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Optimization of Signal Control Plan for Signalized Intersections at Madurai City

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Abstract

Roads are the major contributors to the socio-economic development of a nation helping in improving connectivity. India has one of the largest road networks in the world with about 47 lakh km of road length. Transportation of over 60% of consumer goods and over 85% of passenger traffic happens on roads in India. In India, 2018-2019, the highest allocation of budget is towards road infrastructure, which helps in developing new roads and improving the condition of existing roads. India's urban population was around 377.11 million in the 2011 census. This rapid urbanization has also led to rapid motorization. Urban roads have a high volume of traffic making it necessary to install traffic signals at intersections for better control over the flow of traffic. Though urban signalized intersections helps in regulating the traffic flow in a shared space, it also acts as the zone of major congestions, accidents and increased levels of air pollution. In this study, a simulation of traffic flow at Goripalayam and Periyar signalized intersections is to be carried out along with the incorporation of air pollution levels and possible conflicts at intersections. Simulation of the intersections will help in achieving an optimized signal control plan that will help in reducing the total delay, accidents as well as the pollution levels at the intersections which in turn will give rise to a more efficient intersection for the road users.

Keywords: *Signalized Intersection, Simulation, Accidents, delay, Pollution*

INTRODUCTION

The urban sector in most of the developing countries including India accounts for about 50 % of the Gross National Product. Major metropolitan cities in developing countries spend around 25 percent of their annual expenditure for transportation. Urban population is expanding at more than 6 percent annually in most developing countries and urbanization is considered a prerequisite for economic growth of the country. India's urban population was around 377.11 million in the 2011 census. This rapid urbanization has also led to rapid motorization. Within the urban areas the major source of transportation is through roads. Of all the cities, major metropolitan cities have the congested transportation system which results in higher travel times than usual, increased number of conflicts and the most pollution. For example, a recent study of Delhi showed that with an average per capita income of less than $2000 per year, over 80 percent of households have motorized vehicles. Though this provides increased mobility for people, it also results in high environmental costs. This vehicle growth exceeds the ability to increase road space and the major impediment to the efficient working of the urban economies in large size cities, is the level of road traffic congestion. Travel times are increasing and the environment is deteriorating at a faster pace. Growth of Gross Domestic Product is also reduced by freight congestion, delays and unpredictable accidents. The safety of travellers is also diminishing in large cities whose impacts can be valued in monetary terms.

An intersection is an at – grade junction where two or more roads meet or cross. A signalized intersection helps in the use of a shared space which is used alternatively by different approaches for a definite time period. They mainly depend on traffic signals, usually electric, which indicate which traffic is allowed to proceed at any particular time. The various methods that are available for a signalized intersection are pre-timed, partially actuated and fully actuated signalizations. In India, the most prevalent one is the Pre – timed signalization. In this method the shared space is utilized by the conflicting traffic for a pre-defined time interval that reduces conflicts and congestion to the maximum possible extent. The green light indicates that the movement is allowed for a particular phase while the red light indicates that the movement is denied for a particular phase. Invariably during the change over from green to red an amber signal is shown to warn the driver that a red signal is impending. During the amber time for phase, the vehicles of that phase utilizes the intersection but with caution. The major disadvantages of a signalized intersection are Traffic congestion, increased delays, Increased rear-end collisions, Air pollution.

Though traffic signals help in regulating the traffic flow of a shared space, it is also the zone for high traffic congestion causing increased delays during peak hours. Accident report released by Ministry of Road Transport and Highways during 2016 states that the percentage wise distribution of accidents at cross roads, Y and T junctions estimates to about 83.5 percent. The same report furnishes that the percentage wise distribution of accidents at traffic light signals is around 8.6 percent. The accidents at intersections mainly happen due to disobeying of traffic signals and rear-end collisions which are mainly due to misjudgement of the driver. In signalized intersections, vehicles are stopped for a time duration which results in increased air pollution levels because of the fact that quantity of harmful emissions increases with decreasing speeds. Hence it is highly essential to have a signalized intersection with an optimized signal control plan that will help in reducing the adverse effects like pollution, delays and accidents and improve its efficiency. Traffic flow simulation is the mathematical modelling of transportation systems like arterial routes, roundabouts, grid systems, freeway junctions, signalized intersections etc. With the help of softwares that helps in planning, designing and improving the corridor for a particular mode of traffic. There are three types of simulation of traffic flow. They are Macro – simulation, Micro – simulation, Meso – simulation. Traffic simulation packages like CORSIM and VISSIM are frequently used as tools for analysing traffic. VISSIM is one of the widely used simulation software that helps in not only planning a new transportation corridor but also helps in improving an existing one. It is a micro simulation model in which the vehicles are analysed individually for the time period and its functionality extends to travel time measurements, queue length measurements, emissions and fuel consumption measurements and so on. It helps in modelling the desired road network in which the field conditions are generated and the desired results are obtained.

