

Draft

Development of a GIS method to assess exposure of households to roadside NO₂

A report produced for Department of Environment, Transport
and the Regions, The National Assembly for Wales, The
Scottish Executive and the Department of Environment for
Northern Ireland

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Executive Summary

The Government and devolved administrations have recently published a consultation document entitled 'The Air Quality Strategy for England, Scotland, Wales and Northern Ireland'. The air quality modelling work undertaken for this report indicated that policies currently in place or to take effect before 2005 will lead to the NO₂ annual average objective of 40 µgm⁻³ being achieved at all background locations, except inner London, and at most roadside locations by 2005. However, the national modelling identified a number of major urban road links where concentrations at the roadside may exceed the objective.

A pilot study has already been undertaken to estimate the number of households likely to be exposed to exceedances of the NO₂ objective. This considered 102 road links, including a case study of the North Circular Road in London, and involved visits to each road and the use of a postcode to determine numbers of residential addresses. The site visits found that 23 road links have houses within 10m of the kerb, with a total estimate of more than 1,200 houses. Using the postcode data, a total of over 2,600 houses were found to exist along these road links, but the data sets were not detailed enough to determine how many of these are within 10 m of the kerb. The current study aims to consider the location of the houses in more detail through the use of more detailed digital map data.

The Geographical Information System (GIS) method developed in this study used a variety of digital map data: OS Landline, OS Oscar, OS Address Point and aerial photographs, linked together within a GIS. A total of 102 links were analysed, finding an estimated number of households in the range of 1,783 to 2,365. The range of estimates is attributed to various sources of uncertainty mainly related to limitations of the OS data and the interpretation of the Address Point database. However, this result is considered to be more accurate than that provided by the pilot survey, because of the much greater level of detail available concerning the nature of the buildings along the individual road links.

The links considered were those with the highest predicted NO₂ concentrations. However, those with lower traffic flows, and hence lower predicted concentrations, are more likely to be residential roads, and therefore may represent higher risks in terms of exposure.

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1 Introduction

1.1 BACKGROUND

The UK Government and devolved administrations are taking active measures to improve air quality through the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS) (DETR et al 1999a). This Strategy defines Air Quality Standards and Objectives for eight pollutants and identifies their major sources. The AQS gives the following objectives for nitrogen dioxide (NO₂) to be achieved by the end of 2005:

- Annual mean: The annual mean must not exceed 40 µg m⁻³.
- Hourly mean: The hourly mean must not exceed 200 µg m⁻³, not to be exceeded more than 18 times a year.

In addition the European Union 'Daughter Directive' gives the following limit values for NO₂ to be achieved by 1 January 2010:

- Annual mean limit value of 40 µg m⁻³.
- 1-hour limit value of 200 µg m⁻³, not to be exceeded more than 18 times a year.

The annual mean objective and limit value are likely to be the most stringent of the targets, particularly at the roadside.

The Government has recently published a consultation document on the Review of the Air Quality Strategy (DETR et al 1999b). This report sets out proposals for amending the Air Quality Strategy following a review carried out during 1998.

The national modelling of roadside NO₂ concentrations (Stedman et al, 1998), carried out as part of this review, indicated that policies currently in place or to take effect before 2005 will lead to the annual average objective being achieved at all background locations, except inner London, and at most roadside locations by 2005. However, the national modelling identified a number of major urban road links where concentrations at the roadside may exceed the objective.

One of the key uncertainties within the national modelling of NO₂ is the question of public exposure. The approach adopted in the Strategy is to apply the objectives where members of the public are likely to be exposed over the averaging time of the objective. In the case of annual mean, this refers to roadside locations where residential buildings schools or hospitals etc are close to the kerb. The national models used for the review of the Air Quality Strategy simply predicted NO₂ at the roadside and did not consider the location of housing. NO₂ concentrations also decrease significantly with distance from the roadside. If housing is located more than about 10 m from the edge of the road, then NO₂ levels there are likely to be lower than the roadside levels predicted by the model.

