AIR POLLUTION ON THE EDGE OF PEDESTRIAN PRECINCTS

D.M. Priyantha Wedagama[1]

Abstract: The Pedestrian Precincts are encouraged by the UK local authorities in order to reduce air pollution, in particular within the city centre. In fact, the pedestrian precincts are surrounded by road traffic which is potential on generating traffic emission. It is a need, therefore, to investigate the effect of traffic emission to air quality in pedestrian precincts. The Haymarket precinct in Newcastle upon Tyne was chosen as a case study in which the influences of traffic emission to this area are investigated. The influences of wind speed as well as the inter pollutant relationship, pollutant relationship to wind speed and traffic flow are also considered. This study also analyses the effect of the pollutant concentration from certain measurement period on people's health with reference to health related standard.

Keywords: Pedestrian precincts, Air quality, Traffic emission, Health standard.

Abstrak: Area khusus pejalan kaki di pusat-pusat kota telah lama dikembangkan oleh pemerintah Inggris untuk mengurangi polusi udara yang diakibatkan oleh kendaraan bermotor. Lokasi area ini dikelilingi oleh jalan raya dengan tingkat lalu lintas yang potensial untuk membangkitkan gas buang kendaraan bermotor. Untuk itu di dalam studi ini dianalisa sejauh mana efek dari gas buang kendaraan bermotor tersebut kepada kualitas udara pada area khusus untuk pejalan kaki tersebut. Haymarket precinct di kota Newcastle upon Tyne, UK dipilih sebagai kasus studi, karena area ini merupakan pusat kota Newcastle dimana pusat-pusat perbelanjaan banyak berlokasi dan selalu ramai oleh pejalan kaki. Variabel-variabel yang ditinjau adalah pengaruh dari kecepatan angin, hubungan antara masing-masing polutan, hubungan antara kecepatan angin dengan polutan, serta volume lalu lintas. Studi ini juga menganalisa efek dari konsentrasi polutan dari beberapa perioda pengukuran terhadap tingkat kesehatan manusia berdasarkan suatu standar yang ditetapkan oleh Organisasi Kesehatan Sedunia (WHO).

Kata kunci: Area khusus pejalan kaki, Kualitas Udara, Gas buang kendaraan, Standar kesehatan.

Background

The road traffic is still considered as a major contributor to urban air pollution which is resulted most from the motor vehicle emission (Waterfield, V.H, and Hickman, A.J, 1982). Motor vehicles emit a mixture of pollutant that may damage the environment and affect to health. Therefore, the air quality should be managed on each local area within the framework of National Air Quality. In addition, the local authorities are responsible to their local air quality. As a matter of fact, there are a lot of strategies that have been done which include the development of pedestrian precincts.

The pedestrian precincts are encouraged by the authorities to reduce pollution and to increase safety for the people who want to travel in short distances. People could walk freely on the pedestrian precincts to go shopping or just sightseeing without a motor vehicle. In fact, the pedestrian precincts are surrounded by the road traffic which indirectly influences the air quality in the pedestrian precincts as well as people's health.

[1]Lecturer of Department of Civil Engineering, Faculty of Engineering, University of Udayana, Denpasar

According to this condition there is a need of investigating the air pollution resulted from the emission in pedestrian precincts and its effect on people's health. In so doing, the pattern of emission that is resulted from transport sector in pedestrian precincts should be considered.

The previous study (Watkins, 1981) concluded that pollutant which is resulted from the road traffic may cause cardiovascular disease and synergistic effects by means of increasing mortality and morbidity risk associated with respiratory disease. Furthermore, coughing, sneezing and eye irritation may occur as well. In terms of global effect, the pollutant is considered to contribute the increase of greenhouse gases which are the cause of global climate warming. With reference to these effects, the exploration on the previous study report of the pollutants effects on people's health will be undertaken to conduct the air pollution effect analysis in pedestrian precincts.