LITERATURE REVIEW

Usama Shahdah et al., (2015) [9] has done a research that helps in identifying the possible conflicts in vehicular movements with the help of micro simulation models and they are compared with real world crashes to evaluate the safety performance after providing improvements. The surrogate safety measure that is used to identify the traffic conflicts is Time- to – Collision. By modifying the TTC and analysing the micro simulation model, the effectiveness of countermeasures are studied.

Carolina Osorio and Kanchana Nanduri (2015)[5] has proposed a methodology that helps in addressing transportation optimization problem by incorporating both traffic flow models and emission models which helps in analysing complex environmental metrics. They have used a simulation based optimization approach to achieve the results. The proposed algorithm is computationally efficient and the improvements in performance can be obtained with only a less number of simulation runs. A pre-timed signal control strategy is used with the green splits of the phases as decision variables.

Doughlas Gettman and Larry Head (2015) [7] have derived the surrogate measures of safety from existing simulation models that can be used for crash and conflict simulation. The possible conflicts at intersection can be described by gap time, post encroachment time, deceleration rate and proportion of stopping distance. It also includes queue length, approach speeds, red – violations for an intersection. Driver behaviour like car following behaviour, gap acceptance and lane changing behaviour are incorporated in the micro simulation models. A lower Time to Collision, lower Post Encroachment Time and higher Deceleration Time indicates a higher probability of collision.

Alireza Talebpour et al., (2016) [3] has modelled driver behaviour in a connected environment with integrated microscopic simulation of traffic and wireless telecommunication systems. The main driving related decisions correspond to acceleration choice and lane changing manoeuvres. Lane changing model is derived using a game theory approach. Acceleration model follows a probabilistic nature for congested and uncongested regimes. The technology and driver behaviour modelling were intended to enhance mobility and safety while they reduce emissions and energy consumption.

Ying ni and Keping Li (2013)[10] have selected intersections with Green Signal Countdown Devices and No Green Signal Countdown Devices as they can affect the driving behaviour. This study was used mainly to analyse the rear-end collisions which are the most common type of accident at signalized intersections. The provision of GSCD has proved to adversely affect the safety of the intersection; it has lowered the driver's tendency to stop, lengthened the dilemma zone and resulted in increased crashes at the end of the green signal.

Christian Hofer et al., (2014)[6] has used an agent based network approach that performs a simulation that helps in analysing the carbon di oxide emissions caused by urban motorized traffic. The model developed also includes the cruising, idling, acceleration and deceleration of various vehicles to calculate emissions. A micro simulation model using PTV VISSIM is used to analyse the mobility patterns of the people and several countermeasures like electric vehicles and car pooling were suggested to reduce the emissions.

METHODOLOGY

Methodology was constructed in the form of a flow diagram, consisting of all the tasks to be performed in a sequential order, starting from the problem identification, literature survey, through various stages involving collection and analysis of data from the study area, up to the stage when the results are obtained and useful information could be inferred from the obtained results. This is shown in Figure 1

