An Integrated GIS, Optimization and Simulation Framework for Intelligent Traffic Signal System

By

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DEDICATION

“To my beloved Father whose words of encouragement and push for tenacity rings in my ears”,

“To my Mother who have given me the drive and discipline to tackle any task with enthusiasm and determination”

ACKNOWLEDGEMENTS

All praises to Allah Almighty Who is the most merciful. To Whom all the knowledge belongs and Who is knower of unknown. All thanks to Allah who blessed me with guidance and knowledge to achieve this.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
GA	Genetic Algorithm
GIS	Geographical Information System
GIS-T	GIS for Transportation
ICM	Inner Cellular Model
ICT	Information and Communication Technology
IoT	Internet of Things
ITS	Intelligent Transport System
NADRA	National Database & Registration Authority
OCM	Outer Cellular Model
OSM	Open Street Map
PCP	Phase Cycle Planning
PLC	Programmable Logic Controllers
PSO	Particle Swarm Optimization
RFID	Radio Frequency Identification
SUMO	Simulation of Urban MObility
SUMO-TLS	SUMO Traffic Lights System

ABSTRACT

Installation of traffic signals is an essential prerequisite for effective functioning and to control traffic congestion in urban areas. Intelligent traffic signal control system is considered more effective to manage large queues of vehicles at junctions. In this research, an intelligent traffic signal system is simulated by an integrated Geographical Information System (GIS), traffic simulation and optimization framework, which is aimed to maximize the numbers of vehicles passing through a traffic junction in minimum amount of time through traffic signals cycle optimization. GIS is incorporated to process the data, provide user interface and for the visualization of results. For optimizing traffic signals, Particle Swarm Optimization (PSO) is performed which consider fitness evaluation and velocity value of associated particles to get successful optimization. Fitness measure is a function that measures the closeness of the obtained solution to the given objective. Optimization of traffic signals at mentioned study areas is evaluated in a simulation model, namely, Simulation of Urban MObility (SUMO). The results obtained from baseline and PSO algorithm applied methods are compared with default trip generated in simulation model. Mean travel time for both SUMO-TLS as well as PSO-TLS were collected, simulated, analyzed and compared. Optimized system shows 12% decrease in mean travel time. Mean waiting time of each vehicles moving in traffic light system generated by PSO algorithm is 10% less than SUMO-TLS. PSO traffic light system shows less mean travelling time and mean waiting time as compared to the traffic lights generated in SUMO.

Chapter 1

INTRODUCTION

The rapid development of cities is leading toward haphazard urbanization which is following to numerous city management, planning and operational issues. Around the world more than half of the human population tends to live in cities. It is predicated by United Nations Development Program that population will exceed about two third of worldly population by 2030. Extensively populated cities has already created numerous city management, planning and operational issues. These all are public related issues that leads to awful impact to the accommodating settlements.

Among all these issues, management of traffic flow on roads is a critical problem which is very unfavorable for the economic growth. Traffic congestion is a very complicated issue to be solved as urban traffic system consists of extensive roads networks, large no of vehicles, traffic signals and pedestrians. Many steps are already taken for eradication of this traffic congestion problem but it appears to be an incapable issue to be solved thoroughly. Several solutions such as, construction of new road, road widening and installation of traffic signals are expected to reduce this problem.

Installation of traffic signals are required for effective functioning of an urban area and to avoid traffic congestion. Traffic signals are very basic equipment which governess basic rules and are quite necessary for managing traffic flow. The use of traffic signals- allow maximum usage of existing infrastructure which is particularly necessary as funding resources are scarcer for the development of new infrastructure. Daily thousands of precious hours are wasted while waiting for these signals to turn green which make it need of the hour to find an optimal solution how exactly these signals have designed to behave which avoid such a wastage of time. Traffic signals control is now the matter of concern.

Ideally, formulation of a model which optimize the traffic signals according to traffic flow with theoretical assurance on the given solution is required (Chen and Wang, 2017). Although, it is not easy to model such a problem as large number of variables are considered here i.e. traffic volume, behavior of traffic signals, road layout, etc.

Traffic signals are of two types i.e. fixed time traffic signals and Real time traffic responsive control system. Fixed time traffic signals are the simplest one which does not need any detector to count the traffic flow at the junction. In this type of traffic signals vehicles moves according to the change in traffic lights and have fixed time for green light. Revaluation and recalibration is always required to make fixed time traffic signals work properly and could not respond any exception.

Real time traffic responsive control system need detectors to count algorithm traffic and change the traffic lights accordingly. In addition to the detector, optimization for traffic count is also very important. Recalculation and revaluation is always occurring for determining the lights duration and to keep them synchronized. With the help of real time traffic control system installed at junctions, 10-60% vehicular delays at traffic signals can be controlled. Less traffic congestion, less delay time at red light on traffic signals leads to reduce fuel consumption, environmental pollution, sound pollution, and time and energy waste.

Real time traffic responsive control system is considered more effective to avoid large queues of vehicles at junctions. In this research, an approach for traffic management at road junctions is presented which includes optimization for real time traffic signal cycle. An intelligent traffic signal system is proposed by designing an integrated Geographical Information System (GIS), traffic simulation and optimization framework. GIS is incorporated to process the data, provide user interface and for the visualization of results. For optimizing traffic signals, PSO is used which consider fitness evaluation and velocity value of associated particles (Lights) to get successful optimization. Fitness measure is a function that measures the closeness of the obtained solution to the given objective. Optimization will be evaluated in SUMO simulator. This proposed research will results into an intelligent traffic signal cycle which will increase the number of vehicles passing through a road junction and help in reducing their travel time.

1.1. LITERATURE REVIEW

Over the past few decades, GIS is extensively used in a wide range of transportation planning, management and decision making applications. Among all these years, GIS has evolved from data management and mapping tool to an analysis and modelling tool, facilitating spatial decision problems. Integration of different models with GIS has helped in enhancing the functionalities of GIS. The field of GIS for Transportation "GIS-T" is rapidly growing with the amalgamation of transportation models with GIS. (Thill, 2000; Fletcher, 2000; Miller and Shaw, 2001; Goodchild, 2000). Several studies have been carried out in the field of GIS for transportation, such as, incidents management, pavement conditions, routing, optimization of traffic signals etc.

The capabilities of GIS dealing with spatially referenced information is helping in managing transportation operations (Huang and Pan, 2007). To contend with traffic congestion problem, with the help of different information technology techniques i.e. GIS, optimization and traffic simulation, a smart traffic signal strategy is proposed.

Efforts have been implied for the collection of the vehicle density. In many studies, the vehicle density is calculated through video processing for smart traffic light switching. At least, four cameras are needed to install at each side for capturing vehicles, broadcasting to the server for calculation of vehicle load at each side and then algorithms are applied to optimize traffic light accordingly. MATLAB video processing toolbox is also used with C++ compiler for extracting information from CCTV camera video (Kanungo et al., 2014).

An image mosaic based procedure is also very helpful for designing an intelligent traffic signals system. The vehicular data is collected from CCTV cameras installed at every intersection point. In this procedure, the RFID reader detects RF-active code from the active tag pasted on the car. After receiving the code data is stored in database in the server. Then the data stored in the database is used to calculate the vehicular maximum flow, interval time and average car speed. After collecting all possible congestion roads and car speed, then this data will be used as an input parameter to the traffic signal control simulation model in the server. After getting traffic simulation results, the system is able to give the alternative according to the traffic conditions (Mittal and Singh, 2013). Extracted information could also be helpful in future road management, planning, analysis and decision making. Here, low light after sunset could be a problem in extracting vehicles density information but other weather conditions does not affect much as these conditions would be same at each side of junction. Other than cameras installation, vehicle detecting sensors could also be employed for the computation of vehicular density. On these calculated vehicular density optimization algorithms are than applied for the formation of a real time traffic signal cycle.

In the recent years, trend of using information technology for controlling traffic congestion and eliminating the vehicular delay at traffic junctions has increased. For this purpose, Adaptive traffic signal control system can also be developed by using numerical experiment conducted by Monte Carlo simulation. Intelligent traffic signals are analyzed with and without considering pedestrians and conclusion is made that this method is more effective in the situation where pedestrians are not involved and with low load level of traffic (Andronov and Leverents, 2018).

Several approaches are available for optimization for smart traffic light system. Intelligent traffic signal system is considered to have a real time impact of traffic condition present on the road networks. In this regard, queue theory could be used to determine the queue lengths of vehicles stop at red light (Tubaishat et al., 2008; Zhou et al., 2010).

Over the past few decades fuzzy controllers have been successfully used in number of industries and consumer applications. It is also widely used for adaptive traffic signals system because of its flexibility of dealing with uncertainties and it allows qualitative modelling of complex systems. To overcome traffic congestion, accidents traffic irregularity an intelligent traffic signals control system is established by applying fuzzy logic for multi-agent based system using wireless sensors. The timings of traffic lights (red, green and amber) are according to the real time traffic on road for this purpose image processing techniques are used to obtain the real time parameters such as queue length and traffic density on road. Fuzzy controller is suitable for four way adaptive traffic signals with mixed traffic, including high proportion of motorbikes. This system can give preferred results by minimizing the waiting time of the vehicles. (Salehi et al., 2014).