The study attempts to study air pollution that exists on the pedestrian precinct. The objectives of this study are:

- to recognise emission pattern along the pedestrian precinct that is surrounded by the road. The variables which have to be considered to analyse emission pattern on the pedestrian areas are the concentration of pollutants which consist both of gaseous and particulate pollutants, meteorological factor such as wind speed, and the traffic flow surrounding the pedestrian precincts,
- to analyse the relationship between each variables that are meteorological factor, total pollutants and traffic flows. Total pollutant is the pollutant emitted from the vehicle tailpipes directly at any event. Pollutant is commonly expressed in concentration of each pollutant that is parts per million (ppm) for the gaseous pollutants and μg/m^3 for the particulate pollutants and,
- to consider about the effect of pollutant on people that refer to the previous report of emission effect on people's health.

Literature Review

The section is divided into 3 main themes :

1. Air pollution parameters such as the pollutants from vehicle emission, the meteorological factor, and standards according to UK national air quality strategy.
2. The pedestrian precincts, background and its advantages in context of pollution.
3. Some quantitative and qualitative aspects of pollutant effect on people's health.

Air Pollution Parameters

The Pollutants

The motor vehicles in both of petrol and diesel engine emit pollutants in two forms that are gaseous and particulate pollutants. The first type of pollutants that are the gaseous pollutants defined as carbon monoxide (CO), Sulphur dioxide (SO_2), and nitrogen oxides (NO_x). Those of gaseous pollutants concentration are expressed in parts per million (ppm) while the particulate pollutants are expressed in μg/m^3. The descriptions of each pollutant (Colls, 1997) are as follows:

1. The Nitrogen oxides are resulted from interaction between combination of atmospheric nitrogen and oxygen at high temperatures and pressures in the combustion chambers of the engine. As a result, both nitric oxide (NO) and nitrogen dioxide (NO_2) are forming the nitrogen oxides. The petrol engine consist little of NO, in addition, the ratio of NO to NO_2 is typically > 0.9 for petrol engines and > 0.7 for diesel.
2. In terms of source of pollutants the carbon monoxide (CO) is due to incomplete combustion of the fuel in the engine, meanwhile, most of sulphur dioxides are from domestic and commercial (non industrial)

emission such as coal or oil combustion. In relation to vehicle emission, the content of sulphur dioxide in petrol is a bit higher (0.4 %) than its content in diesel (0.2 %), however, pollution from vehicle emission of this pollutant are small.

3. The second type of pollutants which are particulate are lead and smoke that are emitted from vehicle in particulate forms. As a matter of fact, the lead particles have been added to petrol since many years to improve combustion in the engine. After combustion these particles are directly emitted in both of exhaust gases and particle in 01 - 1.0 μm diameter size range. More specifically, lead is toxic heavy metal to which the nervous system of babies and children are particularly sensitive.
4. Another type of particulate pollutants is smoke which is particle of condensed carbonaceous material, typically 1 μm or less in diameter. This particle is now the major toxic particle emission from vehicles. In the United Kingdom, the diesel vehicles are the largest source (40 %) of total smoke emissions (Colls, 1997).

Meteorological Factors

The air quality is indirectly influenced by meteorological factors including wind direction, wind speed and atmospheric turbulence.

1. The wind direction is important because it is determining the area of ground that can be exposed to the emission from a particular source. The wind direction consists of horizontal and vertical variation which is influenced by the atmospheric stability as well as short term (between second and minutes) and long term variation. The short term in both of horizontal and vertical affect turbulent dispersion that depends on adiabatic lapse rate and the environmental lapse rate. These two terms will be described on no. 3 below.
2. The wind speed is important in some ways of analysing air pollution. Firstly, a proportional factor to the wind speed past the source will dilute any emission. Secondly, the wind speed creates the mechanical turbulence which will increase mixing and dilution of emission.
3. As the height increase the atmospheric pressure will decrease exponentially. Therefore, if the air parcels go up in the atmosphere it will expand and vice versa. In case of dry atmosphere that is containing water vapour but not liquid water droplets, change of temperature by height is called the Dry Adiabatic Lapse Rate (DALR). In addition, the vertical variation of air temperature with height that exist at any particular time and place is called Environmental Lapse Rate (ELR). The atmospheric stability is important due to its influence on determine the magnitudes of both horizontal and vertical variations by balancing the DALR and ELR.
4. In connection with the atmospheric stability, four situations can be described (Strauss, 1984).
   - When temperature drop as the higher altitude and pressures decrease, this situation is called adiabatic lapse rate. Furthermore, in the real situation the temperature change is affected by winds, sunshine and topography.
   - When temperature rate decrease is greater than the adiabatic lapse rate then warm air body such as smoke plume rises fast. This situation is considered as unstable condition, consequently, the air pollution is dispersing rapidly.
   - Conversely, if the temperature rate decrease is lower than the adiabatic lapse rate then warm air body rise slowly and it is called stable, consequently, the air pollution are not dispersed.

