EVALUATION OF URBAN ROAD CARBON MONOXIDE (CO) DISPERSION

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ABSTRACT: The urban air pollution is one of the problems presently encountered by a fast growing metropolis worldwide. The road traffic in urban areas is the primary source of some categories of pollutants that adversely affect the quality of air. Traffic emission, in large city centers, contributes dominantly to the level of the lead (Pb), Carbon Monoxide (CO), Oxides of Nitrogen, HC or volatile organic compounds and other particulate. These vehicle emissions can damage health especially those of pedestrians and persons living or working in open near traffic areas. Reduction and mitigation of urban air pollution due to public utility vehicle emission is one of the problems of the government over the past decade.

Keywords: vehicle emission, air pollutant, air quality

1. INTRODUCTION

Urbanization was a worldwide phenomenon for the last five decades. The pattern of urbanization is characterized mainly by a heavy concentration of economic activities and migration of population from rural to urban areas. Metro Manila for instance is one classic example of urban area that is experiencing problems of overcrowding, pollution and traffic congestion affecting the mobility of the urban populace. Likewise, urban traffic congestion causes severe air pollution problems.

The environmental effects of road transport vehicles are dominant source of emissions having local and trans-boundary regional effects (such as the formation of acid rain). The source of deterioration of air quality in the Metro Manila can be identified as the mobile source (motor vehicles) and stationary (industry), and area sources (construction, aircraft operations and fuel combustion, etc.). In 1999, there are a total of 3,533,732 registered vehicles (Land Transportation Office) that contribute to air pollution in the Philippines. The increasing number of vehicles such as jeepneys, FX's taxi, buses, taxi, utility vehicles, etc. characterizes the dominance of motor vehicles as the source of air pollution. These motor vehicles in motion emit pollutants from its exhaust pipes, engine crankcase that can aggravate disease in the human respiratory system and other human body system.

Urban traffic emission, in large city centers of Metro Manila, contributes dominantly to the level of lead (Pb), Carbon Monoxide (CO), Nitrogen Oxides (NOx), Volatile Organic Compounds and Particulate Matter. These air pollutants are usually released, mixed and dispersed in the atmosphere. The amount of mixing and dispersion of a pollutant is measured by its concentration in air and is measured as weight of the pollutant per volume of air (gram per cubic meter) or parts of the pollutant in a million parts of air.

Government agencies and the non-governmental organizations implemented programs in order to reduce the level of air pollutants and to improve the level of air quality in the urban areas. In 1998, the Clean Air Act (RA 8749) was signed into law to provide a systematic elimination of existing pollution-promotion technologies and prevent the emergence of other sources of pollution that can adversely affect the quality of air.

This paper will present the result of evaluation of predicted Carbon Monoxide (CO) concentration in identified urban arterial during the morning and afternoon peak hours. The evaluated values of CO concentrations in the identified traffic congested urban arterial will be compared to the automobile exhaust emission standard by the DENR-Clean Air Act-Article 4, Section 4 (Pollution from Motor Vehicles) and the World health Organization.

The model, Urban Traffic Environment Analysis Model (UTEM) will be utilized to assess values of carbon monoxide (CO) concentrations in the urban arterial study area. The Urban Environment Transportation Model can estimate the amount of Carbon Monoxide in a particular urban arterial considering the number of vehicles, traffic signalization, characteristic of traffic flow, intersection geometry, speed, section of the road (open area and built up areas or street canyon).

The results of the evaluated value can be used by the government agency in monitoring the urban traffic emission in the arterial in Metro Manila. The MMDA's campaign on roadside emission test to check whether the vehicle is below or above the set standard of the Department of Environment and Natural Resources-Environmental Management Bureau. Listed down below are tables of the standards set by the Department of Environment and Natural Resources that are included in the Clean Air Act.

Table 1. Emission Limits for Light Duty Vehicles

CO (g/km)	HC+Nox (g/km)	PM (g/km)
2.72	0.97	0.14

DENR RA 8749

Table 2. Emission Limits for Light Commercial Vehicles Type

	Reference Weight (RX) (kg)	CO (g/km)	HC+Nox (g/km)	PM (g/km)
Category 1	1250 < RW	2.72	0.97	0.14
Category 2	1250 < RW< 1700	5.17	1.4	0.19
Category 3	RW>1700	6.9	1.7	0.25

Table 3. Summary of Emissions from all sources in Metro Manila, 1992

(in thousand mm)

Pollutant	**Source Category**			
	Area	Mobile	Stationary	Total
Particulate Matter (PM)	1,212	244	358	1,814
PM< 10 microns (PM10)	1,164	156	240	1,560
Sulfur Oxide (Sox)	5	75	326	406
Volatile Organic Compounds (VOC)	1,721	286	19	2,026
Nitrogen Oxide (Nox)	29	198	61	288
Carbon Monoxide	8,134	1,288	56	9,478

Table 4. Motor Vehicles Emissions

MOTOR VEHICLES EMISSIONS IN NCR 88-96 (metric tons)					
Pollutants	**1988**	**1990**	**1992**	**1994**	**1996**
HC	67,259	189,385	104,244	126,443	155,194
VOC	9,831	27,301	14,760	17,678	21,701
Lead (Pb)	386	944	314	103	121
CO	368,664	1,015,003	540,868	628,754	746,748
PM	21,021	58,364	34,707	43,386	53,320
Sox	10,756	30,626	16,696	19,619	16,215
Nox	49,800	135,819	75,747	90,163	107,075
CO2	10,855,070	29,403,569	16,259,685	19,576,365	24,041,256