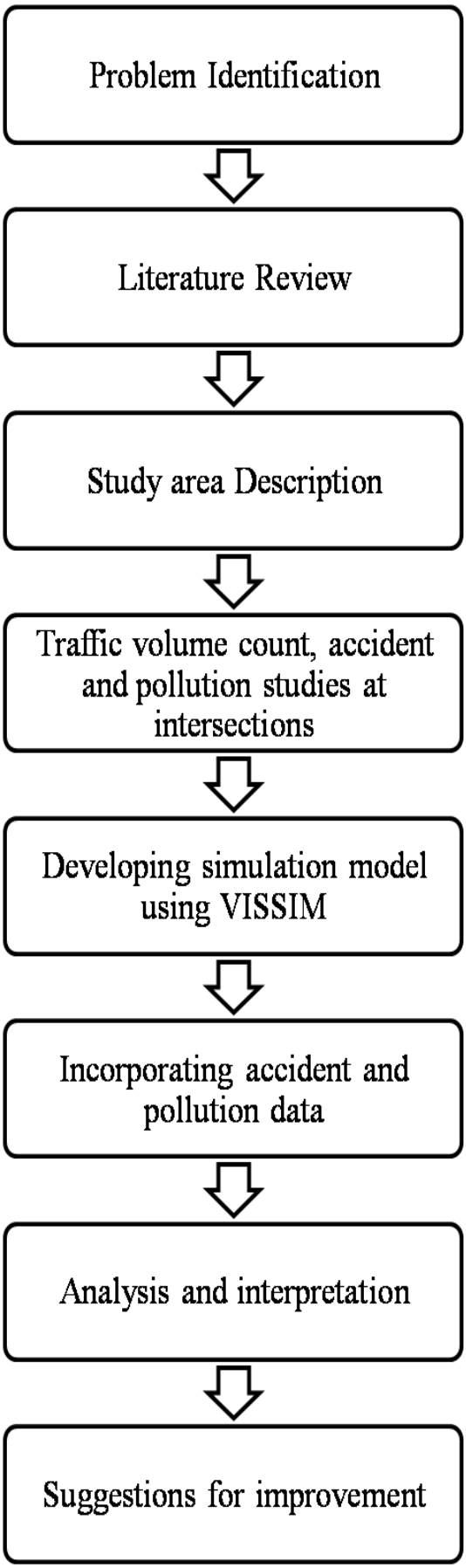

Figure 1: *Project Methodology.*

STUDY AREA DESCRIPTION

Madurai is one of the ancient cities in located in the state of Tamil Nadu in the Indian subcontinent. It is the third largest city in Tamil Nadu and 25th most populated city in India. Located on the banks of River Vaigai, Madurai is one of the oldest cities and has been a major settlement for over two millennia. The total area of the city is about 147.97 km^2 and it clocked a population of over 1,017,865 in the 2011 census. Madurai has a total of 9, 80,207 non-commercial vehicles and a total of 47,969 commercial vehicles as on 31.03.2018. The stretch from Palanganatham to Mattuthavani is selected for study. In this phase, Goripalayam and Periyar intersections are selected for data collection and preliminary analysis as they have significant delays, accidents and air pollution levels than other intersections.

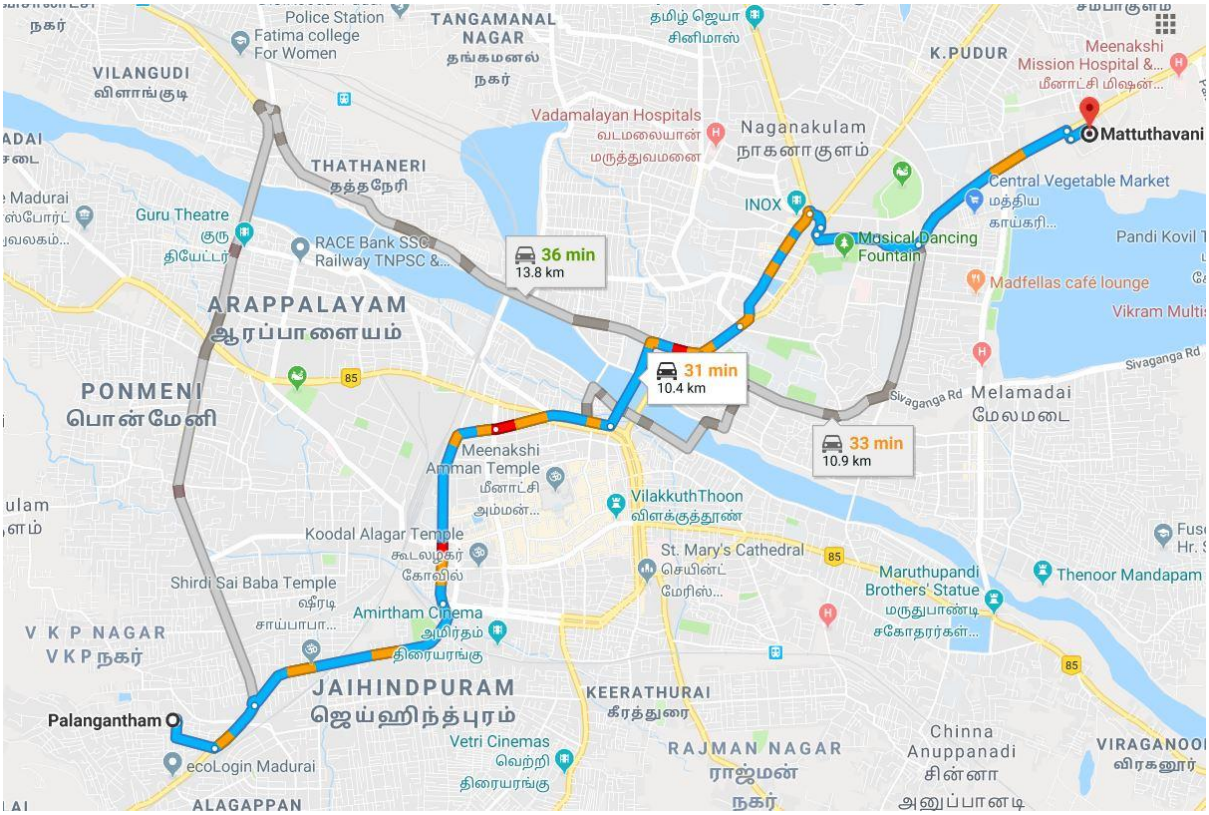

Figure 2: *Study Stretch – Mattuthavani to Palanganatham.*

DATA COLLECTION

To perform the simulation of traffic flow in an urban signalized intersection, incorporating accident and air pollution data the following data has to be collected.

