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Study on Red Signal Violations and Development of Prototype for Automated Enforcement System

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***Abstract:** The violation of red signal are the major reasons for the occurrence of numerous accidents at intersections. An effort has been made to study the current rate of red signal violation in different road networks in Chennai which accounted for 18.27% and also to provide profile of red signal violation with various parameters. Road inventory survey was done at four selected intersections. The primary survey was conducted and 29743 samples were collected and analysed. The result of study provided scalable indicators for monitoring and evaluating road safety strategies to prevent red light violation in the country. The present research work also made an attempt to introduce an automatic traffic control system based on RFID technology and digital image processing. Then developed a prototype to identify red signal violation automatically with penalty system. These findings represent some useful reactions to improving road safety of urban functions in India and other developing countries.*
***Keywords:** Red signal violation, Traffic volume count, RFID, Road safety, Automatic traffic control system.*

I. INTRODUCTION

According to world health organisation (2015), the number of road deaths plateaued at 1.25 million/year, making road traffic injuries a leading cause of death [1]. The main factor in crash risk is road user behaviours. A survey on causes for the crash indicated that driving errors and violations were the key factors (74%) of the crashes [2]. Traffic light system generally regulate traffic at intersections/ crosswalks to improve traffic safety and efficiency. Red signal violation is an undesirable driving behaviour that is illegal which may lead to accidents if not regulated by the police.

Among other factors the probability of a driver stopping at a red signal depends on the speed of the vehicle and the distance from the stop line at the amber point. Overall 35.2% of observed signal phases had at least one red light runner prior to the onset of opposing traffic [4]. Higher red light running rates were observed in cities with larger intersections and higher traffic volumes.

In Tamil Nadu, Chennai is one of the fastest growing smart cities with a population more than 70 lakhs. Increase in population growth and vehicles have created problems and red signal violation. If every driver follows the road rules, the number of road accidents would reduce significantly. The intersection is a crucial node on urban roads, where the proportion of traffic crashes continues to increase from 23.6% in 2007 to 30.6% in 2016. Most intersection crashes are caused by driver's violent behaviour such as speeding, jumping red lights and tailgating. The technique of posting the police officers is adopted at high risk intersection, in order to reduce the violation at intersection. Red light movement is often reported to be very dangerous, but it is not possible to know who the red light runners are, what factors affect their red light running and what behavioural characters are.

II. OBJECTIVE

The financial, economic, cultural and social losses associated with traffic accidents increase the engineering responsibility to conduct the studies to have a better understanding of the cause and to find the solutions. This study focus on the red signal violation at signalised intersection. The main objective of this study formulated as

1) To determine the current rate of red signal violation in selected road networks in Chennai city
2) To provide a profile of red signal runners at selected intersections with respect to different parameters.
3) To develop a prototype for automated red signal violation detection with penalty system using RFID and image processing.

III. METHODOLOGY

Based on Review of Literature the methodology is formulated. To achieve the objectives, different intersections were selected and survey was carried out. The primary survey includes Vehicle Volume Count, Observation study and Road User details. The Road Inventory data collected were Road Geometry, Road Infrastructure, Signal Phasing and Timings. This methodology was proposed to identify the Red Signal Violation in real time. The data was analysed and Red Signal Violation was carried out. Finally developed the Prototype for Enforcement system.

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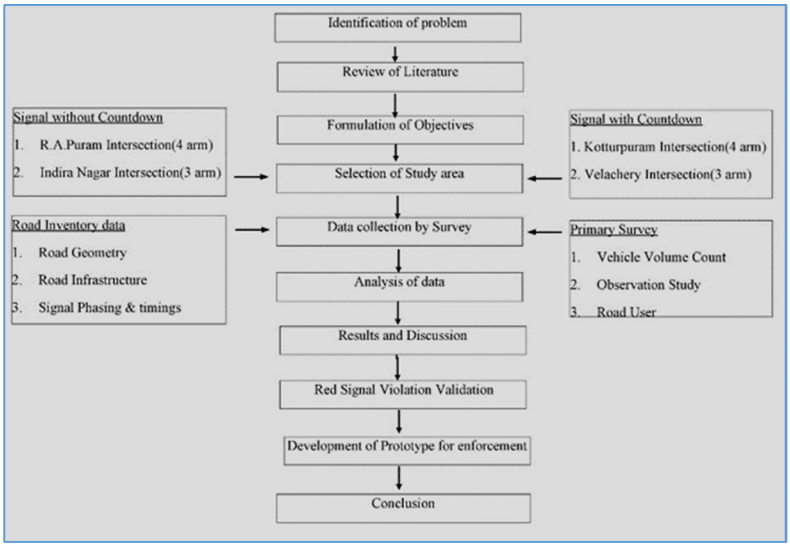

Fig.1 Methodology Flow Chart

The sites selected should fit the requirement of primary survey design, namely having the Intersection with countdown on four arm and three arm and without countdown on four arm and three arm intersection. In that count-down display, red or green coloured timer is counting which give the appropriate direction in correct time for the vehicles. If there is no count-down display, the signals are working with normal red, amber and green lights. To represent these, four intersections were selected in Chennai namely Kotturpuram, Velachery, Indira Nagar and R.A. Puram. Google map view of our study area is shown below in Fig.2.