A pilot study to assess the number of households adjacent to road links with the highest predicted roadside NO₂ has been undertaken (King et al 1999). This considered 102 road links, including a case study of the North Circular Road in London, and involved visits to each road and the use of a postcode to determine numbers of residential addresses. The site visits found that 23 road links have houses within 10m of the kerb, with a total estimate of more than 1,200

houses. Using the postcode data, a total of over 2,600 houses were found to exist along these road links, but the data sets were not detailed enough to determine how many of these are within 10 m of the kerb. The current study aims to consider the location of the houses in more detail through the use of more detailed digital map data.

1.2 STUDY OBJECTIVE

The objectives of this study were:

- to develop an accurate Geographical Information System (GIS) based method for estimating numbers of households exposed to exceedances of the annual mean air quality objective for NO₂ at the roadside;
- to quantify the number of households within 10m of kerb on these links;
- to enable similar assessment of exposure to other pollutants using this method.

For this study, only those road links surveyed in the pilot study (King et al 1999) were considered.

2 Method

2.1 METHOD OVERVIEW

This method uses detailed Ordnance Survey (OS) digital map data to determine the exact location of the road links under scrutiny. The widths of the roads were measured and then the buildings within 10m of the kerb were identified. Postal Address Point data were then used to determine the nature of the buildings identified, and the number of residential buildings was estimated. The results have been compared with those obtained in the pilot study (King et al 1999). Aerial photographs have also been used to provide a further check on the results in some locations.

The method was implemented using ArcView GIS software, customised to provide relevant functionality. However, the data preparation, prior to using this new ArcView functionality, was a significant part of the method because of the nature of the digital data in its raw form.

2.2 DATA REQUIREMENTS AND DATA PREPARATION

Three key data types were required in the development of this method: OS OSCAR, OS Landline and OS Address Point. Aerial photographs have also been used to provide more information about the nature of some of the roads.

2.2.1 OS OSCAR

OS OSCAR data provides an accurate digital map of the whole GB road network, and therefore offers a considerable improvement on the current roadside NO₂ database, which is limited to straight line representations of these links. This straight line representation of the road links was used to compile the 1996 National Atmospheric Emission Inventory and subsequent pollution mapping results (Salway et al 1999). An improved OS Meridian based map of roadlinks, at a resolution appropriate to the national scale mapping, is currently being used to compile the 1997 NAEI.

As with all OS digital maps, the OSCAR data is organised into a series of square tiles covering the whole of Great Britain. In the case of OSCAR data these tiles are 5km across. For each city, the relevant OSCAR tiles were selected and the 'A' roads were extracted, as all of the road links considered within the national modelling for the review of the NAQS are of this type. Figure 1 shows two example OSCAR tiles, one with all the detail and one with just the 'A' roads. The lines in the OSCAR data set actually correspond to the road or carriageway centre lines, and hence for dual carriageways there are two lines.

2.2.2 OS Landline

OS Landline is a very detailed digital map, which, in urban areas, is made up of a series of 500m square tiles. The Landline maps include outlines of every building and of road kerbs. Many other details are also included, such as property boundaries and watercourses. The relevant tiles

adjacent to the road links were selected, and the buildings and kerb lines were extracted. Figure 2 shows examples of the Landline tiles.