- When the warm layer of air covers the colder layer of air that is known as an inversion layer. In reality, this occurs when the sun goes down in the evening and the land cools off.

Table 1. The objectives of the UK National Air Quality Strategy (1997-2005)

Pollutant	Standard		Objectives (achieved by 2005)
	Concentration	Measured as	
Benzene	5 ppb	running annual mean	5 ppb
1,3-Butadiene	1 ppb	running annual mean	1 ppb
CO	10 ppm	running 8 hour mean	10 ppm
Lead	0.5 μ g/m^3	annual mean	0.5 μ g/m^3
NO	150 ppb	1 hour mean	150 ppb, hourly mean
	21 ppb	annual mean	21 ppb, annual mean
Fine Particles (PM10)	50 μ g/m^3	running 24 hour mean	50 μ g/m^{3,} measured as 99th percentile
Sulphur Dioxide	100 ppb	15 minutes mean	100 ppb, measured as 99.9th percentile

Source: www.aeat.co.uk/netcen/airqual

Air Quality Standards

The certain air pollution concentration level during given time period that is acceptable to the environment and health is defined as air quality standards. In addition, the standards can be used as a benchmark to determine whether the air pollution is getting better or worse.

In comparing between pollutants the standards may be expressed in terms of different averaging times. For example, if the pollutant concentration higher than the standard will be recorded in the tables. The standards used in the UK are the National Air Quality Standards which is part of the National Air Quality Strategy adopted by the UK government in July 1997.

The summary on Table 1 contains the standard of each pollutant concentration and the criteria of each pollutant measurement. For example, in order to obtain either the value of carbon monoxide or lead is on different way. The carbon monoxide is measured as running 8 hour mean, meanwhile, the lead is measured as annual mean.

According to Table 1 there is a percentile compliance number which is a certain number that 100 % - percentile number of measurement should be at or below the specified value. For example, assume in one year there are 20000 measurements with 99.9 percentile so that 0.1 % of measurements that is 20 measurements should be at or below the specified value. In addition, the value of each pollutant to be achieved by 2005 is expected the same as the current standard. According to the Department of Environment and Transport and The Regions, some of pollutants criteria has been stated in order to determine the level of air pollution www.aeat.co.uk/ netcen/airqual a shown in Table 2.

Destrian Precincts

The pedestrian precinct enables people (elderly people, children) and disabled to circulate for sightseeing or shopping in traffic free areas especially in the areas where department stores, shops of all kinds, boutiques, cinemas and restaurants mostly located. In other words, by calming the area which is potential in rising traffic problem such as congestion, traffic accident, pollution both noise and air pollution can be reduced.

According to Transport and Environment Studies in 1976, the pedestrianisation has some advantages in terms of environmental improvements. Table 3 shows changes in air pollution level before and after pedestrianisation in some developed cities.

It can be seen that carbon monoxide which is considered has a profound impact on people's health can be reduced over 10 times in Gothenburg by pedestrianisation. The particulate matters which are lead and smoke in average can be reduced 4 times in Cologne, about 8 times and 5 times in Durham. Furthermore, one important thing should still be considered is to what extent the current air pollution level after the pedestrianisation affects people's health.

Table 2. Air Pollution Level

Pollutant	Air Pollution			
	Low	Moderate	High	Very High
Nitrogen dioxide (Hourly mean concentration)	<150 ppb	150 $\leq$ X<300 ppb	300 $\leq$ X<400 ppb	$\geq$ 400 ppb
Sulphur dioxide (15 minutes mean concentration)	<100 ppb	100 $\leq$ X<200 ppb	200 $\leq$ X<400 ppb	$\geq$ 400 ppb
Carbon monoxide (8 hours mean concentration)	<10 ppm	10 $\leq$ X<15 ppm	15 $\leq$ X<20 ppm	$\geq$ 20 ppm
Particles (24 hours mean concentration)	<50 ug/m^3	50 $\leq$ X<75 ug/m^3	75 $\leq$ X<100 ug/m^3	$\geq$ 100 ug/m^3

Table 3. Changes in Air Pollution Level before and after Pedestrianisation

Location	Pollutant	Unit	Before	After
Philadelphia	CO	ppm	6.86-8.28	2.98
Gothenburg	CO	ppm	65	5
Cologne	Lead	μg m^{-3}	4	1
New York	CO	ppm	23	8
Durham	Lead	μgm^{-3}	0.83	< 0.1
	Smoke	mg/100 m^3	22.6	< 4

Source: Roberts, 1981.

