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Develop Prediction Models for Air Pollution Closed to Selected Busy Traffic Routes

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ABSTRACT

There are many methods used in monitoring air pollutants such as CO_2, CO, SO_2, NO_X, CH_4 and particular matter, which can be detected by either using chemical or solid state sensors. This paper studies the concentration of selected pollutants by analyzing the given test data of vehicular emission by the Air Resource Management Center (Air Mac) in Sri Lanka, with counted vehicles considering three types of roads in four sessions of a day. Monitoring pollution at selected sites close to busy traffic routes together with the traffic parameters would carry out to develop prediction models. With these models, it is intended to predict the pollution for different traffic volumes, which are useful when designing new highways, and to help develop alternative mechanisms to reduce air pollution within city limits.

1. INTRODUCTION

1.1 The Mechanics of Vehicular Exhaust Emissions

An exhaust generated from fuel-air combustion is the main contributor for vehicle emissions, which includes 100 percent of the carbon monoxide, 100 percent of the nitrogen oxides and 65 percent of the total hydrocarbons produced from all three sources combined [1]. Since, the main source of vehicle emissions is from the exhaust, modeling efforts mainly focused on exhaust emissions.

The combustion of Hydrocarbon fuel with Oxygen in air produces by product of emissions, which are mainly included in Carbon Dioxide (CO_2) and water (H_2O). Normally air contains nitrogen (N_2) with other gases, and due to that the internal combustion is not perfectly done. As a result of the incomplete burning of fuel it produces Hydrocarbon (HC), Carbon Monoxide (CO) and other organic compounds like Sulfur Dioxide (SO2), particles, which contain Carbon and other contaminants like PM_{10} and $PM_{2.5}$ These are characterized by its micrometer sizes. In addition to that, Nitric Oxide (NO) and a small amount of Nitrogen Dioxide (NO_2) observed to be produced due to high temperatures with some pressure generated at the combustion chamber [2].

CO, HC and NO_x are regarded as the most serious pollutants and many countries legally had restricted their emission rates. When these primary pollutants are released into the atmosphere, they take part in many chemical reactions influenced by sunlight. As a result, it produces secondary pollutants. Sometimes the effects from these secondary pollutants to the environment are more severe than the original primary pollutants.

1.2 Developed Emission and Traffic Flow Models

Hong Kong Island developed a Traffic Flow Model using the Lagrangian function [3] and also an emission factor based traffic-related air pollution emission model for the simulation of traffic flow on a complex road network. The traffic flow model is simple but quite efficient. With the specification of three types travel behavior (random turning trip, preferred turning trip and shortest path trip) and providing traffic flow data at selected stations, the model is capable of simulating traffic flow on a road network. They have established a traffic information database for Hong Kong Island and the model have been applied successfully for traffic flow simulation. It is shown by specifying three types of traffic routes (random turning trip, preferred turning trip and shortest path trip) and providing traffic flow data at selected stations, the model is capable of simulating traffic flow on the road network.

The simulated traffic flows carried out in two ways. First one done in three cross-harbour tunnels and secondly in three counting stations on the island for weekdays and weekends. These were compared with observations and successive results have been found. The temporal variations of traffic flow in the cross-harbour tunnels and at the counting stations are reproduced by the model at satisfactory level. These were confirmed by comparing the simulated model and the observed traffic flow patterns at several monitoring stations. The simulated traffic flow is then used as the basis for the estimation of traffic induced emission of air pollutants on the island. Using empirical emission factors for a number of vehicle categories, the emission rates of major air pollutants, CO, NO_x and PM_{10}, are estimated. The predicted emission rates are compared with measurements for several air quality monitoring stations.

The research carried out by the Department of Urban and Regional Planning and Geo-information Management [4], International Institute for Geo-Information Science and Earth Observation, Netherlands has aimed to support decision making in fields like air quality impact analysis, human health assessment, etc., through spatially modeling traffic-induced air pollution dispersion in urban areas at street level.

2 RESEARCH METODOLOGY

The study was carried out using real vehicle emission test data of Air Resource Management Center and survey of counted vehicle categories for four session of a day.

