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Word count: 2972
Character count: 15566

Relation of traffic-related air pollution and people's duration of stay at sidewalk café/restaurant

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Abstract. Air pollution is one of the main factors causing adverse health effects, such as cardiovascular disease, morbidity, and even mortality to humans. In the urban environment, transport is known to be the primary source of air pollution. This paper aims to assess people awareness of air pollution in open public spaces by investigating the relationship between people's dwell time and traffic-induced pollution at sidewalk café/restaurant. First, air pollution was analysed by descriptive statistics. Next, correlation and multivariate analysis were used to seek the relations between traffic, air pollution, and dwell time. The results show that pollution level doesn't significantly influence people duration of stay, but traffic does. It portrays the unawareness of people towards air quality in their surroundings. Furthermore, the unexpected result found in this study is that there are other significant pollution sources such as from cooking and smoking activities. Therefore, policies to improve air quality in urban areas are highly needed from the transport sector and eventually beyond it.

Keyword: Air Pollution, Road Traffic, Sidewalk Café/Restaurant, Awareness, London

1. Introduction

Open public space (OPS) has an essential role in urban society related health and well-being [1, 2] as well as the quality of life [3, 4]. The existence of open public space is able to promote physical activity [5], social interaction and integration [6], and mental health [7]. In the city, streets and its sidewalk are vital elements as public spaces because it offers one of the urban delights [8], where citizens can do various activities such as travel, shopping, playing, interaction, and recreational.

Nowadays, cities face great environmental challenges, one of them is poor air quality. Air pollution is well-known to cause adverse health effects to humans. Studies found that exposure to air pollution contributes to respiratory and cardiovascular morbidity, premature mortality [9], and cancer [10]. According to United Nations [11], air pollution has caused 4.2 million people deaths in 2016. In the urban environment, transport is found to be the primary source of air pollution through vehicle exhaust emission [12, 13], which is proved by the clear connections between traffic volume and air pollution [14, 15].

OPS is vital to the urban society but dwelling there can be harmful. People who spend time eating, drinking, resting and socializing at sidewalk café/restaurant have direct exposure to traffic-induced pollution without realizing it. Understanding people's behaviours in open public spaces can reflect their awareness of air pollution. Studies identify the relations of people awareness by asking their perception about air quality, however, it is rare to find studies that examined their actual behaviour related to air

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pollution. This study aims to assess people awareness by directly investigating people's behaviour in sidewalk café/restaurant. Duration of stay is an indicator of behaviour towards OPS quality [8] that can also portray exposure toward air pollution.

The study is taken place in London, a world-class city that is also the most polluted place in Europe [16]. Since 2009, the city government has implemented transport improvement programs to tackle the issue called London's Great Outdoors and Better Street programs. However, the nitrogen dioxide (NO^2) concentration and particulate matter number still exceed the EU limit [17, 18].

The study is conducted by quantitatively measuring traffic flow, air pollution level, and people's dwell time in three different streets with has distinct traffic volumes but similar activity functions. The hypothesis in this research is pollution level affects people's duration of stay at sidewalk café/restaurant, on which if pollution level in a > pollution level in B, the dwell time in A < dwell time in B. The findings of this study may provide useful information to policymakers in such decision planning to optimize air quality management policies to create a better quality of life and sustainable cities.

2. Materials and Methods

2.1. Study area

This study focuses on three streets in Central London which categorized by different "movement" functions and similar "place" functions. Different "movement" functions are defined by traffic volume and "place" by activities or land use. Based on that, the roads chosen were: (1) Exhibition Road with low traffic, (2) The Cut with medium traffic, and (3) Upper Street with high traffic. All of those streets have distinct road layouts and have sidewalk cafes and restaurants.

Table 1. Summary of road conditions.

Street Name	Traffic Volume	Street Length (m)	Number of Lanes	Information
The cut	Medium	340	2	High street with residential access
Exhibition Road[a]	Low	590	1	Important route (A1)
Upper Street	High	340	4	High pedestrian use

[a]Vehicle restriction applied

2.2. Data collection

Data in this study are mainly primary data that is gathered through surveys. Data collection was conducted in the summer, considering the best weather for people to sit outside. Three sunny days were chosen to minimize the bias of data, considering the weather will influence people behaviour in outdoor places. The surveys were conducted on 6, 7, and 8 July 2016.

2.2.1. Traffic and duration of stay. Traffic and people's dwell time were collected through video recording by Tracsis Traffic Data Ltd. The camera started on those three days from 06:30 – 19:00. The cameras captured two cafes/restaurants at The Cut, two at Exhibition Road, and one at Upper Street.