Figure 1 Two OSCAR tiles

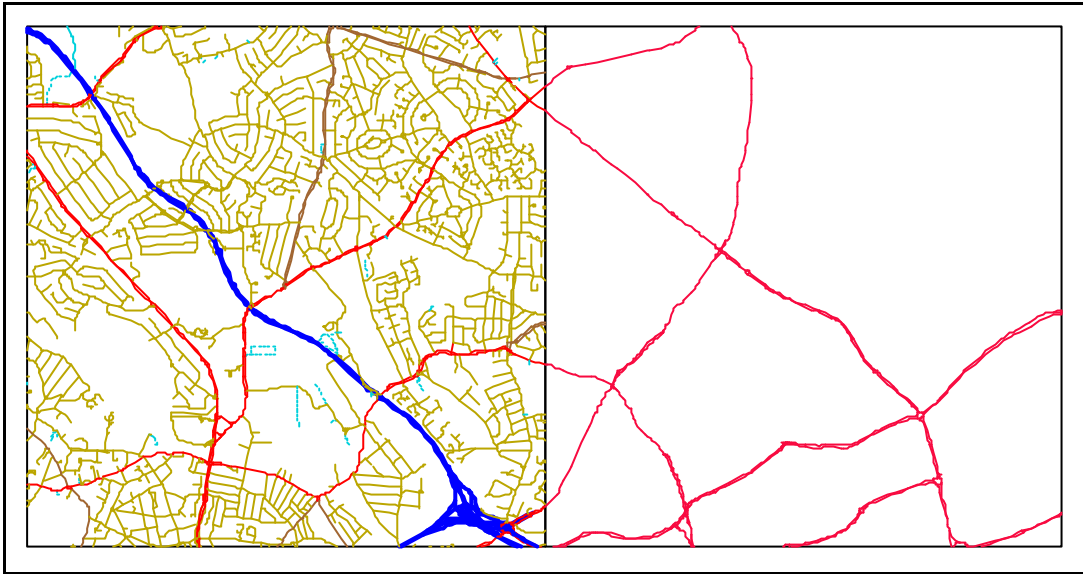
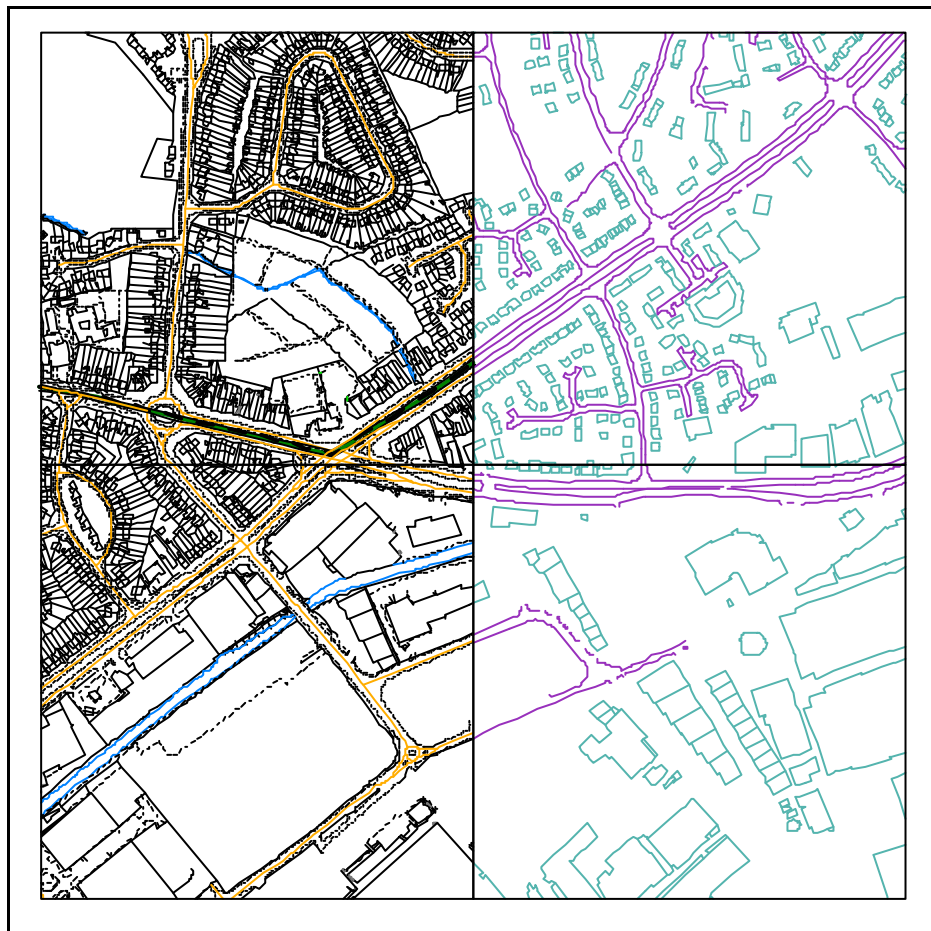


