AWARENESS OF HEALTH IMPACTS OF NO_2, AND POTENTIAL RESPONSES TO DIESEL VEHICLE BANS AND PROPOSALS TO CEASE THEIR PRODUCTION

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Word count: 6,500 words text + 4 tables x 250 words (each) = 7,500 words

Submission Date: 1st August 2018.

ABSTRACT

Evidence of associations between ambient concentrations of NO_2 and a range of effects on health has strengthened in recent years. On average, transport is responsible for 40% of NOx emissions influencing ambient NO_2 concentrations at the road side. Diesel engines emit a higher percentage of NO_2 and their recent popularity in the context of emissions is of some concern. Diesel engines have been popular because of their higher efficiency and the lower costs of fuel but recent proposed bans of diesel vehicles in major cities and proposals by some car manufacturers to stop producing them is likely to influence changes in user behaviour. The research reports on the findings of a survey of 730 individuals that 1) examined current general awareness of the impacts of NO_2 and air pollution on health 2) determined if geographical, transport and socio-economic variables could be linked with self-reported health status of the participants in the context of respiratory conditions, and 3) assessed the potential responses to diesel vehicle bans and proposals to cease their production. Awareness of the impacts of NO_2 on health was measurable and higher than expected. Discriminant analysis found a number of transport and location predictor variables could be linked to respiratory medical conditions although the strength of association was not sufficient to give high performance in classification. Potential responses to cessation of diesel vehicle production included hybrid and electric vehicle purchase with a significant number suggesting they would keep their current diesel vehicle as long as it would keep going.

Keywords: nitrogen dioxide, health impacts, diesel vehicle bans

INTRODUCTION

On average, road transport is responsible for 40% of NOx emissions influencing ambient NO_2 concentrations at the road side *(1)*. Diesel engines tend to emit a higher percentage of NO_2 *(2)* and their recent popularity in the context of emissions is of some concern. Just over 71% of passenger cars purchased in Ireland in 2015 were diesel vehicles compared with 73.4% in 2014 and 72.5% in 2013 *(3)*, This large share is a direct consequence of a change in car taxation policy in 2008 when car taxation was no longer related to engine size but to CO_2 emissions.

Old polluting buses, coaches and lorries also contribute to high NO_2 levels and have been the target of policies in the UK and other countries *(4)*. An example includes the recent diesel vehicle bans which prevent old diesel cars from entering some major UK and European cities *(5)*. Even more recent proposals by some car manufacturers to phase out diesel car production are also likely to significantly change car purchasing behavior in favour of other fuel types.

A large number of countries across the EU are facing challenges in meeting existing NO_2 targets. The UK Government has committed over €2 billion to help bus operators upgrade their fleets, reduce pollution from a range of vehicles such as refuse trucks and fire engines and promoting the use of clean alternative fuels *(4)*. In order to bring the UK into legal compliance, and following an agreement by the EU to allow an extension to reduce the average yearly concentration to below $40\mu g/m^3$, Clean Air Zones are currently being introduced in 5 cities.

In Ireland, the Air Quality Standards Regulations *(6)* transposed the EU Directive on ambient air quality and cleaner air for Europe (CAFÉ) *(7)* into Irish law. The limits on NO_2 require the average hourly ambient concentration not to exceed $200\mu g/m^3$ more than 18 times in a calendar year and that the annual mean over a calendar year should not exceed $40\mu g/m^3$ The EPA manages the Irish ambient air quality monitoring network of over 30 monitoring sites and logs exceedances of the required hourly limit. Data on the EPA website *(8)* shows 1 exceedance up to the end of May 2016. In 2015, there were a total of 5 exceedances, 3 of which were at the same location. To date in 2018 there have been no exceedances recorded. The EPA *(2)* noted that, although NOx levels in Ireland are currently not a pressing concern, even a slight increase in traffic volumes in an urban area allied to favourable meteorological conditions for air pollution may lead to an exceedance of the limit value in the future due to continued reliance on motor vehicles. Non-exceedance of the limit values for NO_2 does not imply the absence of human health effects.

In terms of public awareness of air pollution and its impact on health, Mirabelli et al *(9)* found that 49% of respondents they interviewed were aware of air quality alerts and 27% always/usually avoided busy roads to reduce air pollution exposure. Orset *(10)* observed that improving travellers' confidence in air pollution recommendations would be a good way to lead travellers to choose low-emission transport rather than high-emission means.

The focus of the study presented here is a comprehensive survey completed by 730 participants which had three main aims. The first was to assess how people perceive air pollution, to what extent they are aware that NO_2 has an impact on health and if and how they take action to reduce their exposure to air pollution. The second objective was to determine if there was a link between their self-reported health status and how close they live to a road and their exposure to traffic. The third and final objective was to establish their opinion on the proposed policy changes in relation to diesel vehicles – both the diesel bans in some cities and the proposals by car manufacturers to cease their production – and to assess how they intend to change their car purchasing behavior as a result.

BACKGROUND

The Committee on the Medical Effects of Air Pollutants (COMEAP) issued a statement on the evidence for the effects of nitrogen dioxide (NO_2) on health in March 2015 *(11)*. The background

to their review was the association of NO_2 with adverse effects on hospital admissions for various diagnoses; decrements in measures of lung function and lung function growth, increases in respiratory symptoms, asthma incidence, cancer incidence, adverse birth outcomes and mortality by the US EPA and the World Health Organisation *(12, 13).* They concluded that the evidence of associations of ambient concentrations of NO_2 with a range of effects on health had strengthened in recent years, that the associations were robust to adjustment for other pollutants including some particle metrics and that it would be sensible to regard NO_2 as causing some health impact. In a later submission to the Department for Enviornment, Food and Rural Affairs *(14)*, COMEAP refined their recommendations for quantifying mortality effects on the basis of long-term average concentrations of NO_2.

The US EPA *(15)* noted that in-vehicle and near roadway concentration levels can be 2-3 times higher than those measured at monitoring sites and that 16% of housing units in the US are within 300 ft of major transport arteries covering a population of 48 million people, a higher proportion of which are non-white and economically disadvantaged. In an Integrated Science Assessment *(15),* the US EPA noted that results from recent studies strengthen the body of evidence indicating that short-term exposure to NO_2 can cause respiratory effects, in particular, asthma exacerbation. Results also strengthen the evidence that the respiratory effects of short-term NO_2 exposure are independent of the effects of many other traffic-related pollutants. In terms of long-term exposure, again there is now stronger evidence for respiratory effects, particularly the development of asthma in children. Other results suggested that short-term exposure may be associated with cardiovascular effects, diabetes, poorer birth outcomes, premature mortality and cancer. However, it is uncertain whether these effects are independent from the effects of other traffic-related pollutants *(15).*

One of the inputs to the COMEAP review, among others, was a study by Atkinson et al *(16).* Their meta-analysis revealed a mild to moderate increase of 6% in the prevalence of asthma with a $10\mu g/m^3$ increase in ambient NO_2. In their time series studies of hospital admissions and mortality, they found that a $10\mu g/m^3$ increase in 24-hour NO_2 was associated with 0.7% and 0.57% increases in all-age all-cause cardiovascular and respiratory mortality respectively. They recommended that further work be undertaken to determine if the associations between NO_2 and health are causal or indicate the effects of a correlated pollutant or other confounders.

Dent et al *(17)* found that the incidence of asthma, allergic rhinitis, and eczema in children was associated with maternal exposure to traffic-related NO_2 during entire pregnancy but after adjustment for other pollutants the association was significant only for particular trimesters. Simons et al *(18)* found that medication purchase prescribed for asthma and chronic obstructive pulmonary disease (~3 million prescription purchases from mandatory Belgian health insurance system) was significantly associated with NO_2 concentrations. They calculated an annual cost saving potential of €107,845 in R03 sales (WHO classification for drugs of obstructive airway diseases), for a 10% reduction in NO_2 for a city of 1 million inhabitants.

METHODS

An online survey using SurveyMonkey *(19)* was designed and distributed electronically to a survey panel managed by Delve Research and to the academic networks of the authors. The sample selection was not random as it was directed to an existing survey panel for the most part. Ethics approval was sought and obtained from the TCD School of Engineering Ethics Committee before commencing with data collection, and responses were anonymous.

