Modelling Traffic Congestion based on Air Quality for Greener Environment: An Empirical Study

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***Abstract*—The primary focus of this research is to govern traffic congestion on urban road networks based upon a cumulative approach comprising of traffic flow modelling, vehicle emission modelling and air quality modelling. Based upon the traffic conditions, a simulation model is proposed and further tested for performance metrics which is relative to three main aspects; namely, the waiting time of the vehicles at the junctions/intersections/signals, the type of pollutant emitted by a vehicle, and traveling time. The experimental analysis and validation is carried out for different case studies in Malaysia, such as Petaling Jaya, Shah Alam, Mont Kiara and Jalan Tun Razak. Three different scenarios (morning, afternoon and evening) are analyzed and tested to explore the traffic usage parameter. The results showed that when traffic is modelled and governed based upon traffic flow, vehicle emission and Air Quality Index (AQI), nearly 75% of traffic congestion is mitigated; hence making the atmosphere pollution free as well as avoiding Urban Heat Island Effect (UHI) due to heat generated from vehicles. The experimental results are tested, validated and compared with existing solutions for performance analysis. The proposed model is aimed towards overcoming the major drawbacks of existing approaches such as single path suggestions, traffic delay during peak hours/emergencies, non-recurring congestion consideration, congestion avoidance instead of recovering from it, improper reporting of road accidents and notifications about traffic jam ahead to the users and high vehicle usage rate.**

***Index Terms*—Traffic modelling, Vehicle congestion, Air quality, pollution, emission, transportation.**

I. INTRODUCTION

OVER the last decade, vehicle population has been increased sharply in the world. This large number of vehicles leads to a heavy vehicle traffic congestion, air and noise pollution, accidents, driver frustration, and costs billions of dollars annually in fuel consumption [1]. Finding a proper solution to vehicle congestion is a considerable challenge due to the dynamic and unpredictable nature of the network topology of vehicular environments, especially in urban areas [2]. Vehicle Traffic Routing Systems (VTRSs) are one of the most significant solutions for this problem [3] [4]. Although most of the existing VTRSs obtained promising results for reducing travel time or improving traffic flow; however, they cannot guarantee consideration of non-recurring congestion (unexpected events such as working zones, vehicle accident/breakdown and weather condition) as well as reduction of the traffic-related nuisances such as air pollution, noise, and fuel consumption. Advancements in population of vehicle fleet has put environmental conditions of urban areas under serious threat leading to global warming, health hazards to human beings and drastic climate changes. Many recent research contributions in the field of air pollution and vehicular emissions have found that in countries like Malaysia, nearly 66% of air pollution is caused from ground-based transport that mainly includes harmful emissions from cars, heavy duty vehicles and motorcycles [5]. The air pollution issue becomes more serious when the regular flow of traffic is disturbed and interrupted due to unexpected delays, accidents, breakdowns and poor climatic conditions. As a result of such situations, the smooth vehicular traffic flow is disrupted especially at intersections, junctions, traffic signals and accident spots. These piling up of vehicles along with road characteristics and traffic pattern cause the considerable shift of air quality index (AQI) [6].

The shift in AQI is attributed towards the emissions of longer waiting time of vehicles during peak hours or emergency situations. The AQI here refers to the number that is used by government agencies to communicate the level of air pollution in the atmosphere to the public. The values of AQI can increase or decrease based upon increase of air emissions. It considers pollutants such as particulate matter (PM_{10}/$PM_{2.5}$), nitrogen oxides (NO_2), sulphur oxides (SO_2), carbon monooxide (CO), ground-level ozone (O_3), ammonia (NH_3) and lead (P_b) into the air on a 24-hour averaging period [6] [7]. The key for communication of different range of AQI values is through depiction of colour codes standardized by government agencies of individual countries. The harmful emissions into the atmosphere also pose serious threats to human health leading to respiratory illness affecting in particular the children and elderly people. The rate at which vehicles emit harmful gases also depend upon traffic use, characteristics, type of vehicles and road intersections. The manufacturing year of vehicle followed by the quality of maintenance also contribute towards the emission rate. Therefore, the quality of air in urban areas is dependent mostly upon vehicular emissions which in turn is a result of either traffic pattern, road design or vehicular characteristics. The traffic congestion can be modelled by quantifying and managing the effect of each of these individually contributing factors. Hence, in this

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research, we aim to present intelligent green traffic congestion model that reduces fuel consumption and consequently CO_2 emissions via combination of vehicle routing mechanism with fuel consumption and air pollution models. This model utilizes various criterion such as average travel time, speed, distance, vehicle density along with road map segmentation to reduce fuel consumption by finding the least congested shortest paths in order to reduce the vehicle traffic congestion and their pollutant emissions. The proposed approach will be evaluated and validated through simulation environment and tools (i.e. NS-2, SUMO and OpenStreetMaps). Experimental results will be conducted on various scenarios (e.g. various vehicle densities, air pollution index and UHI effect) considering different environmental evaluation metrics (e.g. noise and air pollution, emission and fuel consumption). This green model will alleviate traffic congestion and reduce air pollution hence making the city greener and mitigating health hazards due to contaminated atmosphere.

The rest of the paper is arranged as follows. Section 2 describes some of the related work in the area of UHI effect and the role of intelligent transportation system (ITS) in minimizing the pollution. Section 3 presents the proposed modelling approach based upon three aspects namely, traffic flow modelling, vehicle emission modelling and air quality modelling . Results and discussion is presented in section 4. Finally, section 5 concludes the current proposed work and also presents some future directions.

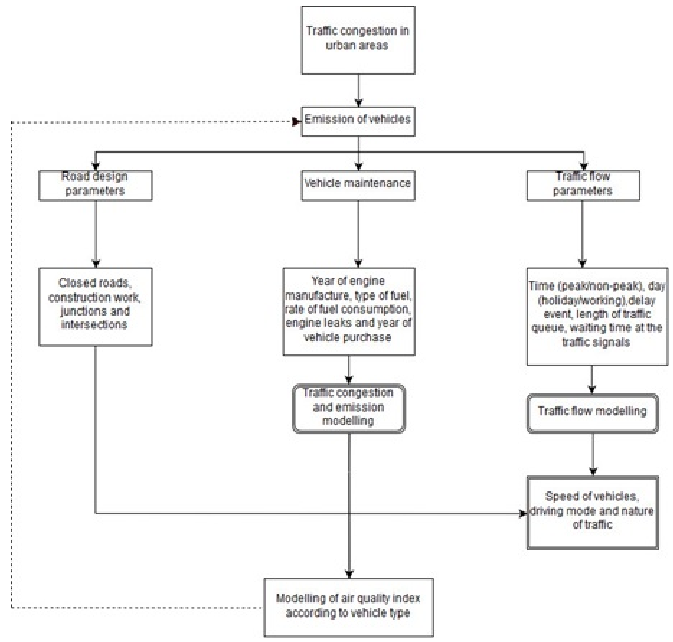


Fig. 1: Taxonomy of traffic congestion in urban areas

II. Related Work

During the past few decades, vehicle population has been on an alarming rise in the world [8]. Research contributions showed that during 2005, the transportation sector has contributed to about 21% towards greenhouse gases emissions and 56% towards NO_x emissions [9]. The researchers also suggested that the emission-based evaluation and examination with regards to temporal and spatial variations of flow in traffic pattern needs the implementation and design of traffic congestion modelling at microscopic levels as shown in Figure 1 . Studies have also shown a significant transformation in the usage of registered vehicles at Malaysia taking the total count to about 28,181,203 by the end of 2017 [10]. Such a rapid increase of vehicle fleet poses serious threats in terms of CO_2 emissions, global warming, ozone depletion and climatic changes.

The authors in the literature have also stated that exhaustible vehicular emissions on the road intersections depend majorly upon factors such as vehicle speed, rate of traffic flow, traffic pattern, waiting time of traffic signals, the length of queue in idle mode of vehicles on a road and occurrence of emergency conditions [11]. The researchers have found that a considerable number of factors which are dependent on the nature of traffic, characteristics of vehicles and road configurations directly affect the vehicular emissions. The researchers in [7] aim to provide decision making process in urban areas by providing data about the vertical and horizontal variations of traffic induced air pollution. The outcome of the dispersion model is integrated into the spatial database of urban traffic data and eventually leads to the three-dimensional visualization of air pollution levels. In the study proposed by researchers of [12], a Lagrangian model is proposed for simulation of traffic flow and subsequently used for traffic induced air pollution estimation. An empirical modelling of emission factors is used for estimation of vehicular categorization-based air pollutants such as CO, NO_x and PM_{10} in the current research contribution. The heat from traffic congestion majorly accounts to UHI effect thereby contributing towards hindering the overall air quality in the atmosphere as shown in Figure 2. Hence, vehicular density is clearly one of the major causes of UHI, increased emission of harmful pollutants and thereby, deteriorates the quality of air. An experimental study in [11] found that in Malaysia, the levels of emissions of CO_2 during the period 2000 to 2020 is estimated to be nearly 68.86%, indicating towards the release of 285.73 million tons of CO_2 at the end of the period, if no preventive measures are taken.Over the past few decades, congestion due to road traffic and the levels of harmful emissions has evolved to be the most attention seeking research related to environmental protection and preservation. The authors in [13] and [14] have suggested that CO_2 emissions and rate of fuel consumption have direct impact on each other.

The correlation between fuel consumption rate, speed of vehicles and level of CO_2 emissions can give satisfactory and best possible solutions to mitigate the environmental hazards. Figure 3 depicts the two parameters as a function of average travel speed. It states that, the fuel consumption and the harmful air pollutant (CO_2) emission increases exponentially by around 30% with increase of average travel speed of vehicles, idle time on the road and acceleration/deceleration during vehicle congestion. Subsequently, higher speed of vehicles leads to more fuel consumption and higher CO_2 emissions. Every vehicle works optimally in terms of fuel consumption

