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THE RELATIONSHIP BETWEEN AIR POLLUTION, HEALTH AND SOCIAL DEPRIVATION IN LEEDS, UK

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ABSTRACT

This study examines the relationship between air pollution, social deprivation and health in the city of Leeds, UK under a baseline and three distance-based road user charging (RUC) scenarios set at 2 pence, 10 pence and 20 pence/km. The RUC scenarios were compared with the 'base' scenario, all set for the year 2005. The RUC initiatives result in the differences in ambient concentrations of two pollutants PM_{10} and $NO_{2.}$ The study correlates their concentrations with derived indices of social deprivation and health. The study concludes that positive relationship exists between air quality and social deprivation, and indicates that deprived population groups are disproportionately exposed to higher NO_2 levels. The relationship between air quality and health status of the population is weak. RUC scenarios result in reducing disparity between affluent and deprived populations. There is a strong relationship between social deprivation and health status of the population.

Key Words: Air Quality, Social Deprivation, Health, Road User Charging, Environmental Justice

1 INTRODUCTION

A great deal of interest has been expressed in the relationships between social deprivation and health (Hawker et al., 2003; Burr et al., 1997), and air quality and health (WHO, 2004; Samet *et al*., 1999; Vedal, 1997; Schwartz, 1994). These studies have shown that air quality and social factors impact upon health, but little is known of their effects upon one another. In literature, little information exist which explicitly links social factors and air quality. In a number of studies of health and air pollution, social indicators were included as explanatory factors for poorer health. For example, overcrowding (defined as more than one person per room), or the presence of a smoker, was frequently cited as a contributing factor to poor respiratory health. The relationship between air quality and social deprivation is also used to test the concept of environmental justice. The concept of environmental justice has gained greater recognition in recent years, as social goals (e.g. equity, fairness, and justice) have themselves gained greater prominence through almost universal efforts to promote sustainable development. The concept draws attention to the questions of whether certain socio-economic groups, including the economically and politically disadvantaged, bear a disproportionate burden of environmental externalities, and whether policy and practice are equitable and fair (Wilkinson, 1998).

Relationships between air pollution and health and deprivation, potentially result in the most cost to both the public and the government in terms of increased mortality and morbidity, hence establishing causal links between them is very important and can be justified.

The main aim of this study was to investigate the possibility of a relationship between local air quality and measures of health and deprivation. The supporting objectives were: (a) to establish if a positive correlation exists between areas with poor air quality and those which are socially deprived and/or experience poor health; and (b) to determine what impacts road user charging initiatives have on air quality, and consequently on deprivation and health in Leeds.

2 METHOD

Traffic assignment, pollutant emission and dispersion models were applied to a 12 x 12 km area of the city of Leeds city, as shown in Figure 1, so as to assess the air quality impacts of five road user charging (RUC) schemes. This work has been described by Mitchel et al. (2002) in detail. This involved the application of a chain of dynamic simulation models of traffic flow (SATURN, SATTAX), pollutant emission (ROADFAC) and dispersion (ADMS-Urban), integrated within a geographic information system model TEMMS (Namdeo et al., 2002). Schemes were evaluated with reference to: exceedance of air quality standards for six pollutants; emission of greenhouse gases; redistribution of pollution, and road network performance as traffic speed and trip distance. Results were compared to alternatives of do nothing, network development and clean fuel promotion. The scenarios addressed included "business as usual" traffic growth to 2015; network development; road pricing with cordon charging; road pricing with distance charging; and the wider adoption of clean fuel vehicle technology. Modelled air quality data from this study forms the base of the current study.

Figure 1. City of Leeds Showing Study Area Boundary

2.1 Air Quality

Out of the several scenarios selected in the original study, the base and three road user charging (RUC) scenarios have been selected for the current study to investigate the possibility of a relationship between local air quality and measures of health and deprivation. The three scenarios selected are road user charging set at three levels – 2 pence, 10 pence and 20 pence/km. NO_2 and PM_{10} levels for the base and three RUC scenarios for the year 2005 have been predicted for 3600 cells of 200 x 200 m size in the study area. Annual mean NO_2 levels for the Base Scenario are shown in Figure 2. Contribution of major radial and ring roads is clearly evident from this figure.