- Geometry of the intersection
- Traffic volume at the intersection
- Signal control plan
- Peak hour details
- Possible conflicts
- Most prevalent climate

For this phase, geometry of the intersection, classified traffic volume count, pedestrian count, cycle time and splits and vehicular flow patterns were studied at Goripalayam and Periyar intersections.

Goripalayam Intersection

The following data of classified traffic volume count, pedestrian count, cycle time and splits and vehicular flow patterns were studied using observers at selected locations.

Cycle time and Splits

Goripalayam signal is manually operated by traffic police depending on the number

of vehicles arriving at each arm. The signal does not have any green signal countdown devices. There is a separate signal for pedestrian traffic. An observation of the general timing during peak hour (3.00 pm to 5.00 pm) was made. The results are as follows.

- Red – 45 seconds
- Green – 40 seconds
- Amber – 3 seconds
- Pedestrian red – 41 seconds
- Pedestrian green – 45 seconds

Vehicular Flow Pattern

Figure 3: *Vehicular flow pattern –Goripalayam.*

The observed intersection was a three phased intersection. The observed vehicular flow patterns are as follows.

1. Straight flow of traffic from Mattuthavani to Simakal
2. Straight flow of traffic from Simakal to Government Rajaji Hospital
3. Right turning traffic from Government Rajaji Hospital towards Mattuthavani
4. Free left turn from Government Rajaji Hospital to Simakal
5. Free left turn from Simakal to Mattuthavani
6. Free left turn from Mattuthavani to Government Rajaji Hospital

These were the traffic flow patterns observed. Left turns were permitted for the entire time and the rest of the traffic flow was ordered as mentioned above.

Pedestrian Volume Count

Goripalayam intersection has a separate signal for pedestrian traffic which was observed during 3.00 pm to 5.00 pm. The volume count was taken for every 15 minutes and the bar graph below shows the pedestrian volume for an hour. The pedestrian crossing is laid across the entire stretch of the road connecting Thamukam Grounds and Devar statue. The pedestrian volume counts showed that the peak hour was from 4.00 to 5.00 pm which might be due to the schools and colleges present in the area.

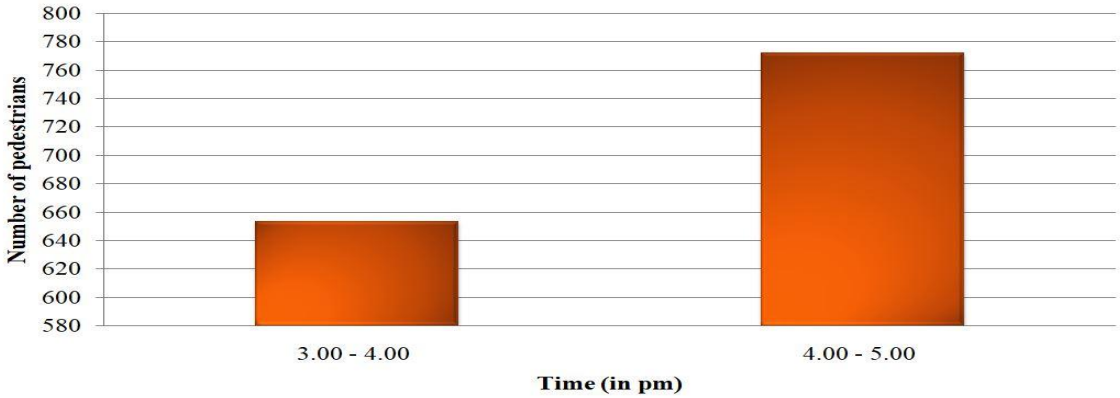

Figure 4: *Pedestrian volume count.*

Classified Traffic Volume Count

Classified traffic volume count was done at the intersection which showed the following results and the amount of traffic which was approaching the intersection from each arm. The figure is shown for both the hours separately. Classified traffic volume count of each hour was taken separately and was converted to PCU per hour values by multiplying with the following coefficients.