The first part of the survey established whether the respondents had previously heard of NO_2, its sources and whether they were aware it was harmful to health. The next part asked

questions about the type of area they live in, such as if they are based in a city centre, suburban area or in a rural location. It then asked how long they had been living at that address, how far is the nearest road to the front façade of their home, how they would describe traffic levels on the road, its speed limit, whether traffic conditions worsen during peak times and for how long traffic queues would be present on a typical day. This was followed by questions about their health so that the association between exposure to traffic levels and health status could be assessed. They were asked if they or anyone in their household ever had asthma, chronic lung disease, hay fever or cardiovascular disease. Questions then followed about the medications they had been prescribed, during which months of the year their symptoms were worse in the case of respiratory conditions, and any actions they take, e.g. staying indoors, when air pollution levels are high.

This was followed by questions about their knowledge or not of the EPA's Air Quality Index for Health website *(20)* and how often they would use it. The aim of the website is to give warning on days when air pollution is high so that those sensitive to air pollution are made aware. They were also asked to rank the importance of various factors, including air pollution, in their decision to live in their current location and whether they would consider moving house to avoid air pollution if they or one of their family had a respiratory condition such as asthma.

The next section of the survey focused on those who owned a car, the first question of which asked them to rank how various factors influenced them in their choice of car fuel type. They were then asked if they had heard about the diesel vehicle bans employed or proposed by some major cities across Europe, and whether they agreed or not with the policy. The next question asked them to rank a number of policies in terms of their effectiveness in reducing negative health impacts of diesel emissions including banning cars from streets with high pedestrian and cycling flows, promotion of hybrid and electric vehicles, reducing car tax on gasoline vehicles, introducing a congestion charge, introducing higher taxes on diesel vehicles, banning cars near schools, improving public transport and banning diesel fueled buses.

The next part of the survey focused on recent announcements by some car manufacturers of their intentions to phase out diesel car production. The first question asked if participants agreed with this policy and why they thought manufacturers had taken this decision. They were then asked, since becoming aware of the policy, had they purchased a gasoline, diesel, hybrid, electric vehicle, not changed their car or sold their car and not replaced it. The next question asked them what type of vehicle they will buy if they change their car between now and when diesel vehicles are no longer available followed by a similar question asking what type of vehicle they will buy when diesel vehicles are no longer available.

The penultimate section of the survey asked them to agree or disagree (5 levels) with a series of attitudinal statements on environment and health to measure attitudes that could influence their preferences. The final section of the survey focused on socio-economic characteristics of the participants and included questions about gender, age, highest education level attended, main status e.g. full-time working, etc. and what region of Ireland they live in.

The statistical techniques used in the work include frequency distribution, cross tabulations and discriminant analysis. Cross tabulations enable relationships within the data to be examined that might not be obvious when analyzing total survey responses. Discriminant analysis is a technique used to characterize the relationship between a set of predictor variables and a grouping variable. In this case, it is used to determine if there is a relationship between self-reported health conditions, geographical, transport related and socioeconomic variables.

RESULTS AND DISCUSSION

The breakdown of socio-economic characteristics of the participants are presented in Table 1

alongside the 2016 census summaries of the population of Ireland. Sixty per cent of the sample was female compared with 51% of the population. The age groups of 16-24, 45-54 and +65 are under-represented, those in age groups 25-34 and 35-44 are over-represented and the proportion in the 55-64 age group are similar for the sample and the population. It is likely that the differences are significantly influenced by the fact that the survey was conducted on-line in which case some age groups would have more access than others. It is difficult to map education level with that of the population because of the way the census statistics are presented, however, the sample is well educated and more than likely to a higher level on average than the general population. Fifty six per cent of the sample have completed a third level degree with a further 13.8% having completed a doctorate; indicating that a large proportion of the sample are well educated. In the case of main status, 60.8% of the sample are working full- or part-time compared with 53.4% of the population, 6.4% of the sample are unemployed compared with 7.9% of the population and the remainder (students, looking after family, retired from employment and unable to work) total 32.8% in the sample compared with 38.6% in the population.

TABLE 1 Socio-economic characteristics of the survey participants and Irish population

Socio-economic Characteristics					
Variable	**Categories**	**Survey participants**		**Irish population (2016 census)**	
		(N)	(%)	(N)	(%)
Gender	**Female**	438	60	1,915,464	51
	Male	292	40	1,839,849	49
Age	**16-24**	52	7.1	576,452	15.4
	25-34	176	24.1	659,410	17.6
	35-44	181	24.8	746,881	19.9
	45-54	167	2.9	626,045	16.7
	55-64	101	13.8	508,958	13.6
	Over 65	53	7.3	637,567	17.0
Highest level of education attended	**No formal education**	1	0.2		
	Primary level	11	1.5		
	Secondary level	206	28.2		
	Third level	411	56.3		
	Fourth level	101	13.8		
Main status	**Working full-time**	444	60.8	2,006,641	53.4
	Working part-time				
	Unemployed	47	6.4	297,396	7.9
	Student or pupil	51	7		
	Looking after family	75	10.3		
	Retired from employment	65	8.9		
	Unable to work	48	6.6	1,451,276	38.6
Total		730	100	3,755,313	100

Awareness of NO_2 and its Effects

Sixty nine per cent of females said they had heard of NO_2 prior to taking the survey compared with 80% of males. Awareness of NO_2 was then related to age, highest level of education achieved and main status in Figure 1. Awareness is generally high, on average 70%, in most age groups with the proportions of the younger age groups indicating even higher levels of awareness. As education level increases so too does awareness and, in the case of main status, most categories demonstrate similar levels except in the case of student where awareness is much higher.

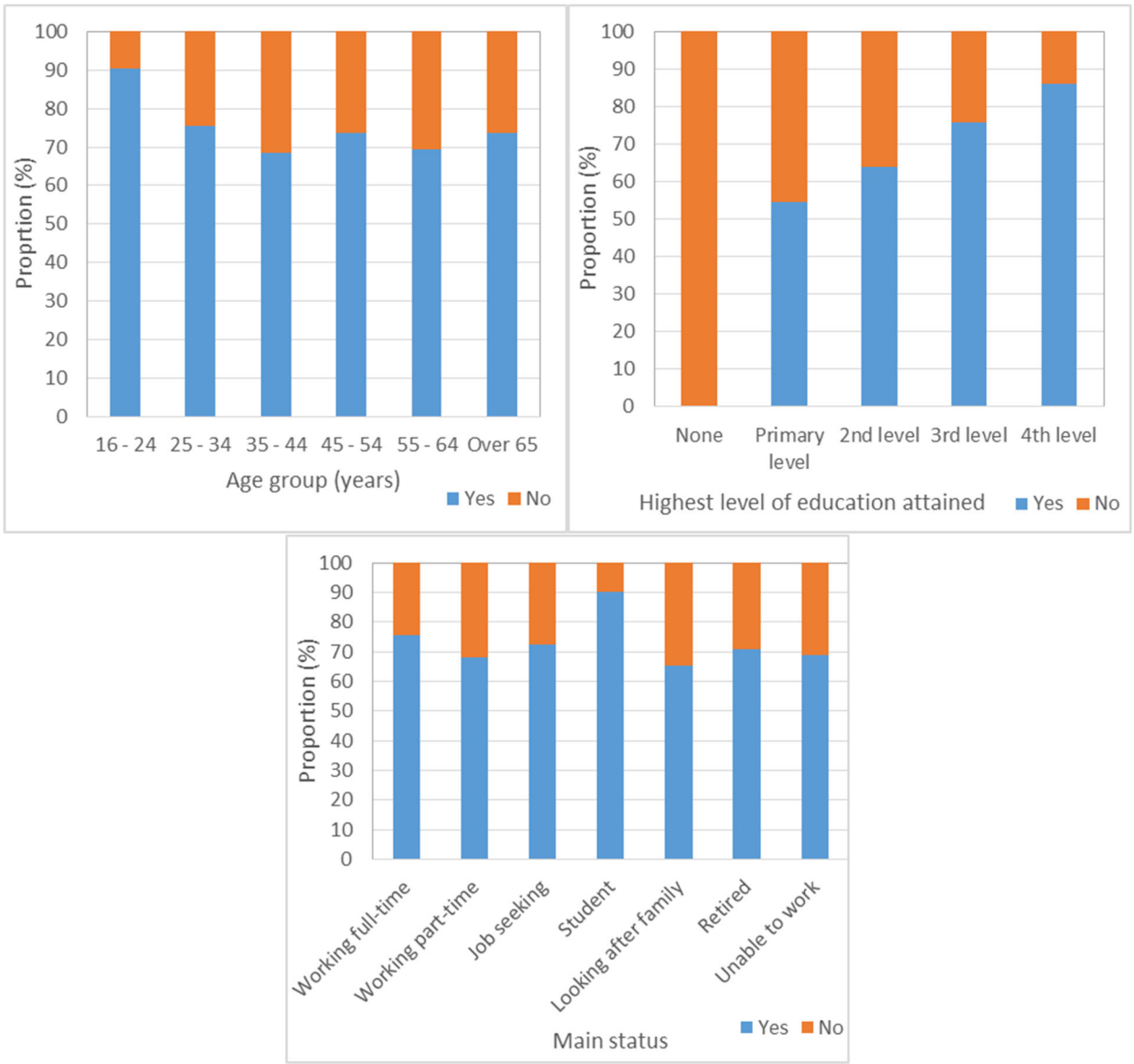

FIGURE 1. Awareness of NO_2 by socio-economic category

When asked about where NO_2 comes from, 61% included burning fuel as one of their selections, 48% petrol vehicles, 52% diesel vehicles, 3% electric vehicles, 32% gas stoves and 25% said they didn't know. When offered the opportunity to mention a source not mentioned in the question, answers included agriculture, smoking, natural processes, fertilisers and industrial activity. In responding to the next question which asked if NO_2 was harmful to health, there was a great degree