Several other studies used fuzzy logic operations to determine the time required for any color state of traffic signal (Zou et al., 2009). These type of systems are implemented on a single board computing devices which can apply their own control logic and present solutions by communicating with modern traffic signal devices (Jintamuttha et al., 2016). Moreover, in different studies, for minimization of the queue length at a junction fuzzy traffic light controller along with Genetic Algorithms (GA) optimization are also used (Jin et al., 2017).

It has been widely recognized that adaptive traffic signals at intersections provide most effective and economic way to resolve serious urban traffic problems. To optimize these traffic signals are now the challenging as well exciting problem. An inner and outer cellular automation (CA) mechanism along with PSO is conducted to establish an effective global traffic signals optimization method. The combination of Inner Cellular Model (ICM), Outer Cellular Model (OCM) and fitness function is IOCA-PSO method. ICM deals with the conservation of traffic light schedule setting and flexibly control the change in them, OCM optimizes the setting in ICM and fitness function calculates the fitness value and is link between OCM and OCM. Whereas, fitness value evaluates the settings in ICM and helps in optimization in OCM. This method can be very effective for global scheduling of traffic signals for urban traffic which includes, timing control, phase sequence control and special traffic control in case of any emergency. This method is efficient for controlling dynamic as well as optimize traffic light system. In ICM, Different types of transition rules helps phase cycle planning (PCP) algorithm in achieving phase control of complex traffic problems. The combination of PSO and OCM benefits in proposing a strong ability to figure out the optimal timing control. By comparing IOCA-PSO method with PSO method, RANDOM method and GA, IOCA-PSO methods achieves better scheduling, in limited time, under different traffic conditions (Hu et al., 2016).

The Biham Middleton and Levine (BML) model has been used to capture the fundamentals of traffic congestion and trends of traffic flow. This model has capabilities to provide effective results in the means of dynamic and uncertain traffic flow condition in any urban area. Enhance BML model is helpful in simulating the traffic at urban network while timing schedule optimization (TSO) algorithm on the basis of quantum particle swarm optimization is devoted for scheduling the timings of traffic signals. Firstly, the actual two ways road network are mapped into BML model. Now, vehicular flow can be controlled by the introducing rules in simulation. Form the information acquired by simulation, the testing of the traffic flow from the intersection will be optimized and thus, results in getting optimized traffic signals (Hu et al., 2018).

Initially, GA and PSO both uses random population/ particle and get optimized results as generations updated. It is proved that PSO can be implemented at the same scenario where GA could be implemented and also agreed by experimental results with the fact that PSO is far better than GA (Wijiaya and Uchimufra, 2015). PSO consider particles associated fitness evaluation and velocity value to get successful PSO optimization (Panovski and Zaharia, 2016). Fitness measure is a function that measures the closeness of the obtained solution to the given objective. New set of particles is formed by computing and comparing 'pbest' and 'gbest' values. Programmable Logic Controllers (PLC) is the common technology behind traffic light controllers. PLC are devices with the ability to perform task without human involvements at all time, without considering duration and weather condition. PLC is the common technology behind traffic light controllers. In this research, PLC module with PSO algorithm is used for optimizing the green light timing of the signals. The module presented has the ability to determine three states of present traffic condition on road i.e. crowded, normal or empty. It is concluded from the results that the traffic light module based on PSO algorithm provides improvement in the traffic flow ratio up to 85% to 95% at different intersections (Kareem and Mejbel, 2018).

The intelligent methods have been proved essential for the traffic signals cycle program optimization (Angulo et al., 2008; Sa´nchez et al., 2008). Intelligent method like PSO algorithm (Montes de Oca et al., 2009; Kennedy and Eberhart, 2001) can be very helpful to achieve optimal phase cycle for the traffic signal system. For traffic signals optimization the features compel to use PSO algorithm instead of other is its fast coverage which is highly required in for phase cycle optimization where this cycle has to be changed according to continuously updating traffic conditions.

PSO algorithm is considered easy to implement because it has a few tuning parameters and it has the ability to predict future issues for this system by the help of independent agents in the system (Clerc and Kennedy, 2002; Montes de Oca et al., 2009; Kennedy and Eberhart, 2001). Using this algorithm phase cycle of lights are obtain for two heterogeneous metropolitan areas having hundreds of traffic signals installed there. The solution is then evaluated in the microscopic traffic simulator under different roads traffic situations. This system results in reduction in travelling time of vehicles as compare to static signals system (García-Nieto et al., 2012)

PSO could also be adopted under SUMO simulation model. SUMO is a continuous, microscopic, multi-modal traffic simulator which has ability to simulate even a single vehicle moving through a traffic network. In SUMO, there are two component of traffic light system i.e. color state program and time duration. Throughout the process, all color states with duration have fixed set of combination that could only be changed once simulation is finished.

To cope with traffic congestion problem, it is beyond doubts that it is a necessity to install smart traffic signal system with optimized cycle that is in-sync with adjacent traffic junctions. For this purpose, traffic volume data and road network information from Open Street Map (OSM) will be used. Road network will be generated for simulation of the process by using Netconvert plugin in SUMO. Here, Python libraries will be used for route mapping and to run the simulation. An optimization technique based on PSO, will be used to implement on traffic light cycle. Several features of PSO leads to choose this optimization technique i.e. it has fast convergence, which is highly needed for optimized traffic light cycle to address the updated traffic scenario. It requires a small amount of parameters for implementation and is easy to implement. It is a kind of swarm optimization can predict future issues. For the evaluation of the proposed traffic signal optimization, SUMO simulator will be than be used.

1.2. RATIONALE

Worldly population has become 7.7 billion in year 2019, which shows an increase of approximately 1 billion from the year 2007, so, it can be estimated that population size has capacity to reach between 8.5 to 8.6 billion till year 2030. Growth in population leads to increase in vehicles on roads and lack of efficient traffic management system which results into huge economic and environmental issues. With the increase in population size, the biggest hindrance which is restraining city's economic development is traffic congestion by resulting into high consumption of fuel which results into increase in cost of commutes and also pollutes environment. To reduce this traffic congestion smart traffic management system is the most promising approach that can adapt according traffic situations and hence, reduce the traffic congestion problem.it is cost effective method, it could be integrated with already existing infrastructure. Intelligent traffic signal system will reduce the travel time and stop frequency and thus, will be helpful in reducing rear-end collisions. The propose study will significantly present a low cost, easy to adapt solution to the traffic congestion. It will save the driver money, reduce vehicle emission and hence, reducing the congestion cost like fuel and lost time. Reduction in traffic congestion could be a factor that helps in economic stability as traffic congestion cost 3 million per day in Pakistan.

1.3. OBJECTIVES

The specific objective of the research is as follows:

- To maximize the numbers of vehicles passing through a traffic junction in minimum amount of time through traffic signals cycle optimization.

1.4. SCOPE OF THE STUDY

The work displayed in this research indicates that to cope with traffic congestion problem our major cities demand application and implementation of effective intelligent traffic signals system. This study covers the concept of amalgamation of GIS for Transportation (GIS-T) in the form of intelligent traffic signals system, its benefits and evaluation of this system by simulating intelligent traffic signals. Strategies and challenges faced during the efficient implementation of this system. For this purpose, three junctions present on khayban-e-iqbal road near Shah Faisal Mosque, Islamabad are taken as case study by taking count of their six month traffic volume. PSO is used for optimizing the traffic signals and an urban mobility simulating software named SUMO is used for evaluation of this optimization.

1.5. RESEARCH CONTRIBUTION

A metaheuristic optimization technique is used for solving the optimization problems which is suitable to solve the traffic light signals timing problems. This research addresses the traffic flow management and congestion problem at traffic junctions in urban areas and as a solution to it a signal optimization method is proposed. In the research, an open source simulator

SUMO is used with PSO optimization technique that results in minimization of time of the vehicle and minimized the amount of vehicles passing through a signal. In the presented work optimization technique is proposed which will be beneficial for finding optimum light cycle for traffic signals. This optimization technique is based on PSO algorithm which is evaluated in SUMO simulation model. For this purpose, experiments were conducted on three traffic junctions with an average of six months traffic volume data. The results were then analyzed for both STLS and PSO based traffic signals simulations and were benchmarked against each other. The obtained results show that PSO outperformed STLS solution. We observed a remarkable decrease in mean waiting time (waiting duration) in PSO technique as compared to STLS technique. The obtained results show that our proposed solution can lead to real improvement in real time traffic congestion situation. Use of GIS, Remote Sensing will help minimize the average waiting time and average travel time.