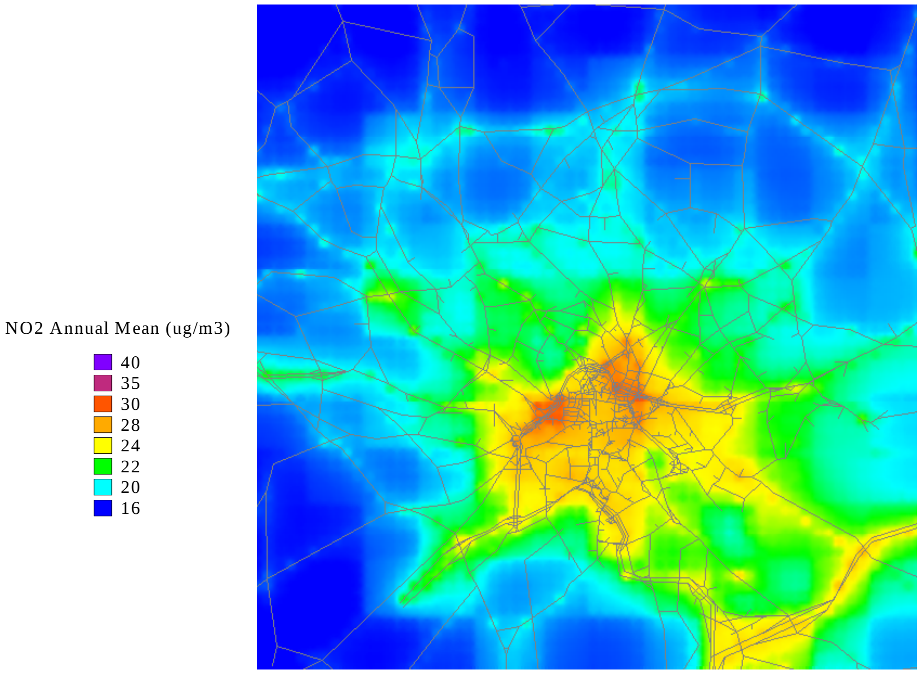

Figure 2. NO_2 Annual Mean for the Base Scenario

2.2 Social Deprivation and Health Indices

The UK Census 2001 data (National Statistics, 2004) have been used to derive indicators of health and deprivation levels of the population in the study area. Census has its own measure of deprivation, which ranks the Census Output Area (COA) population as being deprived in terms of any number of four dimensions. It lists the number of households in the COA which were not deprived, as well as those deprived in one, two, three or all four dimensions. Similarly, for health, it lists the number of households which rated themselves as either having good health, fairly good health or not good health. Cumulative Deprivation Index (CDI) and Cumulative Health Index (CHI) for each COA were derived on a scale of 0 to 100, with 100 representing most deprived or least healthy areas.

CDI was derived by calculating what percentage of the total households in each COA was deprived to each degree, followed by weighting and scaling it to arrive at a score ranging from 0 to 100 with 0 representing least deprived and 100 representing most deprived. The first step was to work out what percentage of households were deprived in each number of dimensions. It was decided to give the degrees of deprivation a weighting between zero and four, with the least deprived being given the smallest weighting, and the most deprived the heaviest. Therefore, the number of households who weren't deprived in any dimension were given a weighting of 0, so were multiplied by 0/10 (as 1+2+3+4 = 10), those deprived in one dimension were multiplied by 1/10 (0.1), those in two dimensions by 0.2, in three dimensions by 0.3 and so on. This resulted in a range of scores from 0 to 40, which was then scaled (multiplied by 2.5) to give an index (CDI) between 0 and 100.

A similar process was intended to devise a single index value for health (CHI), but with this data there were only three possible variations – good health, fairly good health and not good health. As these were quite vague, it was decided that the first two concerned only with people who were not of poor health. The third class was assumed to represent 'not healthy'. The percentage of people 'not healthy' has been used as cumulative health index (CHI) with 0 representing most healthy and 100 representing least healthy.