of similarity across most socio-economic categories with over 90% in most categories stating that it was harmful to health except in the cases of primary level students, those currently seeking employment and those looking after family where the proportions were 73%, 89% and 88% respectively. When asked to select the health conditions with which they thought NO_2 had an association (allowed to select more than one), 83% said lung disease, 73% asthma, 41% cancer, 24% heart disease and 3% suggested other. These percentages indicate a good awareness of the health implications of NO_2 amongst the survey participants.

The next section of the survey concentrated on the location in which the participants lived and in particular to assess how close that location was to road traffic and congested conditions. This was followed by questions about the health status of the individuals in their household with the aim of testing if there was an association between proximity to traffic and health. Fifty three per cent of the sample own their own property while the remainder rent. Fourteen per cent live in a city centre, 31% in a suburban area, 26% in a town, 10% in a village and 19% in a rural location. Just under 20% have lived at that location for less than 2 years, 21% for 2-5 years, 13% for 6-10 years and 46% for more than 10 years. Eighty eight per cent of the participants would like to see an air pollution monitor installed near their home.

Medical Conditions and Possible Influences

The association between the respiratory conditions of the participants/household members and a number of the other variables generated from the survey, in particular those associated with traffic conditions near their home, were assessed using cross tabulations and discriminant analysis. The variable frequency distribution for both analyses are presented in Table 2.

1 **TABLE 2. Variable and frequency distribution for medical condition analysis**

Variable and Frequency Distribution			
		Frequency	**Percent**
Asthma	No	435	61.4
	Yes	274	38.6
COPD	No	654	92.2
	Yes	55	7.8
Hay fever	No	362	51.1
	Yes	347	48.9
No medical condition	No	438	61.8
	Yes	271	38.2
Type of area living in	City centre	97	13.7
	Suburban area	217	30.6
	Town	190	26.8
	Village	72	10.2
	Rural location	133	18.8
Time living at that address	< 2 yrs	137	19.3
	2-5 yrs	152	21.4
	6-10 yrs	93	13.1
	>10 yrs	327	46.1
Distance from front facade of house to nearest road	< 5 m	228	32.2
	6-10 m	195	27.5
	11-30 m	160	22.6
	>30 m	126	17.8
Traffic conditions on nearest road	Very light	149	21.0
	Light	295	41.6
	Heavy or very heavy	265	37.4
Speed limit on nearest road	30 km/hr	249	35.1
	50 km/hr	248	35.0
	60 km/hr	51	7.2
	80 km/hr	91	12.8
	100 km/hr	9	1.3
	120 km/hr	2	0.3
	I don't know	59	8.3
Duration of traffic queues per day on nearest road	Less than 20 minutes	328	46.3
	21-60 minutes	75	10.6
	1-2 hours	33	4.7
	Longer than 2 hours	20	2.8
	Not applicable	253	35.7
Mode used to travel to work or college	Bus	63	8.9
	Car	348	49.1
	Cycle	59	8.3
	Rail (including Luas)	21	3.0
	Walk	127	17.9
	Work from home	91	12.8
Car fuel type	Diesel	239	33.7
	Electric	6	0.8
	Hybrid	13	1.8
	Petrol	256	36.1
	Total	514	72.5
	Missing	195	27.5
Gender	Female	431	60.8
	Male	278	39.2
Age group	16 - 24	50	7.1
	25 - 34	174	24.5
	35 - 44	179	25.2
	45 - 54	163	23.0
	55 - 64	94	13.3
	Over 65	49	6.9
	Total	709	100.0

2

Cross tabulation Results

The first variable pairing was to examine the type of area in which the participants lived and medical condition, as shown in Figure 2. The distributions for each medical condition are broadly similar with the rates in towns and rural areas tending to be very close. Some variation is seen in the case of city centres with a particularly low level of chronic obstructive pulmonary disease (COPD) compared with others and, interestingly, villages have the lowest rate of no medical condition.

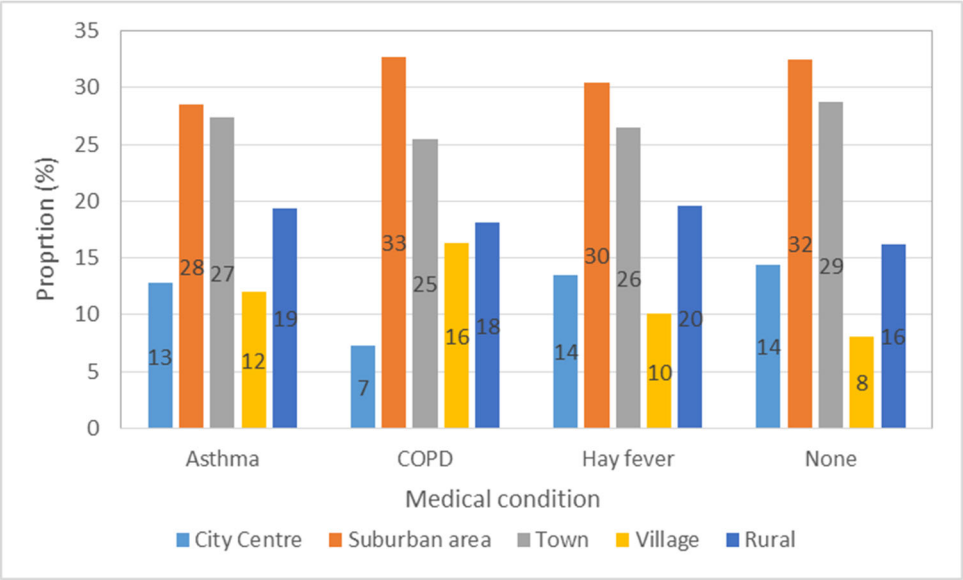

FIGURE 2. Cross tabulation between medical condition and type of area in which participants live

The next variable to be explored was the time spent living at their current address with the aim of assessing if long-term exposure to a particular environment may increase the incidence of a medical condition. Once again, as shown in Figure 3, the distributions are broadly similar with the dominant >10 yr categories tending to reflect a higher proportion of them generally in the survey population.

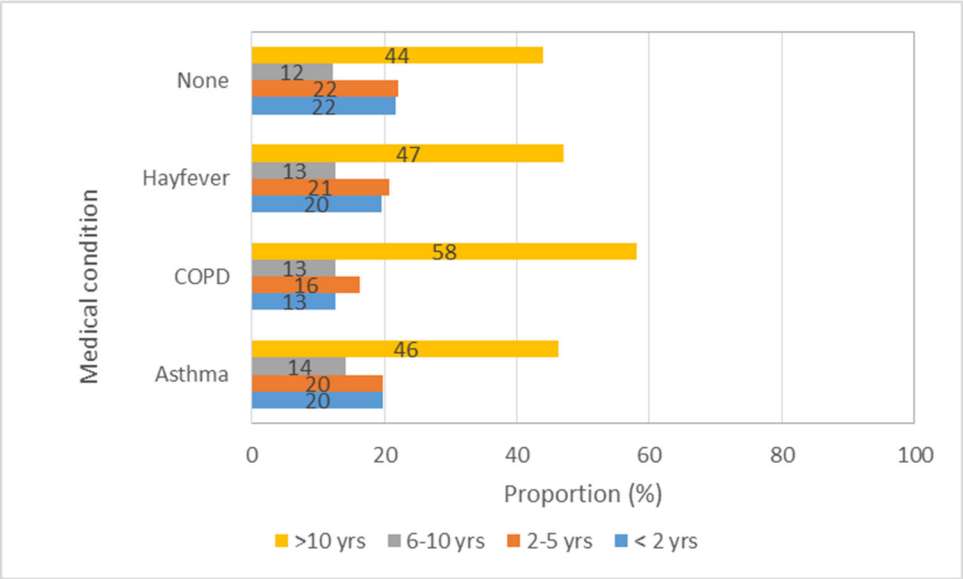

FIGURE 3. Cross tabulation between medical condition and number of years living at current address

Proximity of their home to the nearest road was then explored to establish if long-term proximity to traffic and its pollutants may increase the incidence of respiratory related disease but Figure 4 suggests rather similar distributions once again.