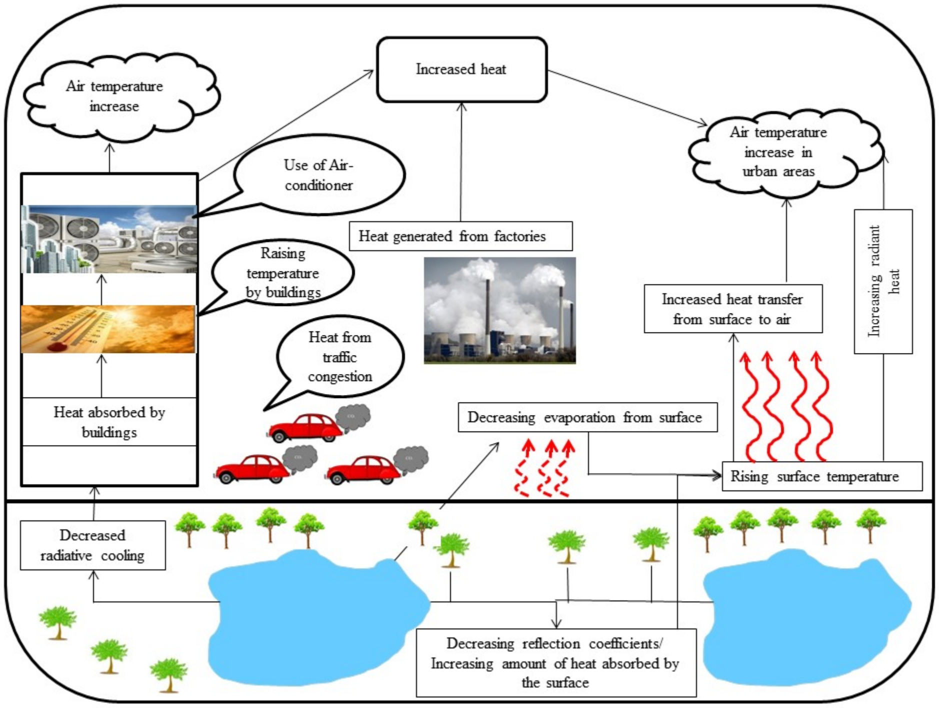


Fig. 2: The causes of the Urban Heat Island effect

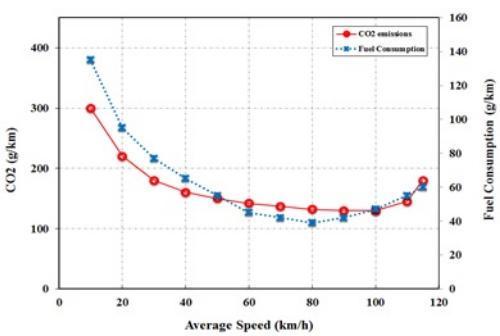


Fig. 3: Fuel Consumption Vs CO_2

if the engine Revolution Per Minuit (RPM) is kept within a predefined range (typically 2000 to 2500 RPM) as described by the manufactures. Therefore, moderate travelling speed of vehicles result in comparatively lesser fuel consumption and lower levels of CO_2 emissions. Thereby, the emission of harmful air pollutants and greenhouse effect can be minimized by leveraging on smoother trips of stop and go mode and lesser waiting time at traffic signals by avoiding the longer idle time of engines. The research contribution by [15] have suggested that reduction of fuel consumption and minimization of pollutant emission can be achieved by finding cost effective solutions for mitigation and governance of traffic congestion. ITS [8] is a novel and progressive system which conjugates network-based information (e.g. vehicular networks, wireless sensor network) and electronic technologies (e.g. sensors, cameras) with transportation technologies. ITS involves a wide variety of mechanisms and technologies such as Vehicle Traffic Routing Systems (VTRSs), electronic toll collection system (ETCS), and Intelligent traffic light signals (TLSs) to reduce the levels of CO_2 emission and rate of fuel consumption. The ITS technologies supports and encourages the mitigation of fuel consumption with two aspects, that is, firstly to reduce congestion that allows each vehicle to maintain optimal speeds of stop and go driving states and secondly to provide alternative paths with minimal time duration instead of shortest path distances to the driver for a green fuel efficient path [16]. TLS and VTRS are two most popular solutions of ITS for fuel consumption and CO_2 emission issues [17]. However, considering the cost and time limitations, VTRS is a better solution than TLS. Although most of the existing VTRSs approaches obtained promising results for reducing travel time or improving traffic flow pattern, they cannot guarantee reduction of the traffic-related nuisances such as air pollution, noise, and fuel consumption [18], [19], [20] and [21]. Hence, this research aims to propose an intelligent green traffic congestion model that is environmentally friendly, and vehicles are routed through greener paths. Green paths are the routes with less traffic congestion, lowest fuel consumption along with lowest levels of greenhouse and CO_2 emissions [22].

III. Modelling Approach

The proposed model is based upon three major aspects- Firstly, the flow of traffic is modelled, followed by vehicular emission modelling and then air quality modelling. The modelling approach is a cumulative method, where initially the flow of traffic is modelled. In this process, the number of nodes (vehicles), junctions and the emission of vehicles are defined. The next step is to model the emission from the vehicles based on the mobility and waiting time of vehicles at the traffic signals. Finally, the AQI is calculated from the concentration of each of the harmful gases emitted from the vehicles in the previous step. In this way, each of the modelling approach are interrelated and connected to each other. The concept here is that, based on the traffic flow on the road, the calculation of how many vehicles are emitting harmful gases are modelled followed by calculation of AQI during the subsequent air quality modelling. The process carried out during each of the modelling approach along with algorithm are explained in the following sub-sections. The subsequent sections provide explanation of how the modelling approach is carried upon to avoid and govern the traffic congestion and to give an idea about experimental effects on air quality, emission and traffic use for urban cities in Malaysia.

A. *Traffic Flow Modelling*

The traffic flow pattern determines the nature of congestion on roads [23]. The traffic use and flow are modelled based upon the road network performance metrics such as throughput and delay. The traffic flow parameter is directly proportional to the waiting time of vehicles at junctions, traffic signals and predominantly upon vehicular density during peak/non-peak hours [24]. Therefore, the traffic flow is modelled using equations mathematically. Accordingly, the traffic use is based upon three scenarios on a road network- a heavily congested traffic, moderately congested and free flow of traffic (no congestion) [25]. After analysing the traffic data, for four areas of Petaling Jaya, Jalan Tun Razak, Mont Kiara and Shah Alam, a metric labelled as Area Occupied by Vehicle (AOV) is introduced. Let us assume that μ_d is the vehicular density which is the number of vehicles per unit road length and μd_c is the threshold vehicular density which determines the type of traffic flow on the road network. If μ_d is lesser than μd_c on a road segment, then there is free traffic flow for vehicles travelling at an average speed limit of Sa_{cc}. On the other hand, if μ_d is greater than μd_c then there is heavy traffic congestion and vehicles decelerate to a minimum normalized speed of Sd_{cc}. The traffic flow at each road segment for a time interval of $\sum_{i=1}^{n} T_i$ is simulated over the entire network where i is the traffic hours factor starting from 0 to 100 secs of each simulation run. The rate of traffic flow can be determined as,

$$\frac{\mathrm{d}\mu_r}{\mathrm{d}t} = \begin{cases} \left(\frac{R_L * R_W}{\mu_d}\right) \rho_{acc}, \mu_d < \mu d_c \\ \left(\frac{R_L * R_W}{\mu_d}\right) \rho_{dcc}, \mu_d > \mu d_c \end{cases} \tag{1}$$

where R_L is the length of the road segment and R_W is the width. ρ_{acc} and ρ_{dcc} are the vehicle acceleration and deceleration occurrence time respectively. The threshold vehicular density (μd_c) is calculated based upon the length of the road at a given time t.

$$\mu_d\left(R_L, t\right) = \frac{\mu_d}{R_L} = \frac{1}{A_v} \tag{2}$$

$$A_v = \sum_{i=1}^{n} \frac{A_{Vi}}{\mu d}, n \leq \mu d \tag{3}$$

$$\rho_{acc} = \frac{\triangle v}{\triangle t} = \frac{v_f - v_i}{t_f - t_i} \tag{4}$$

$$\rho_{dcc} = \frac{\triangle v}{t} = \frac{v_f - v_i}{t} \tag{5}$$

Substituting equations 2, 3, 4 and 5 in equation 1, the rate of traffic flow can be calculated. This calculation of traffic flow is done for each vehicle during different traffic hours scenario ranging from t=0 to overall end time T. Hence combining the calculated trips with the rate of traffic flow mathematically at each junction and intersections of road segment, the road network is simulated using OpenStreetMap(OSM) as map provider, NS-2 as network simulator and Simulation of Urban Mobility (SUMO) as traffic simulator. After these steps, the instantaneous network throughput and delay are calculated for total number of successful communications and average waiting time of each vehicle.

B. *Vehicle Emission Modelling*

The next procedure after modelling the traffic flow of a road network is the vehicular emission modelling [26]. The total vehicles on a road network are modelled to emit harmful gases for average waiting time ranging from t to $(t+\delta t)$ where t is the initial time and $(t + \delta t)$ is the end time along with waiting delays at signals and counting period of vehicles. The pseudo-code for vehicular emission has been explained in this section.The nodes in the networks are created as shown in Algorithm 1, which represent the vehicles on the road. The junctions are also created by assigning priority and type for each of the vehicle created. The movement and activity of the

Algorithm 1 Node Generation

begin
Generate nodes (vehicles), junctions, priority and type of vehicles and flow of traffic from previous steps
Randomize the trip of the vehicles to produce information on activity and mobility of vehicles.
Initialize the movement with node's information and generated routes.
<configuration>
<input>
<net-file value="map.net.xml"/>
<route-files value="map.rou.xml"/ >
</input>
<time>
<begin value="10"/>
<end value="100"/>
<step-length value="0.1"/>
</time>
</configuration>
end

vehicles is initialized to monitor the travelling time, pattern of vehicle movement, emission of vehicles and therefore to calculate the pollution caused by the vehicles. The vehicular emissions are calculated by the xml coding as depicted in Algorithm 2. The frequency of a vehicle taking a particular route is assigned numerically followed by which edge to have higher emissions on a particular road [27], the xml code is written as an additional file. These highly congested routes

Algorithm 2 Emission Calculation

begin
Add coding for emission of vehicles.
<additional>
<edgeData ID="route1" type="emissions" freq="2" file="map.route1"excludeEmpty="true"/>
<edgeData ID="route2" type="emissions" freq="3" file="map.route2"excludeEmpty="true"/>
<edgeData ID="route3" type="emissions" freq="5" file="map.route3"excludeEmpty="true"/>
<edgeData ID="route4" type="emissions" freq="5" file="map.route4"excludeEmpty="true" />
</additional>
end

are then generated as shown in Algorithm 3. The class of emission, fuel consumption, type of vehicle, noise, speed, angle and direction of vehicle movement is also obtained during the execution and generation of polluted routes.The vehicular emissions for a road network at a given time is obtained through simulation platforms and the results are plotted for different urban areas belonging to greater KL. The flow of traffic on a congested road is mainly determined by the waiting time of the vehicles at the signals and intersections as per the researchers in [28], [29] and [30] respectively.

Algorithm 3 Generation of polluted routes

begin
Generate the routes with emission of vehicles, higher frequency of usage and priority lanes.
The obtained output for vehicular emissions is $VehicleID = 3, eclass = HBEFA3 - PC - G - EU4, CO_2 = 6581.33, CO = 138.70, HC = 0.79, NO_x = 2.87, fuel = 2.83, PM_x = 0.14, electricity = 0.00, noise = 69.28, route = !3, type = DEFAULT - VEHTYPE, waiting = 7.00, lane = u25 - 1, pos = 19.01, speed = 7.37, angle = 0.00, x = 301.65, y = 227.06$
Convert the above obtained xml file to .csv for plotting the values of vehicular emissions as comparative analysis.
Calculate the air quality index for a road network.
end

C. Air Quality Modelling

As specified in the previous sections the quality of air in the atmosphere is mainly due to factors such as vehicular emission and climate change [31], [32] and [24]. The AQI for each of the case study areas is calculated in relation to the traffic hours during the day. The AQI is defined as a real-value linear function of the concentration of air pollutant in the atmosphere [33], [34]. This AQI is computed based on the concentration of the harmful air pollutants over an average period either through an air quality monitoring system or a prototype model. The scale or the level of various ranges related to the numerical values as depicted in Figure 4, are used by government agencies across different countries to communicate with the general public about how polluted the air is currently and how likely it is to become polluted or forecasted to become in the near future. These scales and numerical values are also communicated through warnings related to health concerns [35]. The AQI is calculated as according to the following equation 6 as,

$$AQI = \frac{I_{bh} - I_{bl}}{C_{bh} - C_{bl}} (C - C_{bl}) + I_{bl} \tag{6}$$

where C is the concentration of the pollutant in normalized values, C_{bl} is the breakpoint of concentration that is lesser than or equal to C, C_{bh} is the breakpoint of concentration that is greater than or equal to C, I_{bl} and I_{bh} are breakpoint of index relative to C_{bl} and C_{bh} respectively. The tabulated values of breakpoints standardized by EPA can be referred from the official portal of Department of Environment (DOE), Ministry of Natural Resources and Environment in Malaysia. The various pollutants that determine the indicative values of air quality are SO_x (measured in ppb), PM_x (measured in $\mu g/m^3$), O_3 (ppb), NO_x (ppb) and CO (ppm). The values of SO_x and PM_x are measured for an average period of 24 hours whereas 8-hour averaging duration is computed for CO followed by every 1-hour calculation of pollutants for NO_x and O_3 respectively. The AQI values are represented using color codes for different categories as depicted in Figure 4. The

Numerical value	Air Quality Index levels of health concern
0 to 50	Good
51 to 100	Moderate
101 to 150	Unhealthy for sensitive groups
151 to 200	Unhealthy
201 to 300	Very Unhealthy
301 to 500	Hazardous

Fig. 4: AQI values with color codes [35]

AQI values are usually monitored and communicated by the designated government bodies to the public for notifications on the level of air quality [36]. These values are generally monitored by embedded air pollution monitoring equipment's specially designed for sensing humidity, pressure, CO_2 levels, other pollutants level, wind direction, wind speed and rainfall [37], [38]. These values of air quality can be used for modelling the road traffic to avoid traffic congestion and mitigate global warming [39].