2.1 Emission Test Data

Air Resource Management Center (Air Mac) is the main responsible institution for control of vehicle emissions in Sri Lanka. Two authorized private companies are carrying out the emission test. They are Cleanco Lanka (Pvt.) Ltd. and Laugfs Eco Sri (Pvt.) Ltd. Test records of all the stations of those two companies are uploaded in the Air Mac Center database. Here, these three months' test records were analyzed to build a model for vehicular emissions in selected three kinds of road categories in Sri Lanka. For this analysis, 50,000 Petrol and 27,629 Diesel vehicles were used and selected vehicles had passed the emission test. Failed vehicles in the test should alter its engine to perform at required condition in order to get the renewal licenses. Considering the pass status in three months period, vehicles were sorted into 39,800 Petrol and 22,125 Diesel (Table 1).

Table 1: Vehicles, passed in Emission test

Vehicle Categories	Number of Vehicles	
	Petrol	Diesel
Buses	09	83
Dual Purpose Vehicles/Vans	598	9,220
Light Land Vehicles	0	05
Motor Cars	8,680	2.273
Motor Coaches	09	2,026
Motor Cycles	22.551	02
Motor Lorries	256	8,347
Motor Tricycles	7,697	153
Prime Movers	0	16
Total	**39,800**	**22,125**

2.2 Vehicle Survey

The study was carried out by considering the number of vehicles travelling at three type of roads (main roads-category A, secondary roads-category B and local roads-category C) with different widths of about 25 km boundary, Colombo capital city in Sri Lanka. In this distance traffic congestion is less and also has a quite smooth traffic flow. Two locations were selected for each road category (L_1- Location 1, L_2- Location 2).
Measurements were taken for duration of 3 1/2 hours on a day categorized as, morning (1 hour - 7.00 a.m. to 8.00 a.m.), noon (1 hour - 1.30 p.m. to 2.30 p.m.), evening (1 hour - 5.00 p.m. to 6.00 p.m.) and night (1/2 hour - 8.30 p.m. to 9.00 p.m.).

Table 2: Vehicle densities against the day schedule for Main Road – Type A

Vehicle Type	Time ranges							
	Morning		Noon		Evening		Night	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Buses	165	182	123	146	142	141	65	57
Dual Purpose Vehicles/Vans	249	306	182	252	310	286	141	117
Light Land Vehicles	3	1	4	3	0	6	0	0
Motor Cars	234	247	153	150	277	192	111	111
Motor Coaches	120	109	76	64	118	103	49	32
Motor Cycles	320	496	300	196	461	362	136	118
Motor Lorries	224	154	235	236	211	245	88	106
Motor Tricycles	114	177	127	106	153	138	55	70
Prime Movers	7	14	16	9	19	9	15	12

Table 3: Vehicle densities against the day schedule for Secondary Road – Type B

Vehicle Type	Time ranges							
	Morning		Noon		Evening		Night	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Buses	111	91	67	73	81	75	20	18
Dual Purpose Vehicles/Vans	163	249	104	222	93	128	29	34
Light Land Vehicles	1	0	3	13	4	1	0	0
Motor Cars	69	213	39	110	51	180	32	60
Motor Coaches	24	61	21	42	20	52	6	6
Motor Cycles	449	437	159	265	425	319	120	110
Motor Lorries	35	47	60	83	65	66	19	14
Motor Tricycles	147	179	124	159	132	188	49	52
Prime Movers	1	0	2	0	1	0	1	0

Table 4: Vehicle densities against the day schedule for Local Road – Type C

Vehicle Type	Time ranges							
	Morning		Noon		Evening		Night	
	L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
Buses	10	14	19	16	2	13	0	02
Dual Purpose Vehicles/Vans	50	24	58	22	21	36	4	13
Light Land Vehicles	0	01	0	02	0	0	0	0
Motor Cars	32	05	25	04	27	08	10	0
Motor Coaches	8	02	5	02	10	02	0	02
Motor Cycles	100	161	54	71	59	117	22	72
Motor Lorries	04	05	08	08	09	12	02	04
Motor Tricycles	50	43	39	39	35	56	04	30
Prime Movers	0	0	0	0	0	0	0	0

3. RESULTS AND DISCUSSION

3.1 Pollutant concentrations - by Vehicle Categories

3.1.1 Petrol Vehicles

By examining Pollutants variations of Petrol Vehicles, Motor Cycles and Motor Tricycles add higher concentration of HC and CO, while adding more CO_2 observed with Cars, Coaches, Dual Purpose Vehicles/Vans and Lorries. Table 5 has actual average numbers of pollutant concentrations for Petrol Vehicles. HC and CO are the most dangerous pollutants added by Petrol Vehicles.