Fig.2 Google Map view of Study Area

A. Primary Survey

Considering that the road traffic crash rates were reported more on peak hours and vary with the type of day the primary survey was conducted at each intersection on two types of days, one on weekend and one on weekday during peak hours. The selection of weekday and weekend were determined at random. Volume of vehicle was captured during primary survey. In order to accurately collect the traffic violation data, the enumerators were carefully positioned at intersection approaches to record the action of approaching vehicles using pro-forma checklist. The enumerators were positioned unobtrusively, so that most drivers were unaware that their driving behaviour was being monitored. Thus the location of enumerators did not influence driver behaviour in terms of red signal violation. At each cycle, enumerators monitored vehicle approaching the intersection during the red interval and identified the characteristics of drivers and vehicles that ran the red light including vehicle type, estimated age, gender etc., using the pro-forma checklist. Road Inventory Survey was done to know the basic information of four selected intersections. Road geometrics were measured during Road Inventory Survey. Signal Phases, signal timings, green light for pedestrian to cross the road, width of roads and crosswalks and type of traffic signal were also collected. The traffic signal phases at intersections kept constant when being observed because Chennai as well as many other cities in India does not adopt automatic traffic signal system that can adjust signal phase based on traffic volume and time of day. The location of the stop line at each approach was defined through the Road Inventory Survey.

B. Study on Kotturpuram Intersection

Kotturpuram intersection is four arm intersection Signal with countdown connecting Gandhi mandapam road, kotturpuram road Ranjith Street and Ponniamman Street. Volume count was done manually on this site. Volume was high in morning when compared to afternoon at all four approaches. Red signal violation rate on weekday and weekend had not much difference. Red signal violation rate was high on Gandhi mandapam road towards cancer institute, since traffic flow is high on this road. But Red signal violation rate is low on Gandhi mandapam road towards Nandanam even though traffic flow is high because traffic police was present on that approach. The red signal violation rate is more though the traffic police presence in the signal which is due to the vehicles coming from Ranjith Street and entering into Gandhi mandapam road and Ponniamman Kovil Street had very less signal timing which is approximately less than 10 seconds. Congestion prevailing at intersection due to commercial land use makes the driver to jump the signal and find their way towards cancer institute.