D. Proposed Network Model

The network model as shown in Figure 5 corresponding to govern the traffic congestion consists of pollution sensors to sense the temperature, level of pollutants, humidity, pressure, wind speed, wind direction and other environmental factors affecting the quality of air in the atmosphere. These sensors belong to the physical layer of IEEE 802.11. The logical link control sub-layer at the data link handles the flow control and error management mechanisms. At the network layer and

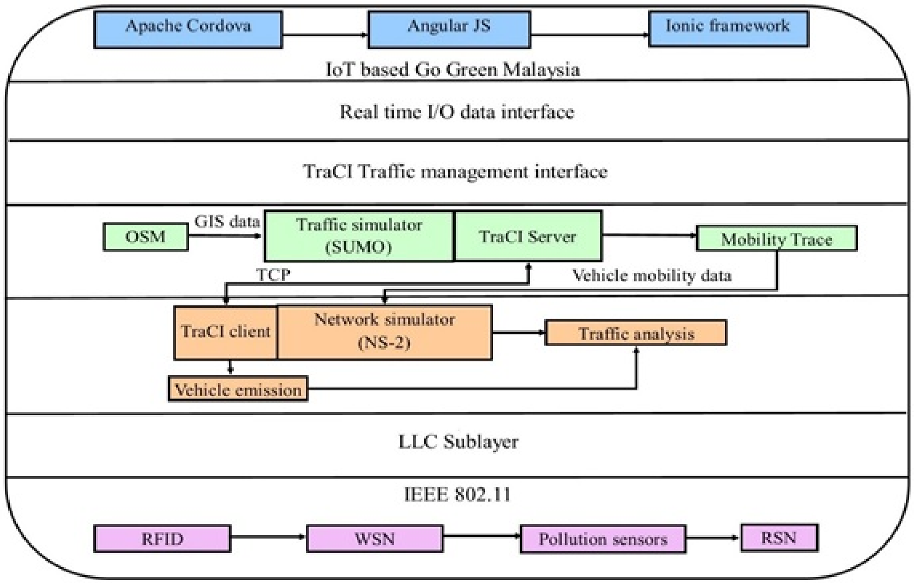


Fig. 5: Proposed network model for modelling traffic congestion

transport layer, the Traffic Control Interface (TraCI) uses TCP based client server architecture to access the SUMO in a road traffic, thereby allowing to edit the behavior/actions of the simulated objects. The GIS data is obtained from OSM after which both traffic and network simulator combined with the TraCI client-server to provide the vehicle mobile data and model the emission of pollutants over a TCP connection. The TraCI serves as the traffic control and management interface at the session layer. The real-time input/output data interface serves as the syntax layer for transferring and formatting of information to the application layer for further processing. The application layer is employed for development and implementation of the real-time mobile application to integrate the AQI values using ionic framework, angular JS and Apache Cordova.

E. Process Flow Diagram

The process of the proposed system follows two states-offline and online as depicted in Figure 6. The basic difference between using two different map sources for traffic flow and road transportation is that google maps are employed when the system is online and connected to the internet whereas OSM is used when the system is in offline mode. The offline process includes simulations and obtaining .xml files for the simulated road traffic. The traffic modelling module is simulated and experimented to obtain the network performance metrics. The traffic modelling data from the offline module is further classified into three sub-modules in the online state. This data is used to further model the traffic flow, vehicular emissions and air quality. The related traffic data from each of the sub-modules is stored on to a database after which the air quality index is obtained, through spatial mapping phase and the updated AQI values are stored in air pollution monitoring database. These stored values are then further integrated in the form of real time mobile application for the end user to obtain updates and notifications on the level of air quality. This mobile application is developed on different mobile OS platforms for the visualization of AQI values on a real-world map and for avoiding heavily congested routes.

F. Experimental Setup

The proposed model as shown in Figure 5, utilizes vehicular networks for real-time data gathering and for distributing route guidance information among vehicles. Due to the unique characteristics of these networks such as lack of central coordination, dynamic topology, error prone shared radio channel, limited resource availability, hidden terminal problem and insecure medium, experimentation and performance evaluation of our developed framework can be achieved via simulation tools. Real test-beds construction for any vehicular networks scenario is an expensive or in some cases impossible task if metrics such as testing area, mobility and number of vehicles are considered. Besides, most experiments are not repeatable and require high cost and efforts [15]. Simulation tools (e.g. NS-2 and SUMO) can be used to overcome these problems. The network parameters used are tabulated in Table I for better understanding of the criteria for simulated road traffic. The nodes are connected to the sink through a TCP connection to carry the FTP packets. The movement of the nodes is obtained from OSM and SUMO modelling whereas for packet transfer and communication between the nodes, Adhoc On-Demand Distance Vector (AODV) routing protocol is used using network simulations. Extensive and various simulation runs, and tests are carried out to evaluate and validate the performance of our approach compared with other existing approaches. Different simulation scenarios with various vehicle densities, air quality index, city maps with different sizes, and accident (and weather) conditions are considered, to have comprehensive comparison between our approach and existing solutions. The proposed solution is aimed at

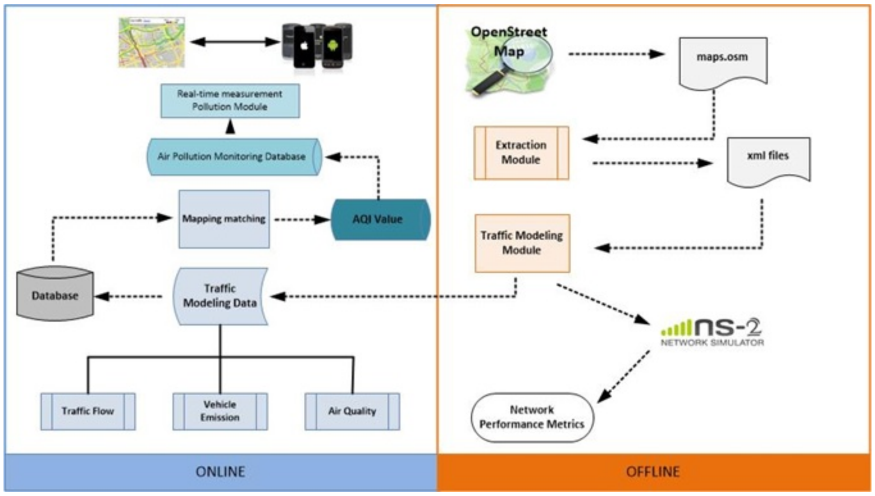


Fig. 6: Process flow diagram of proposed system

TABLE I: Simulation Parameters

Parameters	Values
Radio propagation model	Two Ray Ground
MAC layer	IEEE 802.11
Network topology	Cluster
No. of packets	50
No. of mobile nodes	Petaling Jaya (Case 1) 77, Mont Kiara (Case 2) 14, Shah Alam (Case 3) 89, Jalan Tun Razak (Case 4) 72
Routing protocol	Ad hoc On-Demand Distance Vector (AODV)
Network traffic flow connection	TCP
Period of simulation	100 (secs) for both SUMO and NS-2

modelling the congested road traffic to avoid traffic jams which is the major cause for air pollution and emission of harmful pollutants. The evaluation parameters include Urban Heat Island (UHI) effect, vehicle density, emission and air pollution. The results are analyzed and compared with existing solutions for performance analysis. The coordinates of any area in the world are taken for further editing OSM application. The output of this collaborative mapping serves as the input for creation of Extensible Markup Language (XML) codes for creating routes, junctions, vehicles, activity and movement of vehicles, buildings, trips and emission of pollutants using SUMO as described in Algorithm 2. These XML codes are then utilized for creation of network animation (.nam) file and trace file (.tr) using network simulator. The Air Quality Index (AQI) values are calculated using the obtained emission values of SUMO files. The traffic flow network model is then mapped into the spatial Air Pollutant Index of Malaysia (APIMS) database for generation of real-time AQI values on a 24-hour or 8-hour averaging period for each of the individual air pollutants. These AQI values are stored in the back-end database for further visualization in the user interface through a real time mobile application.

IV. Results and Discussions

The Map as shown in Figure 7, shows the Greater KL.According to statistics, the population at Greater KL was estimated to be nearly 7 million during the year 2010 [40]. The case study areas that are considered for testing and experimentation are Petaling Jaya (PJ), Jalan Tun Razak (JTR), Mont Kiara (MK) and Shah Alam (SA), belonging to Greater KL as shown in Figure 8 and 9. The demographics for each of the areas are tabulated in Table II. The results for traffic flow modelling, vehicular emission modelling and air quality are plotted with respect to various parameters.The transport statistics of Malaysia during the year 2016 states that there

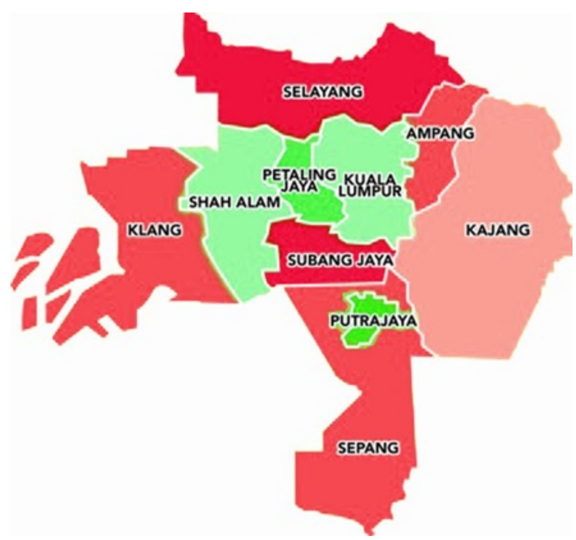


Fig. 7: Greater Kuala Lumpur

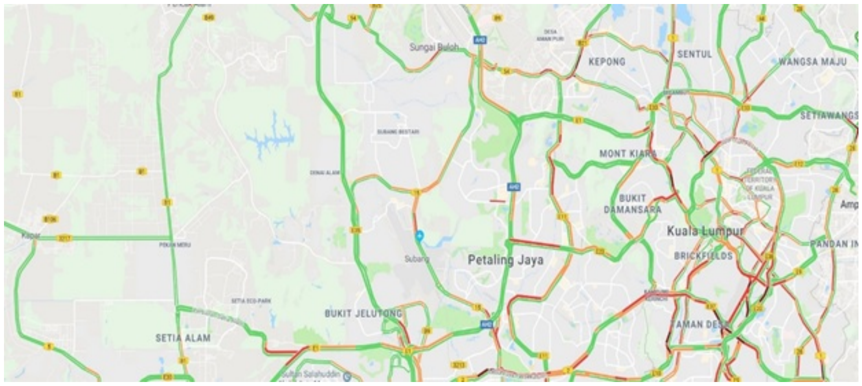


Fig. 8: Traffic flow of urban areas in Greater KL (Source :Google Maps)

Fig. 9: Road transportation for Greater KL (Source: OSM)

TABLE II: Demographics for the case study areas belonging to Greater KL

S.No.	State/ Administrative district	Area (Sq.km)	Population density (per sq.km)
1.	Selangor	7,931	793
1.1	Hulu Selangor	1,746	131
1.2	Kuala Selangor	1,178	205
1.3	Sabak Bernam	997	122
1.4	Kuala Langat	858	304
1.5	Hulu Langat	829	1,598
1.6	Gombak	653	1,204
1.7	Klang	627	1,581
1.8	Sepang	556	445
1.9	Petaling	487	4,283
1.9.1	Shah Alam	290	1866
1.9.2	Petaling Jaya	97	6329
2.	W. P. Kuala Lumpur (Mont Kiara, Jalan Tun Razak)	243	7,598

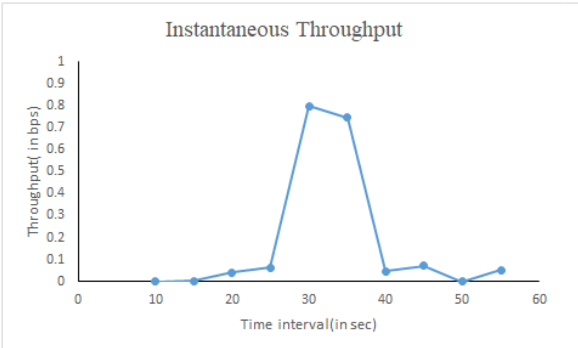
is a gradual increase in number of vehicle travelling in and around KL. The increase in average daily traffic (ADT) for 1 year is approximately 40000 [40] vehicles by which it is evident that vehicles are increasing on every day basis and so the traffic flow must also be taken into consideration for modelling of vehicular congestion.