2.2.2. Air pollution data. Air pollution measurement was carried out using TSI Model 3007 CPC equipment which can assess Particle Number Concentrations (PNC) with the size range of 0.01µm - 1.0µm, called ultrafine particles (UFP). PNC is highly potential to measure traffic-induced pollution because it contains 90% of UFP [19], the primary emission of road traffic [20, 21]. UFP (<0.1 µm) is also more relevant to health risk [22], so it will have more advantage in examining the well-being of people using public space related to their exposure.

The measurement was conducted on the selected roadside environments on three different days. Background level was also measured from the 7th floor of Palestra Building for those three days. The measurement was supposed to be taken from 08:00 am until 07.00 pm, however, it was not possible due to the equipment limitations.

Table 2. Summary of Survey Days and Times.

Date of	Sample Site	Video Recording Time	Café/Restaurant	Roadside Sampling Time	Background Sample Time
6 July 2016	The Cut	06:30 – 19:00	Café Nero Pret a Manger	09:48 – 12:11 12:41 – 15:24 16:00 – 19:00	08:51 – 13:45 15:12 – 19:00
7 July 2016	Exhibition Road	06:30 – 19:00	Roots & Bulbs Café Fernandez& Wells	10:23 – 15:50 16:28 – 19:00	08:19 – 13:40 14:58 – 19:00
8 July 2016	Upper Street	06:30 – 19:00	Costa	11:28 – 14:52 15:05 – 17:54 18:22 – 18:59	10:18 – 16:38 17:12 – 19:00

2.3. Data analysis

Data were analysed using some software. First, air pollution data were analysed using R software to show the pattern of air pollution. R software is a powerful software in processing large data set such as air pollution data. Next, correlation analysis was applied using SPSS software to find the correlation between pollution, traffic volume, and duration of stay. Lastly, analysis was continued by multivariate regression analysis to predict the relationship between those three variables.

3. Results and Discussion

3.1. Traffic and Air Pollution Results

Traffic data from video recording confirms the initial assumption which shows the different traffic levels on those three streets. Exhibition road has the lowest volume on average for only 36 Per car unit (PCU)/hour. Upper Street, as expected, has the highest traffic volume with an average of 1,307 PCU/hour. The Cut is the medium one, with an average volume of 685 PCU/hour.

3.2. Air Pollution

The Cut has the lowest mean of PNC (26,458 particles cm^{-3}) with medium traffic volume, and as expected, Upper Street with the highest traffic has the highest mean of PNC level (48,098 particles cm^{-3}). Anomaly results are found at Exhibition Road with the lowest traffic but present the high PNC level (42,430 particles cm^{-3}), slightly below Upper Street. Thus, indicate that there might be other factors affecting PNC level other than traffic.

Table 3. Descriptive statistic of air pollution.

		Particle Number Concentrations (particles cm^{-3})		
Date	Site	Mean	Median	Standard Deviation
06-Jul-16	The Cut	26458	22682	15532
07-Jul-16	Exhibition Road	42430	40224	16424
08-Jul-16	Upper Street	48098	46663	16018

Furthermore, to understand the genuine traffic contribution to the PNC, the background level of PNC should also be alleviated from roadside contribution [23]. The PNC gap at Exhibition Road is big although it has low traffic. Exhibition road has more cafes and restaurants along the road compared to The Cut and Upper Street which means more cooking activities occur. According to Dennekamp [21], cooking activities contribute high PNC (50.000 – 225.000 particles cm^{-3}), higher than the vehicle traffic itself. In addition, more people smoking at Exhibition Road that also contributes to 62.500 - <75.000 particles cm^{-3}. Both activities can explain the cause of the high PNC in Exhibition Road.

Exhibition Road shows unexpected results in this study. As consequences, policies beyond transport sector are needed to improve air quality in urban areas. Pollution from cooking can be reduced by changing gas cooking into electric cooking which emits less UFP [24]. Moreover, regulation, in general, is needed to manage the public space.

The PNC gap at Upper Street is large which is caused by traffic activities. However, The Cut with medium traffic also shows the gap but insignificant. Traffic data shows that cars and light good vehicles volumes are approximately the same in both streets (The Cut: 460 car/hour; Upper Street: 545 car/hour and The Cut: 118 LGV/hour; Upper Street: 161 LGV/hour). The differences are found with bus and heavy goods vehicles (HGV) numbers. Average HGV passing The Cut is 37 HGV/hour, while it gets almost three times larger in Upper Street (101 HGV/hour). Lastly, The Cut has very low bus passing (0,75 bus/hour), whereas it reaches 166 bus/hour in the Upper Street.