Figure 3 shows the map of cumulative deprivation index of the study area. It shows that that deprivation is highest in the southern and eastern parts of the city. Deprivation levels are lowest to the north of the city. Map of baseline health status using CHI (Fig. 6) shows that it follows a similar pattern of distribution of CDI. The areas in which poor health is more common are, again, primarily adjacent to main radial routes into the city.

3 ANALYSIS

3.1 Relationship between Social Deprivation and Health

Figure 5 shows the scatter plot of cumulative health and deprivation indices along with the best-fit-line. It is evident from this plot that social deprivation and health are strongly, and positively related, with a high correlation coefficient (r =0.68), and a trend-line gradient of 0.35. This shows quite clearly that as levels of deprivation increase, as do levels of poor health.

3.2 Impact of RUC Scenarios on Air Quality

Three RUC scenarios studied have different effects on the level and distribution of air pollutant concentrations, the general trend being that all distance based road user charging regimes investigated produce a significant improvement in city wide air quality, a consequence of trip suppression and emission reduction. Figure 6 and Figure 7 show change in NO_2 concentrations between the base, 2p/km and 20p/km charge scenarios. It is clear from these figures that 2p and 20p charge scenarios results in significant reduction in NO_2 concentrations, though 20p charging regime results in greater improvements which are distributed to a wider area. Effects on PM_{10} concentrations are not this strong, and are not shown here.

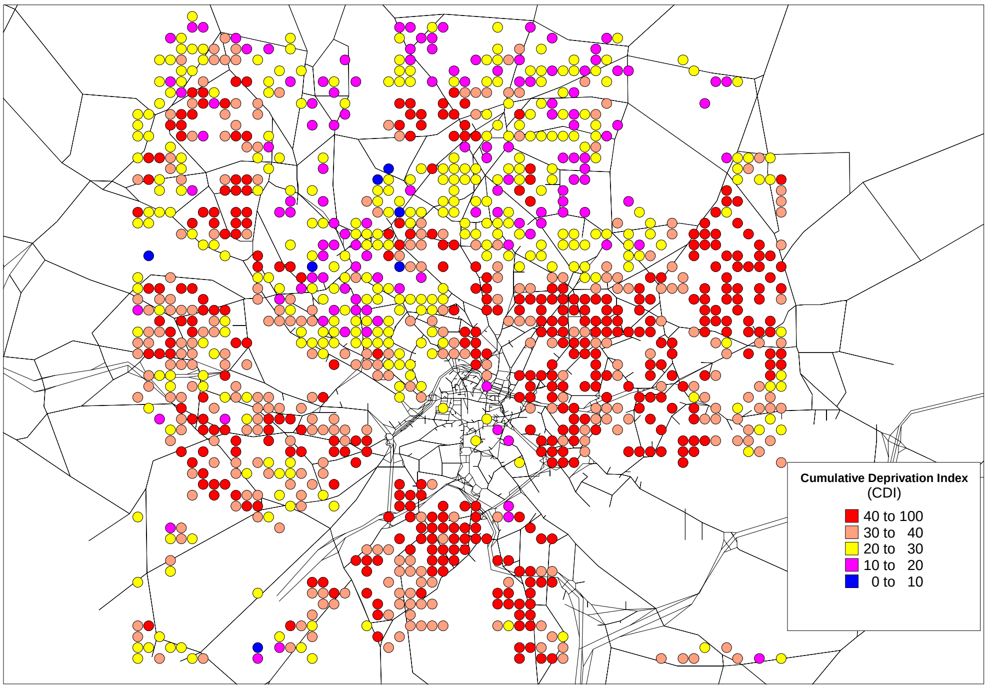

Figure 3. Deprivation (CDI) in Leeds – Census 2001
(Note: 0 = Least deprived; 100 = Most deprived)