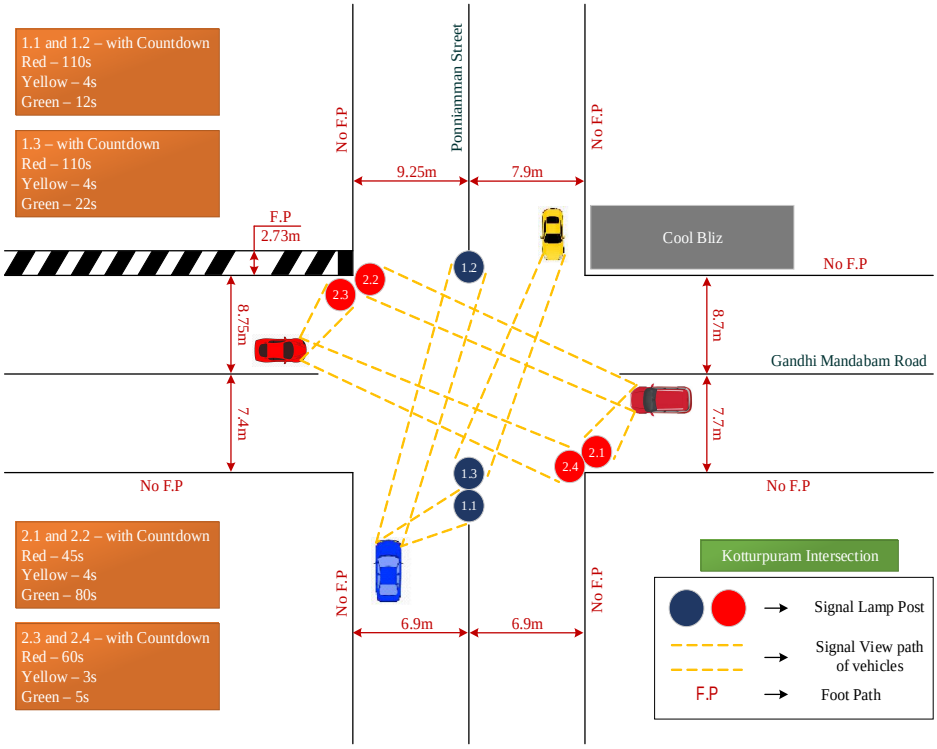

Fig.3 Geometric Picture of Kotturpuram Intersection

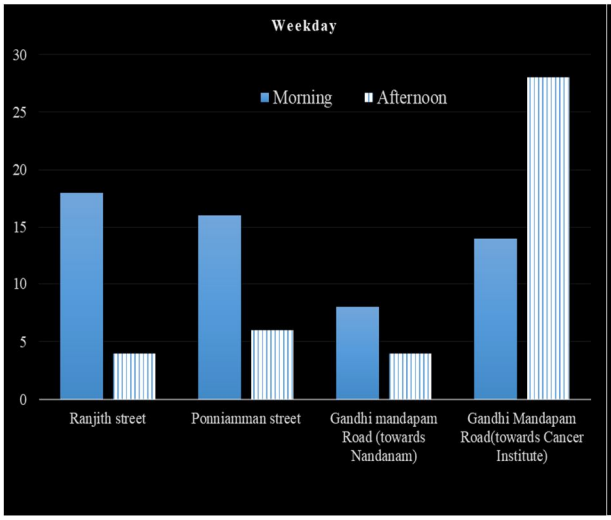

Fig.4 Red Signal Violation rate (%) on weekday

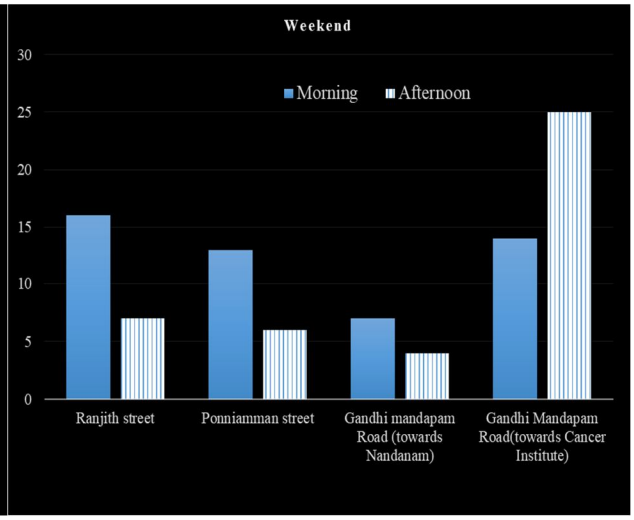

Fig.5 Red Signal Violation rate (%) on weekend

C. Study on R.A.Puram Intersection

R.A.Puram Intersection is a four arm intersection signal without countdown connecting C.P.Ramaswamy Iyer road and 3rd Cross Street has the highest volume during morning and CP Ramaswamy has the highest volume during afternoon. Video recording was done to measure the volume count. Red signal violation rate was high on all approaches since no police were present at this intersection on entire survey Traffic signals too not working properly in this intersection. 3rd Cross Street has high volume during morning and C.P.Ramaswamy Iyer Road has high volume during afternoon. 3rd Cross Street has high violation rate both on weekday and weekend. During primary survey it is observed that heavy vehicles too violates red signal mainly MTC bus violated more than 30 times within 8 hours survey period.

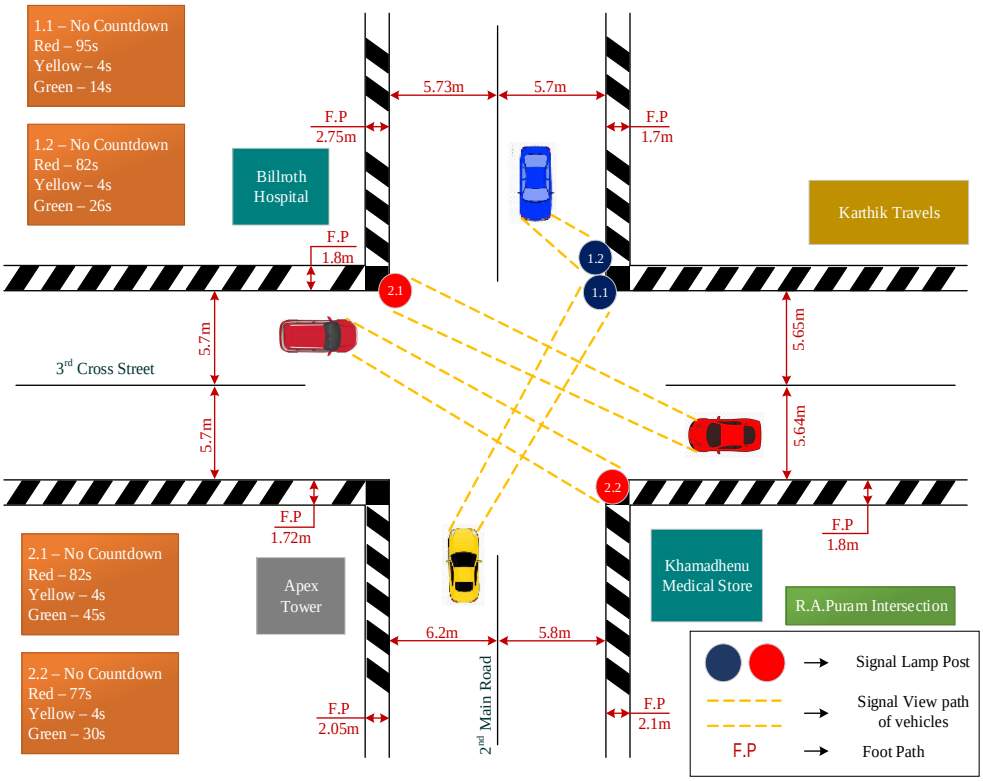

Fig.6 Geometric Picture of R.A. Puram Intersection

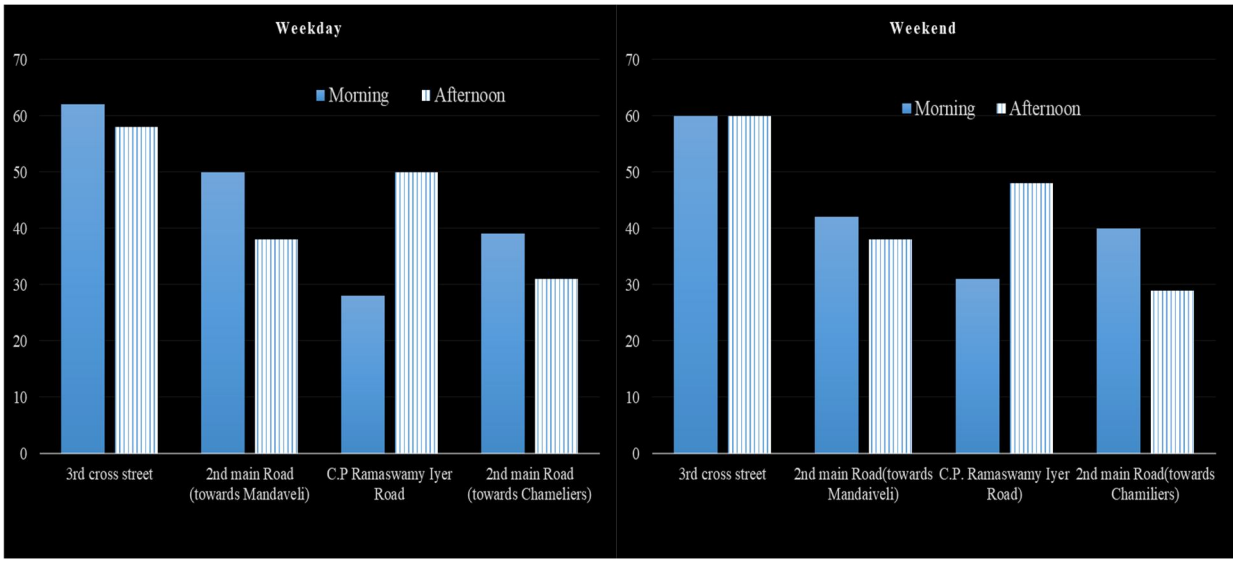

Fig.7 Red Signal Violation rate (%) on weekday

Fig.8 Red Signal Violation rate (%) on weekend

D. Study on Indira Nagar Intersection

Indira Nagar Intersection is a three arm intersection without countdown connecting Rajiv Gandhi IT corridor and Adyar L.B Road. Volume was captured from top view of Indira Nagar foot over bridge. Traffic police was present during the entire survey period both on morning and afternoon. The drivers were not sure when the signal turns to red from green, this makes them to cross the intersection at higher speed which results in the red signal violation. There are many IT sectors and Colleges along the corridor which results the higher volume count throughout the day. The metro project along the corridor reduces the width of the road and increases the traffic congestion.