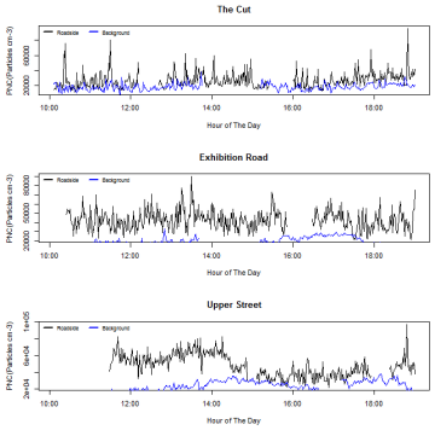

Figure 1. Time series of roadside and background PNC

Table 4. Number of bus and HGV in The Cut and Upper Street.

	Total Bus/hour		Total HGV/Hour	
Time	The Cut	Upper Street	The Cut	Upper Street
Average	0,75	166	37	101

Bus and HGV in the UK have been exclusively powered by diesel [25], which emit UFP from unburnt fuel and incomplete combustion [26]. Study found that bus itself emits significant UFP around 30,000 – 110,000 particles cm^{-3} [21]. While both buses and HGV have vital roles for people and goods movement, it is important to minimize the adverse impact by using more sustainable fuel such as biodiesel or even electric vehicles.

3.3. Duration of Stay

There is a total of 310 samples collected during the video recording and air pollution measurement: (1) The Cut: 101; (2) Exhibition Road: 156; (3) Upper Street: 53. The average dwell time at The Cut is the lowest (35.2 minutes) and then followed by Exhibition Road by 45 minutes on average. Survey found that people at Upper Street spend the longest time by 46,2 minutes on average. Overall, the average duration of stay in all three places is 41,5 minutes.

Table 5. Duration of stay.

Location	Café/Restaurant	Average Duration of Stay (minutes)
The Cut	Café Nero	39.2
	Pret a Manger	31.2

Exhibition Road	Roots & Bulbs Café	36.4
	Fernandez & Wells	53.7
Upper Street	Costa	46.2

3.4. Correlation Analysis

Spearman's correlation analysis shows a significant positive correlation between PNC level and dwell time. A similar correlation is also found between average traffic flow with people's duration of stay. In summary, traffic flow and PNC are positively associated with people's dwell time at sidewalk café/restaurant.

Table 6. Correlation analysis of duration of stay.

Variables	Dwell Time	*p*-value
PNC Level	0.143*	0.012
Average PCU/15 minutes	0.675**	0.000

Significant codes for *p*-value: ** p-value < 0.01; * p-value < 0.05

3.5. Multivariate Regression Analysis

Multivariate regression results present a significant positive impact of traffic flow on the duration of stay, which means the more crowded the traffic, the longer people dwell and vice versa. Meanwhile, PNC level doesn't significantly influence people's dwell time, which indicates the unawareness of air quality in their surrounding area. Some studies have tried to seek the relationship between perceived and actual levels of pollutants but it's not possible [27, 28]. UFP are identified as tiny particles, much smaller than $PM_{2.5}$ and PM_{10}. It is also more numerous and more toxic [21, 29]. Due to its characteristics, UFP are invisible and odourless [30]. All these criteria of UFP may make it hard to be sensed by human sensory, just like many air pollutants such as $PM_{2.5}$ and PM_{10}. Since they cannot feel it, they cannot perceive it, and as a result, they become unaware of it.

Table 7. Correlation analysis of dwell time.

Factors	**Standardized β**	**Standard Error**	**t-value**	***p*-value**
PNC (Particles/cm^{-3})	0.04	0.000	0.94	0.349
Average PCU/hour	0.669**	0.013	15.73	0.000
N	310			
Adj. R^2	0.454			
F-stat	129.44	*p*-value	0.000	

Significant codes for p-value: ** p-value < 0.01

4. Conclusion

OPS is vital to the urban society, but dwelling there has a risk of traffic-induced pollution. The finding of this study proved that people are unaware of air quality in open public spaces which is performed by their duration of stay. An unexpected result found in this paper is that other significant pollution sources exist from cooking and smoking activities. Therefore, policies to improve air quality in the urban area is highly needed from the transport sector and eventually beyond it.

Acknowledgments

The project was funded by Transport for London in 2016. The author thanks all parties who have participated in data collection. All statements and interpretations in this study are the authors' responsibility and only reflect the authors' view.

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