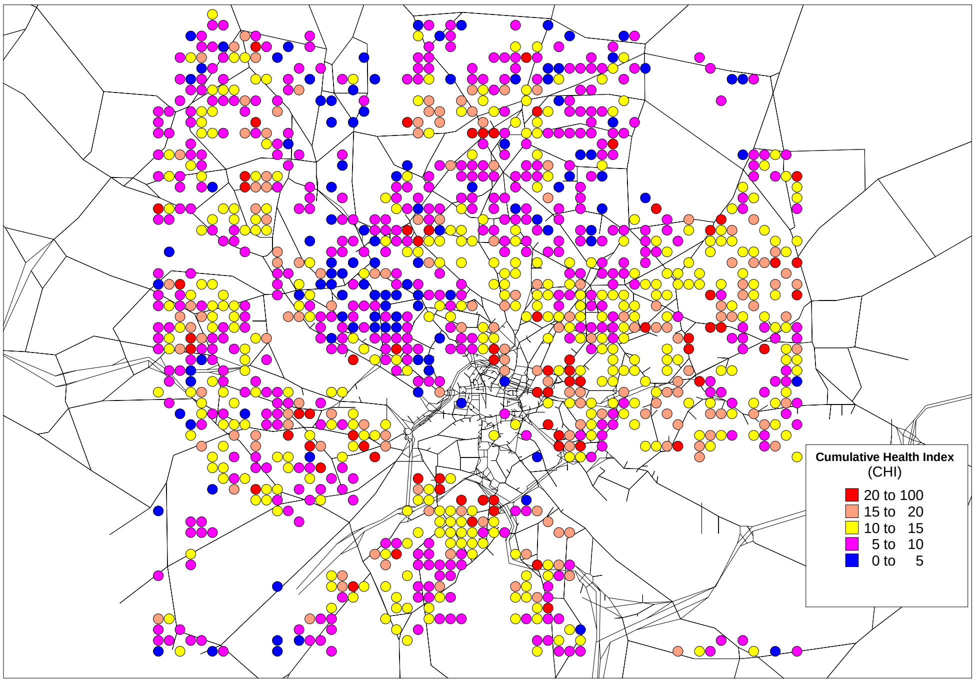

Figure 4. Health Status (CHI) in Leeds – Census 2001
(Note: 0 = Most healthy; 100 – Least healthy)