1.6. STRUCTURE OF THESIS

The following is a breakdown of the thesis's structure. The literature review of available research follows the introduction in Chapter 1; Chapter 2 explains the technique utilized for this work, including the study area, tools and technology, and the step-by-step technique employed in this study; Chapter 3 presents the results gained while implementing the technique and their analysis, while Chapter 4 wraps up the current work by describing the study's uncertainties and outlining future directions.

Chapter 2

MATERIALS AND METHODS

2.1. STUDY AREA

Islamabad is designed by the Greek architect CA. Doxiadis in 1960s as a capital city of Pakistan, is the first and only planned city of Pakistan. It is located at latitude 33.7214813 and longitude 73.0432892, in the northern hemisphere. It is renowned for its safety, high quality of living, and superabundant greenery. It attracts people from all over Pakistan, which make it one of the urbanized and cosmopolitan cities of Pakistan.

With increasing population in Islamabad, the traffic on the roads is also increasing that causing traffic congestion. For traffic management fixed type of traffic signals are present here and from 80 traffic signals only 40% are functioning properly. Study area is selected on the recommendation of NADRA officials (safe city project) according to the availability of properly working traffic signals and CCTV cameras on them. Therefore, three junctions on khayban-e-Iqbal road near Shah Faisal Mosque are taken as study area which is shown in Figure 2.1.

2.2. DATA SOURCES, QUALITY AND LIMITATION

For research this, we have studied the literature and the research arenas that are available online for advance technologies that are in use. Dataset used

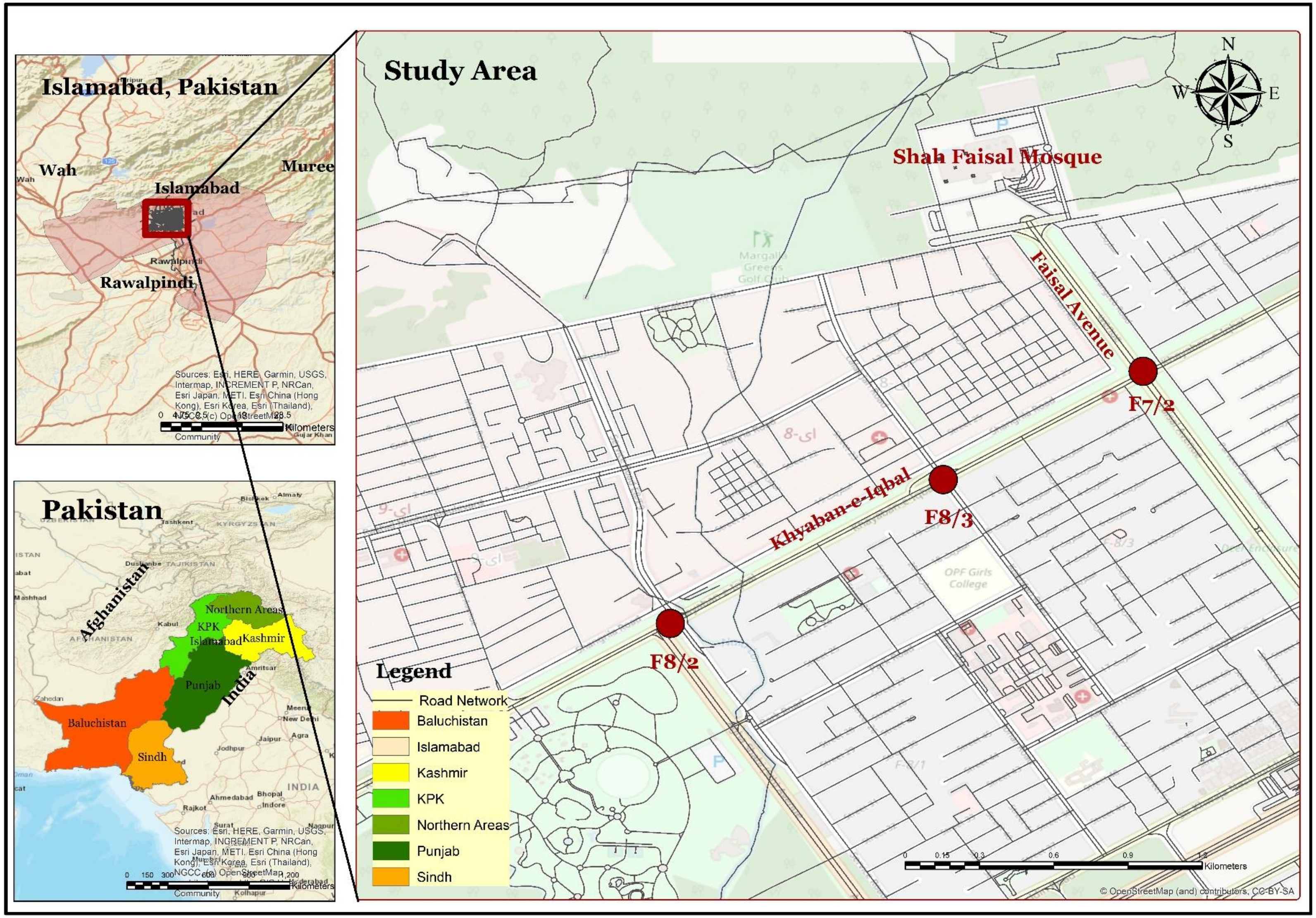

Figure 2.1. Location map of study area

with their source of retrieval along with the software used in research work are discussed below.

2.1.1. DATASET

Vehicular information of all four sides of selected junctions are acquired form safe city project, NADRA, Islamabad. NADRA has implemented this safe city project in Islamabad, capital city of Pakistan. For intelligent video surveillance almost 2000 security and CCTV cameras were installed all over the city. Electronic RFID tags, Smart ID cards, Smart Vehicle Registration Cards, citizens and vehicles databases are facilitating in implementation of the project for both vehicles and individuals authentication. Already built system is than complimented by installation of CCTV/IP cameras and RFID tag readers and placed at strategic locations all over the city, which is resulting in an effective monitoring and control system.

For the management of traffic fixed light plan traffic signals are present in Islamabad and only 40% of 80 signals are functioning properly. 1800 CCTV cameras are installed as the part of Islamabad Safe City Authority, out of which 600 cameras are not in working condition. Cameras located at Motorway Chowk, Faizabad, F-10 Markaz, Kashmir Highway, Ninth Avenue, Trnol and Sangjani are not functioning.

In our research, study area is selected on the recommendation of NADRA officials (safe city project) according to the availability of properly working traffic signals and CCTV cameras on them. Study area map along with it positional information i.e. longitude and latitude are imported from OSM, dataset details are

Table 2.1. Dataset used for developing intelligent traffic signal system

Data	Type	Time Duration	Source
Traffic Data	Volume of traffic at selected junctions	Six Month	Safe City(NADRA-Islamabad)
OSM	Road Network	Latest	Open Street Map(OSM)[1]

Table 2.2. Software deployed for developing intelligent traffic signal system

Software	Purpose
SUMO (Simulation of Urban MObility)	Network Generation Vehicle Routing Simulation
Python	Running Particle Swarm Optimization (PSO)

[1] https://www.openstreetmap.org

given in Table 2.1. It is a joint project in which information is freely changed by anyone. Unavailability of map data of are two aspects which support use and development of OSM. Map data can be accessed free at any time and is available on internet. This map could be more detailed than any commercial map as it undertakes from an update almost every minute.

2.1.2. SOFTWARE DEPLOYED

For intelligent traffic signals simulation, PSO algorithm the basic problem solving technique, is adopted under SUMO simulator which evaluates the solution acquired. These two techniques are explained as follows, Software required for this research and their purpose are given in Table 2.2:

SUMO is a continuous, microscopic, multi-modal traffic simulator which has the ability to simulate even a single vehicle moving through a traffic network. It is also capable of modelling traffic on networks larger than single city, e.g. highway networks, without any changes. In this simulation model, total demand of vehicles will be created on already generated road network and then successful simulation will be performed.

Network generation by using Netconvert (a plugin in SUMO), digital road network will be extracted from OSM in .net.xml format. OSM is proposed to be used because it contains both geographic as well as traffic light information data. This file have the information about the structure of map i.e. nodes, edges and the connection between them.

Route generation after generating road network, vehicular route will also be generated in .rou.xml format that can further be simulated in SUMO model.The information about each vehicle departure, arrival and waited time, total duration of journey and temporal stops in driving will be registered in a file in format .tripinfo.xml. This journey information file will then be used for the evaluation of traffic signals cycle programs.

Python programming language is an open source, object oriented programming language. It is easy to understand and use, and concise. This programming language has become common to engineers for software generation and is also being used by companies for making commercial software.

PSO is an intelligent optimization algorithm based on the paradigm of swam intelligence and is inspired by the social behavior of animals like birds and fish. Initially, it was designed for continuous optimization problems. Each particle solution to the problem is known as particle position and particle population are called the swarm. It can optimize larger scenarios traffic signal cycle programs including hundreds of traffic signals, vehicles, and other elements. The best optimized cycle of color states of traffic signals will be computed with the help of particle's (vehicle) personal best and global best values.