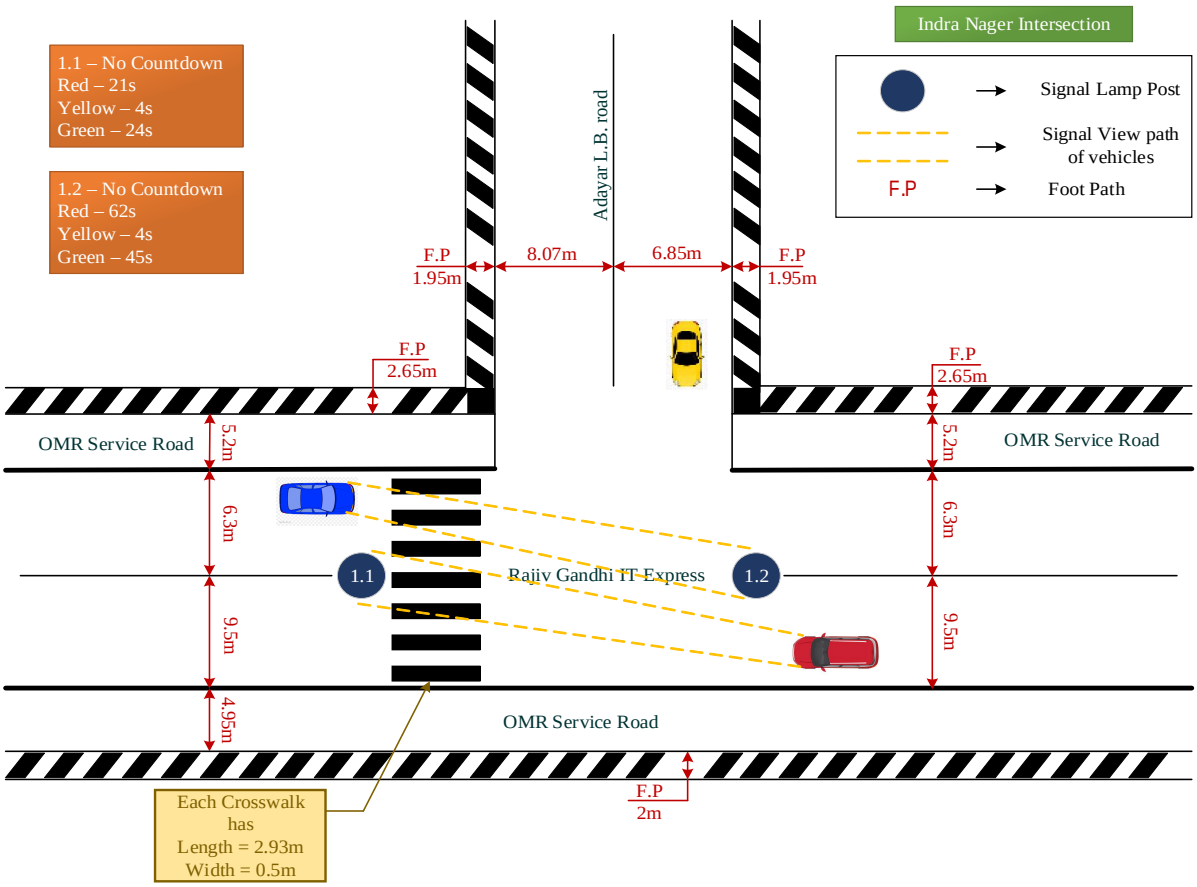

Fig.9 Geometric Picture of Indira Nagar Intersection

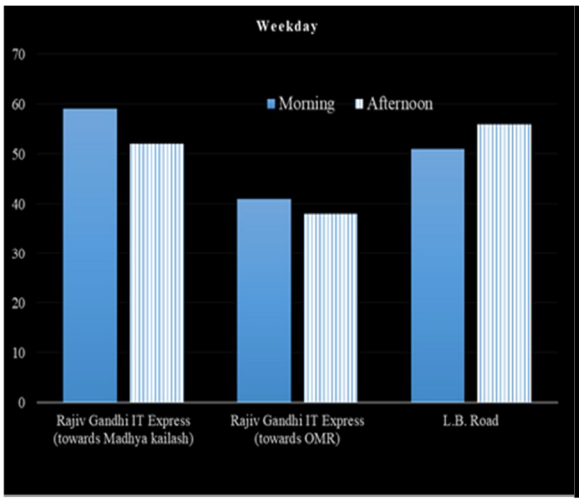

Fig.10 Red Signal Violation rate (%) on weekday

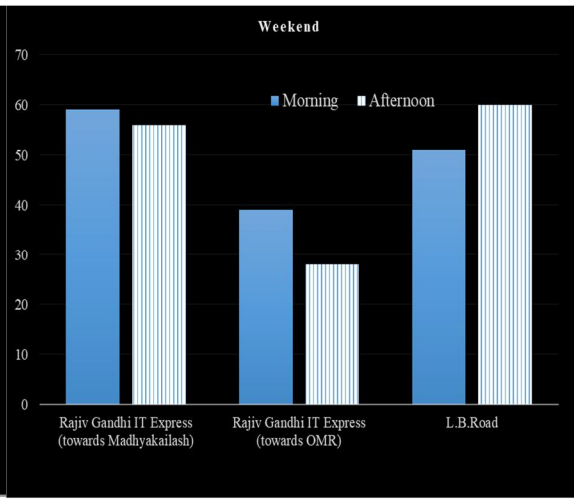

Fig.11 Red Signal Violation rate (%) on weekend

E. Study on Velachery Intersection

Velachery Intersection is a three arm intersection with countdown connecting Velachery Road and Guru Nanak road. Video was recorded for the volume count. The main fault observed on this intersection is the inadequate yellow timing which tends to violate red signal. Vehicle towards Guru Nanak road has cycle length of 157 seconds. Green interval has 120 seconds followed by amber of 4 seconds and red interval of 33 seconds. In green interval of 120 seconds last 37 seconds was not allowed for right turn. After 37 seconds, amber of 4 seconds was given and followed by red signal. This yellow interval of 4 seconds play a vital role which is the time where the drivers tend to violate