A. *Results of Traffic Flow modelling*

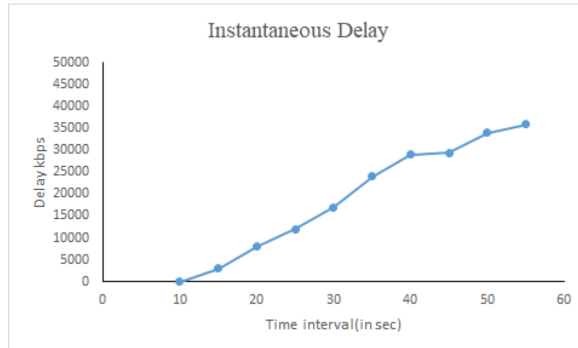
The flow of traffic is experimented and visualized on simulation platforms. The vehicular density and speed of vehicles are considered as the dependent variables for governing the traffic use during morning (peak), afternoon (non-peak) and evening (peak) hours. The results for instantaneous throughput and delay for all the areas such as Petaling Jaya, Jalan Tun Razak, Mont Kiara and Shah Alam belonging to Greater KL as shown in Google Maps of Figure 8 is plotted against time. The results clearly show that the throughput of the network increases and decreases exponentially over time which means that the flow of vehicles is dependent on the traffic hours during the day as depicted in Figure 10. Hence, this observation concludes that modelling the traffic use based upon the peak/non-peak traffic hours will considerably mitigate the traffic congestion. Comparatively, the results for delay, state that it varies randomly depending upon the packet received and dropped between the communication nodes (vehicles on road). The conclusive observation is that the rate at which the flow of traffic can change from free flow to heavily congested is independent of the time factor and hence is random in nature. Therefore, modelling traffic flow based upon factors such as vehicle usage can significantly reduce the waiting time of vehicles at the junctions, intersections and traffic signals.

B. *Results of Vehicle Emission modelling*

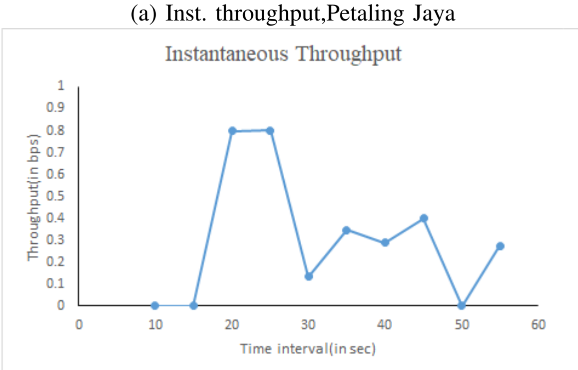
The vehicular emission factor is experimented with regards to various traffic parameters on simulation platforms and the results for all the case study areas of Greater KL are plotted as depicted in Figures 11, 12, 13 and 14 respectively. The results show that CO_2 emission values is the highest during



