgaon, and Faridabad, as people from these areas visit Delhi everyday and people from Delhi also travel to these areas daily in connection with service or business.

Traffic flow can be considered as a hybrid system which is characterized by two major behaviours : continuous ones on highways and discrete ones on road junctions. In future studies, the modelling of the traffic system can be taken up based on Petri nets. The proposed model will suggest a mathematical framework for the analysis and control design for traffic management in Delhi.

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Appendix 1A

Questionnaire

As a part of our academic interest, we have undertaken this research titled "An In Depth Study of Traffic Congestion Detection and Management in Delhi".We would request you to please give your observations by filling up this questionnaire. The information provided by you will be kept confidential and will be used for research purpose only.

Please Tick Mark(√)on the appropriate Box against each statement in the Table below:

Statements	*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
A. Reasons of unsmooth traffic flow in the city :					
1. More traffic on the roads as compared to the traffic carrying capacity of the roads.					
2. Busy road crossings should have flyovers or underpasses.					
3. Traffic Police takes much time to act when there is any unusual traffic jam.					
4. Broken-down vehicles are allowed to stay on the roads for a long time other than removing these from the road very quickly.					
5. Bus stops in many places on the roads obstruct traffic movement to a large extent.					
B. Measures to control traffic congestions :					
1. By manipulation of traffic signals.					
2. Converting two way traffic to one way traffic on narrow roads (wherever possible and applicable) in busy hours.					
3. Restricting parking of vehicles on roads.					
4. Designing large sized crossings.					
5. Restricting movement of heavy traffic on the roads from 7.00 AM to 11.00 PM.					
6. Widening the narrow roads wherever possible.					
7. By providing road dividers wherever possible.					
C. Commuter's observations about Traffic Safety					
1. Traffic signs are easily visible on the roads.					
2. Traffic signs are at the needed locations.					
3. Traffic signs are large enough to notice.					
4. There are too many signs, which creates confusion.					
5. When raining, you can still see lane markers.					
6. Road dividers are easily visible at night.					
7. Traffic lights on your routes work properly.					
8. Traffic lights are visible from a safe distance.					