since drivers are in confusion whether to proceed or not moreover they have to wait for 33+34+4 Hence one will be violating followed by many vehicles. This inadequate yellow interval was the main reason for high violation rate in Guru Nanak road and mainly red signal violators were right turning vehicles.

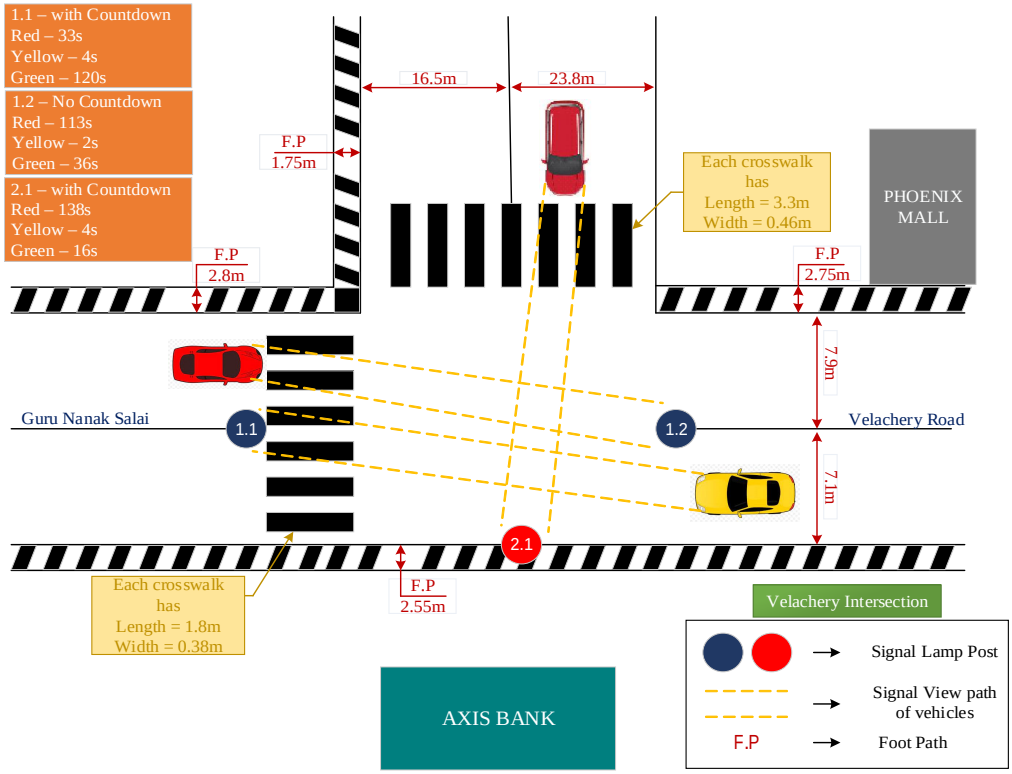

Fig.12 Geometric Picture of Velachery Intersection

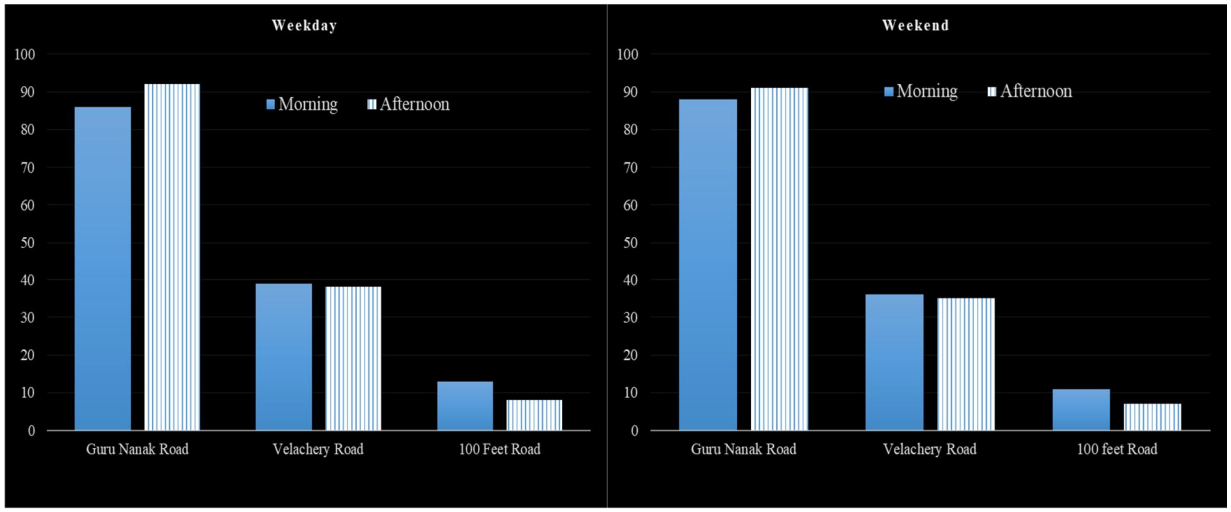

Fig.13 Red Signal Violation rate (%) on weekday

Fig.14 Red Signal Violation rate (%) on weekend

IV. RESULTS AND DISCUSSION

A. *Results*

The total number of 29743 vehicle samples surveyed during the primary survey. The red signal violation rate of the vehicles was analysed with 9 various parameters like gender, age of driver, violation due to passenger presence, mode of vehicles, time of day, day of week, type of intersection, presence of countdown, presence of traffic police. The overall violation rate of red signal violation was found to be 39%.