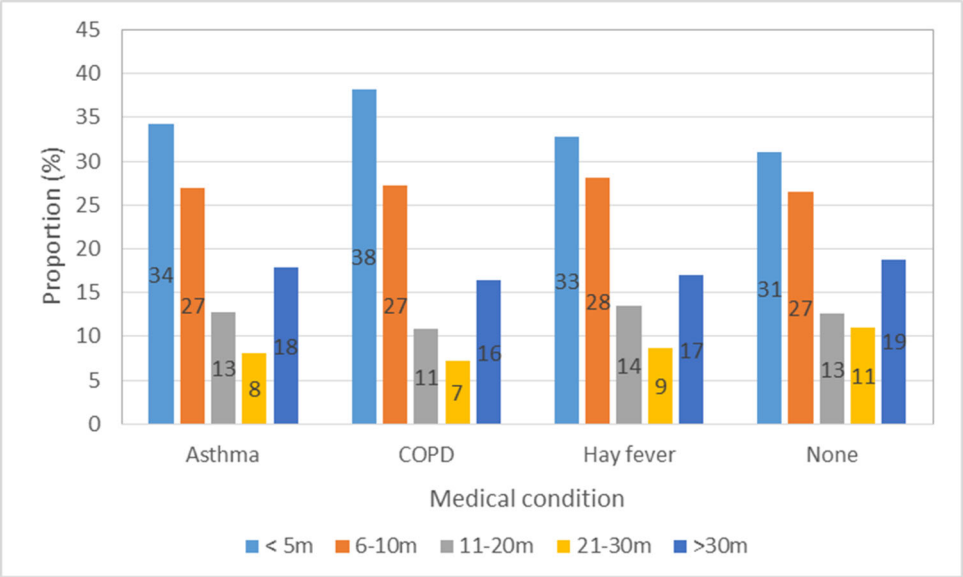

FIGURE 4. Cross tabulation between medical condition and distance from front façade of house to nearest roadway

Figure 5 presents the relationship between medical condition and how the participants described traffic levels on the road nearest their home. Comparing those with asthma to those with no medical condition, 44% of those having asthma rated traffic levels on the road nearest to their home either heavy or very heavy compared with 33% in the case of those with no medical condition. Similar traffic level distributions were evident for those with hay fever and COPD. The speed limit on the road did not appear to influence medical condition greatly as can be seen in Figure 6.

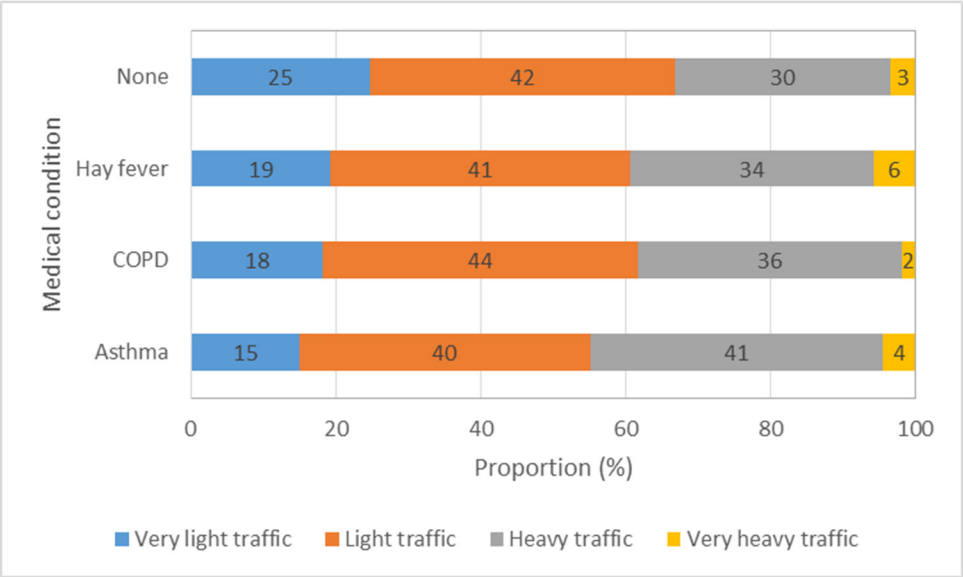

FIGURE 5. Cross tabulation between medical condition and traffic levels on road nearest home

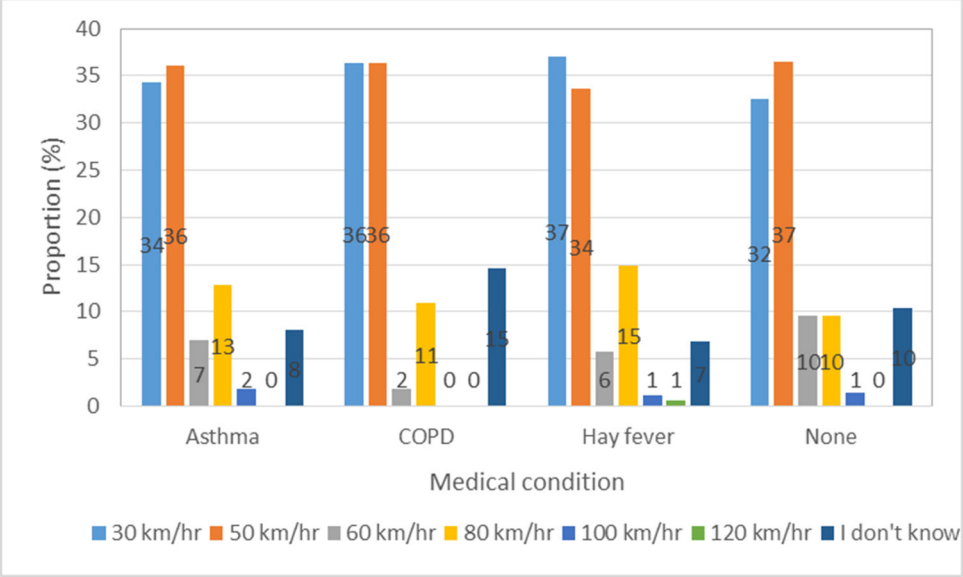

FIGURE 6. Cross tabulation between medical condition and speed limit of nearest road to home

When examining the duration of queuing on the road per day (Figure 7), 50% of those with asthma live close to roads on which queuing lasts for <20 mins per day compared with between 42-45% for the other conditions including for those with no medical condition.

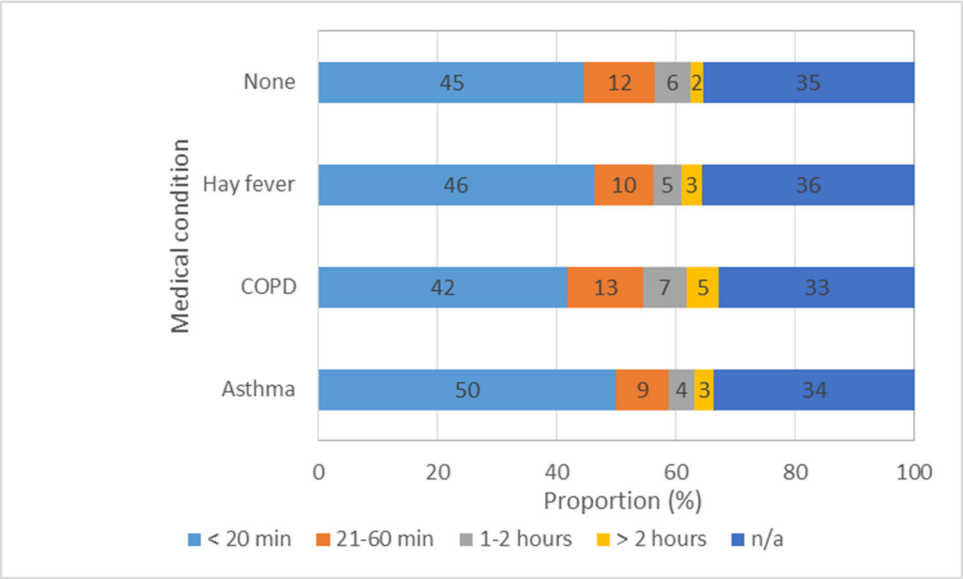

FIGURE 7 Cross tabulation between medical condition and duration of queuing per day on nearest road

The next variable to be examined was the main transport mode the participants used to get to work or college. The first general comment to make about the results presented in Figure 8 is the significant numbers using car. Again distributions by medical condition are broadly similar although the relatively low level of bus users and high level of walkers in the group with asthma can be noted although not to an extent that might be considered significant.