Table 5: Average HC, CO, CO_2 for Petrol Vehicles

Vehicle	Number	HC (ppm v/v)	CO (% v/v)	CO_2 (% v/v)
Buses	09	481.33	1.05	8.94
Dual Purpose Vehicles/Vans	598	221.77	0.88	11.94
Motor Cars	8,680	149.17	0.75	12.44
Motor Coaches	09	317.72	1.51	12.41
Motor Cycles	22.551	1781.70	2.49	5.70
Motor Lorries	256	296.71	1.09	11.46
Motor Tricycles	7,697	3698.04	2.04	5.58

3.1.2 Diesel Vehicles

According to Table 6, Dual Purpose Vehicles/ Vans, Light Land Vehicles and Motor Cars of Diesel category have significantly higher Smoke Densities, than other vehicles.

Table 6: Average Smoke Density (K) for Diesel Vehicles

Vehicle	Number	K (m^{-1})
Buses	83	0.41
Dual Purpose Vehicles/Vans	9,220	0.68
Light Land Vehicles	05	0.86
Motor Cars	2.273	0.75
Motor Coaches	2,026	0.54
Motor Cycles	02	0.25
Motor Lorries	8,347	0.52
Motor Tricycles	153	0.53
Prime Movers	16	0.50

3.2 Pollutant Concentrations - By Day Schedule

From the Vehicle survey,
Buses, at morning, in Type A road,
If, a = counted number of Buses from location 1
b = counted number of Buses from location 2

Average number of Buses in Type A road = $\frac{(a+b)}{2}$

From the Emission test data,
If, c = Tested Petrol Buses
d = Tested Diesel Buses

Ratio of Petrol Buses from all buses = $\frac{c}{(c+d)}$

Normally higher rate of HC, CO and CO_2 were emitted from Petrol Vehicles.

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If, e = counted average value of HC

HC concentration at morning for Type A road = $e * \left[\frac{(a+b)}{2}\right] * \left[\frac{c}{(c+d)}\right]$

This formula can be used for other times of the day.