Table 4. The carboxyhaemoglobin content of blood

		CO Hb in the blood after 30 minutes exposure (%)		CO Hb in the blood after 60 minutes exposure (%)	
CO Concentration	Equilibrium of CO Hb in the blood (%)	Rest	Heavy work	Rest	Heavy work
30	4.8	0.27	0.99	0.54	1.98
50	8.0	0.45	1.65	0.90	3.30
125	20	1.12	4.12	2.24	8.24
250	40	2.25	8.24	4.50	16.48

Source: (Watkins, 1981)

Pollutant's Effect on People's Health.

In order to analyse the pollutant effect on people's health two methods will be used that are the quantitative method and qualitative method.

The Quantitative method

According to the California State Department of Public Health, the carbon monoxide which has less than 100 ppm for continuous exposures the equilibrium condition equation is:

$$[CO] * 0.16 = \% \ COHb$$

where:

- [CO] is the concentration of carbon monoxide in part per million.
- % COHb is the percentage of carboxyhemoglobin at equilibrium at sea level for healthy subjects.

However, there is an assumption on relationship between the exposure to carbon monoxide and the resulting carboxyhemoglobin. They are not immediately obvious from the measured data because of the time delay between exposure and the build up of carboxyhemoglobin levels in the blood.

The Qualitative Method

Health problem such as cardiovascular disease, interfering haemoglobin with oxygen absorption may be induced by the carbon monoxide. In addition, combining to the other types of pollutants can increase mortality and morbidity risk associated with respiratory disease (synergistic effects). Increasing the greenhouse gases which cause global climate warming is also contributed from this pollutant.

Table 4 describes the effect of carbon monoxide concentration in interfering the haemoglobin. There are three factors that can influence the content of carboxyhaemoglobin in blood that are the CO concentration, the job type and length of time exposure.

Table 5. The sign and symptoms at various concentrations of carboxyhaemoglobin.

CO Hb	Sign and symptoms for an average man
0-10	no signs or symptoms
10-20	tightness across the fore head, possible slight headache, dilation at the cutaneous blood vessel
20-30	headache and throbbing in the temples
30-40	severe headache, weakness, dizziness, dimness of vision, nausea vaunting & collapse
40-50	same as above, greater possibility of collapse, syncope and increased pulse and respiratory rates
50-60	syncope, increased pulse rate, coma, intermittent convulsions and Cheyenne-stokes respiration
60-70	coma, intermittent convulsions, depressed heart action & respiratory rate & possible death
70-80	weak pulse, slow respirators, respiratory failure & death within a few hours
80-90	death in less than an hour
90 +	death within a few minutes

Source: (Watkins, 1981)

At the moment there is no unequivocal epidemiological evidence that nitrogen dioxide has any adverse effects at the concentrations commonly encountered in polluted air, however, according to laboratory evidence the nitrogen dioxides may induce some respiratory diseases like coughs and sore throats. Furthermore, the most serious health hazards such as bronchitis, asthma or emphysema are due to a combination of nitrogen monoxide with other air pollutants. In addition, Table 5 describes the sign and symptoms of man affected by the carbon monoxide concentration in haemoglobin. The particulate pollutant which is emitted from vehicle and also as an additive in petrol engine is called lead. The high level of lead may cause serious health problem such as kidneys disease and liver, reproductive system, blood formation, basic cellular system and brain function. On the other hand, the diesel engines also emit Sulphur Dioxides (SO_2) and fine particulate, the latter which are extremely small, penetrate easily into the respiratory system.

Data

Data in this study are taken from both the official web site of Department of Environment and Transport and the Regions and the official web site of The UK Meteorological Office. Meanwhile, the pollutant concentrations are obtained from Newcastle Centre of Air Pollution Monitoring Network Unit in St Mary's Place Car Park.