Results obtained from simulation are in XML Format. XML is Extensible Markup Language which is continuation of internet tracking language named HyperText Markup Language (HTML).XML is a language created for exchange of data among different systems. It is created to store and manage data in simple and easy manner. The main word use in XML is data, which give information after processing. It provide both standardized as well as modified means to describe information present in document.

2.3. ANALYTICAL FRAMEWORKS

Through Netconvert which is a plugin in SUMO, road networks are generated from exported open street map which form nodes, edges and connection between them. Then, using vehicular density data that is acquired from safe city project (Islamabad), number of vehicles route are generated in extracted road network. Then in this simulation traffic signals indication are also added.

For optimizing these added signals by PSO algorithm random initial values are taken, fitness of fit of particles are evaluated. By Personal best and global best of the particles their position and velocities are updated. By reaching at their max iteration optimized algorithm is than created. Than this optimized traffic signal cycle will be evaluated by simulation in SUMO simulation model as shown in Figure 2.2.

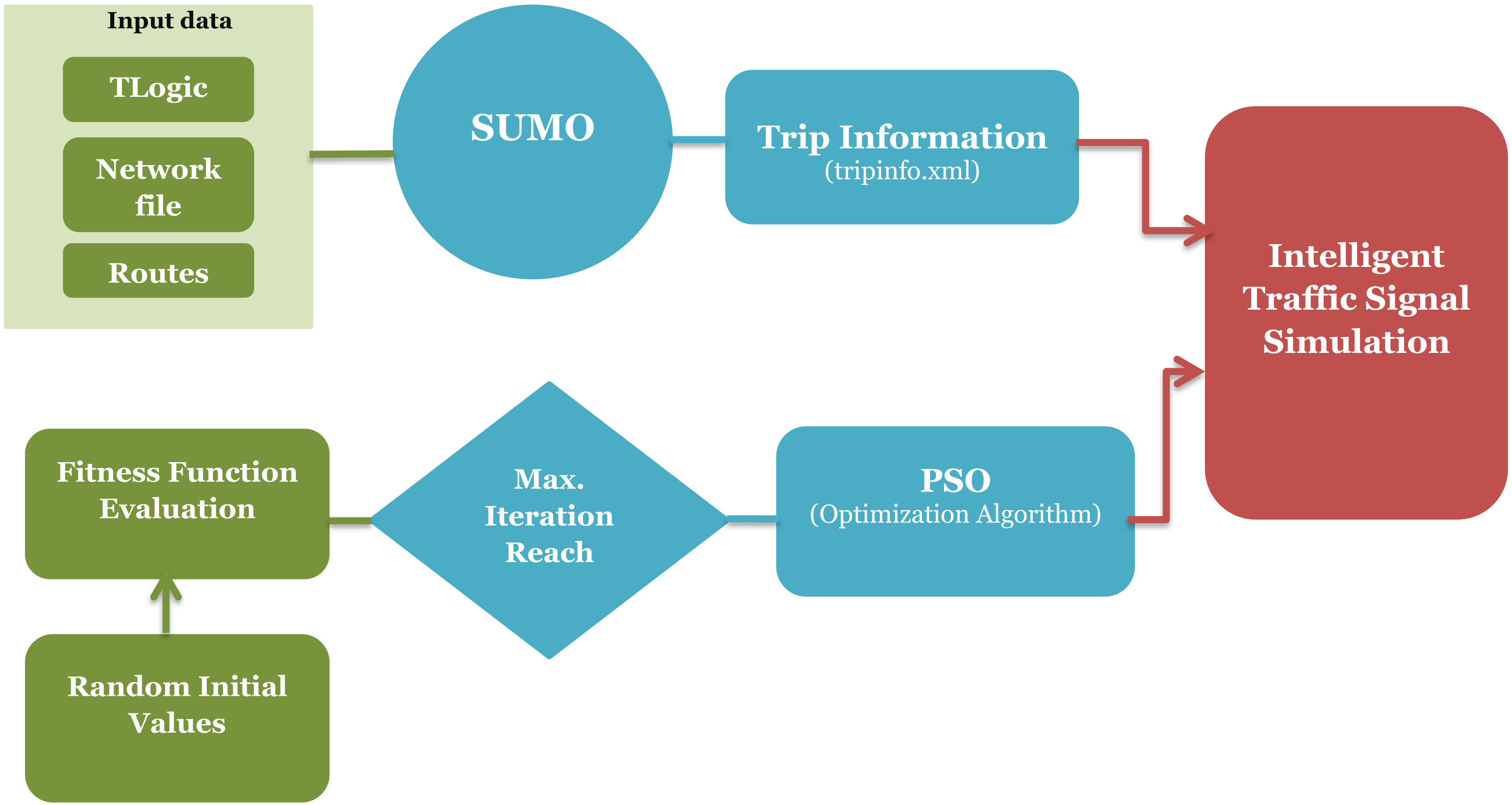

Figure 2.2. Methodology flowchart of intelligent traffic signal system simulation

2.2.1. VEHICULAR SIMULATION

Advance technology is recommended to sort out this traffic congestion issue at very lowest possible financial support. The solution is to estimate the vehicular density at metropolitan area using urban mobility simulation which is form on the bases of Intelligent Transport System (ITS). ITS is intended to attain traffic efficiency by reducing traffic issues. It gives traffic temporal data including real time data, which helps the commuters by reducing their travel time as well as providing them safety and comfort.

ITS is a system which is based on Information and communication technology (ICT). The information acquired from ICT can be applied to ITS, it supports the concept of smart city. SUMO can accurately simulate vehicles individual behavior in their actual environment and is known as a realistic traffic simulator. A large number of traffic problems can be treated using traffic simulators. Movement of each vehicle have to explicitly model on its own path of movement in the road network.

Vehicular information is acquired form requested data and then adjustment of this information on Open Street Map (OSM). OSM is freely available and is digitally developed which gives positional information i.e. longitude and latitude of each point. With the help of positional information vehicular information is estimated and will be continuously updated to get its updated location information which results in stable vehicular information.

Open Street Map is freely available on internet. It is an open source software, as it has slippy map interface and gave access to its API. OSM data of study area is downloaded from OpenStreetMap website which is shown in Figure 2.3. In this map, road network of all three junctions taken as study area are imported.

Road Network Generation

Netconvert is an application, which is used for network generation in SUMO. It has capacity to read shapefile and OSM format. Here, OSM format is used for generation of road network and to import downloaded OSM data to SUMO following command is used:

Netconvert --osm-files Map.osm.xml –o Network.net.xml

Where,

INPUT -- Map.osm.xml = OSM data file

OUTPUT -- Network.net.xml = generated road network file

The command is used in this research and generated road network in SUMO is shown in Figure 2.4. SUMO also have capability of reading XML format. In the XML representation of road network files are divided into further five types i.e. edges, nodes, edges types, connection and also fixed traffic light plans for the junction present in road network.

Road network here is generated for merely for routing purpose. As the road generated have lack of details required for microscopic traffic simulation such as; no of lanes on road, particularly near intersections, information about two lane connection and light plan and position of traffic signals etc. Using graphical

Figure 2.3. Open Street Map road network of study area

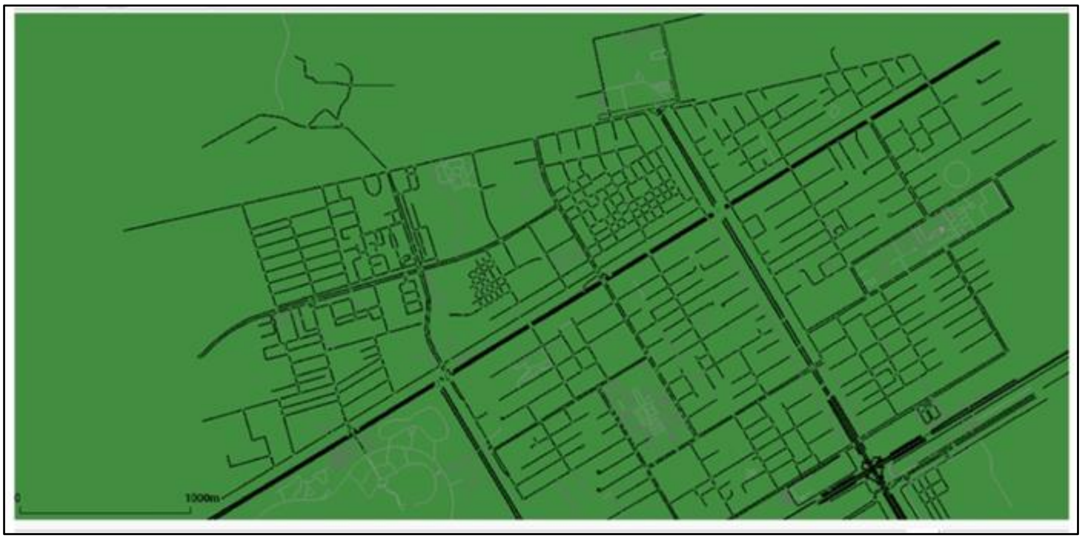

Figure 2.4. Imported road network into SUMO simulation model

network editor in SUMO, named "*Netedit*" road networks are edited, which has graphical user interface almost similar to SUMO-GUI.