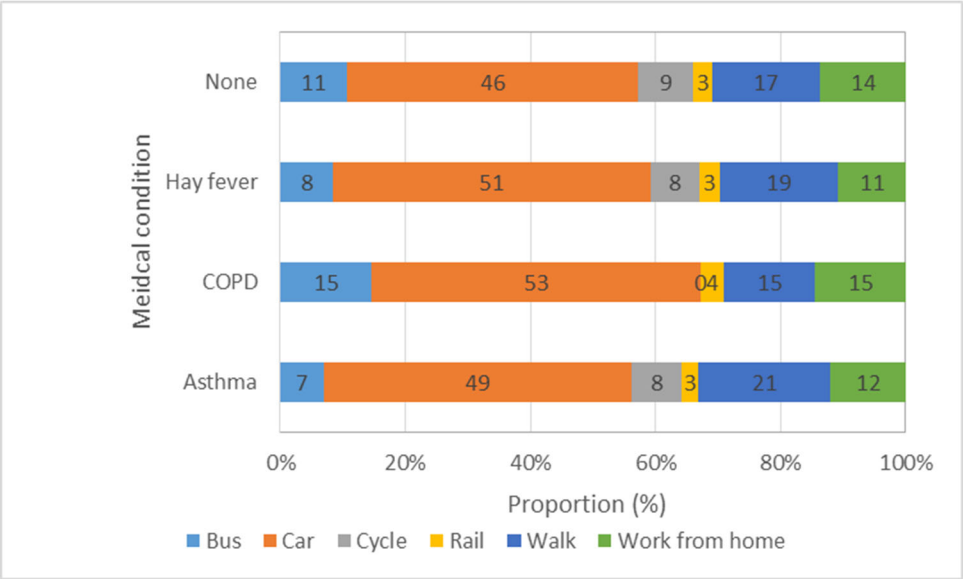

FIGURE 8. Cross tabulation between medical condition and main transport mode used to go to work or college

A review of medical condition by fuel type of the participant's car is shown in Figure 9. One result of note is the relatively high number of those who own petrol cars in the no medical condition category and the relatively higher level of diesel vehicle owners in the asthma and hay fever categories. In terms of gender shown in Figure 10, the large proportion of female asthma and hay fever sufferers is evident and particularly striking.

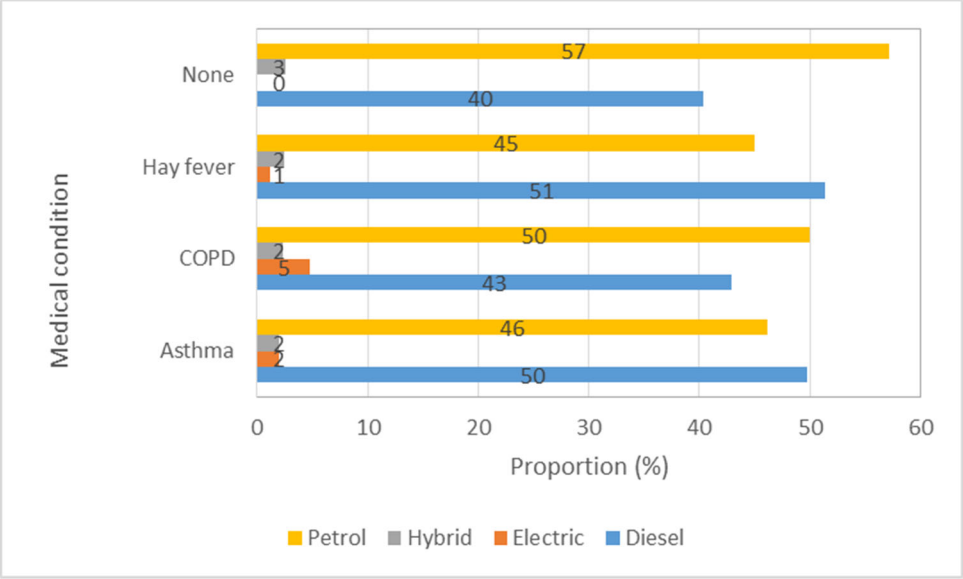

FIGURE 9. Cross tabulation between car fuel type and medical condition

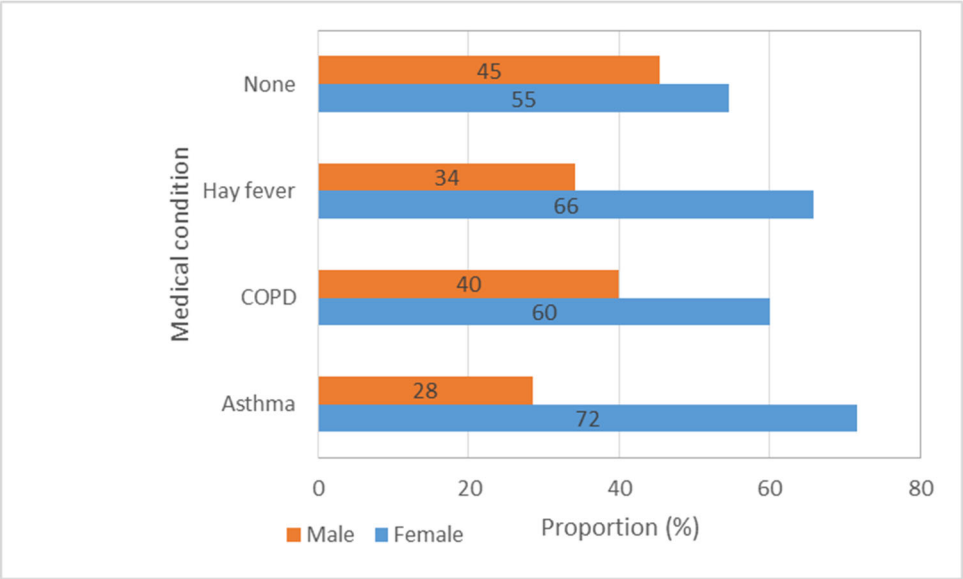

FIGURE 10. Cross tabulation between gender and medical condition

Finally the relationship between medical condition and age group is shown in Figure 11. The profiles for the higher age groups are broadly similar but, in the case of COPD, smaller numbers in the 25-34 age group category are evident, as one might expect.

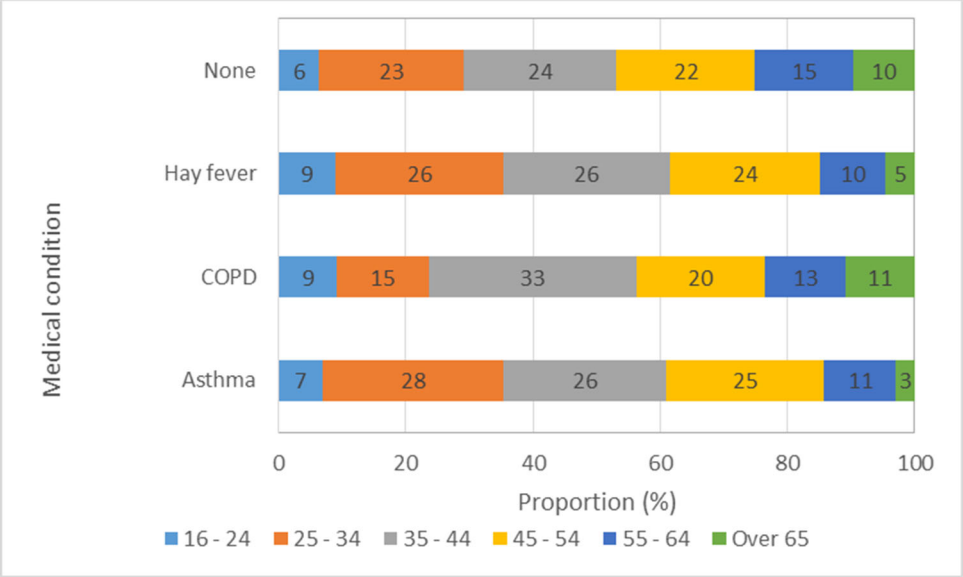

FIGURE 11. Cross tabulation between medical condition and age group

As can be seen in Figure 12, participants found their respiratory symptoms are worse in the months of May through August with much lower instances of problems during the Spring and Autumn months. This increase in the summer months is more than likely reflecting higher instances of hay fever during summer months. Winter months also seem to an issue for some of the participants but not to the same degree as during the summer.