Table 1: *PCU Values*

Serial No.	Type of vehicle	PCU Values
1	Car/Jeep/Mini van	1.0
2	Bus/Truck	2.8
3	Two wheelers	0.75
4	Cycles	0.5
5	Auto	1

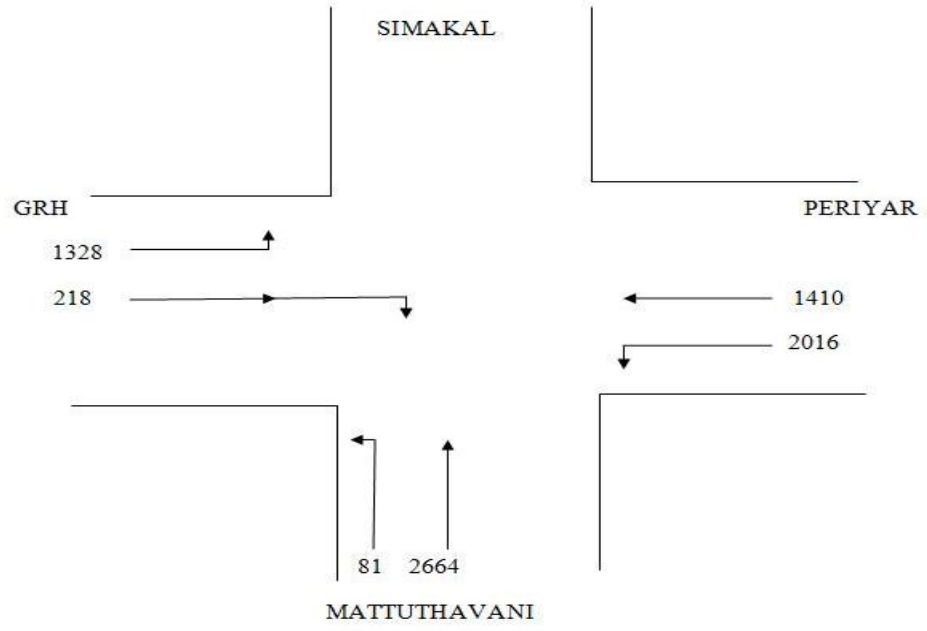

Figure 5: *Traffic volume count (3 to 4 pm).*

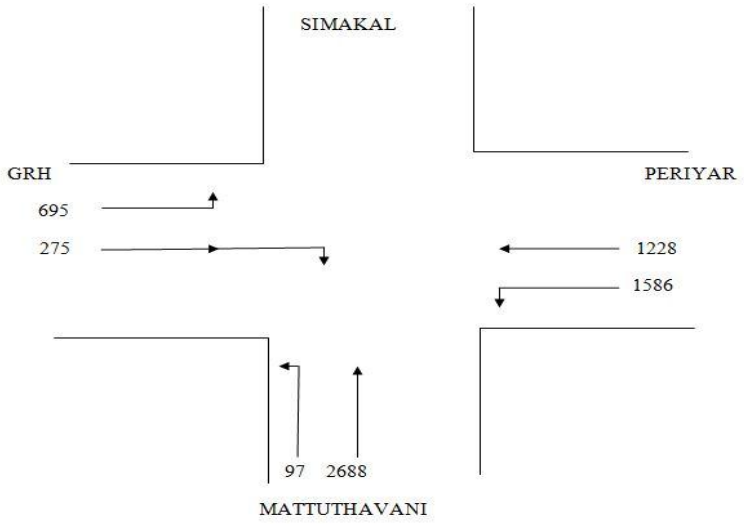

Figure 6: *Traffic volume count (4 to 5 pm).*

Periyar Intersection

The following data of classified traffic volume count, pedestrian count, cycle time and splits and vehicular flow patterns were studied using observers at selected locations.

Cycle Time and Splits

The signal at Periyar intersection is computerized and is operated automatically. There is no separate signal provision for pedestrian traffic. The signal has green and red signal countdown devices. An observation of the general timing during peak hour (3.00 pm to 5.00 pm) was made. The results are as follows.

- Red – 71 seconds
- Green – 33 seconds
- Amber – green to red – 5 seconds, red to green – 2 seconds

Vehicular Flow Pattern

Figure 7: *Vehicular flow pattern – Periyar.*

The observed intersection was a three phased intersection. The observed vehicular flow patterns are as follows.

1. Straight flow of traffic from Periyar to Mattuthavani, Right flow of traffic from Periyar to Keelavasal
2. Right flow of traffic from Mattuthavani to Kalavasal
3. Straight flow of traffic from Kalavasal to Keelavasal
4. Free left turn from Periyar to Kalavasal
5. Free left turn from Mattuthavani to Keelavasal
6. Free left turn from Kalavasal to Mattuthavani

These were the traffic flow patterns observed. Left turns were permitted for the entire time and the rest of the traffic flow was ordered as mentioned above.