Vehicles Route Generation

After creation of road network vehicles are added to it. In SUMO, which is clearly a microscopic simulation model, vehicles are added explicitly. Unique ID is provided to each added vehicle with their departure time and exact route. Route is the movement of a vehicle from starting edge to destination edge along with the information of all edges through which vehicle passes. In SUMO very fine detail of each vehicle such as, vehicle velocity, its lane, movement on edge, vehicle type and its physical properties, is described. Vehicles can be assigned into different classes on the basis of available pollutants and noise emission. Additionally, there are variables which deals with appearance of the vehicles in simulation.

In our research, we have number of vehicles passing through a signal and our concern is to add vehicles according to the data acquired. For this purpose, we have added random routes of certain number of vehicles in the road network and then routes were manually changed accordingly. For creation random routes following command is used

Random trips.py –n Network.net.xml –r routes.rou.xml –e 105

Where,

INPUT -- Network.net.xml = generated road network file

OUTPUT – routes.rou.xml = generated routes

Figure 2.5. Netedit showing connection information

```
<input>
    <net-file value="Network.net.xml"/>
    <route-files value="trips.trips.xml"/>
</input>

<output>
    <output-file value="route.rou.xml"/>
    <alternatives-output value="route.rou.alt.xml"/>
</output>

<time>
    <begin value="0"/>
    <end value="105.0"/>
</time>
```

Figure 2.6. Configuration for generation of route file

While randomTrips.py is python script file which here used for random trips generation in road network. It works by selecting origin, destination and in between edges randomly. Once random trips are generated, vehicle routes are manually adjusted using NetEdit to get the exact number of vehicles passing through junction. Then the formed route file (.rou.xml) is updated by adding consecutive edges to create the actual Trips.

For vehicles routes generation:

- Begin value = departure time of first vehicle
- End value = departure interval end
- Vehicle id = unique identity of vehicles
- Depart = Time at which vehicle enter the network
- Route edges = edges on which a vehicle move.

  are assigned to the route (.rou.xml) file.

Simulation

Time discrete simulation is performed in SUMO. Step length size is 1s by default but can be increased or decrease as required. Speed of vehicle is computed in network according to speed limit information obtained from osm file. This simulation model generate various outputs for every run and all SUMO generated outputs are always in XML format. For the simulation of routes created and run through the road network configuration file (.sumocfg.xml) is formed as shown in Figure 2.7.

```xml
<configuration>

<input>
<net-file value="Network.net.xml"/>
<route-files value="route.rou.xml"/>
</input>

<output>
<summary-output value="summarySUMOTLS.xml"/>
</output>


<time>
<begin value="0"/>
<end value="900"/>
</time>

<report>
<verbose value="true"/>
<no-step-log value="true"/>
</report>

<processing>
<time-to-teleport value="-1"/>
</processing>


</configuration>
```

Figure2.7. Configuration XML code for simulation

Figure 2.8. SUMO-GUI showing inserted vehicles

As the result, simulation will run in SUMO-GUI. Figure 2.8. is showing simulation model in which vehicles are moving through road network. Delay button is a button with the help of which simulation can be slow down for waiting selected number of milliseconds.

Time button is showing simulation running time in seconds and is shown in digital digits. Output obtained from this simulation is stored in the given location. It gives the information about moving each vehicle at each time Lapse, edges and lanes.

2.2.2. PSO ALGORITHM

Traffic simulation is already created by introducing vehicles in generated real time road network. Now, the only purpose is to optimize the traffic signals present at junctions. For signals optimization, an algorithm named PSO is selected which is metaheuristic algorithm.

The concepts of PSO is formed by getting inspired from visual behavior of various animals like flocks of birds and fish. PSO is considered appropriate for solving broader range of functions as a few assumptions about them are needed to be optimized. It has fastest convergence in comparison with other global optimization algorithms such as GA and Simulated Annealing (SA). Swarm of particles are used which are associated with position of particles in solution space and its velocity. No large memory or neither complex mathematical functions are required in this algorithm.

By taking set of randomly distributed particles which are potential solution, results are improved by their fitness of fit (quality measure). The algorithm calculates results by considering both personal best and global best of particles, which is calculation of particle position on the basis its velocity and updating particle position by considering all neighbor particles performance, respectively. The particles form swarm by clustering together in the search space.

Traffic lights are required to be optimized according to the road network and traffic volume passing through it. So, traffic lights will be modeled as where traffic lights i.e., red, green and yellow will be taken as particles.

The optimal values obtained are dependent on the required solution of the problem and search time. The basic PSO is influenced by these control parameters and the parameters used in our research:

- Swarm Size
- Neighborhood size
- Number of particles
- Number of iterations
- Acceleration coefficients ($c0$ and $c1$)

The number of iterations are based on desired precision. Generally, n-dimension optimal solution search space is perceived as n-dimensional hypersurface. The suitability of parameters a dependent on relative evenness or unevenness of this hypersurface.

```
</timestep>
<timestep time="558.00">
    <edge id=":256316574_4">
        <lane id=":256316574_4_0">
            <vehicle id="94" pos="14.00" speed="12.80"/>
        </lane>
        <lane id=":256316574_4_1"/>
    </edge>
    <edge id="158494586#7">
        <lane id="158494586#7_0">
            <vehicle id="43" pos="71.64" speed="15.28"/>
        </lane>
        <lane id="158494586#7_1">
            <vehicle id="39" pos="75.60" speed="19.26"/>
        </lane>
        <lane id="158494586#7_2"/>
    </edge>
    <edge id="23656880#2">
        <lane id="23656880#2_0">
            <vehicle id="95" pos="87.99" speed="14.91"/>
        </lane>
        <lane id="23656880#2_1"/>
    </edge>
    <edge id="23657578">
        <lane id="23657578_0">
            <vehicle id="19" pos="70.10" speed="19.92"/>
        </lane>
    </edge>
</timestep>
<timestep time="559.00">
```

Figure 2.9. Configuration output Information

```
INPUT:
Road network, information of traffic flow, Traffic light distribution, phase of each intersection, given time period
OUTPUT:
Optimized phase cycle of traffic signals
Initialize Xi, Vi and xbest i for each particle i;
  for i=1, N do
    pi= Xi
  g= arg max_n f(Xn)
 for t= 1, T do
   for i= 1, N do
     Vi= Vi + c1 x r0 x (pi – Xi) + c2 x r1 x (g - Xi)
     Xi =Xi + Vi
     if f (Xi) < f(pi) then
      Pi = Xi
      if f(Xi) < f(g) then
        g = Xi
 return g;
```

Figure 2.10. PSO algorithm for intelligent traffic signals optimization

2.2.3. OPTIMIZATION OF TRAFFIC SIGNALS

This Input file is generated by running PSO algorithm. Each tlLogic have same states but different phase duration according to their traffic condition.

For running the simulation integrated with PSO algorithm formulation of SUMO configuration is necessary. Network file, generated routes, TLS file are input of the configuration. By running this configuration summary file, trip information file, duration, beginning and ending time are obtained.

Summary file contains the simulation-wide number of vehicles that are loaded, inserted, running, waiting to be inserted, have reached their destination and how long they needed to finish the route. In trip info file, Information is generated for each vehicle as soon as the vehicle arrived at its destination and is removed from the network.

Chapter 3

RESULTS AND DISCUSSIONS

This chapter present results and discussions obtained by following the methodology outlined in the previous chapters. Presence of traffic counts on traffic signals equipped roads, implementation of PSO on these signals and the results obtained from the developed simulation are discussed in detail.

The discussion primarily involves the visual interpretation of vehicular movement along signals, their numeric results and decrease in trip time. The comparison of time taken by the vehicles with or without optimized signals and their analytics are discussed at length in subsequent sections.

3.1. TRAFFIC DATA ANALYSIS

Analysis of acquired data are made to get understanding of information present in data, facts and figures gained from this analysis are as follows:

3.1.1. AVERAGE DAILY TRAFFIC (ADT)

Average Daily Traffic (ADT) is also termed as mean daily traffic, ADT is average vehicle counts passing through a certain point on road for a specific time period. Traffic flow counts varies with time and is estimated by dividing total volume of traffic in a specific time period by the number of days in that period.

Average traffic data at F8/2 signal is shown in Figure 3.1, it is observed that there are more number of vehicle passing through this traffic signal during weekdays than on weekend, as more number of educational institutes are present on the north side of this junction. Presence of Air University, Bahria (Bahria University) and National Defense University (NDU) is one of the main reason of more traffic volume presence on weekdays than weekends.

While, at the north side of F8/3 signal, Naval complex including PNS Hafeez - Naval hospital is present while on south side OPF college is present. By analyzing average daily traffic data, it is observed as shown in Figure 3.2, that there is highest vehicular movement from North to South.