In Table 4 (Motor Vehicles Emissions) shows the different pollutants that contributes to the decreasing level of air quality in Metro Manila. This is due to the substantial increase of number of vehicles in Metro Manila. The Environmental Management Bureau (EMB) emission inventory in 1990 revealed that motor vehicles are responsible for 93.53% of airborne pollutants in Metro Manila. As result of air pollution, there is an increase in cancer cases, brain damage, cardio-vascular disease and respiratory illness (Ibon Facts & Figures). In the study conducted by the MMUTIS revealed that the residents' general impressions are that Metro Manila's environment has deteriorated and traffic congestion and the pollution are the most serious environment problems in most of the areas in the metropolis.

In 1990, the registered motor vehicle population by fuel type in Metro Manila region is 675,610. Chart 1 gives us the percentage of gasoline-fueled and diesel fueled motor vehicles that contribute to the decreasing level of air quality in the metropolis.

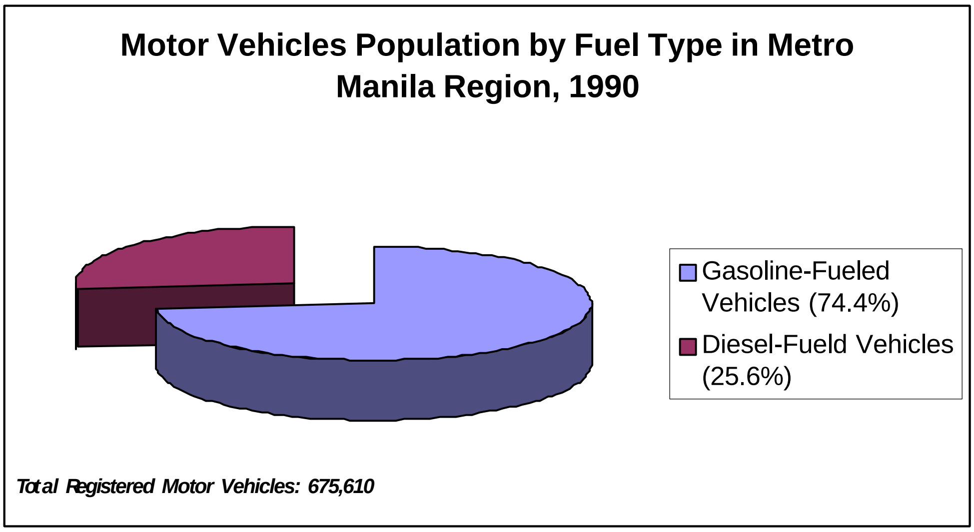

Chart 1. Motor Vehicles Population by Fuel Type in MMR (1990)

Traffic generated air pollutants emit or release into air by vehicle in motion. In Table 5 shows the type of pollutants and their effects to the quality of air and to human health. Table 6 shows the air quality standard set by the World Health Organization (WHO), USA and the EEC. The said standard can help the study to have a specific comparison of standards and control of air quality. The higher the standard, the higher is the expected air quality in an area. The purpose of putting a standard is to control the possible impact of traffic operations on air quality in an urban area.

Table 5. Traffic-Generated Air Pollutants

Types of Pollutants	Characteristics	Effects
Carbon Dioxide (CO_2)	Colorless, odorless gas that is a natural constituent of air (about 0.0 3%). It is a product of combustion of petrol or any other fossil fuel. A vehicle emits about 2 kg of CO_2 per liter of fuel.	It is a green house gas, its presence in air prevents heat from exit by absorption of ultrared ray reflection radiated from the sun thus contributes to increases in atmospheric temperature. It affects heightening of sea surfaces,

		inundation of some areas, changes in the distribution of rainfall regions and disease pattern in the human body.
Carbon Monoxide (CO)	Colorless, odorless and tasteless gas that is slightly lighter than air. It has a natural occurrence range of between 0.01 and 0.23 mg/ cu.m.	The effect of CO in the air is the that it reduces human body's oxygen carrying capacity. If affects the functioning of the central nervous system in terms of impairment of vision and slowing down of reflexes and mental functions.
HC (Volatile Organic Compounds -VOC)	Combination of chemical compounds such as benzene which is a usual element of gasoline.	Stimulate eyes, membranes and skin. It cause photochemical smog.
Nitrogen Oxide (NOx)	Includes nitric acid and nitrous oxides and nitrogen dioxide. It consists of about 70% NO and 30% NO2.	It can lead to acidification of soil and water. It forms a strong nitric acid which induces respiratory diseases and even lung cancer and increases the probability of catching a circulatory disease.
Lead (Pb)	A bluish or silvery gray soft metal whose baseline levels in the atmosphere aare in the range of 5x10e-5 ug/cu.m.	It is a poison that contaminates food.