TABLE I
RED SIGNAL VIOLATION RATE FOR VARIOUS PARAMETERS

Signal Violation Parameters	Signal Violation Rate (%)
Drivers Gender	Male – 37 Female- 2
Age of drivers	Below 25 - 8 25-50 - 28.11 Above 50 - 3
Mode of Vehicle	TW -29 LMV -9 HV - 1
Time of Day	Morning- 20 Evening - 19
Day of Week	Weekday –21 Weekend -18
Intersection type	4 arm –13 3 arm - 26
Presence of countdown	With countdown –10 Without countdown -29
Presence of Police	Presence - 14 Absence - 25

1) *Driver's gender:* The red signal violation percentage of female drivers was less as 2% and the red signal violation percentage of male driver was 37.09%. This low rate of red signal violation by female drivers is consistent with earlier studies.
2) *Age of drivers:* The red signal violation made by drivers below 25 years was 8%, 25-50 years was 28.11%, >50% was 2.95%. The middle aged drivers made higher violation than young aged drivers. The drivers are likely to violate traffic rules on roads, based on prior experience to judge the behaviour is safe to certain solutions.
3) *Pillion rider presence:* The violation rate is low when there is a presence of pillion rider. The presence of a pedestrian crossing obstructs vehicle to violate and significantly reduced the number of red light violations.
4) *Mode of vehicle:* The violation rate of various type of vehicles are 29% for two wheelers, 9% for Light moving Vehicles (LMV) and 1% for Heavy Vehicles (HV). The violation rate of two wheelers were found to be higher than other mode of vehicles. The higher violation rate by two wheeler was because of smaller in size, easy to manoeuvre fast moving due to less weight and go undetected in high crowd [9]
5) *Time of day:* It was found from the survey that the frequency of red signal violation was varying in morning and afternoon time and not had much difference in violation rate. The violation rate at morning time was 20% and afternoon time was 19%.
6) *Day of week:* The red signal violation rate at weekday and weekend was 21% and 18%. During weekdays, more people were supposed to go to the workplace and are tried to reach their work place at specified time. This emerges high traffic violation during weekday.
7) *Intersection type:* The violation rate at 4 arm intersection was 13% and at 3 arm intersection was 26%. The 3 arm intersection has more violation rate when compared to 4 arm intersection.
8) *Presence of countdown:* The red signal violation rate of the countdown case was less as 10% and the violation rate was high as 29% for non-count down case. Countdown signal control is a relatively new control mode that can inform a driver in advance about the remaining time to pass through intersections or time needed to wait for other drivers and pedestrians. But drivers in intersection without countdown had no prior information about the amber and red phase which resulted in last second attempt to pass which results in more red signal violation.
9) *Presence of police:* The red signal violation rate for presence of police was 14% and absence of police was 25%. The presence of police in the traffic will change the attitudes of the drivers to violate or not to violate the red signal.

B. Discussions

The high rate of red signal violation in first few seconds was more because most of the drivers would accelerate their vehicles to pass the intersection, when the traffic signal changes from yellow to red. The high rate of the red signal violation is likely brought about by these aggressive drivers who attempt to cut in between gaps of vehicle traffic. If one driver violates, nearby vehicle drivers get influenced by the violators and tend to violates the red signal.

Basically, these violation can be ascribed to the poor law enforcement. Despite the fact that there is legislation in Chennai for drivers to comply with traffic signals, there is a serious laxity with its enforcement. Although legislation and regulation are not adequate to maximise compliance of red signal violation and must be accompanied by sustained education and enforcement. Presently there was no automatic red light surveillance cameras in the country. The police can enforce this law to violators only when they are physically present at traffic signal. If the police not present at traffic signal, the violators might escape and continue to violate regularly. This is not an efficient way of detecting the violators and also not possible to make the police to available at signal all times. There is a huge opportunity in reducing the high rate of red signal violation by deploying red light detection cameras as a supplement to police efforts to enforce traffic signal laws.

C. Prototype for Automated Violation Detection System

An automatic traffic violation detection system was proposed and developed a prototype with penalty system. This topic discuss about this system in detail based on Radio Frequency Identification (RFID) technology to detect the Red Signal Violations.

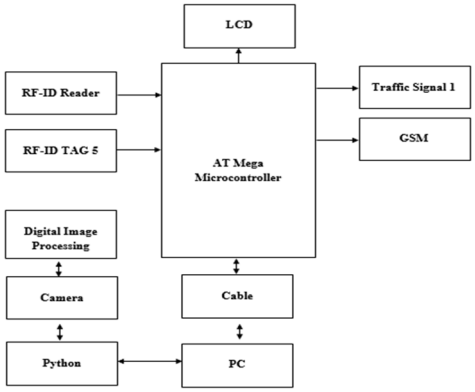

Fig.15 Block Diagram of Proposed Prototype

All the Hardware components were assembled and connected as shown in Fig.11. In this work, an automated system is proposed as this system utilizes RFID readers, traffic signal, Global System of Mobile Communication (GSM) SIM module where a SIM card is inserted and camera which are interfaced to the microcontroller. This automated traffic control approach consists of RFID tags which is to be pre-install in vehicles which contains unique ID consist of owners and vehicle details. In this setup, 5 RFID Tags were used and fetched the details of the known vehicles in that 5 tags and tested. Moreover, image processing technology was also used to detect that the image is vehicle which is simulated and tested on Python using a real digital images. The proposed system involves the functioning only if there is a red signal and any vehicle tries to cross the stop line during red signal, it will detect as the red signal violation and at that moment RFID reader reads the tag along with the image processing data and directs it on the pc using AT Mega micro controller. Finally, it sends a penalty message to the owner using GSM technology. This automatic penalty messages will be very quick and efficient where people will have an obligation to follow the traffic rules.