Towards north side F7/2 signal, the largest mosque of South Asia “Shah Faisal Mosque” is present which is a famous tourist attraction in Islamabad. Junction is directly affected by the traffic generated due to this mosque, as it is adjacent to it. Moreover, mostly embassies are present near this junction. It is observed that there is highest movement of vehicles at Friday from North to South and South to North at this junction and more vehicle moving during weekends, as shown in Figure 3.3.

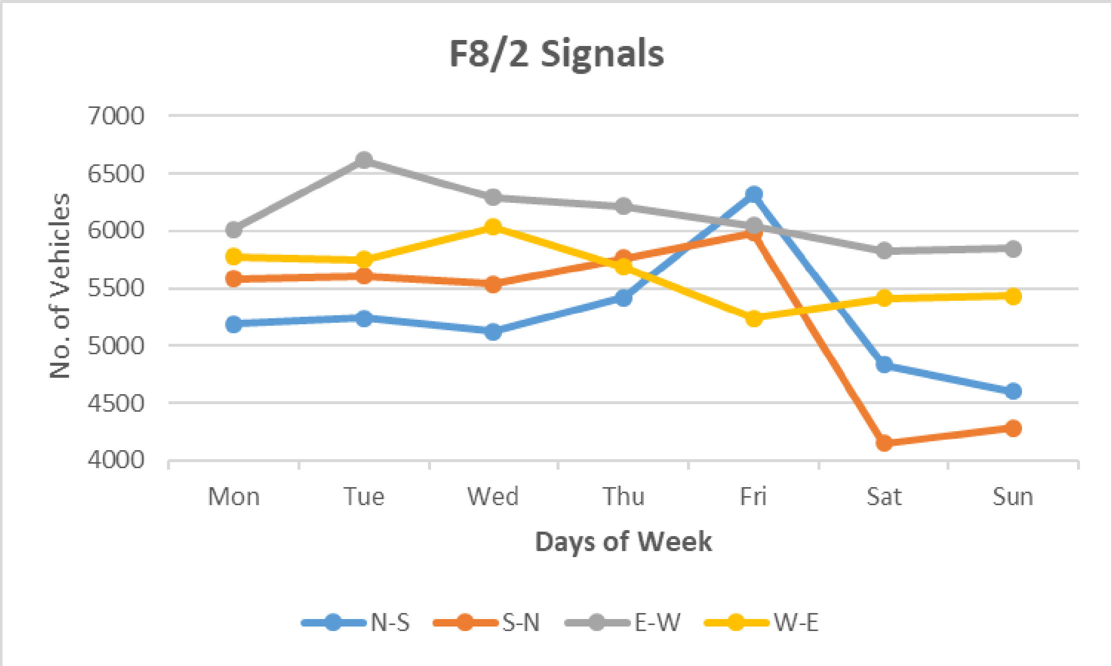

Figure 3.1. Average daily volume of traffic F8/2 signal, Islamabad

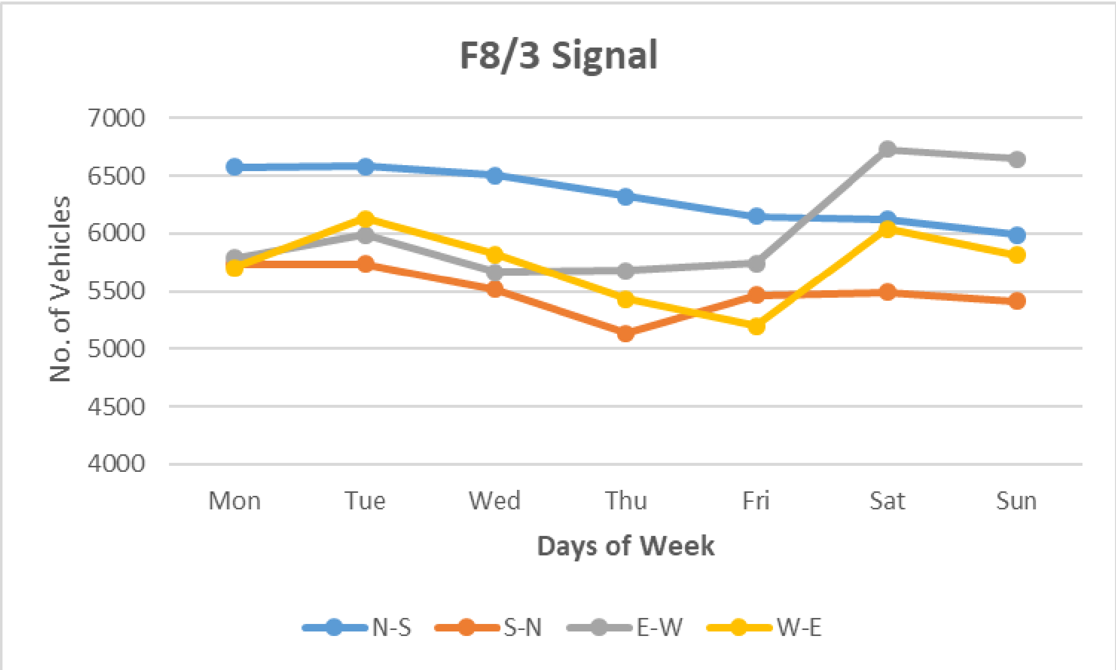

Figure 3.2. Average daily volume of traffic F8/3 signal, Islamabad

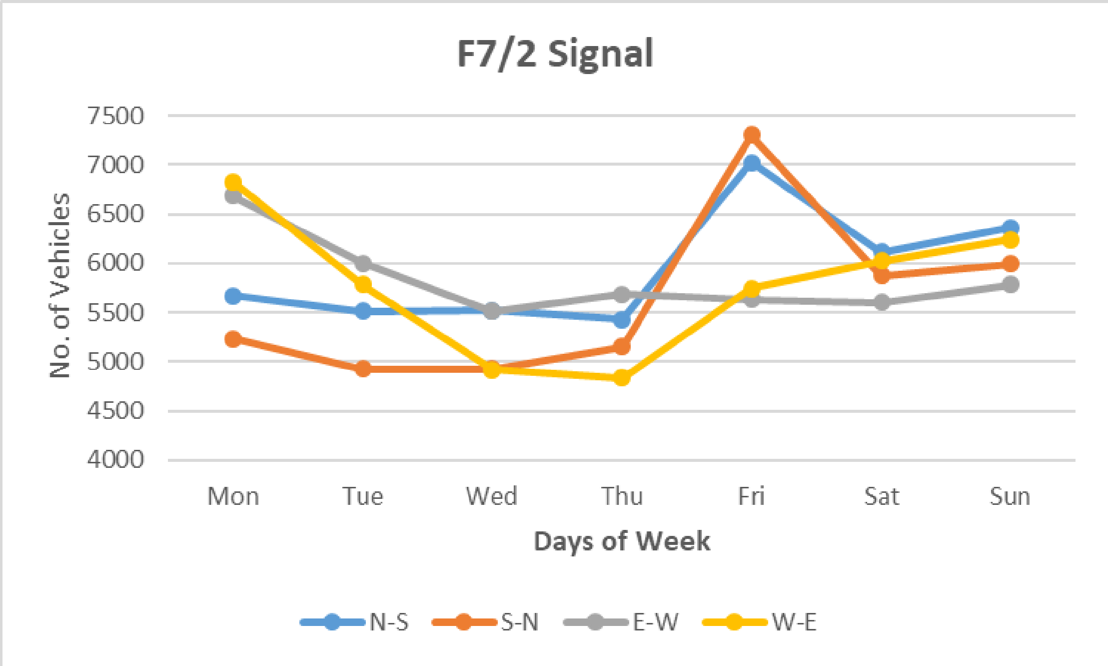

Figure 3.3. Average daily volume of traffic F7/2 signal, Islamabad

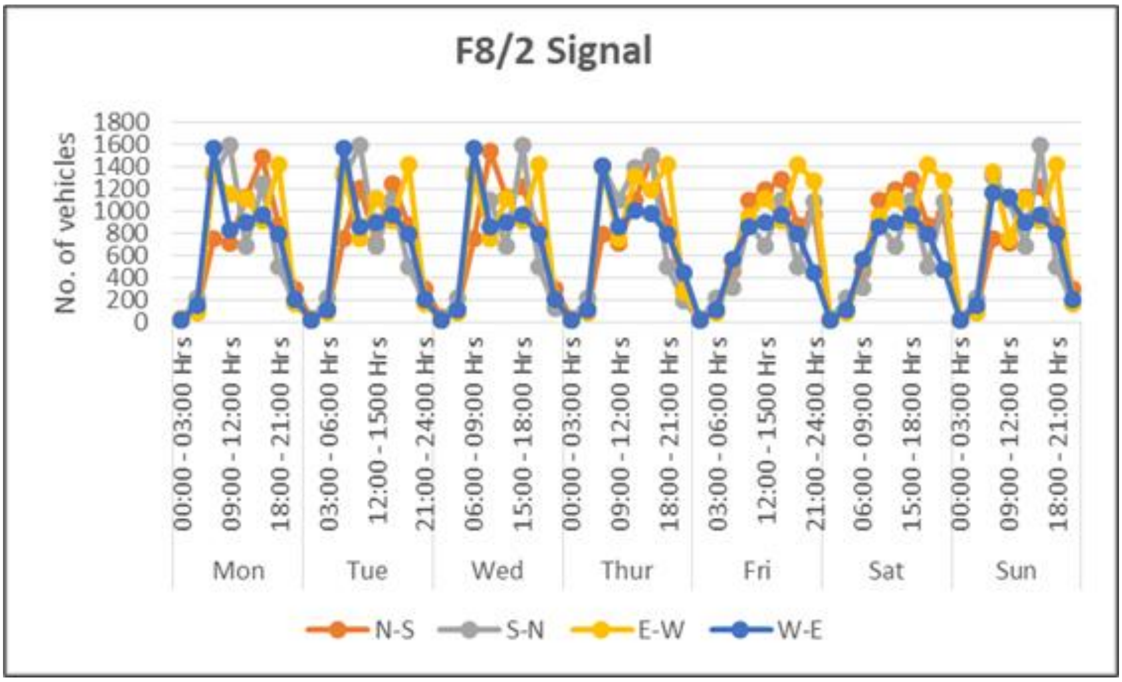

Figure 3.4. Peak hour traffic volume F8/2 signal, Islamabad

3.1.2. PEAK HOUR VOLUME

The highest volume of traffic, at road junctions under consideration, during the hour of the day is peak hour volume. It is normally taken as passenger car units but counting all vehicles as passenger cars will help in making these calculations more like actual condition on road. Peak hour flow rate is numerically identical to peak hour volume and termed as passenger car units per hour.

It is necessary to calculate peak hour volume to facilitate the design and its capacity analysis because the system must be capable of accommodating maximum traffic volume generated in peak hours of the year. Peak hour volume analysis is primarily used for planning purposes. The traffic volume data is traffic data of six months and are in the form of 3 hours interval. So, peak hour volume will be taken as highest volume of traffic in any of three-hour interval of whole day traffic volume.