Table 6. Comparison of Air Quality Standards

Pollutant (mg/cu.m.)	**Period Measured**	**Standard adopted by:**		
		WHO	**U.S.A**	**EEC**
CO	1 hour 8 hour	30 10	40 10	*
NOx	Absolute Limit ammual Annual Mean 24 hour 8 hour	- - - - 0.15 -	- - - 0.10 - -	- 0.20 - - - -
Lead	Quarterly Average Annual Mean 24 hours	- - - .0005-.0001 -	- - - - -	- - - - -

	Absolute	-	-	0.002
SOx	Annual Mean 24 hour 8 hour	- .04-.06 0.10-.15 -	- 0.08 0.365 -	- 0.08-12 0.25-0.35 -

- Standards for particulates typically consider PM-10 (particles less than 10u in diameter) as the indicator pollutant.

2. Emission Factor through Modelling

The basic formulation of emission factor of a vehicle in use can be characterized with the type of vehicle under ideal age and maintenance condition, the age, mileage and quality of maintenance of the vehicle. It can be described as:

$$EF^{actual} = EF^{ideal} * f^{age} * f^{maintenance} \quad \text{-------------------------------- (EQN. 1)}$$

Where: EF^{actual} , EF^{ideal} = emission factor under actual and ideal conditions respectively.

f^{age} , $f^{maintenance}$ = adjustment factor for engine age and maintenance level of vehicle respectively.

The table shown below shows the adjustment factors for age and mileage. The adjustment factor for vehicle maintenance is between 1.0 and 1.5 depending on the quality of maintenance of the vehicle.

Table 7. Deterioration Factor of Vehicle

Age (Years)	**Deterioration Factor, DF**	
	CO	HC
New	1.0	1.0
1	1.06	1.06
5	1.25	1.2
10	1.30	1.2
15	1.30	1.2

3. Pollutant Dispersion Mathematical Modelling

Matzoros (1992) developed a mathematical model to predict the concentration of pollutants along sections of the road under study. There are two model types developed to predict the concentration of pollutants along the sections of the facility. The most popular models to determine the pollutant dispersion models are:

a. Dispersion Model for a Section in an Open Area
b. Dispersion Model for a Section in a Canyon

A. Dispersion model for a section in an Open Area

$$C(j,k,p) = \frac{TE(j,k)\exp\left[- \left(\frac{y_e^2}{2ó^2_y} + \frac{z^2}{2ó^2_y} \right) \right]}{ðó_y \, ó_z \, Ue} \qquad \_\_\_\_\_\_\_\_\_\_\_ \text{(EQ.2)}$$

$ó_z = 1.85 \{1 + \exp [0.39 (\ln x_e)^3 - 4.76 (\ln x_e)^2 + 20.95 (\ln x_e) - 32.67] \}$
$ó_y = 12.5\, ó_z$

If the facility is the x-direction in the conventional x and y coordinate system and that wind subtends an angle á from the figure shown below, then;

$X_e = X_d \cos á + Y_d \sin á$

$Y_e = X_e \sin á - Y_d \cos á$

The X_e and Y_d are the down wind distances along the x and y directions respectively. If the midpoint of the section is actually upwind of the location P, then:

$X_d = 1.3\, X^{1..5}_u$

where Xu = actual upwind distance to P and

$$U_e = \frac{U}{0.59 + 0.11\,U} \qquad \text{-------- (EQN. 3)}$$

U = measured wind speed in mps.

B. Dispersion Model for a Section in Urban Areas with Buildings

Koushki (1991) developed a street canyon dispersion model to determine concentration of a pollutant in an urban area with high buildings.

$$C_l(j,k,P) = \frac{0.7\, TE\,(j,k)}{L_k(U + 0.5)\,[\,(x^2 + y^2)^{0.5} + 2\,]} \qquad \text{(EQN. 4)}$$