Figure 2 Landline data



2.2.3 OS Address Point

The OS Address Point data consists of a series of points defined by grid references. These points correspond to each postal delivery address location, which are nominally the location of the letter box. The digital files are organised by postcode sector. Sectors covering the links under scrutiny in each city were identified, and those points that fall within the area of interest extracted. Figure 3 shows the Address Points that exist within one of the Landline tiles in Figure 2.

Figure 3 Address Point data



2.2.4 Aerial photographs

Aerial photos have been obtained from the National Remote Sensing Centre. These are available in 1km tiles, which cover a selection of cities in the UK. Photographs have been obtained for a small selection of road links in London, Birmingham and Manchester. The data have primarily been used to provide further contextual information to clarify any uncertainty. Figure 4 shows an example of the aerial photography data with the OSCAR data overlaid.

Figure 4 An example of the aerial photography (London A4088 link 57656)



2.3 METHOD USED TO SELECT ADDRESSES

A series of tools were developed using Avenue, the ArcView programming language. These tools provide an element of automation in the processing of the OS data.

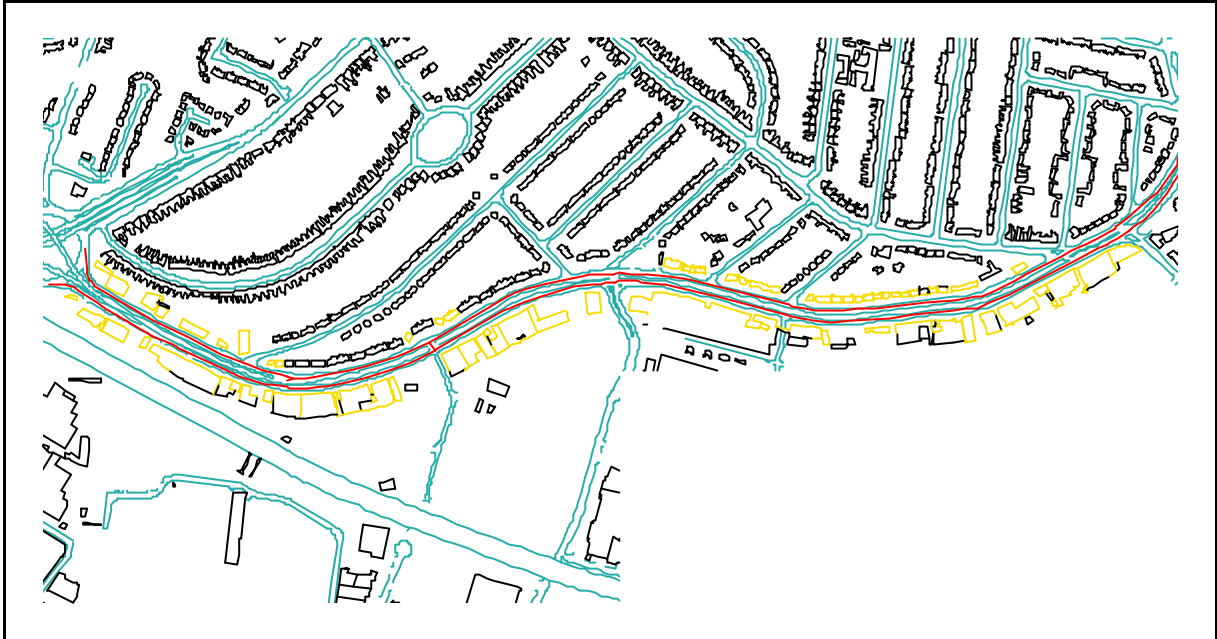
The road links studied were those visited as part of the pilot study, as described in King et al (1999). The OS data were prepared separately for each city in this study. Once the data had been prepared, each link could be examined in detail.