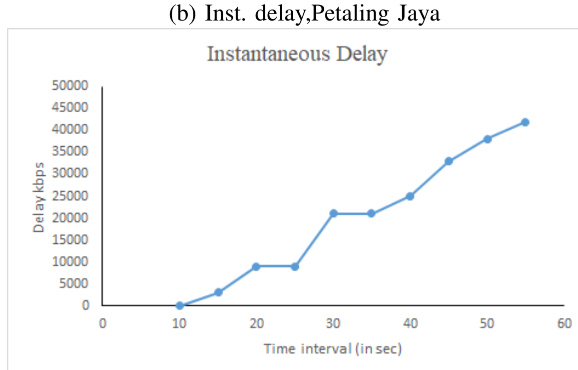
(a) Inst. throughput,Petaling Jaya



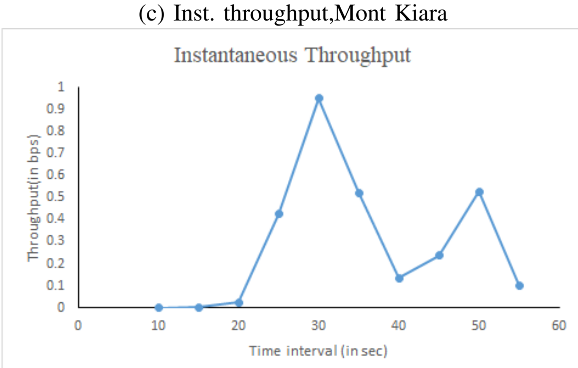
(b) Inst. delay,Petaling Jaya



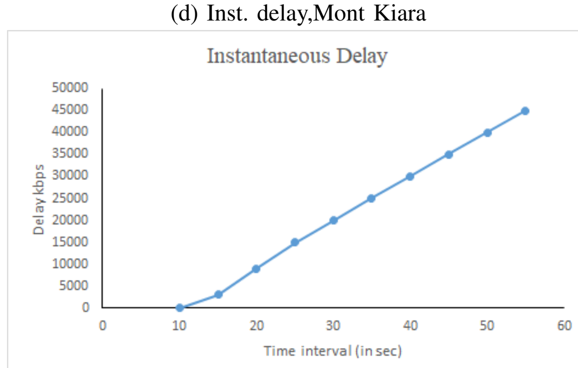
(c) Inst. throughput,Mont Kiara



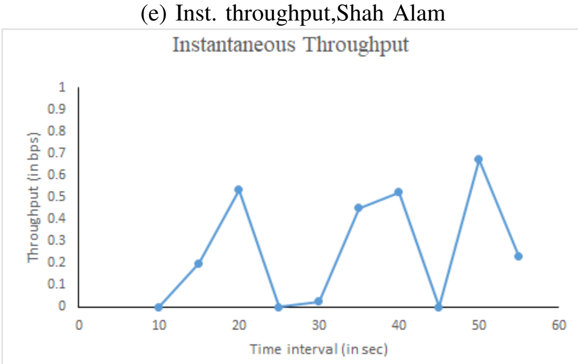
(d) Inst. delay,Mont Kiara



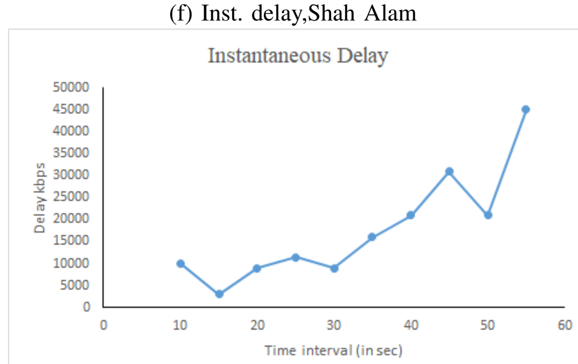
(e) Inst. throughput,Shah Alam



(f) Inst. delay,Shah Alam

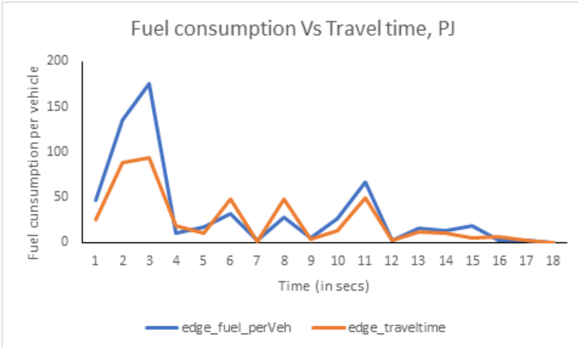


(g) Inst. throughput,Jalan Tun Razak

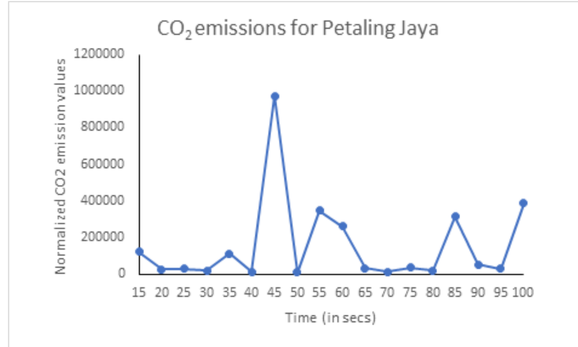


(h) Inst. delay,Jalan Tun Razak

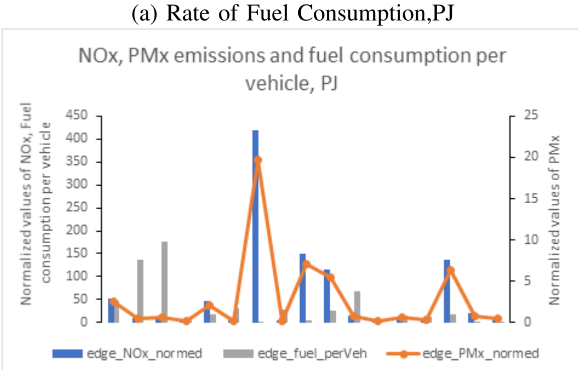
Fig. 10: Traffic flow modelling



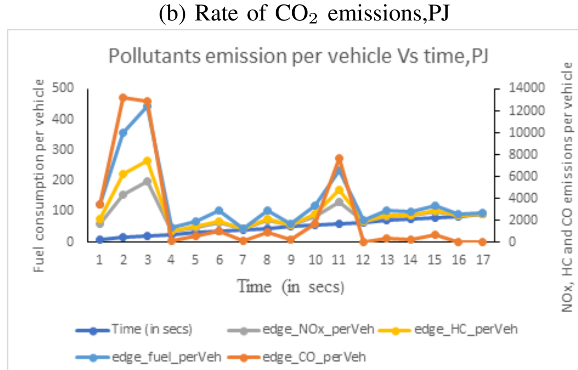
(a) Rate of Fuel Consumption,PJ



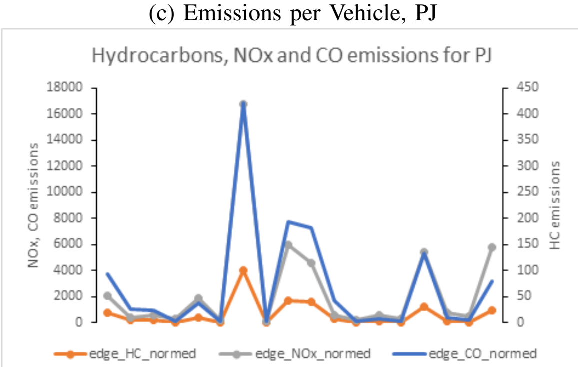
(b) Rate of CO_2 emissions,PJ



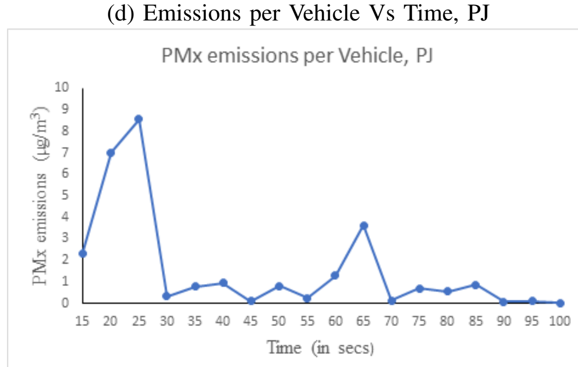
(c) Emissions per Vehicle, PJ



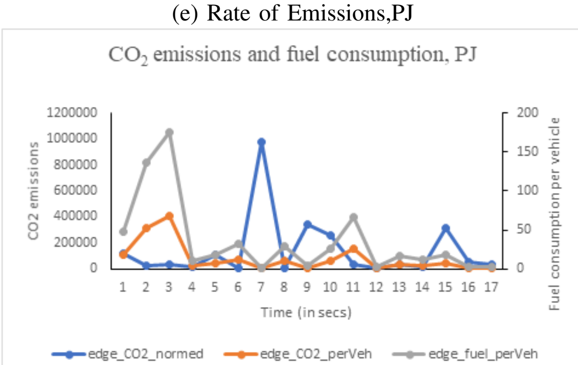
(d) Emissions per Vehicle Vs Time, PJ



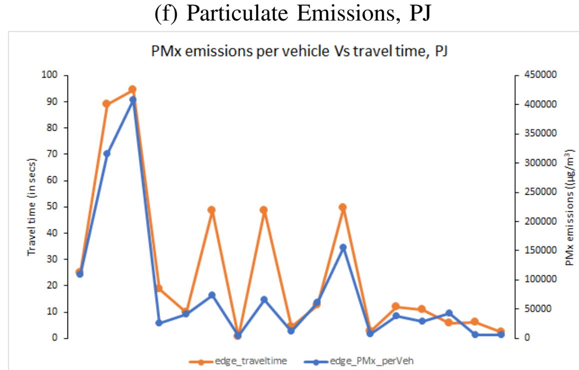
(e) Rate of Emissions,PJ



(f) Particulate Emissions, PJ



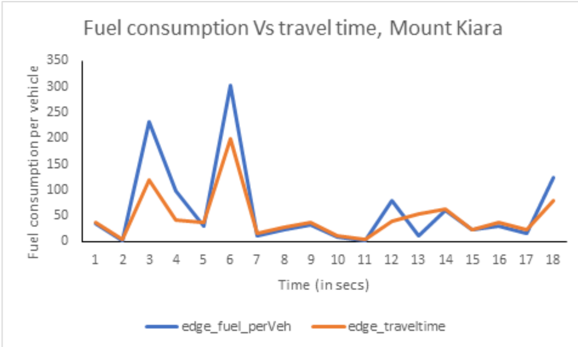
(g) CO_2 Emissions Vs Fuel Consumption,PJ



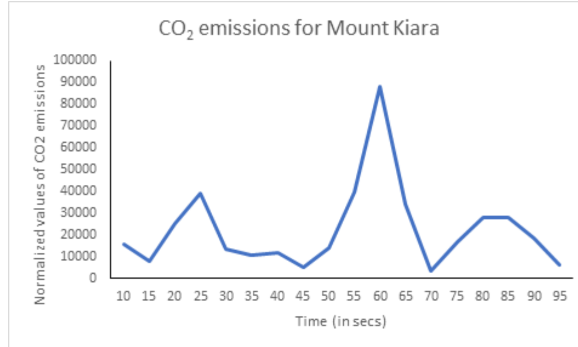
(h) PM_x Emissions Vs Travel time,PJ

Fig. 11: Vehicular pollutant emissions w.r.t traffic parameters for Petaling Jaya

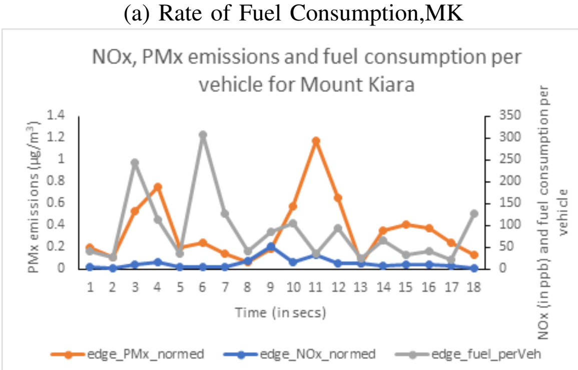
peak hours. The duration of 100 seconds of a simulation run is divided into frequency intervals of peak and non-peak hours. It can be noted that during peak hours there is considerable amount of CO_2 emissions, this might be due to the heavy density of vehicles moving to and from work places or home. Other factors affecting the vehicular density irrespective of traffic hours are accidents, weather conditions, vehicles exiting or entering a state/place due to holidays, festivals and so on. The results also interpret that more the travel time and waiting time of vehicles at junctions and traffic signals,



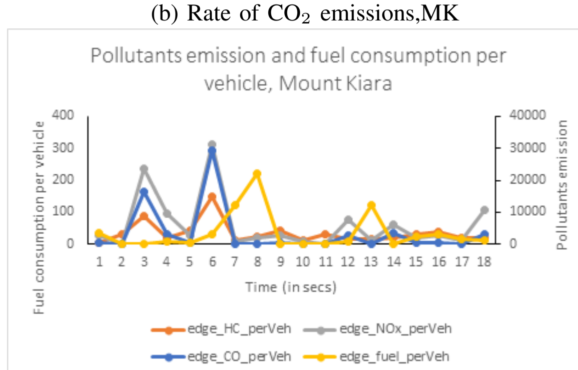
(a) Rate of Fuel Consumption,MK



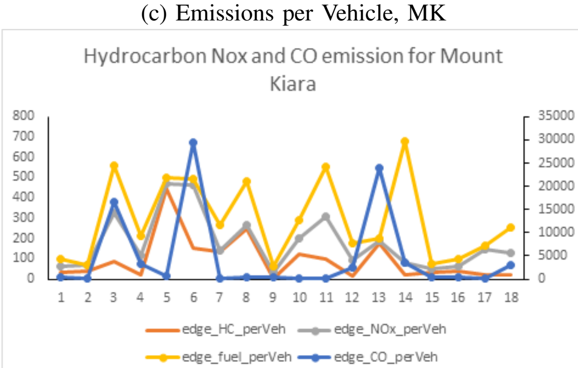
(b) Rate of CO_2 emissions,MK



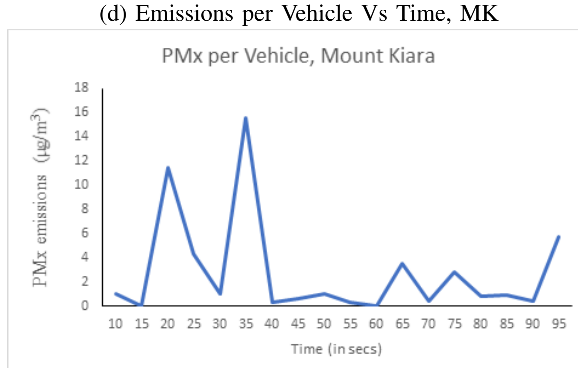
(c) Emissions per Vehicle, MK



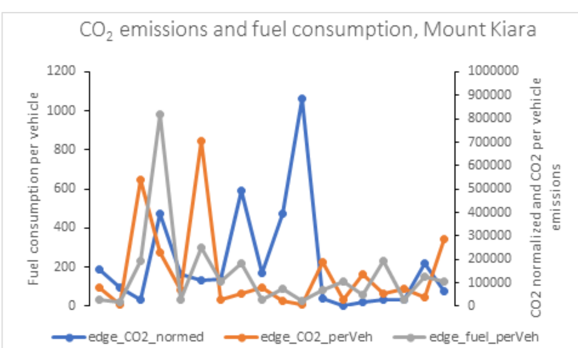
(d) Emissions per Vehicle Vs Time, MK



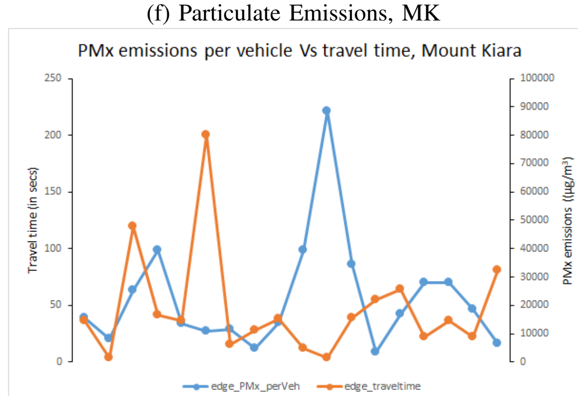
(e) Rate of Emissions,MK



(f) Particulate Emissions, MK



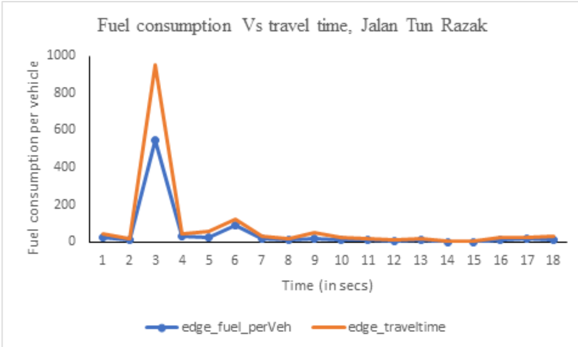
(g) CO_2 Emissions Vs Fuel Consumption,MK



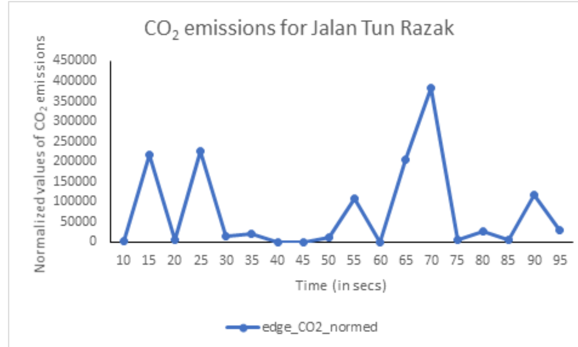
(h) PM_x Emissions Vs Travel time,MK

Fig. 12: Vehicular pollutant emissions w.r.t traffic parameters for Mont Kiara

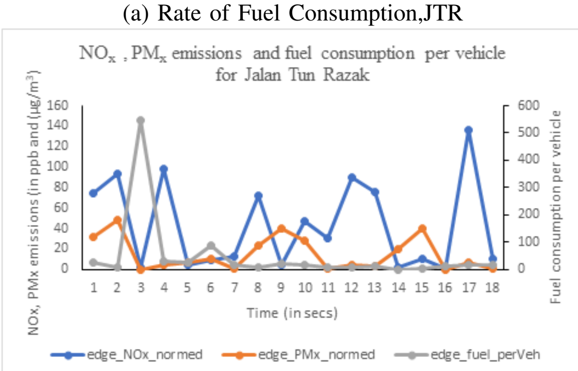
higher is the fuel consumption. The emissions from particulate matter (PM_x) measured in ($\mu g/m^3$) for each vehicle also has significant effect of harmful emissions into the atmosphere irrespective of the traffic hours, followed by emissions due to hydrocarbons (HC), NO_x and CO. It also indicates that the higher the fuel consumption, higher is the vehicular emissions due to the air pollutants. The rate of vehicular emissions also depends upon the factors such as vehicle engine, engine age,