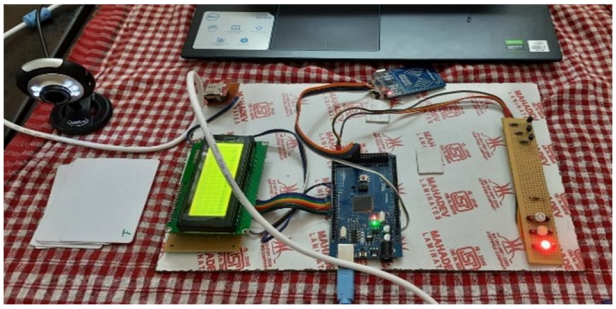

Fig.16 Proposed Prototype Setup

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D. Experimental Analysis of Proposed Prototype

To validate our prototype, experimental analysis was performed on this prototype. Here RFID-RC522 tag detector is used and an image of the car that violates the traffic rule is fetched by the PYTHON code for processing purpose. This RFID-RC522 tag detector will be used to detect the passive RFID tag which will be installed on the vehicles. The RFID tag detector generates an electromagnetic field through its antenna which is of 13.56 MHz frequency that triggers the passive RFID tag. After getting triggered the RFID tag transfers the data stored in it in the form of hexadecimal values to the detector. The RFID RC522 has a 4-pin Serial Peripheral Interface (SPI) which is used for communication with a microcontroller. The programming of Mega microcontroller is performed on Arduino IDE using SPI, MFRC522, Client and Software Serial libraries. Each RFID tag has fetched up with the unique information of each vehicle like the name of the owner of the vehicle, vehicle license plate number, and contact number, type of vehicle and model of vehicle. Further, for the Image Processing part, Open CV on PYTHON3.7 is used which is efficient and reliable. Fig.13 shows the working pictures of Image processing.

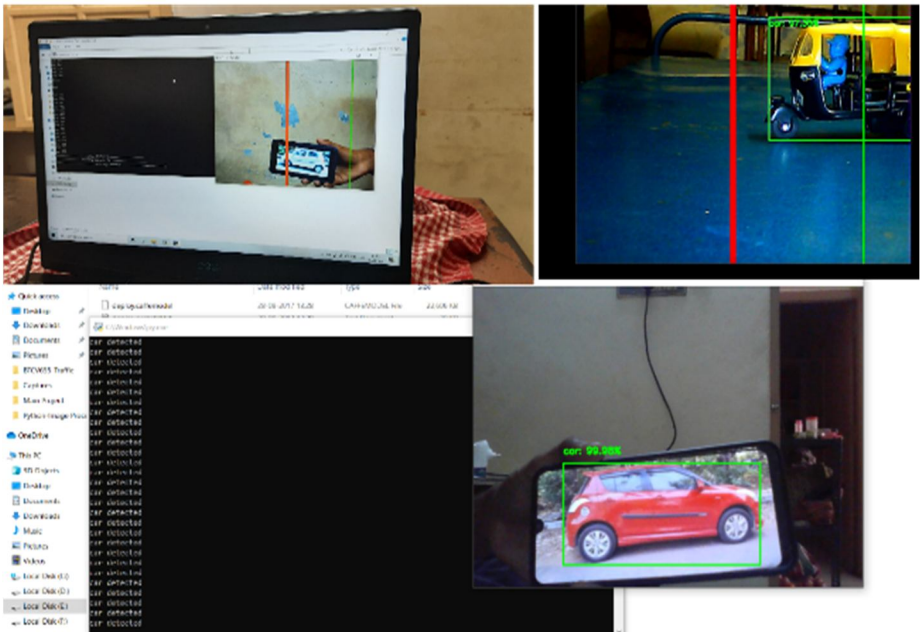

Fig.17 Image Processing Working Pictures

The RFID tag used here is usually passive device and it contains a microchip that stores and processes information, and an antenna to receive and transmit a signal. A Reader generates an electromagnetic field which causes electrons to move through the tag's antenna and subsequently power the chip. Based on the RFID tag placed into the vehicle as it passes by the RFID reader where the information of the vehicle stored in the tag is extracted and then the microcontroller recognizes that a violation has occurred by this certain tag and then a signal via microcontroller is sent to camera to take a snap and triggers the SIM800L Module. GSM SIM modem to send SMS to the number of the owner of the vehicle acquired from the tag and inform about the committed violation. This message contains information about the penalty amount charged as per the law guidelines.

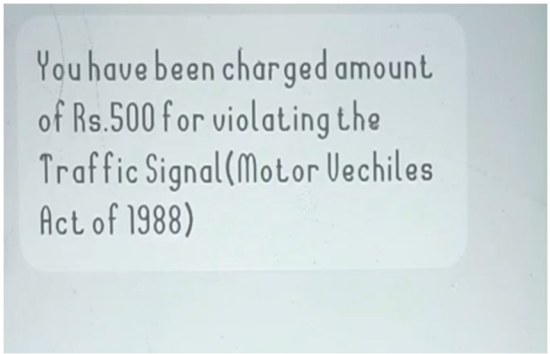

Fig.18 Penalty Message

V. CONCLUSION

The increase of the financial, economic, cultural and sociological losses due to the traffic accidents, needs a solution. Owing to this, an effort has been made to study the red signal violations rate and associated risk factors of red signal violation. The various conclusion drawn from this study are as follows

1) The current red signal violation rate from a sample of 29,743 vehicles was 39% which shows that red signal violation is a substantial problem.
2) The middle age drivers contributed towards higher red signal violation than the young and older age drivers.
3) The male drivers violated red signal more than the female drivers.
4) The presence of the pillion rider in the vehicle tends to decrease the red signal violation rate.
5) Two wheelers contributed more violation than LMV and HV.
6) Time and the type of day had not created much difference in the red signal violation rate.
7) 3-arm intersections had high violation rate than the 4-arm intersection roads.
8) The presence of the count down at the traffic signal influenced in the reduction of the red signal violation.
9) The presence of the police at the traffic signal also led in the reduction of the red signal violations.
10) The proposed automated red signal violation system can be implemented in the existing system which will perform effectively in reduction of red signal violations.