(1) Type A – Main Road

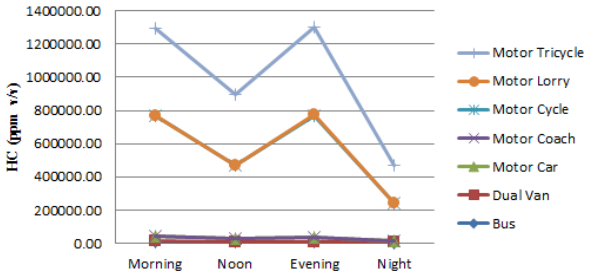

Figure 1: Variation pattern of HC Concentration-Type A Road

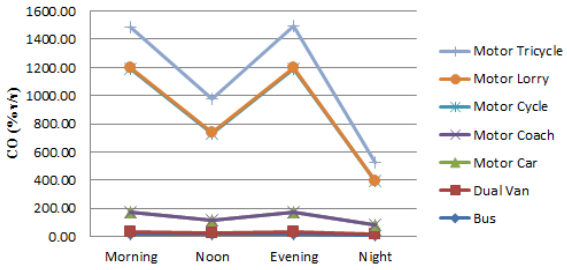

Figure 2: Variation pattern of CO Concentration-Type A Road

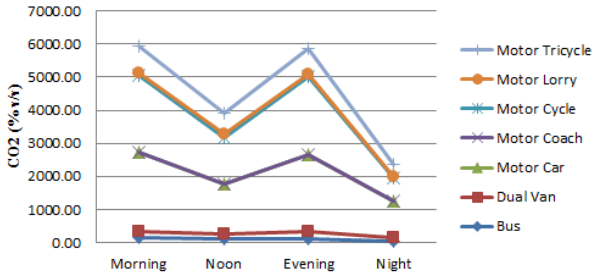

Figure 3: Variation pattern of CO_2 Concentration-Type A Road

(2) Type B – Secondary Road

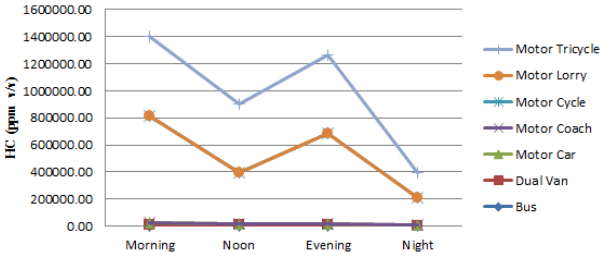

Figure 4: Variation pattern of HC Concentration-Type B Road

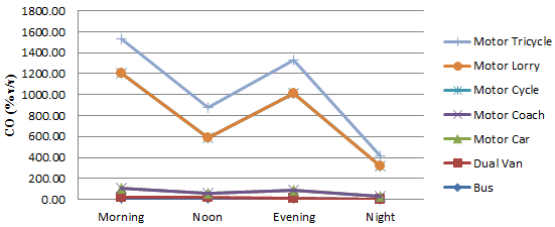

Figure 5: Variation pattern of CO Concentration- Type B Road

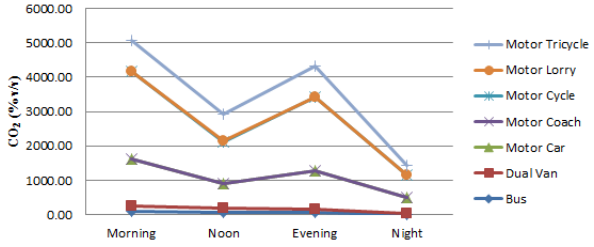

Figure 6: Variation pattern of CO_2 Concentration-Type B Road

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(3) Type C – Local Road

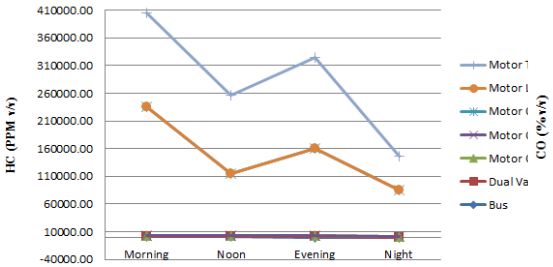

Figure 7: Variation pattern of HC Concentration- Type C Road

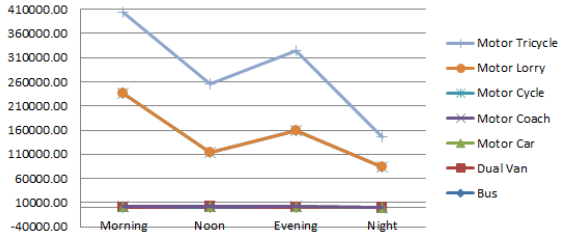

Figure 8: Variation pattern of CO Concentration- Type C Road

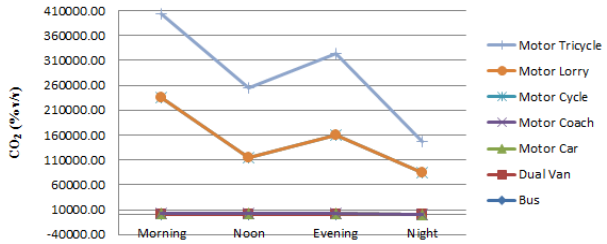

Figure 9: Variation pattern of CO_2 Concentration-Type C Road

Concentrations of HC, CO, CO_2 of Main (Figure 1, Figure 2 and Figure 3), Secondary (Figure 4, Figure 5 and Figure 6) and Local roads (Figure 7, Figure 8 and Figure 9) for day schedule were almost observed behaving in the same kind of a pattern. In the morning, Vehicles had started to move their particular locations. The same thing has seen repeated at evening. At evening, higher percentage of vehicles of morning vehicle densities had reduced back to their original locations. Normally, Pollutants were added into the atmosphere with higher rate at morning and evening of the day.

4. CONCLUTION

Analyzing the vehicular emissions of selected sites close to busy traffic routes together with the traffic parameters had carried out to develop prediction models. Considering these models, it is seen that more pollutants have into the atmosphere in the morning and in the evening of the day.

It is recommended Traffic flow should be controlled carefully at these times. It can be done by programming traffic light signals by allocating more time periods to the vehicles to enter into the city limits in the morning and its opposite action can be done in the evening. Also, flyover bridges can be built over high traffic junctions or find out alternative road to ignore traffic jams. These models could be implemented in future when designing new highways, and to help develop alternative mechanisms to reduce air pollution within city limits.

Motor cycles and motor tricycles of petrol vehicle category are ejected more HC and CO concentrations into the atmosphere. It can be minimized by introducing additional accessories to fix to the vehicles to enhance compete burning in its engines.

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