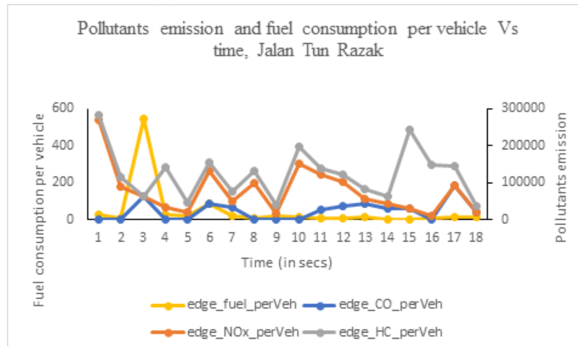
(a) Rate of Fuel Consumption,JTR



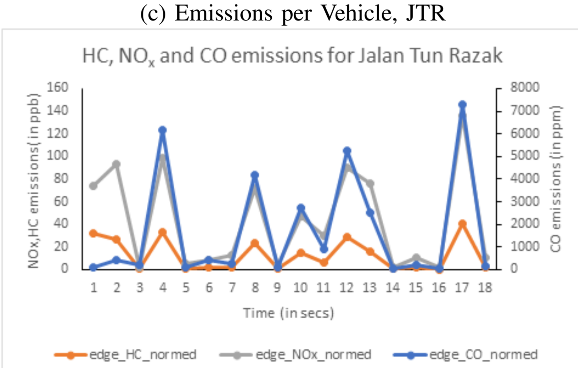
(b) Rate of CO_2 emissions,JTR



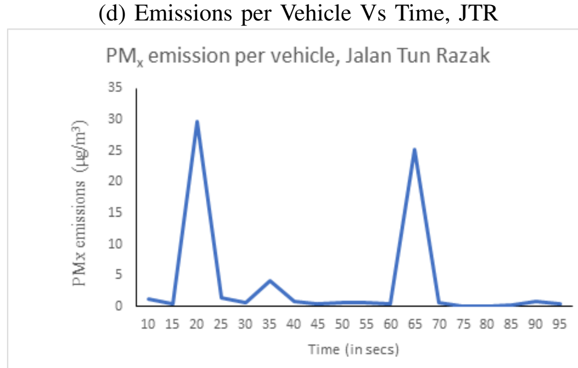
(c) Emissions per Vehicle, JTR



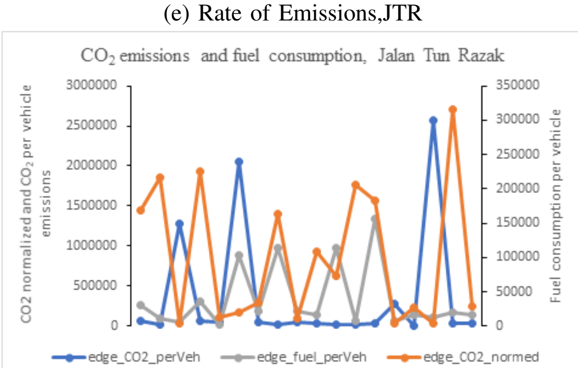
(d) Emissions per Vehicle Vs Time, JTR



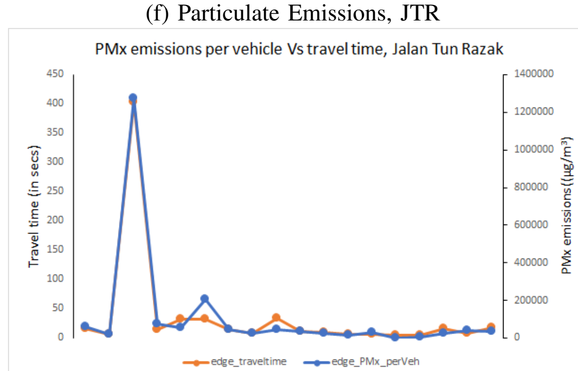
(e) Rate of Emissions,JTR



(f) Particulate Emissions, JTR



(g) CO_2 Emissions Vs Fuel Consumption,JTR



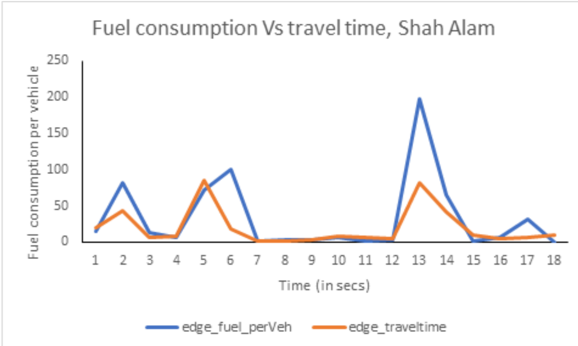
(h) PM_x Emissions Vs Travel time,JTR

Fig. 13: Vehicular pollutant emissions w.r.t traffic parameters for Jalan Tun Razak

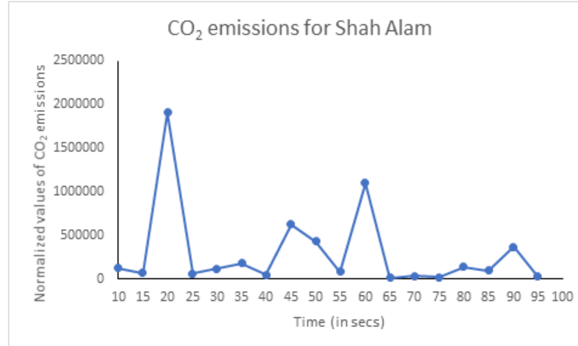
quality of fuel used, year of manufacture for both vehicle and engine, size of engine, exhaust control device and mileage of vehicle per hour. Thus, modelling the vehicular emissions according to fuel and engine parameters can considerably mitigate the traffic induced air pollution and thereby prevent traffic congestion.

C. Results of Air Quality modelling

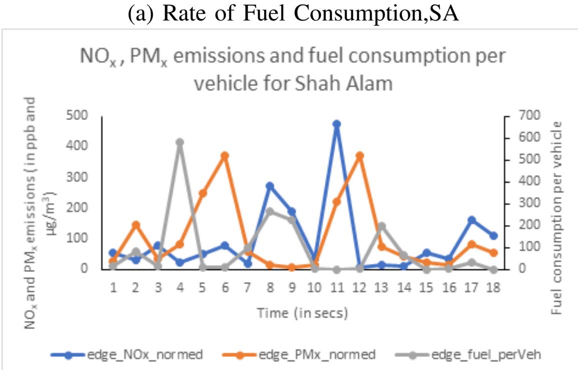
The The AQI is calculated based upon the emissions of air pollutants and vehicular density at a given period. The



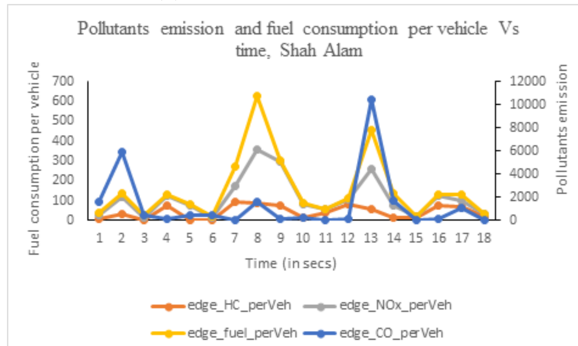
(a) Rate of Fuel Consumption,SA



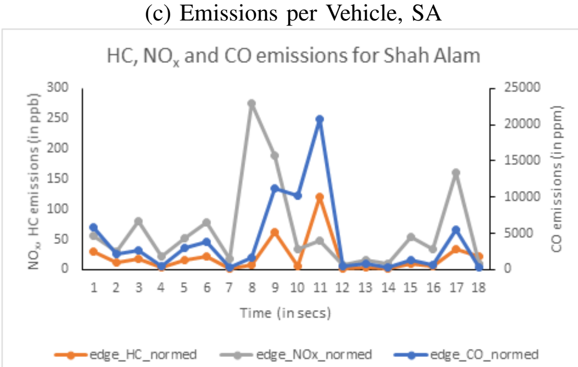
(b) Rate of CO_2 emissions,SA



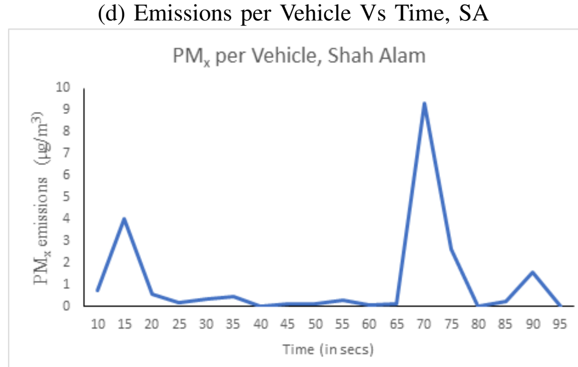
(c) Emissions per Vehicle, SA



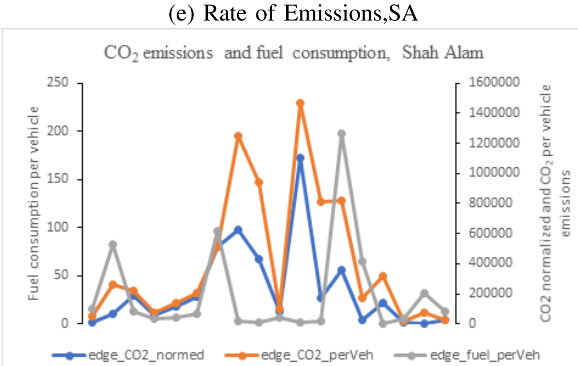
(d) Emissions per Vehicle Vs Time, SA



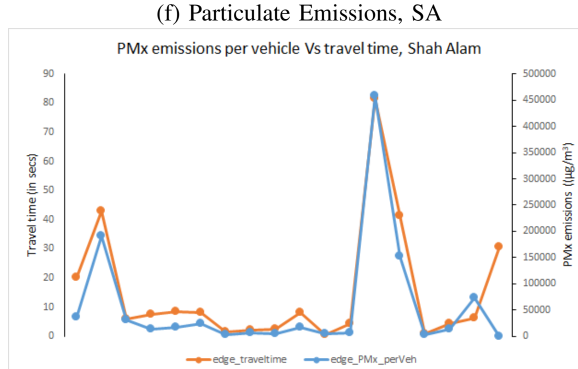
(e) Rate of Emissions,SA



(f) Particulate Emissions, SA



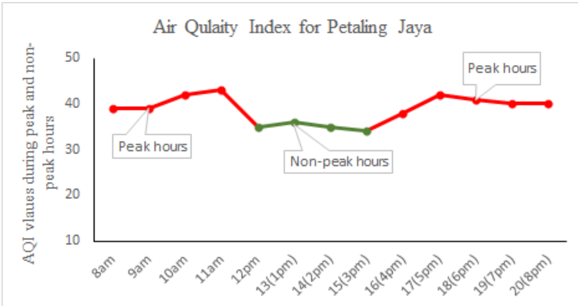
(g) CO_2 Emissions Vs Fuel Consumption,SA



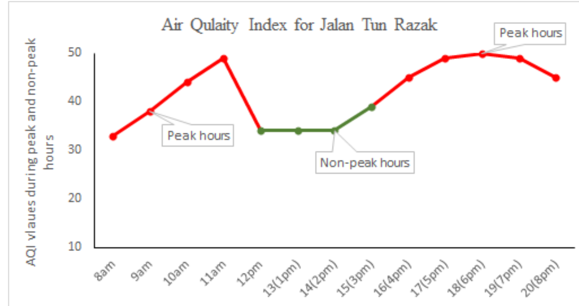
(h) PM_x Emissions Vs Travel time,SA

Fig. 14: Vehicular pollutant emissions w.r.t traffic parameters for Shah Alam

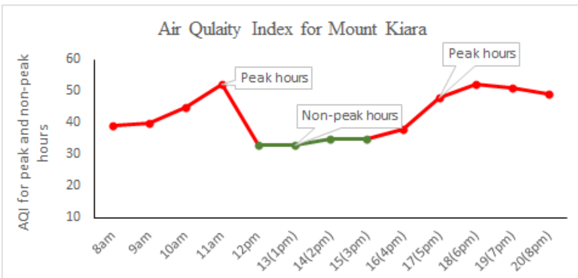
proposed methodology provides modelling of road traffic based upon air quality and hence presents information about the routes that have higher AQI due to heavy traffic congestion. The end users are prompted to take routes having relatively lower AQI values towards their destinations that can significantly reduce the traffic congestion and thereby contribute towards greener environment. The AQI values for areas such as Petaling Jaya, Mont Kiara, Jalan Tun Razak and Shah Alam are plotted against time for morning, afternoon and evening hours as depicted in Figure 15. The results show that