$$C_w(j,k,P) = \frac{0.7\, TE\,(j,k)}{W_r\,(U + 0.5)} \qquad \text{(EQN. 5)}$$

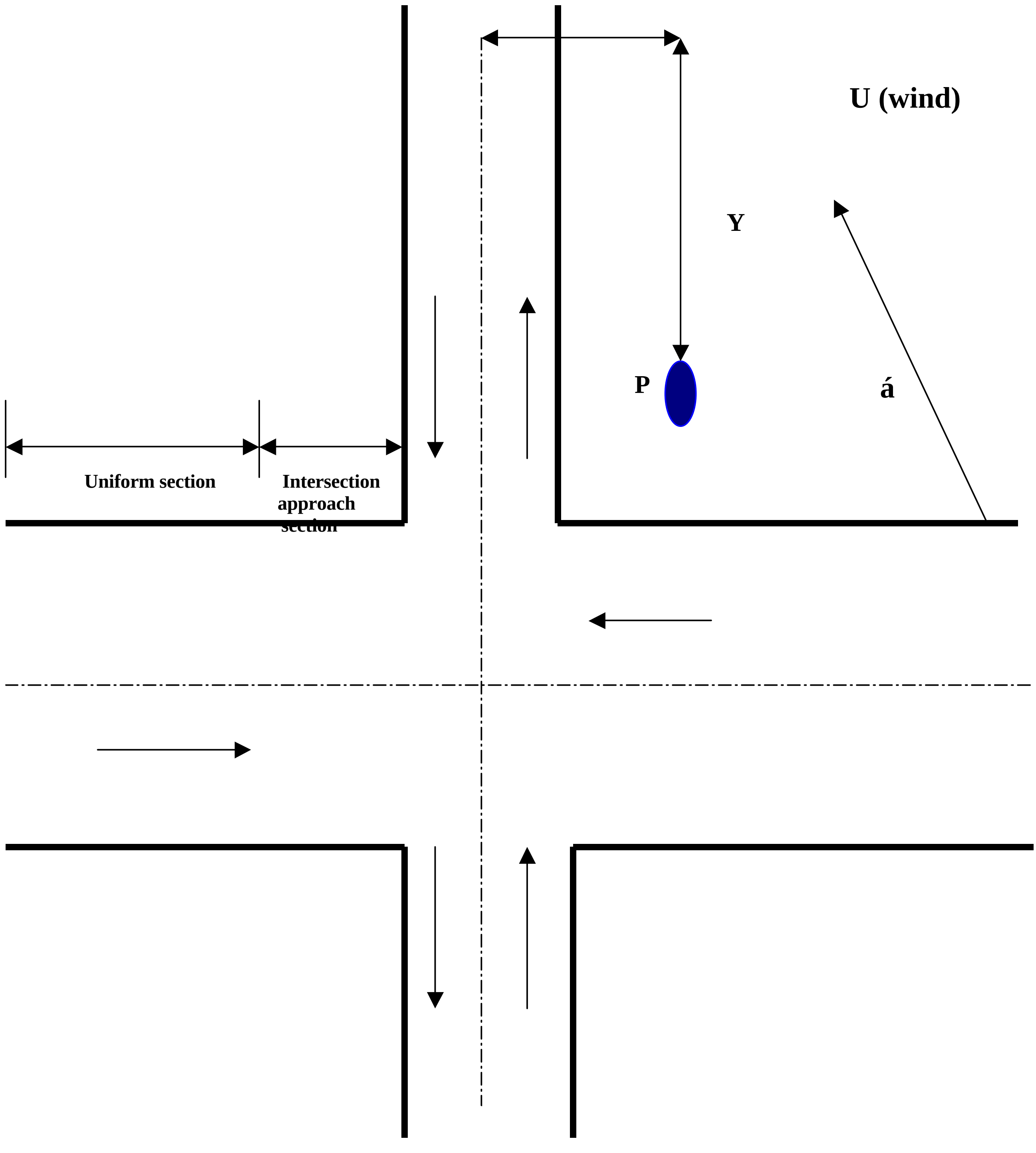

Figure 1 Dispersion Model

C_l & C_w = concentration contributed by emissions at the downwind (leeward) side and upwind (windward) side of the section respectively in gm/m^3.
W_r = right of way width of the section under study (m).
Length (k) = length of section k in km.

4. Urban Traffic Environment Analysis Model (UTEM) Major Modeling Variables

The study will use the Urban Traffic Environmental Analysis Model (UTEM) developed by Dr. E. Akinyemi to evaluate the amount of carbon monoxide (CO) dispersion in air. The amount of dispersion of carbon monoxide as air pollutant is measured by its concentration in air in a particular area. The concentration of the carbon monoxide is dependent to the meteorological condition of the area. The variables needed as input data are the number of lanes of the direction under consideration, lane width, signalization, lane length, pedestrian, speed, maintenance level, wind speed, opposite direction speed, number of vehicles in the opposite direction, right-in capacity, right-in demand, through traffic demand, type of vehicle, vehicle age and radius. There are variables that are needed in the modeling because of different condition that the study area being considered. The result of the CO pollutant emission is presented as gm/cu.m.

The traffic consideration that needed for input to the model is a typical urban traffic. The traffic to be considered is the morning and the afternoon peak hours. The normal condition in the area being considered during the peak hour is congested. The movement of the vehicles can be assumed the level of service of D or E. The traffic lights also in the intersection is assumed to be controlled by a pre-timed signal. Most of the time, peak hour traffic volume on designated arterial exceed to its required capacity, thus, its level of service is being affected. The traffic volume during the peak hour, especially in the afternoon, is normally higher than the required capacity of the road. The arterial intersection being considered is situated in an area with buildings and on-going construction of the LRT track.

5. Background of the Study Area

The Pureza-R. Magsaysay intersection is the area to be considered in this study. The R. Magsaysay is a major urban arterial that connects the busy road of C.M. Recto and Aurora Blvd. The study area is a 4-lane-2 directional road with mix traffic. Each lane has width approximately 3.05 m. with 2-meter median. During the roadside traffic counting, there are about an average of 1203 vph during the morning peak (6-9 AM) and an average of 950 vph during the afternoon peak (4:00-7:00 PM). The traffic situation appeared to have a long queue along the uniform and intersection approach section of the study area. The traffic composition of the study area is public utility vehicle, tricycle, taxi, car, and truck. The speed of the vehicles passing along the uniform section up to the intersection approach is ranging from 30 kph to 40 kph. The uniform section of the length of the study area is 100 meters (from the former NSO building up to the PUP Hasmin Hotel) and the intersection approach section is 15 meters from the intersection of Pureza St. up to the NSO building.).