Pedestrian Volume Count

Periyar intersection does not have a separate signal for pedestrian traffic and traffic volume count was observed during 3.00 pm to 5.00 pm. Since there is no separate signal for pedestrian traffic, they use the stretch when it is free. The volume count was taken for every 15 minutes and the bar graph below shows the pedestrian volume for an hour.

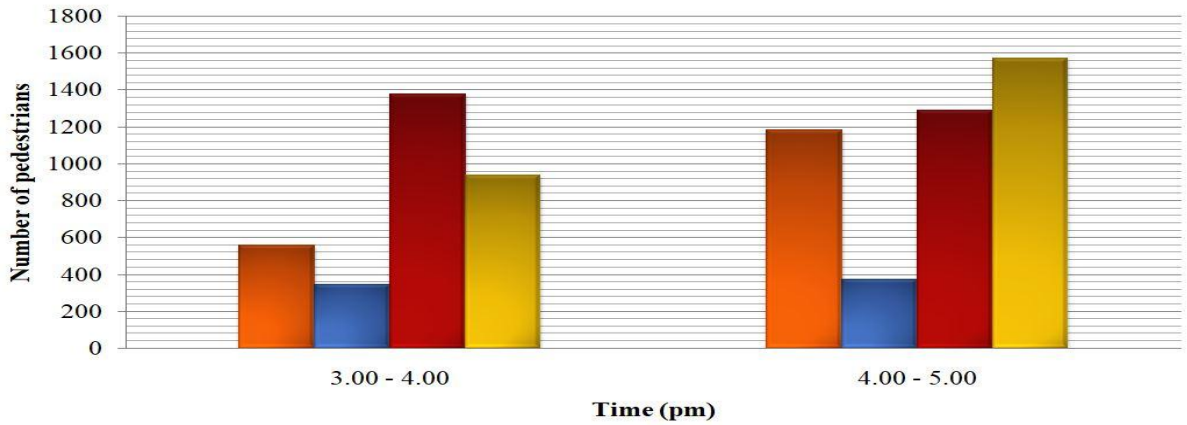

Figure 8: *Pedestrian volume count.*

Classified Traffic Volume Count

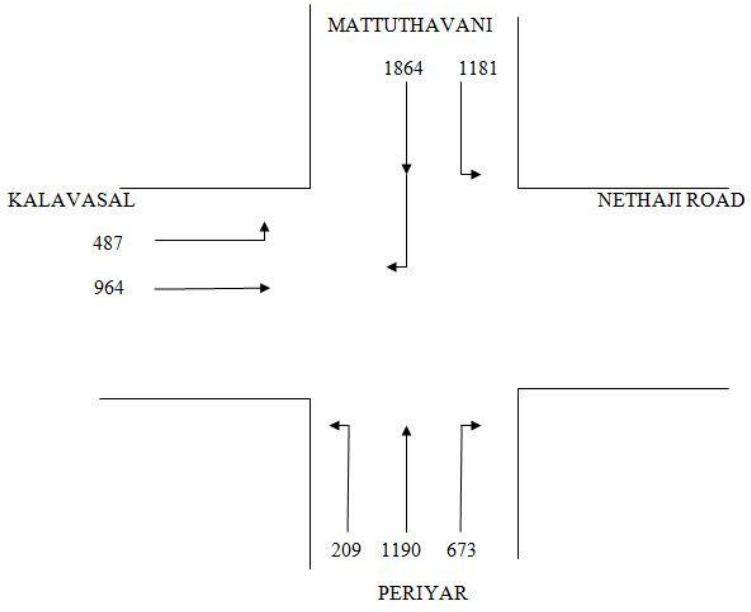

Figure 9: *Traffic volume count (3 to 4 pm).*

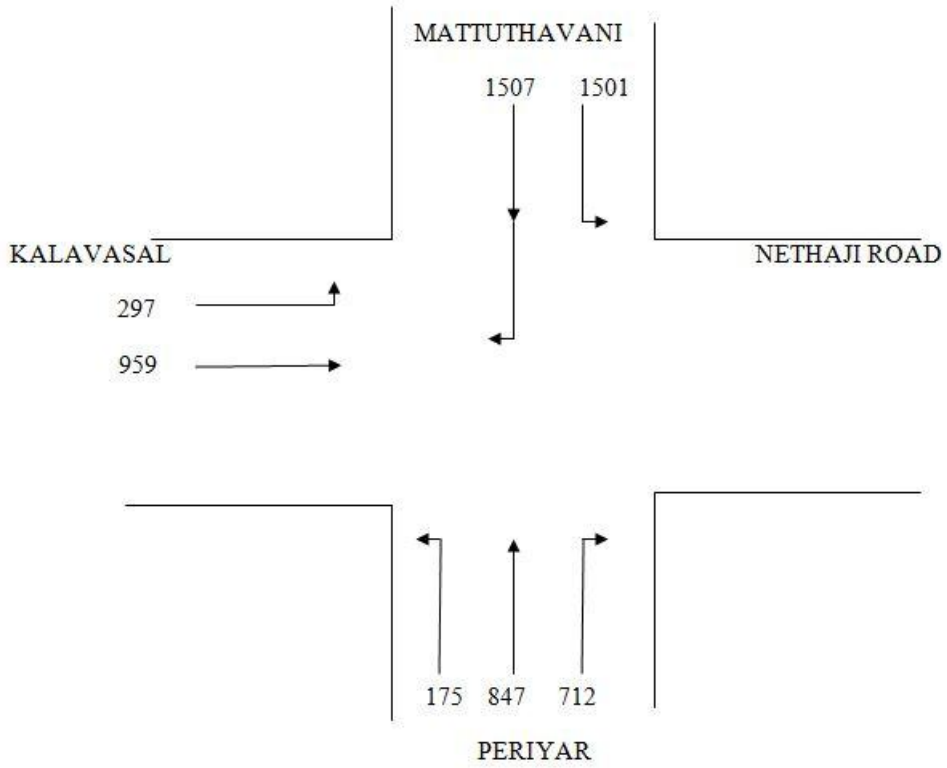

Figure 10: *Traffic volume count (4 to 5 pm).*

The traffic volume count data collected will be used for modelling the simulation of traffic flow in the intersection and also it will help in recognizing whether the intersection is adequate for the traffic that is to be served during the peak hour.

Accident Data

Accident data at the intersections was collected from commissioner office. This includes both fatal and non fatal injury at the three major intersections of Madurai namely Kalavasal, Periyar and Goripalayam.