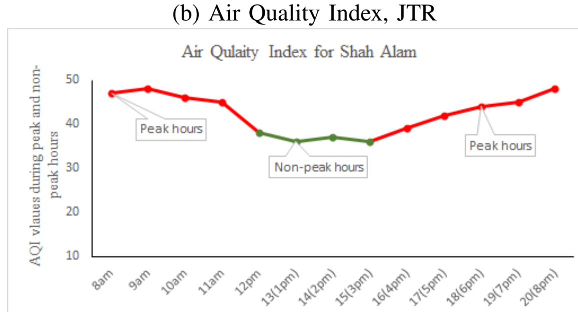
(a) Air Quality Index, PJ



(b) Air Quality Index, JTR



(c) Air Quality Index, MK



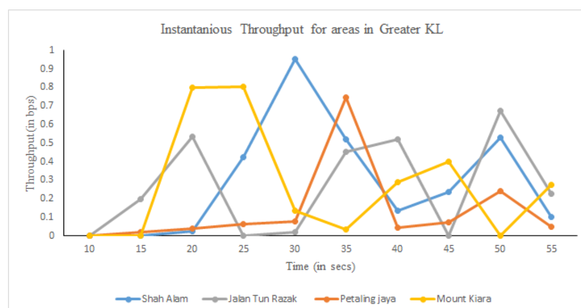
(d) Air Quality Index, SA

Fig. 15: Air Quality Index w.r.t peak and non-peak hours

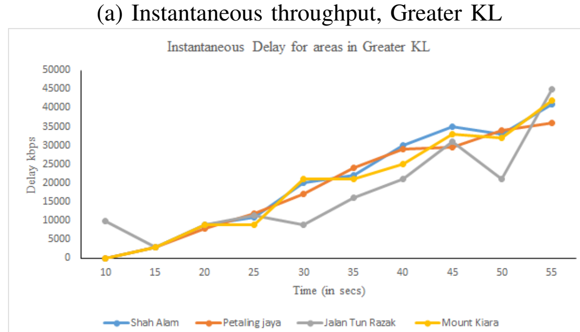
AQI is higher during peak hours. Therefore, modelling the traffic based upon AQI can significantly reduce the congestion occurring during peak hours.

D. Comparative Analysis

As discussed in previous sections, the traffic congestion can be mitigated based upon traffic flow/use, vehicular emission and air quality. The cumulative results are depicted Figures 16, 17 and 18 respectively. The numerical values that are obtained after simulations and calculations using formulas are tabulated in Appendix A, B and C respectively. These three factors are dependent on each other and hence have major contribution towards modelling and governing traffic congestion in urban cities. The case study areas considered in this research belongs to Greater KL according to the demographical information tabulated in Table II. The higher levels of air pollution in such areas can cause increased UHI at the surrounding areas as well. The other areas vary for each parameter depending upon the traffic hours. The results show increase in the pollutant emission with increasing fuel consumption per vehicle and travel time thereby showing high dependency upon the peak and non-peak hours of the day. Urban areas are the major contributors towards increased AQI, therefore, on a comparative basis, to make Malaysia pollution free and to outsmart the traffic congestion, it is necessary to consider the urban areas and hence balance the levels of air quality. These areas also contribute towards increased UHI effects to the surrounding places due to heat generated from vehicle congestion. Hence, the modelling of traffic flow based upon vehicular emissions and air quality index can be a promising solution towards mitigation of traffic congestion [41]. The current work carried out by the authors of this research is to provide user-based solutions for notifications and



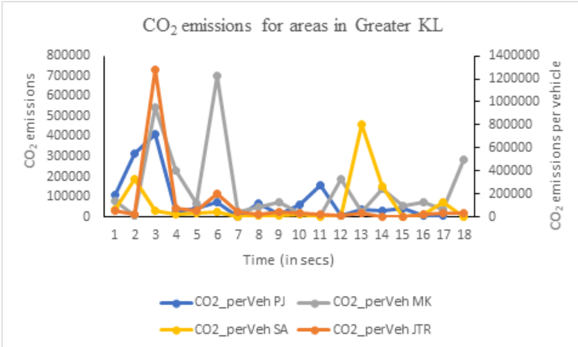
(a) Instantaneous throughput, Greater KL



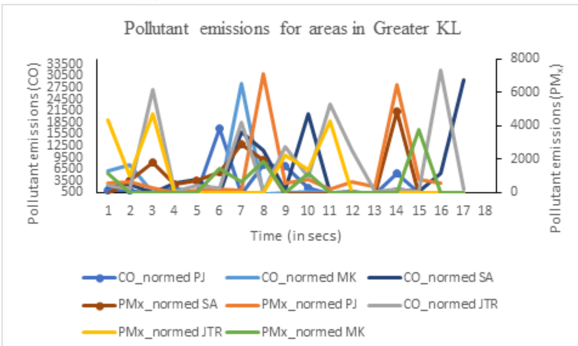
(b) Instantaneous delay, Greater KL

Fig. 16: Air Quality Index w.r.t peak and non-peak hours, Greater KL

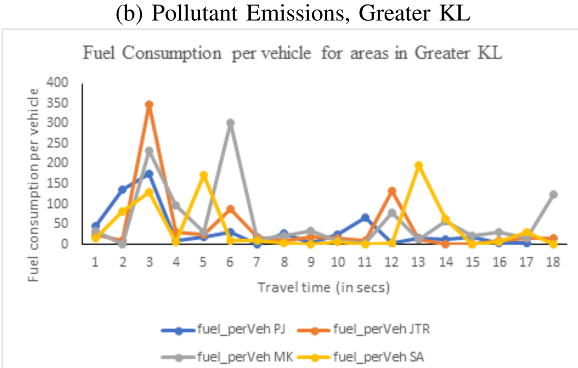
timely updates about the AQI levels different from the existing solutions [42] and [43] which focus on only traffic flow estimation and environmental impacts. This is implemented through integration of obtained AQI values with a real time mobile application for prompting the users with information of minimal traffic congestion and lesser AQI en route to their



(a) CO_2 Emissions, Greater KL



(b) Pollutant Emissions, Greater KL



(c) Fuel consumption per vehicle, Greater KL

Fig. 17: Cumulative vehicular Emissions and fuel Consumption

destination. The quantitative results show that the pollution of an urban city not only depends upon the traffic but also largely upon other factors such as air quality and vehicular congestion. The heat generated from vehicles largely affects the environmental conditions and causes imbalances in the atmosphere. Needlessly, it can be inferred from the above sections that air quality imbalance and traffic use form a cause and effect relation.Therefore, mitigation of traffic congestion in such urban areas needs to be addressed to avoid the adverse impacts of air pollution of urban cities to the country of Malaysia and on the longer run to prevent health hazards caused due to traffic induced air pollution. The comparative results plotted in Figures 16, 17 and 18 show that in Greater KL, Jalan Tun Razak has higher instantaneous delay, pollutant emission and fuel consumption per vehicle leading to higher values of AQI.

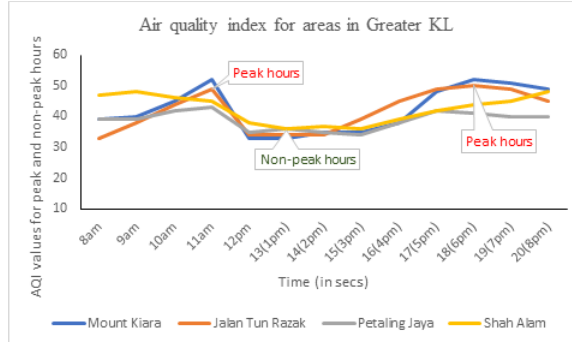


Fig. 18: The Air Quality Index w.r.t peak and non-peak hours,Greater KL

V. Conclusion and Future Work

The relationship between traffic flow, emission of pollutants and their dispersion into the atmosphere determines the air quality level and provides a wider scope to design traffic management strategies for urban road networks. The proposed project has revealed that modelling of road traffic flow can eventually reduce the air pollution level. It can be perceived that when emission and traffic flow model are combined, the emission rate are better estimated for maintaining the air quality in urban transportation. The implementation of the proposed model via simulation has found that air quality is highly dependent on the flow of traffic, density of vehicles, waiting time of vehicles at the junctions/intersections, type of air pollutant, traffic flow rate, fuel consumption rate and acceleration speed. The experimental results provide a wider scope for making the atmosphere free from harmful air pollutants and alleviate the traffic congestion causes. The proposed vehicle routing mechanism shows that around 75% of harmful emission can be reduced by avoiding the traffic congestion caused by dense traffic and efficient routing of the vehicles in the path where there is lesser traffic congestion and lower levels of emission from harmful air pollutants.

The authors currently are focusing upon developing a user friendly mobile application for timely updates on the AQI values and traffic routing from current location towards the destination in minimal time possible. Future work will include recording of the AQI values using deployment of an air quality sensor-based instrument near the traffic signals. The values obtained from such real-time measurements are then compared with existing AQI recording strategies employed by government agencies based on quantitative/statistical analysis for validation and providing the scope for governing the traffic regulation policies in Malaysia.

Appendix A
Traffic Flow Modelling

TABLE III: Numerical values of traffic flow modelling for areas belonging to Greater K.L

	Throughput	Delay	Throughput	Delay	Throughput	Delay	Throughput	Delay
Time	**Shah Alam**		**Petaling jaya**		**Jalan Tun Razak**		**Mont Kiara**	
10	0	19.0733	0	0	0	10001	0	0
15	0.00200002	3000	0.02	3000	0.199986	3000	0.002	3000
20	0.024	9000	0.04	8000	0.53358	9000	0.797911	9000
25	0.426	11000	0.064	12000	0	11495	0.802081	9000
30	0.952	20000	0.08	17000	0.0202664	9000	0.133375	21000
35	0.522	22000	0.746	24000	0.45218	16000	0.0346669	21000
40	0.134	30000	0.045	29000	0.52146	21000	0.288112	25000
45	0.236	35000	0.072	29500	0	31005	0.39971	33000
50	0.528	33000	0.24	34000	0.6724	21000	0	32000
55	0.1027	41000	0.0506	36000	0.228591	45000	0.274286	42000

B Vehicle Emission Modelling

TABLE IV: Numerical values for vehicular emission modelling of Petaling Jaya

ST	ET	edge_CO2_ normed	edge_CO2 _perVeh	edge_CO _normed	edge_CO _perVeh	edge_HC _normed	edge_HC perVeh	edge_NOx_ normed	edge_NOx_	edge_PMx_ normed	edge_PMx_ perVeh	edge_fuel_ perVeh	edge_ traveltime
10	15	121071.7791	109592.8655	3770.623591	3413.127709	20.023098	18.124692	53.11119	48.075675	2.549717	2.307976	47.110105	24.77
15	20	25213.94566	315697.4644	1051.68364	13167.86603	5.380857	67.372359	11.232788	140.642908	0.560228	7.014476	135.709516	88.96
20	25	31499.46381	408686.4595	992.833363	12881.41139	5.262511	68.277889	13.805345	179.115991	0.66129	8.579837	175.680057	94.35
25	30	20085.96884	25702.48893	128.123832	81.8775	1.047334	1.340193	7.367601	9.427759	0.262907	0.336422	11.048416	18.81
30	35	114062.7318	41105.92549	1540.232794	555.06907	9.723916	3.504305	47.282679	17.039731	2.135718	0.76967	17.669551	9.95
35	40	11747.18197	74158.24504	163.822741	1034.18905	1.011798	6.387334	4.462031	28.168148	0.152183	0.960708	31.877889	48.52
40	45	974164.663	4331.61737	16907.18259	75.177687	100.254883	0.445783	419.588471	1.865698	19.757194	0.08785	1.861965	0.59
45	50	10504.27879	66228.33444	141.224583	890.405624	0.879091	5.542575	3.919893	24.714497	0.126103	0.795068	28.469185	48.46
50	55	347203.8867	11616.79106	7783.312116	260.41503	43.682525	1.461535	150.752558	5.043898	7.111223	0.237928	4.993573	4.2
55	60	263211.9672	61471.04143	7279.172666	1699.992327	39.364065	9.193161	114.81282	26.813612	5.463005	1.275841	26.42408	12.68
60	65	33983.7635	155910.3668	1675.687993	7687.704444	8.427646	38.664269	15.306562	70.223291	0.789131	3.620367	67.022309	49.66
65	70	11650.22357	6963.941346	94.520763	56.49995	0.715336	0.427594	4.348526	2.599339	0.213089	0.127374	2.993479	2.63
70	75	36930.03366	37544.00919	294.424546	299.319463	2.243715	2.281018	13.74327	13.971757	0.672215	0.683391	16.138452	12.02
75	80	18547.42394	29500.14882	160.527494	255.323056	1.184107	1.883352	7.002629	11.137859	0.34538	0.549336	12.680754	10.85
80	85	315978.001	42493.93862	5310.237522	714.141195	31.741477	4.268716	135.743275	18.255278	6.420396	0.86344	18.26619	5.66
85	90	52444.73942	5635.599241	425.479783	45.721145	3.159994	0.339566	19.909261	2.139406	0.769762	0.082717	2.4225	5.92
90	95	31416.02744	6031.965983	219.287088	42.10374	1.759942	0.337914	11.436601	2.19586	0.551462	0.105882	2.592869	2.21