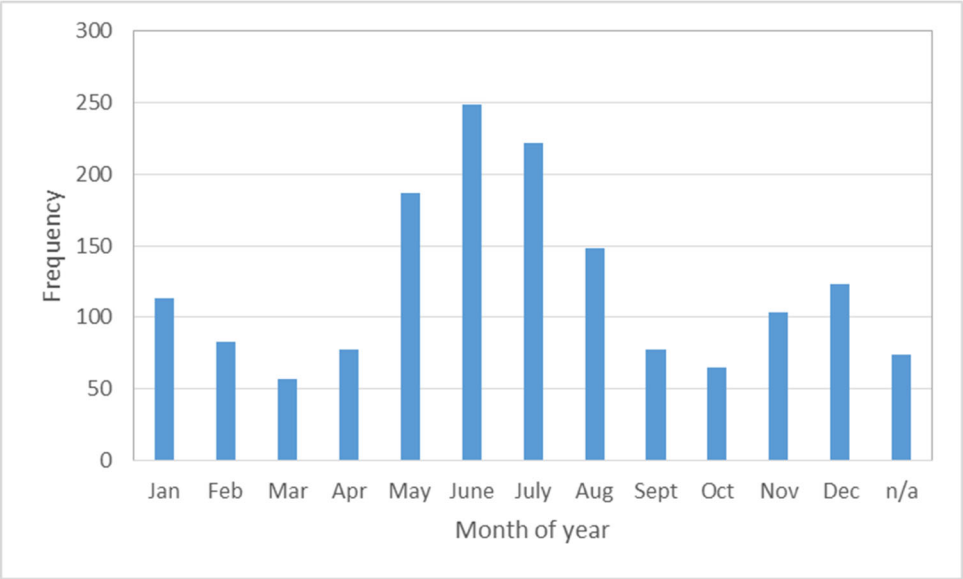

FIGURE 12. Months when respiratory symptoms are at their worst

In terms of actions taken by participants when suffering from respiratory symptoms, 344 take medication, 144 limit physical activity outdoors, 86 stay indoors and 14 indicated an other action ranging from using an air filter, close windows at night, ignore the symptoms and carry on and limit physical activity but not specifically outdoors.

When asked if the participants had heard of the EPA's Air Quality Index website *(20)*, only 20% had heard about it prior to the survey and 7% of them would use it once or twice a day, 10% once or twice a week, 21% once or twice a month and 62% said never. Of those who had not heard about the website, 9% of them said they would use it once or twice a day, now that they knew about it, 29% said once or twice a week, 45% once or twice a month and 17% said they would never use it.

Nineteen per cent of respondents said air quality was a factor in selecting the area they live in. Figure 13 demonstrates how the participants ranked other factors in this decision and shows that house price was ranked highest by 313 followed by safe area by 123, access to services by 87, quiet area by 81 and good commuting options by 52 respondents. Good commuting options received the highest rank 2 selection followed by safe area and access to services.

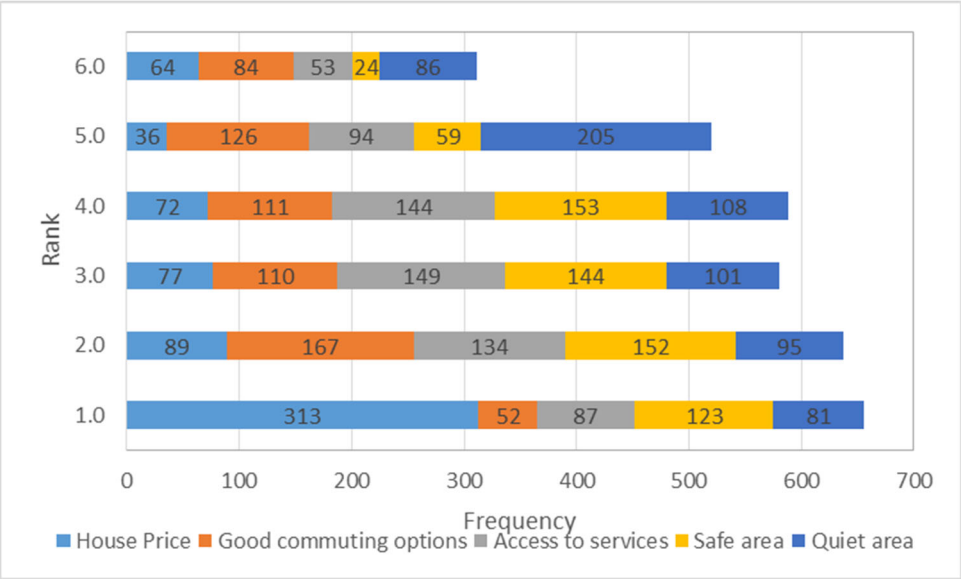

FIGURE 13. Ranking of factors that influenced residence location

Discriminant Analysis

To explore the potential influence of the location, transport related and socio-economic variables on medical condition in more detail, a discriminant analysis was performed using each medical condition as a grouping variable. The predictor variables and their frequency distributions were presented earlier in Table 2. Before proceeding with the analysis it was necessary to see whether the variances for each group are similar for each predictor variable and the Levene test *(21)* for homogeneity of variance was used. Variances were found to be equal for each category of the grouping variables except in the case of gender when considering asthma, hay fever and no medical condition. The next test was the Wilks Lamda test *(21)* to establish statistical significance at the 0.05 level, the results of which are presented in Table 3. All are significant to the 0.05 level except in the case of COPD and it is therefore dropped from further analysis. The next set of results are the Standardized Canonical Coeffcients and they are presented in Table 4. It can be seen that some of the predictor variables have large coefficients indicating that they are more important in terms of predictive power than those with small coefficients. In the case of asthma, gender appears to be the most important but it failed the Levene test and so the next highest coefficient is -0.626 for traffic conditions. Age group, mode of travel to work or college, car fuel type and in what type of area they live in all have coefficients between 0.2 and 0.3 so they also make a strong contribution. When looking at the hay fever function in Table 4, age group has the highest coefficient (0.679) followed by car fuel type, traffic conditions and length of traffic queueing on road nearest their house. Finally when looking at the column for no medical condition, age group, car fuel type again features with a strong coefficient, traffic conditions on the road nearest their house, speed limit etc.

TABLE 3. Wilks' Lambda results

Wilks' Lambda Reults					
	Wilks' Lambda	Chi-square	df	Sig.	Sig.
Asthma	0.929	37.363	10	0.000	0.000
COPD	0.992	4.293	10	0.933	0.933
Hayfever	0.956	22.659	10	0.012	0.012
No medical condition	0.953	24.288	10	0.007	0.007

TABLE 4. Standardised Canonical Coefficients

Standardised Canonical Coefficients			
	Asthma	Hay fever	No medical condition
	Function	Function	Function
	1	1	1
In what type of area do you live?	-0.215	-0.110	-0.237
How long have you lived at that address?	-0.037	-0.191	-0.223
Distance from front facade of house to nearest road	0.004	-0.144	0.025
Traffic conditions	-0.626	-0.388	-0.458
What is the speed limit of the road?	0.191	0.192	0.265
If traffic queues form on the road, for how long in total during a typical day would they form?	-0.097	-0.253	-0.16
How do you travel to school, college or work?	-0.258	0.086	0.021
Car fuel type	0.227	0.415	0.471
Gender	0.658	0.316	0.454
Age Group	0.298	0.679	0.54

While generally the results for the discriminant analysis are useful, the overall performance of the models in terms of their ability to classify correctly is perhaps lower than might be desired; 61.3% for the asthma model, 58.8% for the hay fever model and 57.6% for the no medical condition model.