The monitoring station is located around 20 metres from a major road of the city near Newcastle Civic Centre. The station is self contained, air conditioned housing and surrounded by a private car park and grassed area. Geographically, the station is located on OS Grid Reference: NZ251649. In Figure 1 is drawn the location of the Newcastle Centre of Air Pollution Monitoring Unit.

Since wind speed data are only available from October 1997 up to April 1998, the pollutant concentration data are also taken during these periods. In other words, pollutant concentration data are adjusted to the availability of wind speed data.

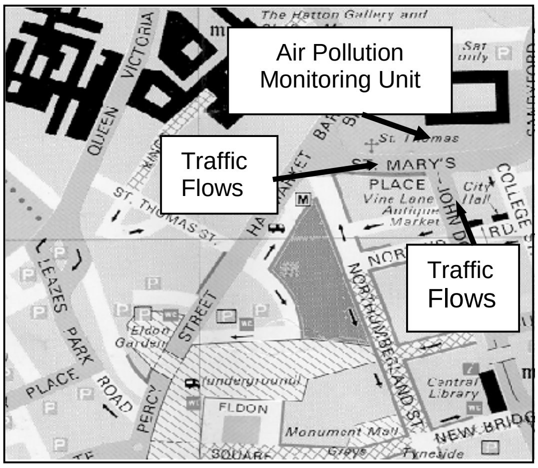

Figure 1. Site Measurement Locations

Traffic Flow Data

In counting the traffic flow the pneumatic tubes and counters is used to obtain hourly traffic data. In order to obtain representative data the traffic counters are moved from site to site on road network. In this study, the traffic flow data is obtained from the Newcastle city council on road network that are surrounding Haymarket precinct as shown in Figure 1. The detail site and time measurement is set by the highway department of Newcastle city council.

Methods

Haymarket Pedestrian precinct located in Newcastle city centre is chosen as a case study area as shown in Figure 2. This area is quite attractive for pedestrians as many shops, pub, bars and restaurant are located in this area.

The Determination of Air Pollution Level

The characteristics of urban areas are both of people and vehicles mostly concentrated in an area with the highest of emission densities per unit area and the worst of dispersion condition take place. Vehicles emissions are recognised have the major environmental impact on town and cities. In terms of air pollution level determination some assumptions taken on this study are:

a) In this study there is no separation between pollutant resulted from the background pollutant concentration and pollutant resulted from current measurement. All results are considered as pollutant concentration.

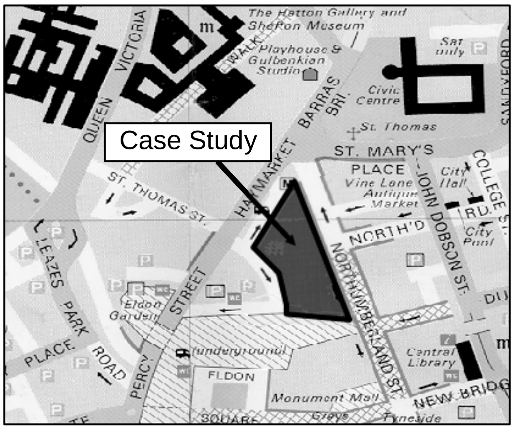

Figure 2. The Haymarket shopping precinct

(Source: Map of Newcastle upon Tyne, not to scale)

b) In terms of traffic flows data, the vehicles classification are cars and taxis, motorcycles, bus and coaches, light vans, and good vehicles. The road classes used in this case study are built up roads which all of those with a speed limit of 40 mph or less.
c) The meteorological conditions such as wind direction, wind speed, temperature and dew point have a significant effect on the pollutant concentration. However, according to the previous study wind speed is considered as the primary factor in analysing pollutant concentration (Hickman and Lunn, 1981).
d) Generally, the pollutants concentration during the monitoring period are considered as long term average level.

Results and Discussion

This section analyses the air pollution effects on people's health in Haymarket

Precinct as a case study area. The analysis is performed with reference to:

- pollutants concentration and the relationship amongst pollutants,
- the relationship between pollutants and wind speed,
- pollutant's effect on people's health according to the health related standard.