6. Presentation of UTEM Results

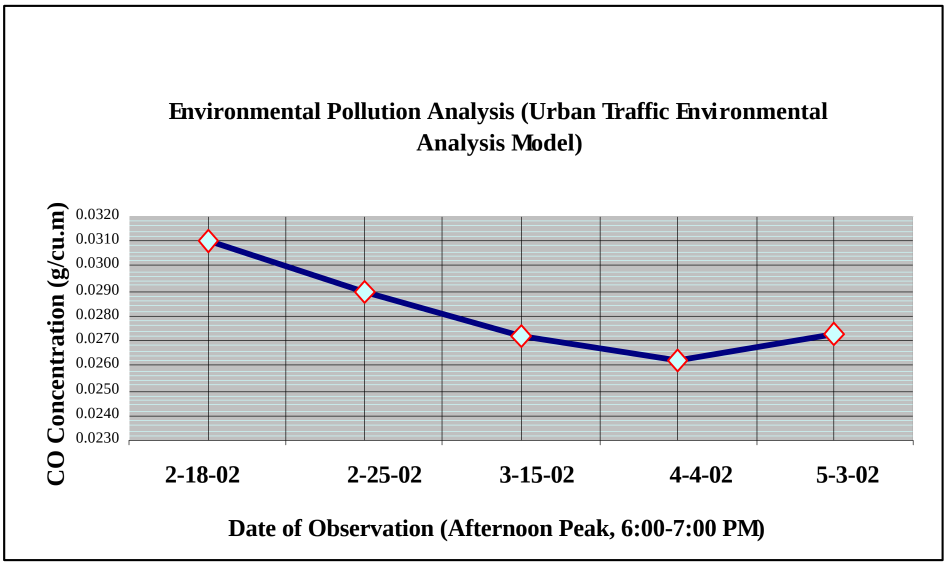

Chart 2. Environmental Pollution Analysis-CO Concentration during Afternoon Peak Hour

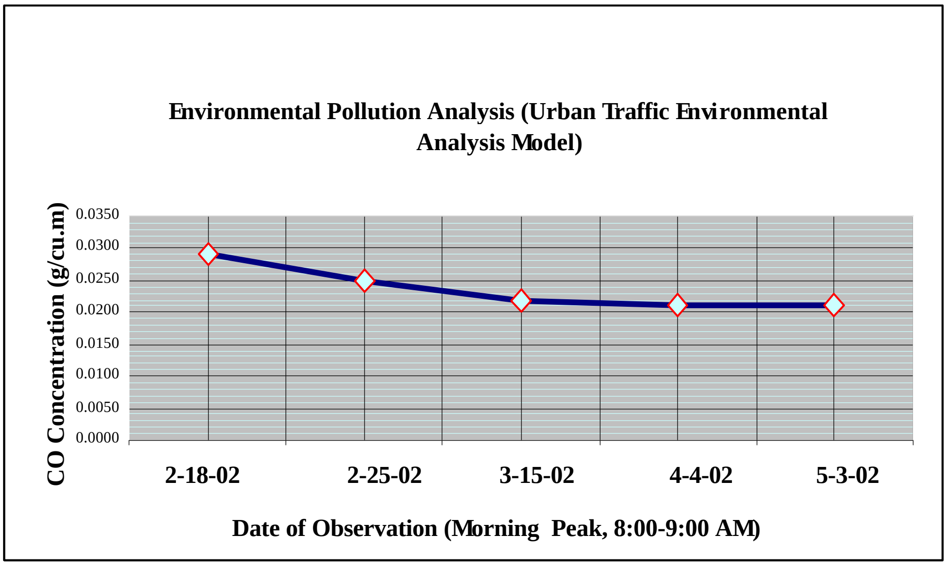

Chart 3. Environmental Pollution Analysis-CO Concentration during Morning Peak Hour

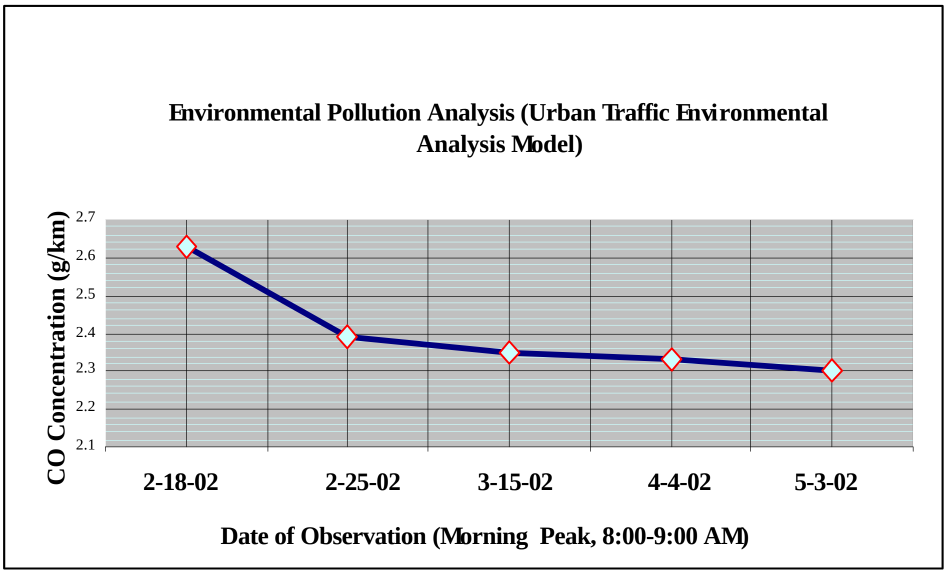

Chart 4. Environmental Pollution Analysis-CO Concentration during Morning Peak Hour