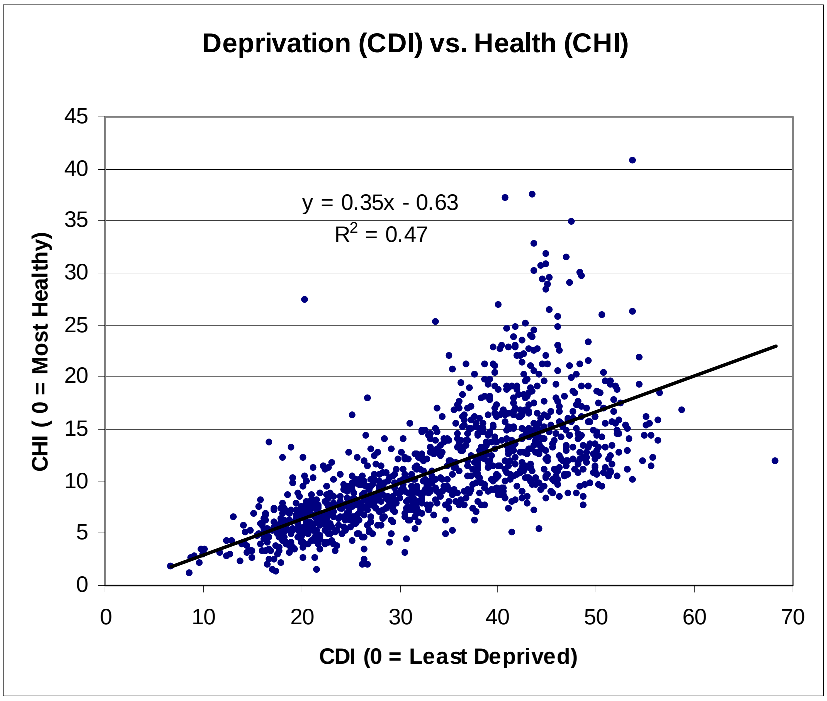

Figure 5. Relationship between deprivation and health

3.3 Relationship between Air Quality and Deprivation

In the environmental justice analysis, air quality data for each 200 m grid cell was paired with social deprivation and health indices for corresponding COA. This analysis focuses on exposure to Nitrogen dioxide (NO_2). Nitrogen dioxide was selected as the study pollutant, as review and assessment exercise carried out, as a fulfilment to NAQS obligations by local authorities in UK, have indicated that NO_2 and PM_{10} are currently the principle pollutants of concern in UK urban areas (ENDS, 2002), and are thought to pose significant risks to health (Vedal, 1997). Secondly, our modelling work (Mitchell et al., 2002) has shown that in the case of Leeds, NO_2 is more sensitive to changes in transport emissions than PM_{10}, due to the large contribution to total particulate emission from point sources.

Two statistical tests were used in the environmental justice analysis. Firstly, for each scenario, an ordinary least squares regression was conducted of annual mean NO_2 and the cumulative deprivation index. Regression is not used here to infer causality between these variables, but is used to test for an association between them. A steeper slope coefficient indicates greater inequality. Jerrett *et al.*, (2001) adopted this approach in their environmental justice analysis of PM_{10} in Hamilton, Canada. Following the regression analysis, different tests were conducted which compared mean NO_2 concentration with deciles, and the upper and lower quartiles of the deprivation index.

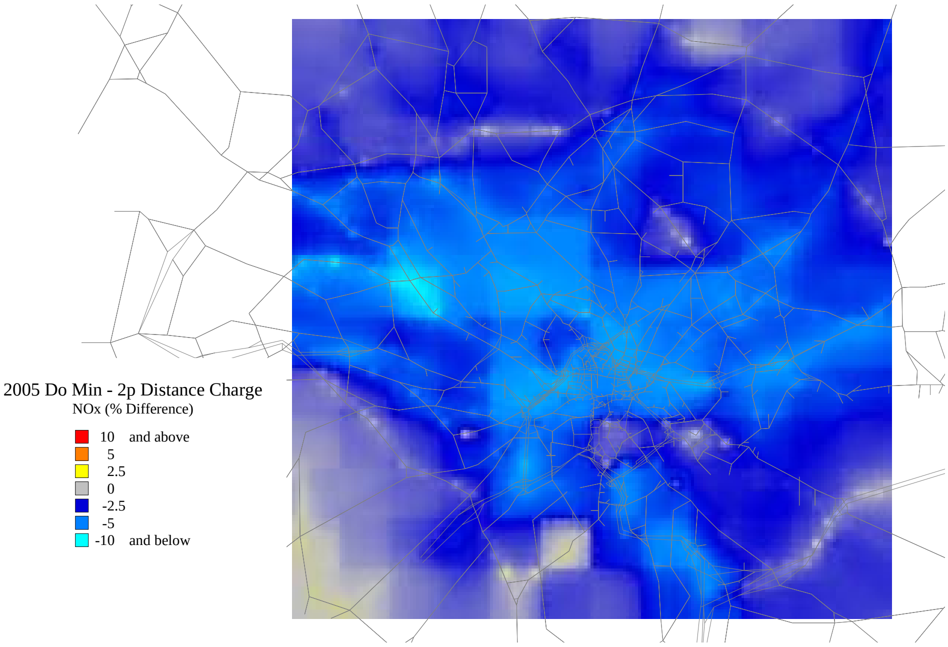

Figure 6. Percentage Change in NO_2 Concentrations between No-Charge and 2p/km Scenarios