A. *Recommendations*

1) Safety education and other intervention programs may use the positive influences of groups to promote law-obeying behaviour, since our study found that other road user's behaviour may influence red-light infringement.
2) More extensive police enforcement could also help to combat prohibited driving behaviour.
3) High rate of red-light runners among two-wheelers suggests the need for an increase in penalties and stricter enforcement for red-light-running behaviours. Enhanced penalties may also reduce red signal violations.
4) Effectively lowering drivers speed at the approach to the intersection may lead to significantly less RLR violations.
5) By increasing the duration of yellow signal timing also we can reduce the red signal violations.
6) Finally, this study recommends to implement the proposed prototype which will be very effective in reducing red signal violations.

B. *Future Scope*

Future studies using questionnaire survey or lab-based experiments are needed to better understand why the red signal violation behavior happens. It is unknown how well the findings can be generalized to other samples, thus video recordings from more sites and under a wider variety of time intervals and weather conditions are needed for further analysis. Further research may adopt advanced traffic information collection systems tracking and recording the dynamics of individual vehicles. The proposed prototype was implemented only with the cars and autos, but from the strudy we found the two wheeler contributed to high violations rate. Hence, in future it can be tested on the two wheeler with some adding additional features with advanced image processing technology.

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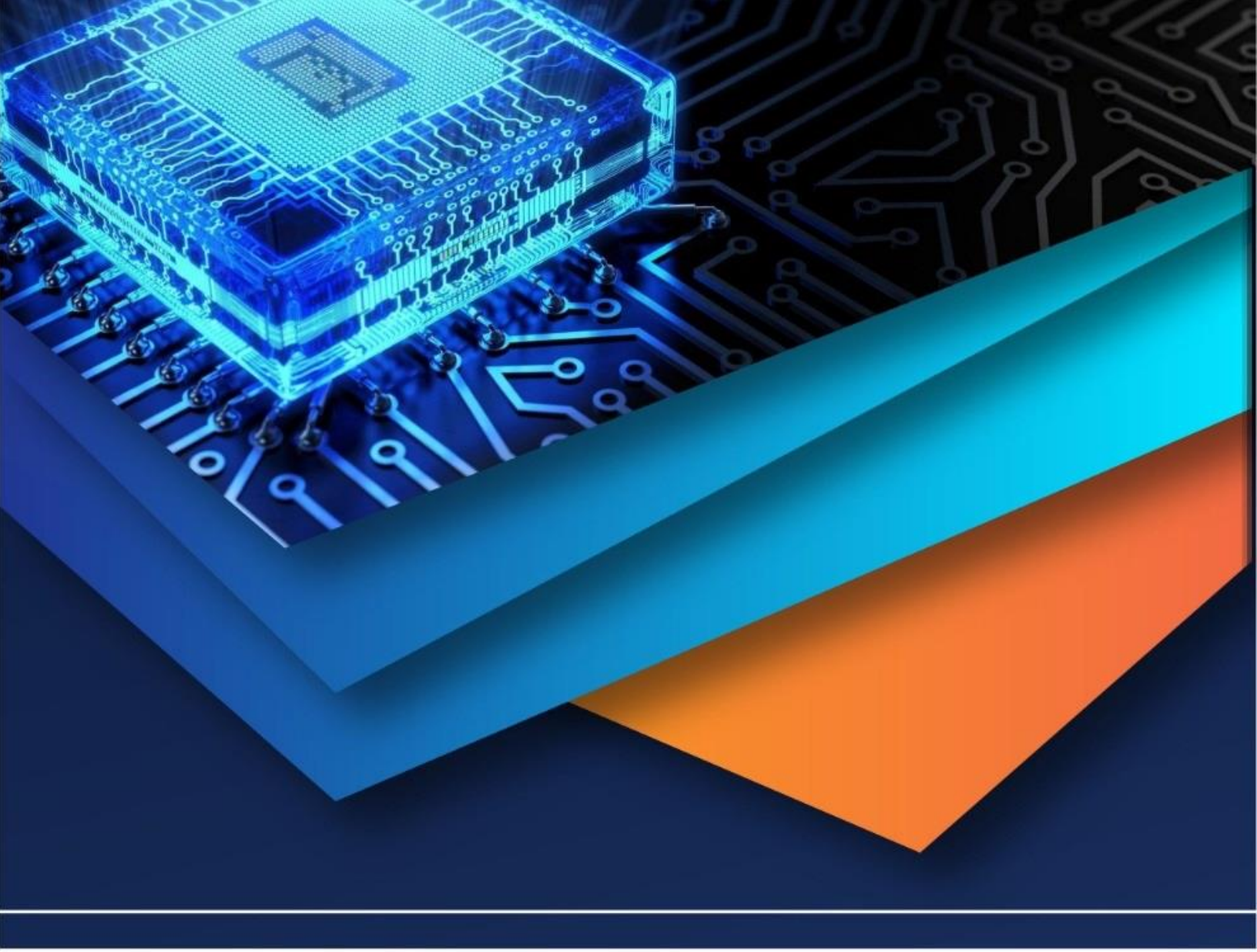

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