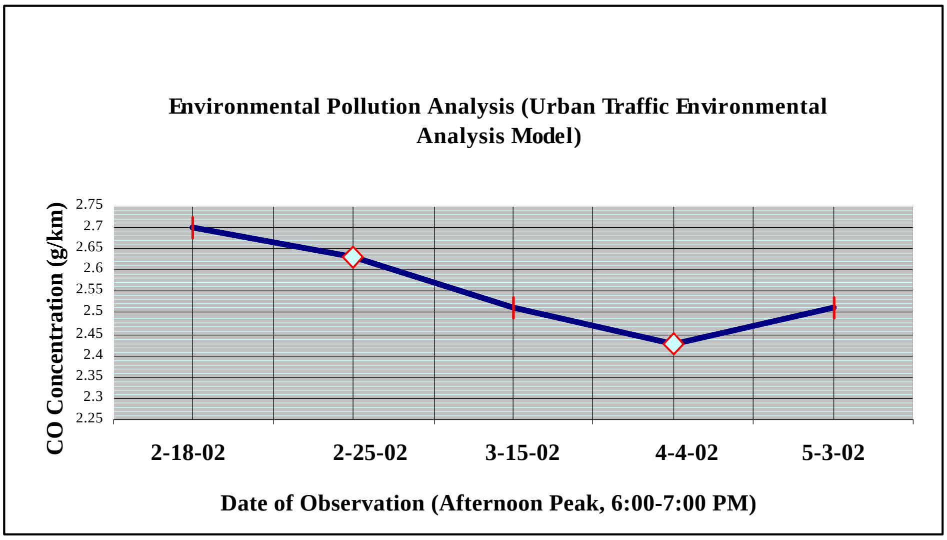

Chart 5. Environmental Pollution Analysis-CO Concentration during Afternoon Peak Hour)

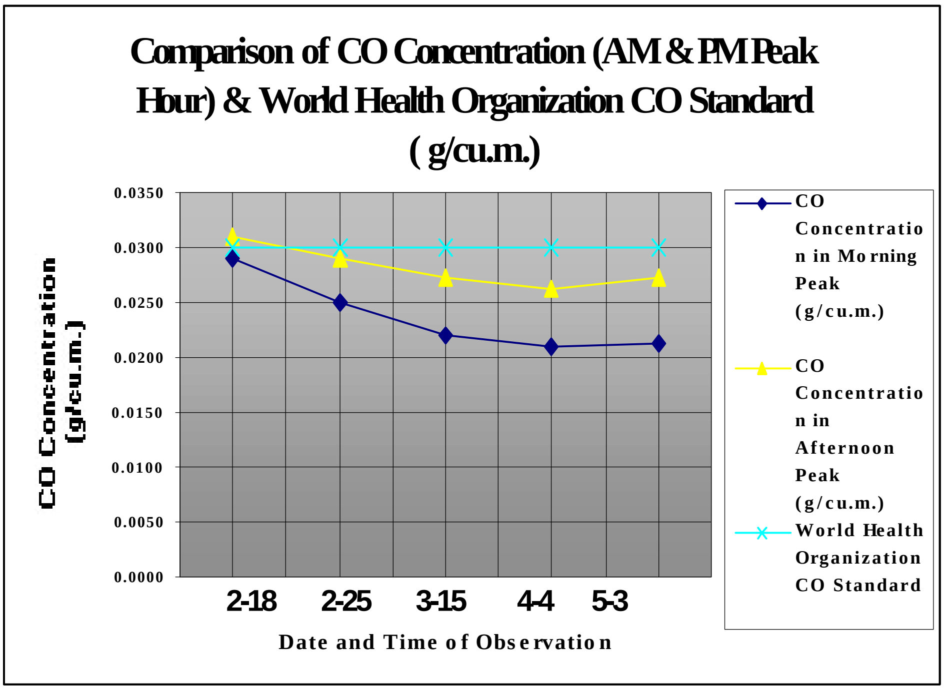

Chart 6. Comparison of CO Concentration During Peak Hours VS the World Health Organization Co Standard (g/cu.m.)