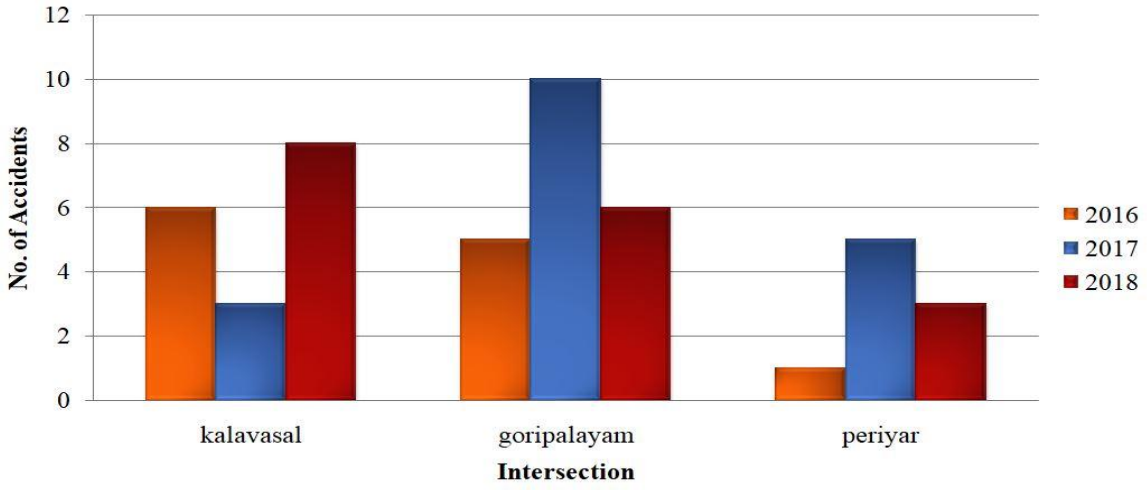

Figure 11: *Accident Data.*

Air Pollution Norms

The emission standards for vehicles are issued by the Central Pollution Control Board and are called Bharat Stage Norms. Currently Bharat Stage – 4 is implemented (2017) and BS – 6 is to be implemented by 2020. Bharat Stage norms are the one which are issued by CPCB and all the vehicles manufactured and sold in the country should comply with these values. This data can be used for modelling air pollution levels at the intersections and compliance with nominal air quality standards can be checked.

Table 2: *Air Pollution Norms*

VEHICLE	CO (g/km)	HC + Nox (g/km)	PM (g/kwhr)
CARS	1	0.18	-
HEAVY DIESEL VEHICLES	1.5	4.46	0.02
TWO / THREE WHEELERS	1	1	-

ANALYSIS AND RESULT

Data collection at Goripalayam and Periyar intersections has been carried out in this phase. Classified traffic volume count, cycle time and splits, geometry of the intersection, pedestrian volume count and vehicular flow pattern are the data that has been collected.