Pollutant Concentration

As a starting point, the descriptive statistic of each pollutant data that has been collected over the entire period (October 1997 up to April 1998) are summarised on Table 6. Originally, each data were measured each day for 24 hours during that period.

Having used standard deviation, variation or each pollutant dispersion concentrations are obtained. Variation of carbon monoxide is 46 %, nitrogen dioxide is 32 %, PM_{10} is 39 % and sulphur dioxide is 53 %. However, these concentration fluctuations or variations are insignificant after having compared with the summary of UK National Air Quality Strategy (see Table 1).

Table 6. Data summary of Pollutant Concentration

Variables	Minimum	Maximum	Mean	Standard. Deviation
CO (ppm)	0.2	1.9	0.62	0.29
NO2 (ppb)	6.0	37.0	21.41	6.87
PM_{10} (μ g/m^3)	7.0	46.0	19.99	7.84
SO_2 (ppb)	1.0	20.0	6.04	3.19
Wind Speed (knot)	1.9	17.7	6.13	2.90
Valid N (list wise)	206			

According to those criteria carbon monoxide concentration is relatively as low as other pollutants along the Haymarket precinct areas.

Temperature as one of meteorological factors that influence the air pollution is quite low during the period of measurement. The highest temperature during October 1997 - April 1998 is on October that is 10^o Celsius and the lowest is on January that is 5.3^o Celsius. Thus, since the temperature is quite low so that the air pollution are not dispersed around Haymarket precinct. Also the pedestrianisation scheme or adding more restricted area, for example, pedestrianisation of Northumberland Street around end of 1998 may reduce the air pollution on this area.

The relationship amongst Pollutants

The relationship of carbon monoxide concentration to other pollutants is carried out to identify connection amongst pollutants. In fact, carbon monoxide is a good indicator to analyse the air pollution by vehicle emission. In addition, this relationship is carried out to provide of pollutants sources in Haymarket precinct as a case study area.

The relationship between carbon monoxide to other pollutants (Hickman & Lunn, 1981) is expressed as follows:

$$\mathbf{P = m\ CO + k}$$

Where:

- CO: average carbon monoxide concentration (ppm),
- P: pollutants types (ppm or μ g/m^3),
- k and m are constants.

The hypotheses of carbon monoxide to each pollutant would be:

$$Ho : m = 0$$

$$Ha : m \neq 0$$

The hypotheses above are to test whether carbon monoxide associated with each pollutants concentration. The results from SPSS are as follows:

Table 7. Model Summary (Predictors: CO)

Dependent Variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
NO_2	.57	.33	.32	5.66
SO_2	.27	.07	.07	3.08
PM_{10}	.39	.15	.15	7.25

Table 8. Analysis of Variance (Predictors: CO)

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
NO_2	Regression	3137.33	1	3137.33	98.04	.00
	Residual	6528.42	204	32.00		
	Total	9665.75	205			
SO_2	Regression	150.58	1	150.58	15.92	.00
	Residual	1929.11	204	9.46		
	Total	2079.69	205			
PM_{10}	Regression	1890.55	1	1890.55	35.99	.00
	Residual	10716.41	204	52.53		
	Total	12606.96	205			

Table 9. Coefficients

Dependent Variable		Unstandardised Coefficients		Standardised Coefficients	t	Sig.
		B	Std. Error	Beta		
NO_2	(Constant)	13.07	.93		14.06	.00
	CO	13.49	1.36	.57	9.90	.00
SO_2	(Constant)	4.21	.51		8.34	.00
	CO	2.96	.74	.27	3.99	.00
PM_{10}	(Constant)	13.52	1.19		11.35	.00
	CO	10.47	1.75	.39	5.99	.00

Table 9 shows that the relationship between Carbon Monoxide and Nitrogen Dioxide is obtained as follows:

NO_2 = 13.07 + 13.49 CO
(0.93) (1.36)

The number in the bracket is standard error of intercept and slope respectively. By using the 95 % confidence level to carry out hypotheses test for slope (b) is ($b-t_{n-2,\ .975}.Sb$). The obtained value is = (13.49-(2).(1.36)) = 10.77.