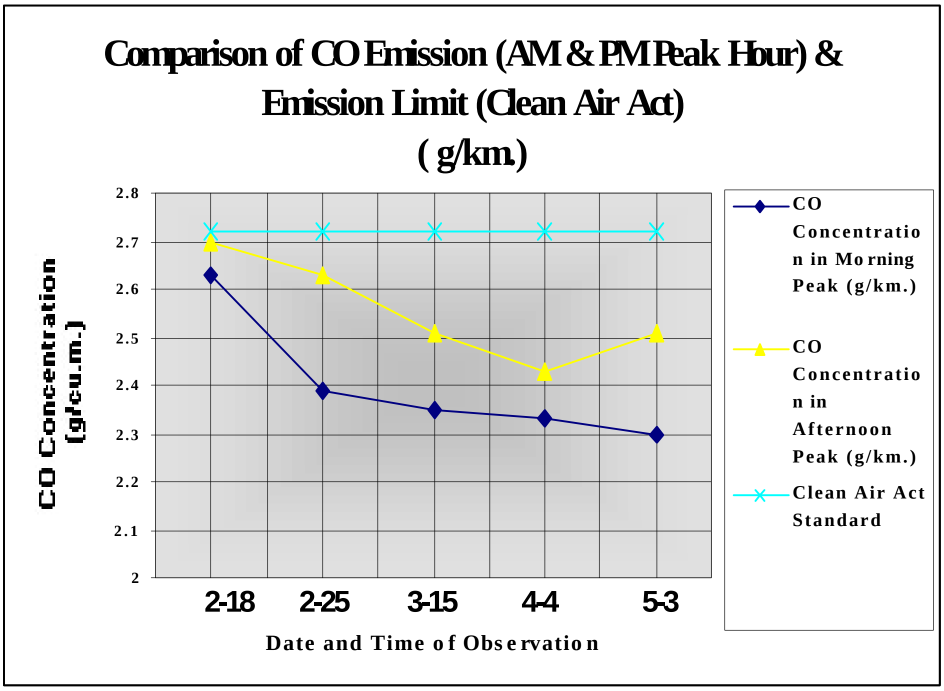

Chart 7. Comparison CO Enission (AM & PM Peak Hour) & Emission Limit (Clean Air Act) (g/km.)

Table 8. Urban Traffic Environmental Analysis Results

Date and Time of Field Observation	CO Concentration (UTEM) (g/cu.m.)	World Health Organization CO Standard (0.03 g/cu.m.)	CO Concentration (UTEM) (g/km)	Emission Limit (Clean Air Act) (2.72 g/km.)
February 18 ,2002				
Morning Peak Hour (8:00-9:00)	0.0290	0.30	2.630	2.72
Afternoon Peak Hour (6:00-7:00)	0.031	0.30	2.70	2.72
February 25, 2002				
Morning Peak Hour (8:00-9:00)	0.025	0.030	2.39	2.72
Afternoon Peak Hours (6:00-7:00)	.0290	0.030	2.53	2.72
March 15, 2002				
Morning Peak Hour (8:00-9:00)	0.020	0.030	2.35	2.72
Afternoon Peak Hour (6:00-7:00)	0.0272	0.030	2.51	2.72
April 4, 2002				
Morning Peak Hour (8:00-9:00)	0.0210	0.03	2.33	2.72
Afternoon Peak Hour (6:00-7:00)	0.062	0.03	2.43	2.72
May 3, 2002				
Morning Peak Hour (8:00-9:00)	0.0213	0.03	2.30	2.72
Afternoon Peak Hour (6:00-7:00)	0.0273	0.03	2.51	2.72