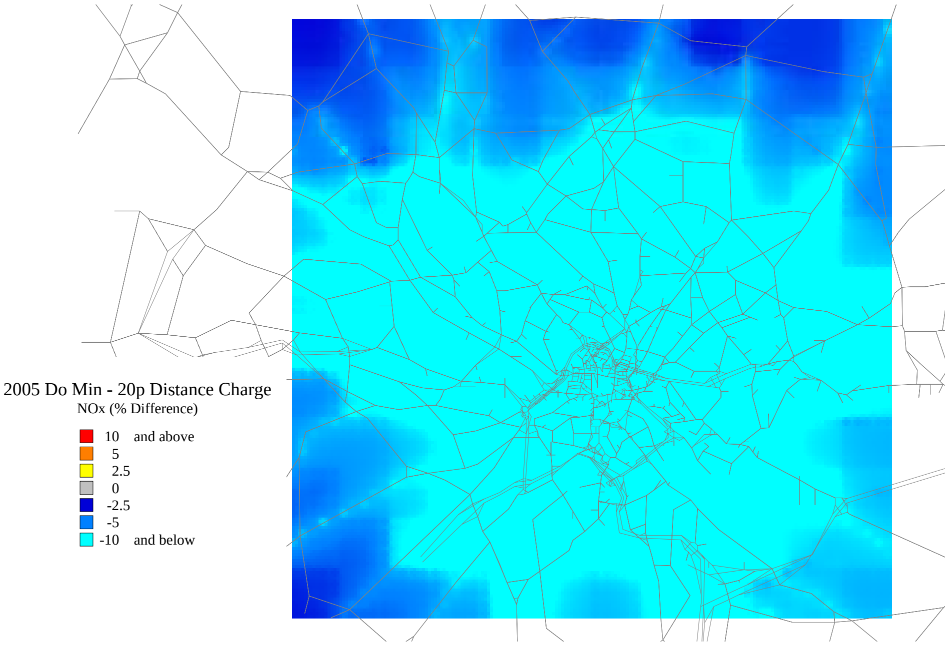

Figure 7. Change in NO_2 Concentrations between No-Charge and 20p/km Charge

Regression analysis shows that for all scenarios, the correlation in terms of the R^2 value was quite low but slopes of the best fit lines were positive (Table 1) indicating that there is an association between air quality and deprivation. The relationship between deciles of deprivation index and NO_2 under the modelled transport scenarios is illustrated in Figure 8. For each scenario, the data (n=1143) have been presented as mean NO_2 against the deciles of CDI classes. For all scenarios, there is a strong positive association between deprivation and NO_2; however 20p and 10p charging regimes result in flatter slopes. This indicates that these scenarios results in reducing the disparity between deprivation and NO_2 exposure or in other words better environmental justice. To assess the statistical significance to the apparent inequalities, difference tests were conducted to compare mean NO_2 concentration in the upper and lower quartiles of the deprivation index. The results of these tests (Table 2) show that deprived groups experience a significantly higher NO_2 concentration in their residential location than affluent groups.

Table 1. Regression Statistics for Pollutants (NO_2 and PM_{10}) and CDI/CHI

	Correlation Coefficient (r)		**RSQ (r^2)**		**Slope**	
Scenario	**CDI**	**CHI**	**CDI**	**CHI**	**CDI**	**CHI**
NO_2						
Base	0.247	0.178	0.061	0.032	1.292	0.470
2p	0.250	0.176	0.062	0.031	1.385	0.494
10p	0.232	0.171	0.054	0.029	2.906	1.080
20p	0.218	0.167	0.048	0.028	3.890	1.505
PM_{10}						
Base	0.225	0.166	0.051	0.027	1.918	0.713
2p	0.139	0.097	0.019	0.009	0.440	0.156
10p	0.128	0.090	0.016	0.008	0.412	0.146
20p	0.126	0.089	0.016	0.008	0.407	0.145