Car Purchase Choices and Opinions on Transport Policy

Almost 73% (532) of the respondents own a car and, of those, 46.2% own a diesel car, 49.8% own a petrol (gasoline) car, 2.8% own a hybrid and 1.1% own an electric car. Factors influencing car choice decision making can be seen in Figure 14. Lower car purchase price received the largest

number of first rankings at 209, followed by fuel efficiency at 125 and lower fuel tax at 51. In the rank 2 and 3 positions, car tax received the highest number followed by fuel efficiency. Twenty seven individuals ranked less polluting number 1, 48 number 2, 43 number 3 and 127 number 4 indicating that it does feature in car purchasing decision making but not to a great extent. An interesting observation in the very large number (252) who listed early adopter last (8th) in their selection.

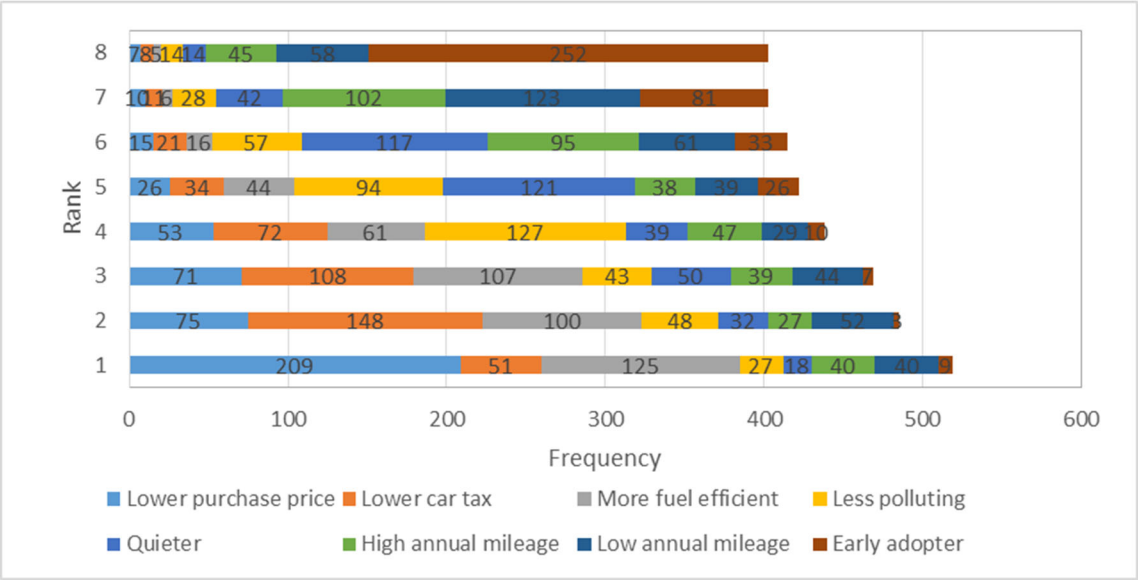

FIGURE 14. Ranking of factors that influence car purchase decision

Sixty eight percent (497) of the survey participants had heard of the diesel bans employed or proposed by some major cities across Europe and almost 70% (507) agree with the policy. When asked to give a reason for their answer, a text analysis shows that the word 'pollution' features very frequently in the answers (61 instances) and 'environment' features 26 times. It is acknowledged that a text analysis, shown in Figure 15, is not particularly accurate but it gives some indication of the relative importance of key words in the responses.

FIGURE 15. Text analysis of reasons for agreeing or not with recent urban diesel ban proposals.

When asked to rank a number of transport policies (see Figure 16) on the basis of their effectiveness in reducing the negative health impacts of diesel vehicle emissions, improving public transport was ranked highest by 193, followed by banning cars from streets with high numbers of pedestrians and cyclists by 187, promoting hybrids and electric vehicles by 146, reducing tax on

petrol vehicles by 76 with the remainder of the policies receiving much lower instances of top ranking. Promoting hybrids and electric vehicles received the highest number of rank 2 selections at 198, followed by promoting public transport by 111, reducing tax on petrol vehicles by 102 and banning cars from streets with high pedestrian and cyclist counts at 100. The same four policies again featured the highest when examining the rank 3 selections.

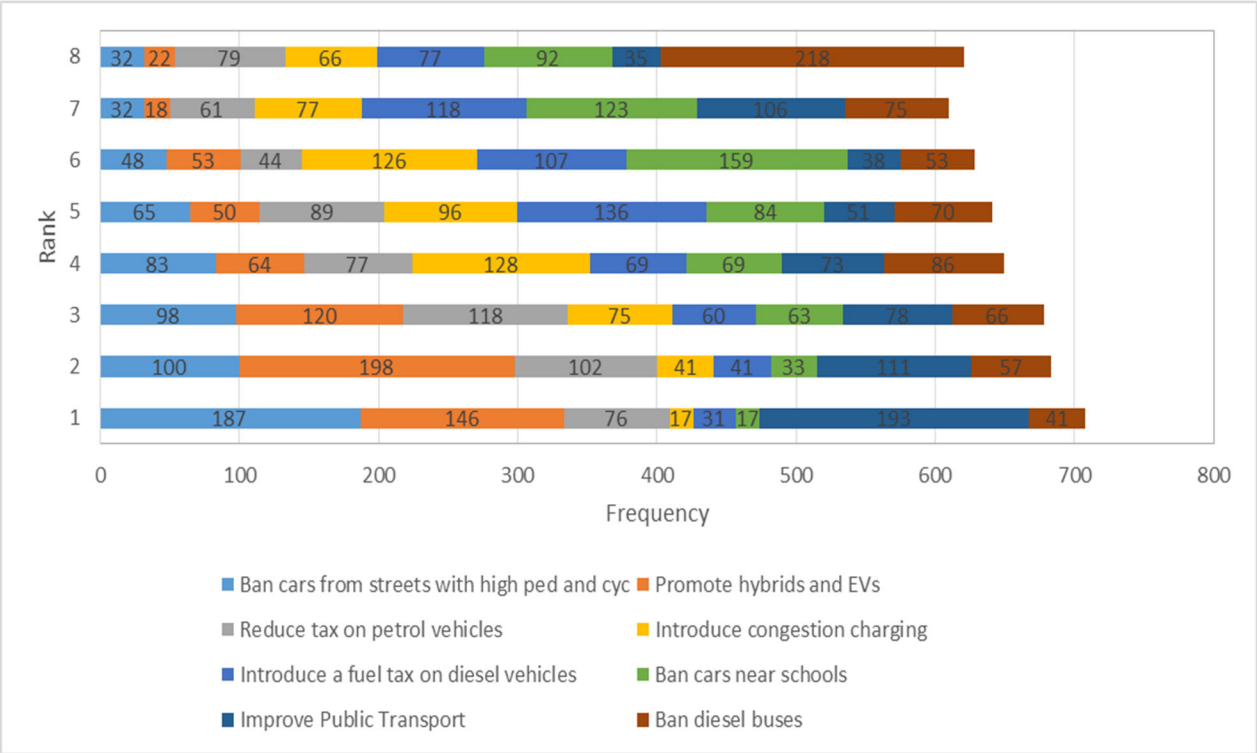

FIGURE 16. Ranking of transport policies

Just over 70% of the participants had heard of the proposals by some car manufacturers to ban the production of diesel vehicles in the near future and 74% of participants agreed with this policy. When asked why they thought the car manufacturers had come to that decision, 420 cited the health impacts of diesel emissions, 319 and 313 suggested that hybrid and EV technology was better respectively, 202 suggested petrol vehicles were becoming more fuel efficient and 188 thought it was to do with high diesel engine production costs.

The final set of questions in this section examined how the decision of the car manufacturers would influence current and future car purchase decision making. The first of the questions asked, since becoming aware of this policy, had they made decisions in relation to car purchase choices. Of the total 730 responses, 555 had not changed their car during the period. In the case of those who had changed their car (175), 29% purchased a petrol vehicle, 23% purchased a diesel vehicle, 14% bought a hybrid vehicle, 8% bought an electric vehicle and 26% sold their car and did not replace it. The latter finding was unexpected and a weakness of the survey was that no opportunity was given to the participants to elaborate on their responses in this section. The next question was similar but asked the respondents to focus on their potential car purchasing decisions between now and when diesel vehicle production will cease. In this case, 35% said they will not change their car, 26% said they would purchase a hybrid car, 16% a petrol (gasoline) car, 13% an electric vehicle, 6% a diesel vehicle and 4% said they would sell their car and not replace it. The final question in this section was similar again to the previous two but in this case the

participants were asked to indicate their choices in car purchasing decision making when diesel vehicles are no longer available to buy at some point in the future. In this case, 33% said they would purchase a hybrid, 24% a petrol vehicle, 22% an electric vehicle, 14% would hold on to their diesel vehicle for as long as it would stay running and 7% would sell their car and not replace it.