Since slope is greater than zero (0) means the estimate slope is significantly different from zero at the .05 level then the alternative hypotheses is accepted which mean carbon monoxide is associated with nitrogen dioxide. However, the R square value (0.33) on Table 7 shows that relationship is less well. In addition, residual value or error sum square on Table 8 indicates wide data variation on the linear model. Statistically, there is an insignificant relationship between carbon monoxide and nitrogen dioxide on these areas.

From Table 9 above, the relationship between Carbon Monoxide and Sulphur Dioxide is obtained as follows:

NO_2 = 4.21 + 2..96 CO
(0.51) (0.74)

Using the same way to the previous relationship that is 95 % confidence level to carry out hypotheses test for slope (b) is ($b-t_{n-2,\ .975}.Sb$), the obtained value is = (2.96-(2)(0.74)) = 1.48. The slope is greater than zero (0) means the estimate slope is significantly different from zero at the .05 level then the alternative hypotheses is accepted which mean carbon monoxide is associated with sulphur dioxide. The R square value (0.07) on Table 7 indicates that relationship is less well. Additionally, residual value or error sum square on Table 8 shows small mean data variation on the linear model. Statistically, there is an insignificant relationship between carbon monoxide and nitrogen dioxide on these areas.

Table 9 shows that the relationship between Carbon Monoxide and PM_{10} is obtained as follows:

NO_2 = 13.52 + 10..47 CO
(1.19) (1.75)

Using the same way to the previous relationship that is 95 % confidence level to carry out hypotheses test for slope (b) is ($b-t_{n-2,\ .975}.Sb$), the obtained value is = (10.47-(2)(0.75)) = 8.97. The slope is greater than zero (0) means the estimate slope is significantly different from zero at the .05 level then the alternative hypotheses is accepted which mean carbon monoxide is associated with particulate matter (PM_{10}). The R square value (0.15) on Table 7 shows that relationship is less well. In addition, residual value or error sum square on Table 8 indicates small mean data variation on the linear model. Statistically, there is an insignificant relationship between carbon monoxide and PM_{10} on these areas.

The Relationship between Pollutant Levels To Wind Speed

The relationship of pollutant level to the effect of wind speed is conducted so that the major influences on the pollutant dispersion can be assessed. The Newcastle city council carries out 12 hours traffic flow count every year in September and October between 07.00 and 19.00 on a series of cordons around the city (City of Newcastle Upon Tyne Highways and Transportation Department, 1997). The data are divided into two classifications that are AM hour classification count and PM hour classified count.

Since traffic flow data (vehicle/hour) around Haymarket precinct have been summarised yearly, so that these data are not implemented in an analysis of the combined effect of traffic flow and wind speed to pollutant concentration. As a consequence, the relationship between the pollutants level to wind speed effect become:

$$\mathbf{P = k\,W^{a} \text{ or } Ln\,P = a\,Ln\,W + Ln\,k}$$

Where:

- P = average carbon monoxide concentration (ppm)
- W = wind speed (knot)
- a and k = constants

The model results are as follows:

Table 10. Model Summary
(Predictors: (Constant),Ln W)

Dependent Variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
CO	.40	.16	.15	.42
NO_2	.56	.32	.31	.29
SO_2	.38	.11	.10	.51
PM_{10}	.37	.14	.14	.37

Table 11. Analysis of Variance

Dependent Variable		Sum of Squares	df	Mean Square	F	Sig.
Ln CO	Regression	6.87	1	6.87	38.16	.00
	Residual	36.75	204	.18		
	Total	43.62	205			
Ln NO_2	Regression	7.96	1	7.96	94.68	.00
	Residual	17.14	204	.08		
	Total	25.10	205			
SO_2	Regression	6.26	1	6.26	24.46	.00
	Residual	52.19	204	.26		
	Total	58.45	205			
PM_{10}	Regression	4.53	1	4.53	33.15	.00
	Residual	27.85	204	.14		
	Total	32.37	205			

From Table 12 shows that the relationship between Carbon Monoxide and Wind Speed is obtained as follows:

Ln CO = 0.10 - 0.40 Ln W
(0.12) (0.07),

the relationship between Nitrogen Dioxide and Wind Speed is obtained as follows:

Ln NO_2 = 3.75 - 0.43 Ln W
(0.08) (0.05)

the relationship between Sulphur Dioxide and Wind Speed is obtained as follows:

Ln SO_2 = 2.32 - 0.38Ln W
(0.14) (0.08)

the relationship between PM_{10} and Wind Speed is obtained as follows:

Ln SO_2 = 3.48 - 0.33Ln W
(0.10) (0.06)

All equations show that wind speed decreases the pollutant concentration. In addition, all R^2 values of the models indicate that the relationship between wind speed and pollutants are statistically insignificant.