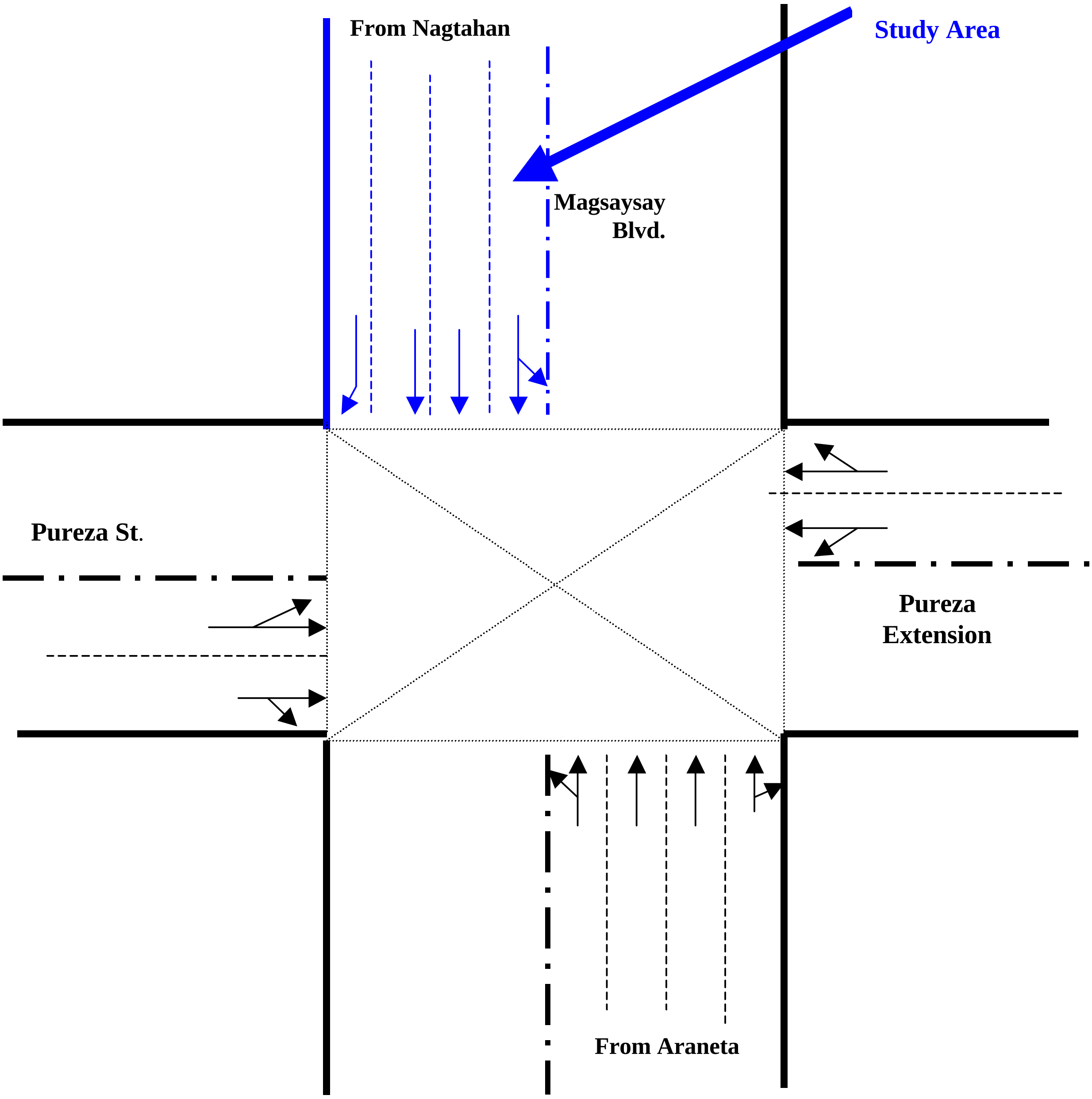

Figure 2. R. Magsaysay-Pureza Intersection

7. Evaluation of the Data and Results

The five field observations that were conducted in the study area provide us with different results of carbon monoxide (CO) emissions. There are different traffic volumes and condition of the prevailing queues along the study area occurred in the morning and afternoon peak hour. Likewise, being commercialized, the different establishments that can be seen along the study area such as banks, fast-food chains, government office (National Statistics Office) and schools (PUP-Hasmin, De Ocampo Memorial School) contributed to the traffic congestion. In addition, there is an on-going construction (scaffoldings occupies the inner lane and the median of R. Magsaysay) of the Pureza MRT Station that affected the congestion of the study area. During the field observation, the usual conditions on the study area are as follows:

a. There are some cars and vans parked in the inner section (in-front of Metro Bank and NSO);
b. Passengers are occupying the outer lane of the study area while waiting to haul; and
c. During the afternoon peak hour, the traffic signal light was usually turned-off and the traffic police managed the traffic in the intersection.

The results of the five different simulation of traffic analysis in order to determine the amount of concentration and dispersion using the Urban Traffic Environmental Analysis (UTEM) along the study area gives us varying values based on different traffic characteristics and condition. Based on the five series of field observation and simulation, the highest value of CO concentration occurred during the afternoon peak hour (6:00-7:00) of 18th of February 2002. The CO value of 0.031 g/cu.m was measured during the one-hour afternoon peak hour and exceeds with the World Health Organization CO standard emission. The value 2.70 g/km CO concentration result from the UTEM simulation is almost relative to the emission limit 0d 2.72 g/km for light duty vehicles set by the Department of Environment and Natural Resources through the Clean Air Act. The 2.70 g/km value is the result of the high volume of traffic and a long queue of vehicles counted during on the 18th of February is 752 vehicles per hour mainly composed of cars, jeepneys and buses. The average speed of the vehicle from the uniform section up to intersection approach section is approximately 25-30 kph because of the prevailing situation of the traffic congestion.

In the five field observations, the highest results of CO concentration occurred in the afternoon peak (see Chart 2 to 5). The results also gave us a decreasing amount of CO concentration due to the following reasons:

1. Months of March, April and May are vacation period that resulted to decrease number of passengers along the study area.;
2. Portion of the Scaffolds of the on-going construction of Pureza Station of MRT was been removed;

Charts 5 & 6 provide us a comparative result of carbon monoxide concentration of the five field observations and the emission limit based on the Clean Air Act (2.72 g/km.) and of the CO concentration set by the World Health Organization (0.030 g/cu.m.).

The field observation of February 18, 2002 gives us a value that is above the standard of World Health Organization. The UTEM result gives us a 0.031 g/ cu.m. of CO concentration during the afternoon peak hour wherein the traffic congestion is quite heavy and the succeeding results provided us a decreasing amount of carbon monoxide concentration in the study area. Likewise, the result of the February 18, 2002 afternoon peak hour CO concentration gives us a result of 2.70 g/km. that almost reach the emission limit of 2.72 g/km set by the Clean Air Act.

8. Conclusion

The estimated values of CO concentration using the Urban Traffic Environmental Analysis Model (UTEM) can be used as a statistical data to monitor the amount of emission in urban roads that are commonly congested during peak hours. The monitoring of CO concentration can be used by the concerned agency to enhance its program in mitigating air pollutants due to vehicle emissions in the urban roads.

The UTEM is considered as a valuable tool in estimating the carbon monoxide in a study area. Using this model, we can easily determine the problem areas in the city where the concentration of carbon monoxide due to vehicle emission is higher than the standard set by the Department of Environment & Natural Resources and the World Health Organization.

The deterioration of air quality in Metro Manila is brought about by the high amount of carbon monoxide attributed to the increasing number of diesel and gasoline fueled vehicles such as jeepneys, buses, trucks, utility vehicles and taxis. At present vehicle growth projection for NCR is 8.5% and 7.6% for the whole country. To counteract the increasing vehicle emission, there is a need for a comprehensive control measure to avoid the increasing number of people who are expose in the poor quality of air in urban roads suffering from respiratory problems.

Monitoring of urban road CO concentration is very important to control the emissions from light and heavy-duty vehicles. There is a need to improve the enforcement through inspection and apprehensions of the vehicles to check whether they violate the emission limit under the provision of the Clean Air Act. The study suggests that there should a continuous monitoring of the vehicle emission in a critical area of urban roads in Metro Manila to measure the level of air quality and make some necessary alternative action.

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