Cycle Time and Splits

Goripalayam has a manually operated signal for allowing three phases of traffic. Since it helps in a better and efficient movement of traffic, manually operated signal is found to be good for the spot. If the signal is computerized, then it will result in queue formation in one arm while another arm gets excessive green time. Another concern is that if the signal is computerized, coordination of signals for the entire stretch of Mattuthavani and Palanganatham can be done which will help in a more efficient movement of traffic. There are no Green Signal Countdown Devices at the intersection. It has been found that the installation of traffic signals with GSCD results in an increased number of rear end collisions during the green phase. Therefore, the occurrence of rear end collisions can be comparatively less in the intersection.

Periyar intersection has a computerized signal for allowing the movement of three phases of traffic in the shared space. Computerized signal can be useful if coordination of signals in the arterial is done. It would also be better to manually operate the signal since automatic signals results in long queue formation in one arm and excess green time in another arm. There are Green Signal Countdown Devices at the intersection. It has been found that the installation of traffic signals with GSCD results in an increased number of rear end collisions during the green phase. Therefore, the occurrence of rear end collisions can be comparatively more in the intersection. To avoid this, the GSCD can be removed and RSCD can alone be operated at the intersection.

Vehicular Flow Pattern

Goripalayam and Periyar intersection has three phases of traffic. Left turning traffic has been allowed for the entire time apart from which there is straight flow of traffic and right flow of traffic. These vehicular patterns have to be studied carefully to ascertain the possible conflicts that can arise due to traffic flow and due to disobeying of traffic signals.

Pedestrian Volume Count

Goripalayam intersection has high number of pedestrian flow during 4 to 5 pm which might be due to the schools and colleges present in the zone. The intersection also has a provision of separate pedestrian signal to facilitate the efficient movement of traffic. Also it is found that the pedestrian crossing lies in the road which is accommodating free left turning traffic. This results in an increased number of accidents in which the pedestrians are the victims. This should be avoided by either having the left turning traffic stop for a while to allow the movement of pedestrians or by having a traffic police who can help in the movement of pedestrians.

Periyar intersection has high number of pedestrian flow during 4 to 5 pm which might be due to the schools and colleges present in the zone. The intersection does not have a provision of separate pedestrian signal to facilitate the efficient movement of traffic. This results in an increased number of accidents in which the pedestrians are the victims. Since the number of pedestrians is very high especially during peak hours, it would be better to have a separate pedestrian signal to help in the safe movement of traffic. The presence of bus stand and railway station also results in an increased number of pedestrians and provision of separate traffic signal for them can help in an efficient movement of traffic.

Classified Traffic Volume Count

Goripalayam intersection has two critical arms which were observed. They are the arm from Mattuthavani to Simakal and the arm from Simakal to Government Rajaji Hospital. These arms had significantly more traffic flow than the other arms. When designing an optimized signal control plan this must be taken into account and extra timing for these arms must be allocated to avoid the formation of long queues. A large number of two wheelers and buses were observed since this route is used for connecting the two major bus stands namely Mattuthavani and Periyar in the city.

Periyar intersection has two critical arms which were observed. They are the arm from Periyar to Mattuthavani and the arm from Mattuthavani to Kalavasal. These arms had significantly more traffic flow than the other arms. Also this serves as an approach way for the four streets that surrounds the Meenakshi Amman Temple which also leads to a large number of vehicles, congestion and delays.

SUMMARY AND CONCLUSION

Urban roads play a major role in improving the connectivity and pave the road to social and economic development of the nation. Huge amounts of fund are allocated for the development of road and road projects.

Traffic signals which are mainly installed to regulate the flow of conflicting traffic in a shared space is one of the zones of major congestion causing delays, zone of accidents and major spot of high vehicular air pollutions. Hence it is highly essential to optimize the signal control plan which will reduce the adverse effects of the signalized intersection to a significant level and will help in improving the efficiency of the intersection providing a safer and sustainable zone for the road users.

Literatures have been studied and the factors to be included and data to be collected to obtain a micro simulation traffic model along with accident and pollution data have been identified. Based on the review of literatures, preliminary data collection has been carried out at the selected intersections. The classified traffic volume count, vehicular flow, regulation of traffic, cycle time and splits for each arm of the selected intersection will be surveyed in the field which will be used to produce a micro simulation model using VISSIM. The possible conflicts that can occur due to access density, access points, violation of traffic signals, rear-end

collisions will be studied and incorporated with the traffic simulation model.

The simulation model will then be used to obtain an optimized signal control plan which will help in reducing the congestion, delays, accidents and air pollution levels at the selected intersections. The difference between the existing signal control plan and the proposed optimized signal control plan will be studied and efficiency will be found out.

This phase is concluded with literature survey, study site selection and preliminary data collection. Phase II will include the development of VISSIM simulation model incorporating accident and pollution data and an optimized signal control plan will be identified which will increase the efficiency of the intersection.

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