Table 12. Coefficients

Dependent Variable		Unstandarised Coefficients		Standarised Coefficients	t	Sig.
		B	Std. Error	Beta		
Ln CO	(Constant)	.10	.12		.90	.37
	Ln W	-.40	.07	-.40	-6.18	.00
Ln NO_2	(Constant)	3.75	.08		47.56	.00
	Ln W	-.43	.05	-.56	-9.73	.00
Ln SO_2	(Constant)	2.32	.19		16.89	.00
	Ln W	-.38	.08	-.38	-4.95	.00
PM_{10}	(Constant)	3.48	.10		4.62	.00
	Ln W	-.33	.06	-.37	-5.76	.00

Traffic Flow Analysis

Using traffic flow data 1997 from Newcastle City Council are to analyse the role of traffic as a contributor to air pollution on the edge of Haymarket precinct. The traffic flow data are taken from St. Mary's Place and John Dobson streets which close to civic centre (see Figure 1) and are measured into AM and PM hour traffic. The summary of traffic flow data are as follows:

Table 13. Summary of traffic flow data

Measurement		Total
12 hour classified unit	inbound flow	3243
	outbound flow	9404
AM hour traffic flows	inbound flow	331
	outbound flow	1149
PM hour traffic flows	inbound flow	321
	outbound flow	1143

According to Newcastle city council report, those two streets compared to other streets in central cordon (roads or streets located around city centre) had the highest traffic flow. However, refer to pollutant data concentration indicated that these traffic flows are not too significant on contributing the air pollution. The evidences are carbon monoxide concentration on the edge of Haymarket precinct which is considered as primarily traffic generated had relatively low concentration.

Furthermore, the values of particulate matters are slightly high (even though below Air Quality threshold). It may be caused by additional lead particles to petrol to improve combustion in the engine. After combustion these particles are directly emitted in both exhaust gases and particle.

Pollutant Effect on People's Health

California State Department of Public Health equation is used to analyse pollutant effect on people's health. Using minimum, maximum and average carbon monoxide concentration from Table 6, the equilibrium condition is obtained as follows:

- Maximum: 1.9 * 0.16 = 0.304 %
- Minimum: 0.2 * 0.16 = 0.032 %
- Average: 0.618 * 0.16 = 0.099 %

Having compared the results to Table 4 indicates that no sign or symptoms effect on people's health. This concludes that carbon monoxide concentrations in this area are harmless. Thus, the traffic flows are not a main contributor on air pollutant on the edge of Haymarket precinct.

According to the World Health Organisation (WHO) on environmental health criteria for oxides of nitrogen concluded that the lowest level of nitrogen dioxide concentration should be 940 $\mu g/m^3$ (0.5 part per million). Moreover, one hour exposure of 190-320 $\mu g/m^3$ (0.10-0.17 part per million) is maximum with only once a month to protect public health.

Based on Table 6 the nitrogen dioxide concentration are as follows:

- minimum: 6.0 part per billion (ppb)
- maximum: 37 part per billion (ppb)
- average: 21.408 part per billion (ppb)

Obviously the nitrogen dioxide concentration is below the threshold mentioned by WHO. Therefore, the nitrogen dioxide concentrations in these areas are harmless to public health.

Conclusions and Further Works

The air pollution pattern investigated are during October 1997 - April 1998 with the maximum temperature 10^{o} Celsius. All of pollutant concentration show low value in particular carbon monoxide which means the effect of traffic to air quality around Haymarket precinct are relatively weak.

Since the pollutant concentration on the edge of Haymarket precinct are low and below air quality threshold, generally, there is no significant effect of pollutant during the measurement period to people's health.

During the summer period, however the temperature higher air dispersion is wider than during the winter, so that the pollutant effect during these periods may different to current case study observation. Therefore, investigation on air pollution should be conducted in every season in Haymarket precinct.

In terms of data collection and case study area, primary data from the precinct has more advantages than secondary data since the real observation and information from the site directly can be obtained.

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