The last section of the survey asked the participants their opinion about the environment and their health. The purpose of this section was to gain a better understanding of the motivating factors of the participants surveyed. The responses to the statements about the environment are presented in Figure 17 where it can be seen that most agree or strongly agree with the statement that they are willing to spend a bit more on a product that is more environmentally friendly and an even greater proportion agree or strongly agree that they are concerned about air pollution. The responses to the other two statements are less clear with most responses gravitating towards the neutral position but with more in the disagree rather than the agree categories. The two statements include 'it is acceptable for an industrial society such as ours to produce a certain degree of pollution' and 'I don't change my behavior solely because of concern for the environment'.

The responses to statements on health are presented in Figure 18. Most of the respondents agree or strongly agree that if they learned something was bad for their health or that of their children they would take action to avoid it. Most of the sample do not smoke, a large proportion disagree with the statement that they do not worry about what they eat or drink with a similar amount agreeing with the statement that they take physical exercise and maintain a healthy diet.

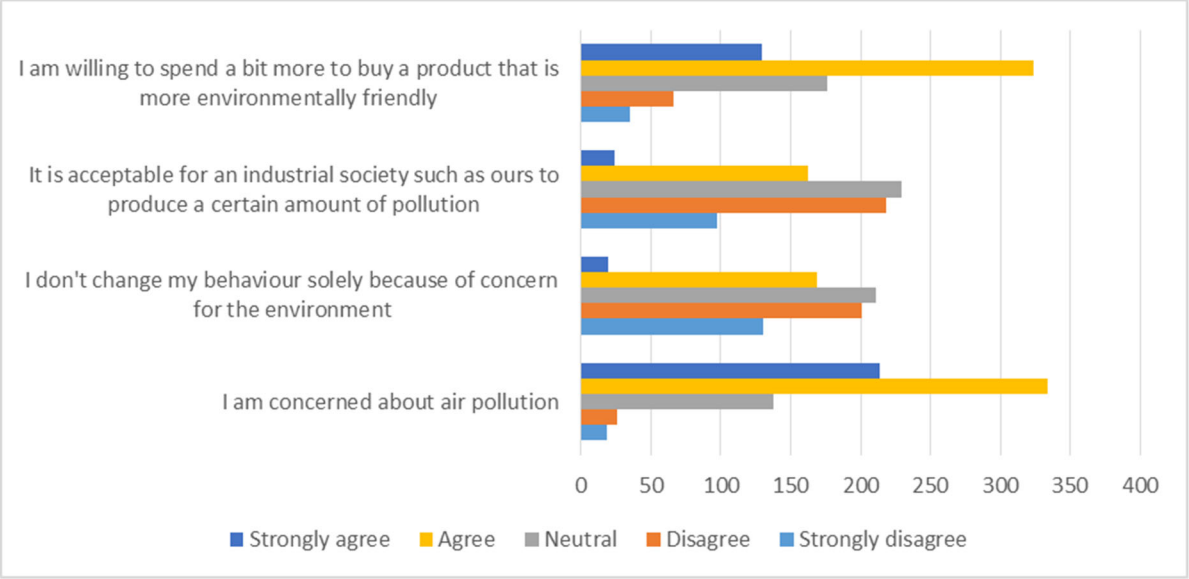

FIGURE 17. Attitudes to environment

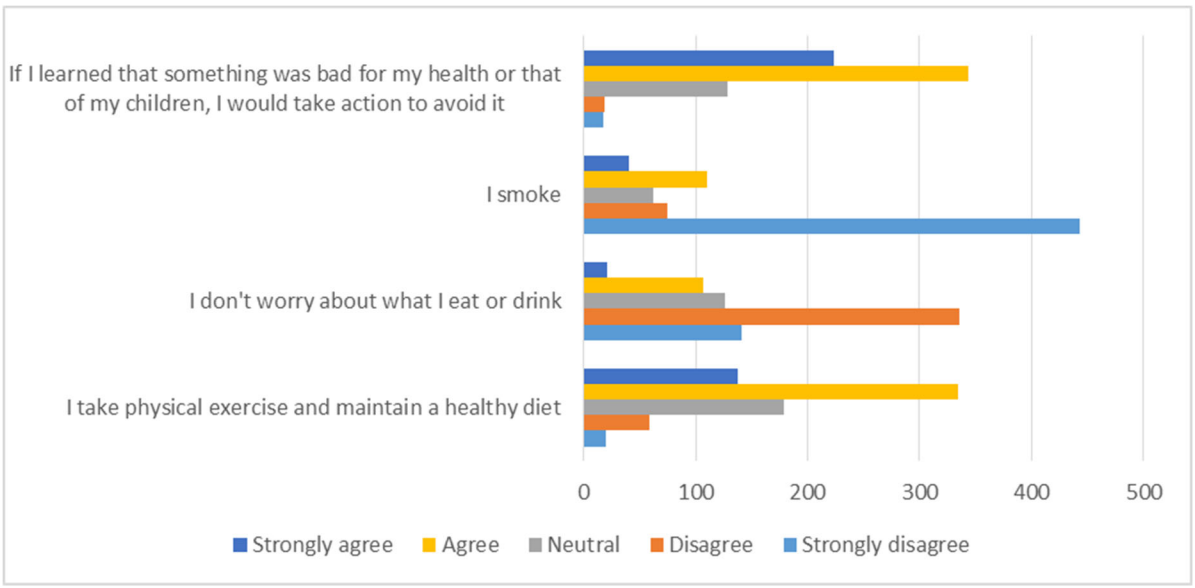

FIGURE 18. Attitudes to health

Limitations of the research include the unrepresentativeness of the sample governed by limited funding for the project and the necessity to use an existing survey panel. Another limitation was the constraint on the length of the survey which limited further exploration of some topics with the participants. The numbers surveyed were insufficient to investigate in a comprehensive way some of the potential associations between health status and exposure to air pollution.

CONCLUSIONS

The research examined a number of aspects of awareness and behavior in the context of transport policies that are directly related to reducing harmful emissions from road transport such as NO_2. Some transport policies can drive changes in user behavior e.g. the change in Irish car taxation in 2008 that removed the link to engine size in favour of CO_2 emissions. The policy strongly discouraged the purchase of petrol vehicles in favour of diesel.

The aim of the research was to 1) examine current general awareness of the impacts of NO2 and air pollution on health 2) determine if geographical, transport and socio-economic variables could be linked with the self-reported health status of the participants in the context of respiratory conditions, and 3) assess the potential responses to diesel vehicle bans and proposals to cease their production.

The conclusions are as follows:

1. Participants in the survey were found to be well informed in relation to the health impacts of NO_2. Awareness increased as education level increased.
2. Mapping medical conditions to geographical, transport and socio-economic variables demonstrated similarities in profile regardless of medical condition.
3. Respiratory symptoms were at their worst from May to August reflecting, in particular, high levels of hay fever during that time.
4. Traffic conditions, age group, mode of travel to work or college, car fuel type and in what type of area participants live were all found to have somewhat of an influence on whether an individual had asthma or not. For the hay fever model, age group, car fuel type, traffic conditions and length of traffic queuing on the road nearest their house all featured as making a contribution. Age group and car fuel type had the highest coefficients in the

discriminant analysis used to assess no medical condition but traffic conditions on the road nearest their house and speed limit also have an impact. Overall, while some associations were evident in the analysis, the performance of the model was not sufficiently high to indicate that the associations were strong.

5. Hybrid and electric vehicles feature in how individuals will respond when car manufacturers cease production of diesel vehicles but some said they would keep their existing diesel vehicle as long as it would keep going.
6. The research highlights the importance of assessing potential user behavior when a new transport policy is planned or introduced.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Margaret O'Mahony, Brian Broderick, Martina Hennessy, John Gallagher; analysis and interpretation of results; Margaret O'Mahony, Brian Broderick, John Gallagher, Martina Hennessy; draft manuscript preparation: Margaret O'Mahony, John Gallagher, Brian Broderick and Martina Hennessy. All authors reviewed the results and approved the final version of the manuscript.

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