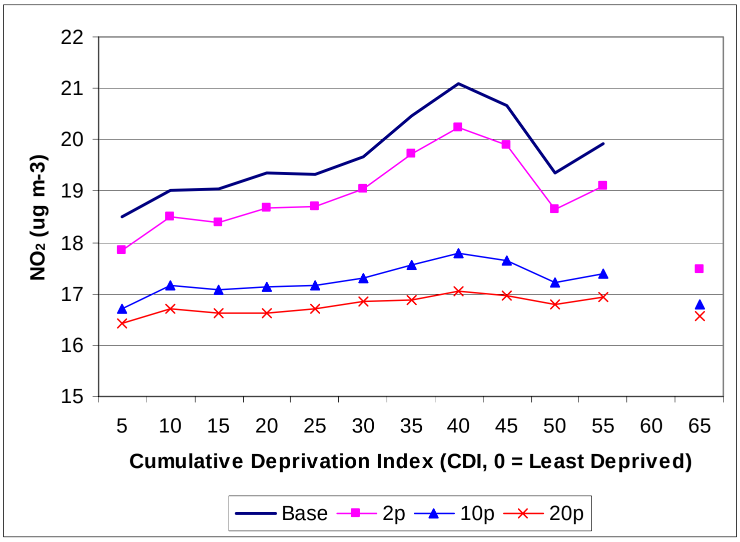

Figure 8. Relationship of Annual Mean NO_2 and Deciles of Deprivation under Base and Road User Charging Scenarios

3.4 Relationship between Air Quality and Health Status

Correlation between health (deciles of CHI) and NO_2 is shown in Figure 9. It is clear from this figure that there is no discernible association between them. This is also evident from the statistics in Table 1.

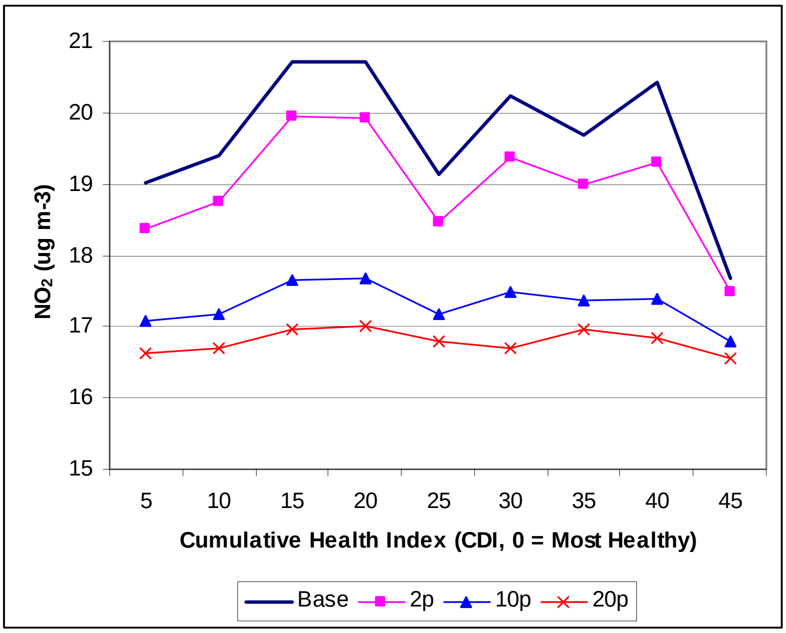

Figure 9. Relationship of Annual Mean NO_2 and Health under Base and Road User Charging Scenarios

Table 2: NO_2 and Quartiles of CDI and CHI

Quartile	**CDI**	**CHI**	**Average of corresponding NO_2 values ($\mu g\ m^{-3}$)**			
			Base	**2p**	**10p**	**20p**
First quartile (25th percentile)	24.53	7.17	19.21	18.55	17.12	16.62
Second quartile (50th percentile)	33.87	10.03	19.46	18.82	17.21	16.75
Third quartile (75th percentile)	42.77	14.03	20.52	19.77	17.59	16.93

4 CONCLUSIONS

The outcome of this study has been that air quality (NO_2) impacts disproportionately on certain, more deprived areas of the city. The analysis shows that there is a significant welfare inequity in the distribution of urban air quality, with more deprived groups clearly experiencing higher atmospheric concentrations of NO_2 in their residential location. The analysis cannot be used to state categorically that deprived communities have a higher exposure, as other exposure specific factors including daily population movement and individual activity rate are neglected. Distance based road user charging scenarios result in varying degree of reduction in NO_2 concentrations. Reduction in NO_2 concentrations in case of 10 p and 20 p per km charge scenarios are significant and in a wider area and consequently results in removing inequity in the distribution of urban air quality, hence better environmental justice.

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