As shown in Figure 3.4, large volume of vehicle pass through F8/2 signal during weekdays. Peak hours are average of no. of vehicles from 6-9 am and 3-5 pm. The highest traffic volume passing through F8/3 signal is 3-5 pm as shown in Figure 3.5. At F7/2 signal peak hour shown in Figure 3.6 is from 12 to 3 pm on Friday. It can be said that the highest traffic volume generated at junction 3 is due to Shah Faisal Mosque present there.

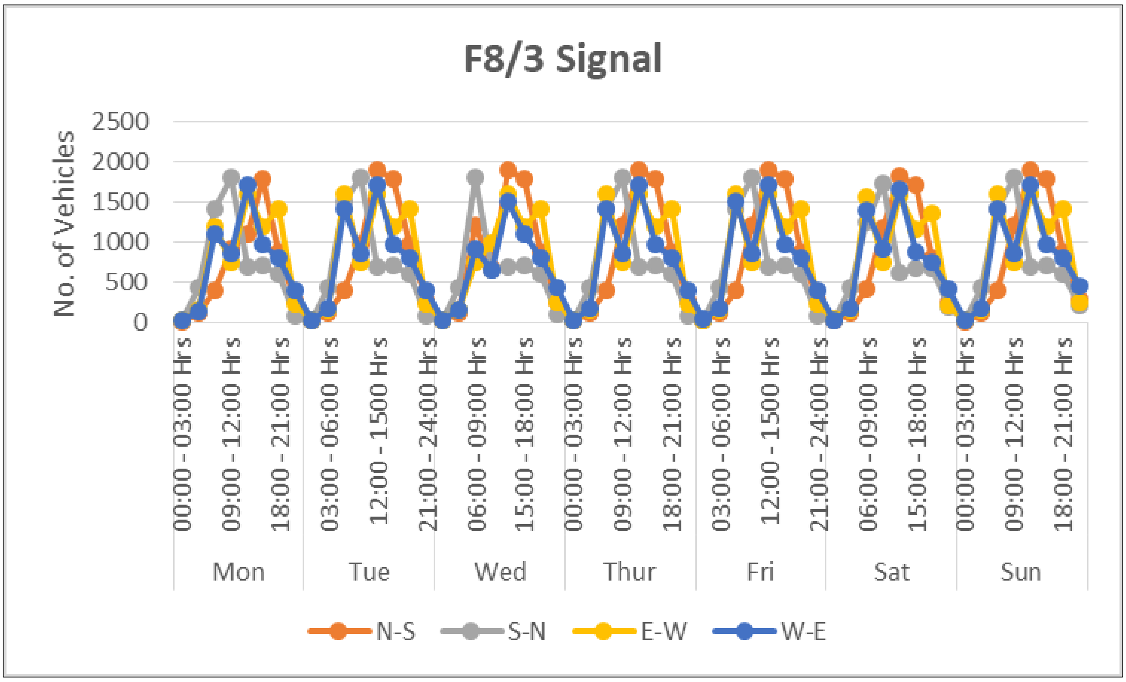

Figure 3.5. Peak hour traffic volume F8/3 signal, Islamabad

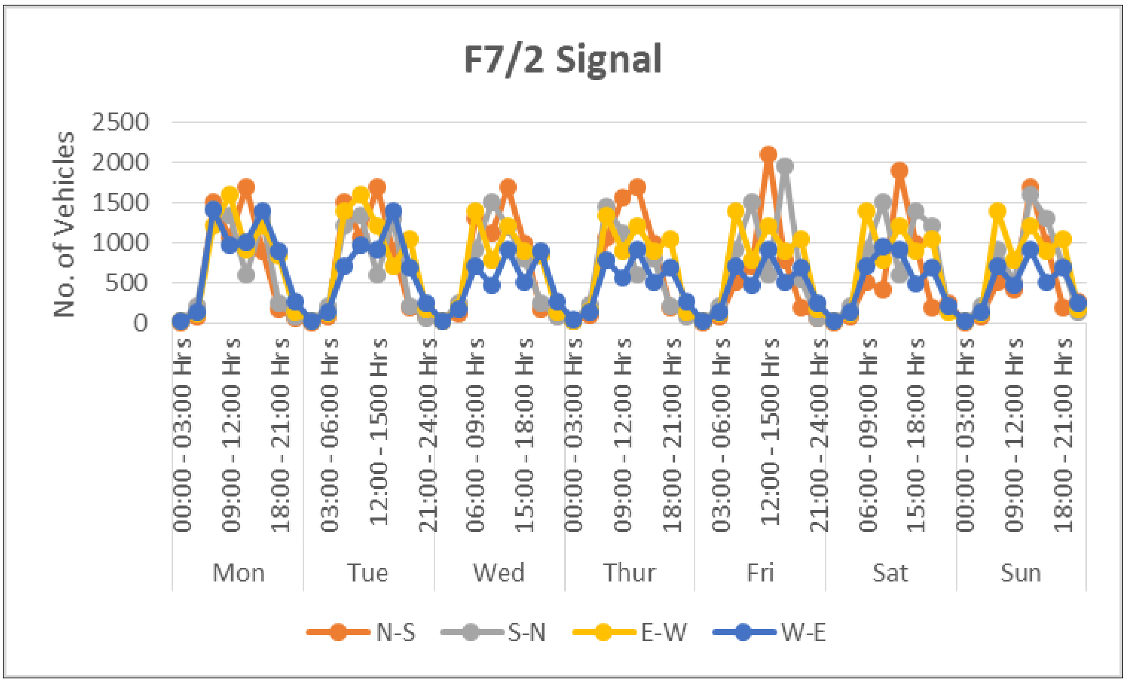

Figure 3.6. Peak hour traffic volume F7/2 signal, Islamabad

3.2. SUMMARY FILE

This output contains the simulation-wide number of vehicles that are loaded, inserted, running, waiting to be inserted, have reached their destination and how long they needed to finish the route.

3.3. TRIP INFO FILE

The simulation is forced to generate this output on the command line, within a configuration. This output contains the information about each vehicle's departure time, the time the vehicle wanted to start at (which may be lower than the real departure time) and the time the vehicle has arrived. The information is generated for each vehicle as soon as the vehicle arrived at its destination and is removed from the network.

3.4. MEAN TRAVEL TIME

Simulation results were collected for overall trip generated. The obtained results were collected, simulated and analyzed for both SUMO-TLS and PSO. All vehicles that have left the simulation within the previous and the reported time. Figure 3.9 shows that mean travel time of vehicles moving in traffic light system generated by PSO algorithm is less than SUMO.

Results clearly shows that SUMO-TLS and PSO-TLS were resulting same average travel time when there were less traffic on road. As the number of vehicles on road increases the average travel time also increases. PSO-TLS reduce up to 12% travel time compared to SUMO-TLS.