TABLE V: Numerical values for vehicular emission modelling of Mont Kiara

ST	ET	edge_CO2 _normed	edge_CO2_ perVeh	edge_CO_ normed	edge_CO _perVeh	edge_HC _normed	edge_HC _perVeh	edge_NOx _normed	edge_NOx _perVeh	edge_PMx _normed	edge_PMx _perVeh	edge_fuel _perVeh	edge_ traveltime
10	15	15591.7618	80211.19518	94.89317	488.174117	0.773224	3.977822	5.65554	29.094698	0.196131	1.008988	34.479441	36.6
15	20	8017.174065	5483.929069	59.266565	40.539676	0.456113	0.311992	3.002133	2.053527	0.112675	0.077072	2.357306	4
20	25	25155.63231	541579.5778	770.747087	16593.53567	4.10313	88.336942	11.041603	237.716404	0.530953	11.430972	232.805677	119.47
25	30	39311.63356	227965.6548	572.574686	3320.324074	3.541736	20.538301	16.449564	95.38997	0.750174	4.350209	97.99202	41.26
30	35	13684.11913	70388.33678	105.892455	544.689339	0.797481	4.102079	5.151937	26.50052	0.195523	1.00573	30.256913	36.59
35	40	10903.90405	702699.3464	456.215137	29400.66943	2.333162	150.360019	4.851617	312.661255	0.241301	15.550554	302.070979	200.46
40	45	11681.12023	28624.59531	68.916827	168.880745	0.563876	1.381779	4.211476	10.320224	0.143644	0.352001	12.304524	15.44
45	50	4950.722074	51177.52628	28.612678	295.780304	0.242882	2.510761	1.791287	18.51723	0.06169	0.637715	21.999085	27.74
50	55	14007.47488	76851.51974	95.616906	524.598803	0.758172	4.159685	5.181404	28.427589	0.188672	1.035142	33.035205	37.8
55	60	39513.56069	20940.00045	313.22852	165.993781	2.337156	1.238563	14.931673	7.91296	0.571508	0.302868	9.001201	11.75
60	65	88496.36716	5716.121797	598.077339	38.630771	4.719137	0.304817	32.626081	2.107371	1.178804	0.076141	2.457119	3.81
65	70	34370.76987	185867.2763	484.50286	2620.052658	3.025273	16.359811	14.354412	77.624547	0.655503	3.544773	79.895795	39.32
70	75	3629.175444	28789.04685	30.056957	238.431888	0.221553	1.757506	1.382476	10.966721	0.053878	0.427393	12.375158	54.65
75	80	17030.71885	138500.8784	432.493943	3517.220361	2.372809	19.296664	7.454596	60.62387	0.354545	2.883308	59.536001	63.79
80	85	28119.93476	54323.45668	230.140112	444.595853	1.700949	3.285977	10.680671	20.633439	0.412965	0.797785	23.351298	22.44
85	90	28113.06145	71995.08393	190.560444	488.008579	1.50082	3.843467	10.366179	26.546874	0.374588	0.959286	30.947637	36.52
90	95	18449.0875	35595.74631	118.063145	227.791524	0.95801	1.848388	6.760401	13.043546	0.240588	0.464192	15.301111	22.41
95	100	6409.643604	287691.9251	66.50157	2984.871853	0.462143	20.742941	2.406887	108.031286	0.128338	5.76036	123.665642	80.51

TABLE VI: Numerical values for vehicular emission modelling of Jalan Tun Razak

ST	ET	edge_CO2 _normed	edge_CO2 _perVeh	edge_CO _normed	edge_CO _perVeh	edge_HC _normed	edge_HC _perVeh	edge_NOx _normed	edge_NOx _perVeh	edge_PMx _normed	edge_PMx _perVeh	edge_fuel _perVeh	edge _travel time
10	15	168237.9658	60877.17083	108.451782	2202.753941	31.671947	11.460544	74.252638	26.868433	3.612725	1.30727	26.169171	15.59
15	20	215718.7985	20655.83243	424.630049	442.824566	26.171191	2.505983	93.182244	8.922527	4.34569	0.416115	8.879072	7.11
20	25	4345.397125	1274734.974	214.001464	62777.95614	1.076494	315.792552	1.959223	574.743778	0.101245	29.700649	547.979265	402.66
25	30	225251.1599	72716.07278	6154.775523	1986.898114	33.350794	10.766376	98.261744	31.721071	4.679668	1.510701	31.257872	14.76
30	35	13539.48184	55309.33455	73.364959	299.698844	0.640552	2.616681	4.861673	19.860133	0.164123	0.670451	23.775191	32.62
35	40	20224.70557	205084.44	416.681767	4225.2752	2.378233	24.115975	8.776996	89.001312	0.41296	4.187532	88.156926	32.3
40	45	34461.67014	43916.99762	264.707981	337.336517	2.047711	2.609547	12.74567	16.242729	0.620983	0.791364	18.877915	14.39
45	50	163792.0467	22760.78231	4200.147981	583.658705	23.004968	3.196804	71.724861	9.966992	3.413838	0.474392	9.783956	7.75
50	55	10674.25284	44858.52291	74.347744	312.446223	0.582025	2.445959	3.95487	16.620332	0.14454	0.607429	19.282772	33.56
55	60	107824.7779	34174.01843	2736.951786	867.450344	15.016414	4.759307	47.175869	14.951935	2.241427	0.710399	14.690048	11.57
60	65	73387.00208	22727.14963	920.878345	285.185923	5.918353	1.832849	30.118497	9.327368	1.348507	0.417618	9.769356	9.46
65	70	205349.2554	14732.29443	5253.585914	376.906039	28.7812	2.064839	89.748556	6.438797	4.252695	0.305099	6.33283	5.75
70	75	183028.3846	31222.51029	2518.562485	429.637421	15.830643	2.700523	76.247983	13.007018	3.476368	0.593028	13.421118	6.86
75	80	4760.316713	274.115813	54.011057	3.110147	0.358844	0.020664	1.921476	0.110645	0.084093	0.004842	0.11783	4.07
80	85	26822.42588	3393.019319	228.930322	28.959536	1.698783	0.214895	10.102074	1.277906	0.497653	0.062953	1.458503	4.84
85	90	4030.07869	25650.516	27.93628	177.807939	0.213122	1.35647	1.48281	9.437739	0.053299	0.339239	11.026072	15.33
90	95	315874.1149	39719.67845	7320.97773	920.578381	40.81523	5.132322	136.72474	17.19249	6.409358	0.805946	17.073867	8.05
95	100	28187.03601	34240.28011	172.605485	209.672991	1.424407	1.730302	10.265782	12.470387	0.359686	0.43693	14.718461	17.79

TABLE VII: Numerical values for vehicular emission modelling of Shah Alam

ST	ET	edge_CO2 _normed	edge_CO2 _perVeh	edge_CO _normed	edge_CO _perVeh	edge_HC _normed	edge_HC _perVeh	edge_NOx _normed	edge_NOx _perVeh	edge_PMx _normed	edge_PMx _perVeh	edge_fuel _perVeh	edge_ travel time
10	15	128845.6342	35811.25526	5901.203488	1640.175904	29.854341	8.297692	56.546265	15.716425	2.72918	0.758546	15.394439	20.11
15	20	68668.64044	191370.2867	2114.681324	5893.333094	11.24781	31.346137	30.098906	83.881612	1.442844	4.021012	82.26329	42.96
20	25	190896.8083	30450.36623	2699.764991	430.645402	16.809209	2.681274	79.898693	12.744815	3.665152	0.584636	13.089206	5.94
25	30	61233.65994	13545.59874	409.368226	90.557019	3.280705	0.72573	22.599889	4.999359	0.818775	0.181123	5.822679	7.59
30	35	119526.855	16954.06062	3034.270915	430.390418	16.647531	2.361338	52.300969	7.418532	2.485412	0.352539	7.287875	8.51
35	40	180993.917	23453.78494	3798.574742	492.231764	21.604193	2.799542	78.540301	10.17751	3.716358	0.481578	10.081773	8.08
40	45	50980.9428	2241.839164	241.054627	10.600151	2.183307	0.096009	17.942119	0.788988	0.572651	0.025182	0.963675	1.36
45	50	627410.1857	6206.013312	15944.64205	157.716057	87.470679	0.865214	274.767001	2.717851	13.082963	0.12941	2.667717	2.03
50	55	430183.8038	5131.989956	11277.94571	134.543197	61.52727	0.734006	188.174166	2.244873	8.925609	0.10648	2.206042	2.3
55	60	81553.15957	16135.99058	1013.281112	200.48634	6.553795	1.296725	33.447401	6.617855	1.496528	0.296101	6.93612	7.99
60	65	1103669.646	3637.871427	20872.7568	68.79994	121.294542	0.399806	475.658007	1.567845	22.198238	0.073169	1.56376	0.56
65	70	17611.81508	6324.243217	399.317744	143.391384	2.23797	0.803635	7.736427	2.778081	0.371504	0.133404	2.718523	4.39
70	75	36123.96185	459060.5244	819.409922	10412.99816	4.587623	58.299155	15.636118	198.702582	0.734926	9.339386	197.331155	81.42
75	80	23468.45796	151468.1009	273.014838	1762.068863	1.797361	11.600372	9.478591	61.175907	0.412216	2.660489	65.109262	41.35
80	85	137696.0773	1829.611503	1233.592867	16.39114	8.842102	0.117488	53.145841	0.706166	2.130399	0.028307	0.786469	0.92
85	90	95528.74382	13234.89006	661.097609	91.590801	5.336685	0.739363	34.753342	4.814851	1.674741	0.232025	5.689081	4.13
90	95	373420.0438	73453.37519	5503.067678	1082.477766	34.176477	6.722664	160.409045	31.553169	8.133297	1.599856	31.574007	6.34
95	100	2755797.349	29.442279	29468.71186	0.314837	201.819068	0.002156	1084.62001	0.011588	54.868124	0.000586	0.012656	9.02E-03

C AIR QUALITY MODELLING

TABLE VIII: Air Quality Modelling numerical values for areas belonging to Greater K.L

State	Location	8am	9am	10am	11am	12pm	13 (1pm)	14 (2pm)	15 (3pm)	16 (4pm)	17 (5pm)	18 (6pm)	19 (7pm)	20 (8pm)
W.P. KUALA LUMPUR	Mont Kiara	39	40	45	52	33	33	35	35	38	48	52	51	49
W.P. KUALA LUMPUR	Jalan Tun Razak	33	38	44	49	34	34	34	39	45	49	50	49	45
SELANGOR	Petaling Jaya	39	39	42	43	35	36	35	34	38	42	41	40	40
SELANGOR	Shah Alam	47	48	46	45	38	36	37	36	39	42	44	45	48

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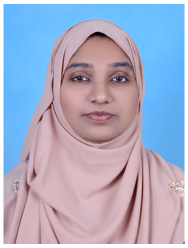

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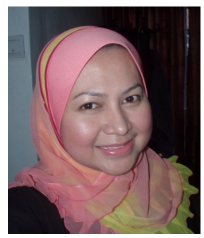

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