3.5. MEAN WAITING TIME

Mean Waiting Time of vehicles is the time in which the vehicle speed was below or equal 0.1m/s. Figure 3.10 shows that mean waiting time of vehicles moving in traffic light system generated by PSO algorithm is less than SUMO. Results obtained from the experimental groups show clearly that PSO outperforms SUMO-TLS successfully.

When average waiting time is considered it is clear from results that almost every vehicle in simulation is having less waiting time in optimized traffic light as compared to fixed traffic lights throughout the trip. PSO-TLS reduce waiting time 10% on average as compare to SUMO-TLS for each vehicle in simulation.

```xml
<summary>
    <step time="<SIMULATION_TIME>" \
            loaded="<LOADED_VEHICLE_NUMBER>" \
            inserted="<INSERTED_VEHICLE_NUMBER>" \
            running="<RUNNING_VEHICLE_NUMBER>" \
            waiting="<NUMBER_OF_VEHICLES_WAITING_FOR_INSERTION>" \
            ended="<ENDED_VEHICLE_NUMBER>" \
            meanWaitingTime="<MEAN_WAITING_TIME>" \
            meanTravelTime="<MEAN_TRAVEL_TIME>"/>

    ... further time steps ...

</summary>
```

Figure 3.7. Route summary information file output in xml format

```xml
<tripinfos>
    <tripinfo id="<VEHICLE_ID>" \
            depart="<DEPARTURE_TIME>" departLane="<DEPARTURE_LANE_ID>" \
            departPos="<DEPARTURE_POSITION>" departSpeed="<DEPARTURE_SPEED>" \
            departDelay="<DEPARTURE_DELAY>" \
            arrival="<ARRIVAL_TIME>" arrivalLane="<DEPARTURE_LANE_ID>" \
            arrivalPos="<ARRIVAL_POSITION>" arrivalSpeed="<ARRIVAL_SPEED>" \
            duration="<TRAVEL_TIME>" routeLength="<ROUTE_LENGTH>" \
            waitingTime="<SECONDS_WAITING_FOR_TRAFFIC>"
            waitingCount="<NUMBER_OF_WAITING_EPISODES>" \
            rerouteNo="<REROUTE_NUMBER>" \
            devices="<DEVICE_LIST>" vtype="<VEHICLE_TYPE_ID>"/>

    ... information about further vehicles ...

</tripinfos>
```

Figure 3.8. Trip Information file output in xml format

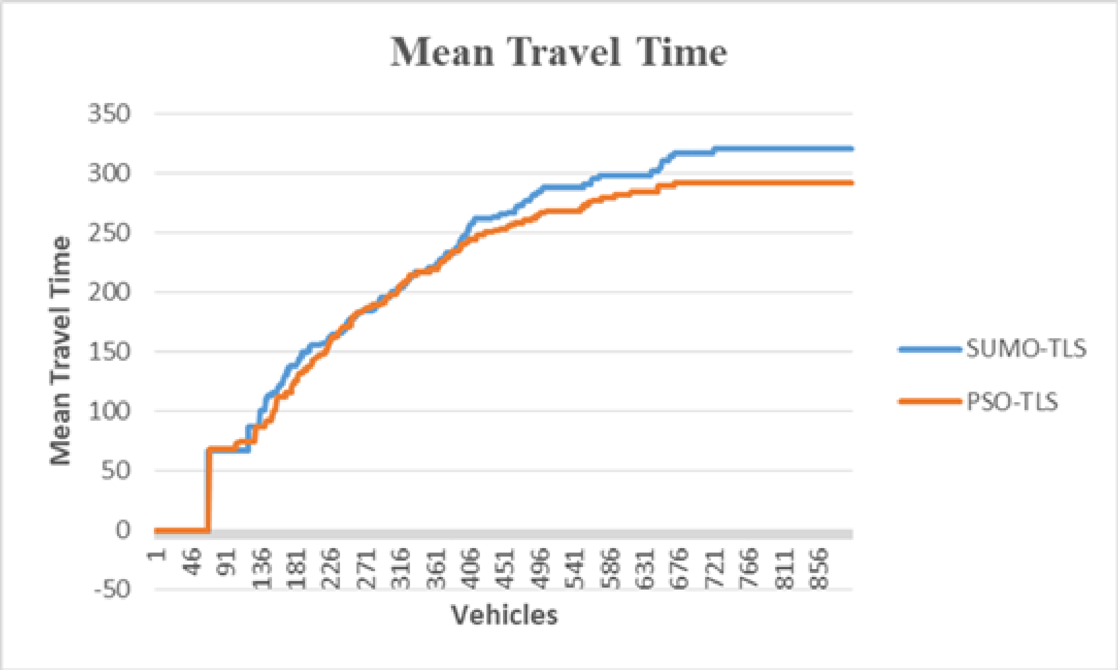

Figure 3. 9. Mean travel time of vehicles

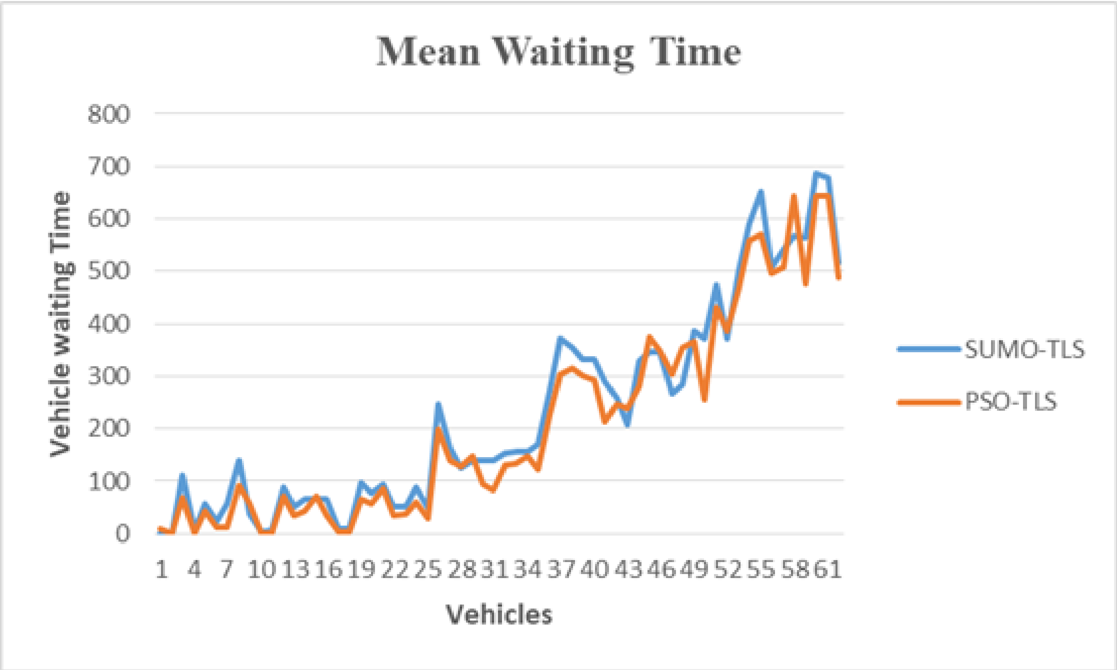

Figure 3.10. Mean waiting time of vehicles

Chapter 4

CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSIONS

Increasing population in Islamabad is leading towards increase in traffic on the roads that causing traffic congestion. For traffic management fixed type of traffic signals are present here and from 80 traffic signals only 40% are functioning properly. 1800 CCTV cameras are installed as the part of Islamabad Safe City Authority, out of which 600 are not working.

Average traffic data at F8/2 signal is more in numbers in weekdays than on weekend, as more number of educational institutes are present on the north side of this junction. While, at the north side of F8/3 signal, average daily traffic data that there is highest vehicular movement from North to South. Towards north side of F7/2 signal, it is observed that there is highest movement of vehicles at Friday from North to South and South to North at this junction and more vehicle moving during weekends.

Mean travel time for both SUMO-TLS as well as PSO-TLS were collected, simulated, analyzed and compared. Optimized system shows 12% decrease in mean travel time. Mean waiting time of each vehicles moving in traffic light system generated by PSO algorithm is 10% less than SUMO-TLS. Results obtained from the experimental groups show clearly that PSO outperforms SUMO-TLS successfully.

4.2 RECOMMENDATIONS FOR FURTHER RESEARCH

For future research, we still believe that there is a significant room for further experimentation in intelligent traffic signal system. For PSO algorithm we can use non constant values for c0 and c1, and can show a whole trend of difference in results by experimenting gradually increasing or decreasing their values. Intelligent traffic signals optimization is an active area for research.

There are a lot of research going on optimizing signals for better mobility. Based on the current work there is another application of we can use PSO integrating with other optimization tools for getting real-time output. Signals optimization can be done by using artificial techniques in sensing vehicle images and IoT (Internet of Things) networking for counting vehicle counts. This study opens up further future directions for researchers.

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