Firstly, in order to determine which buildings were within 10m of the kerb, the distance of the kerb from the road centre line was measured manually at a number of points along the road link. This was required because the kerblines data was not in a format that could be used to measure the distance from the buildings directly. The average distance of the road centre to the kerb was often 3 to 6 metres and therefore the distance used to test for exposure was 13 to 16m

from the road centre line. If large variations in road width existed then a maximum and minimum distance were used for the next part of the analysis.

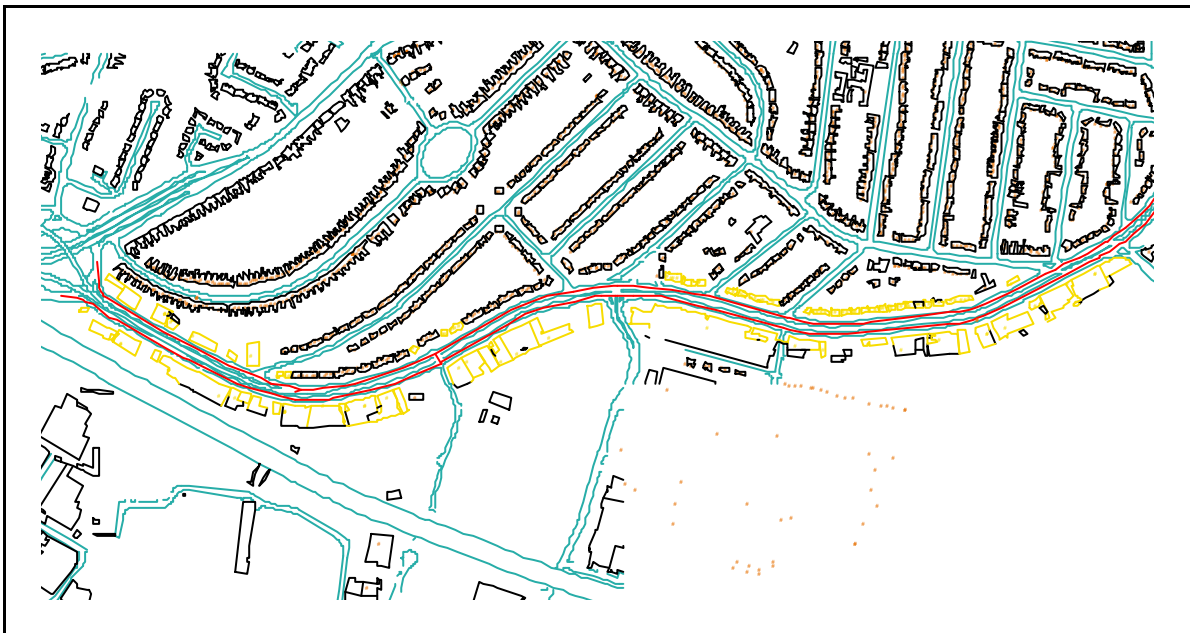
Secondly, all buildings were selected that had a façade within the calculated distance from the road centre line. Figure 5 shows this selection, with buildings within 10m of the kerb coloured yellow.

Figure 5 Selected buildings



Once the buildings had been selected and checked, the Address Point map was queried to select those points that correspond to the selected buildings. Again, the results of this selection were checked manually to ensure that no Address Points were missing or had been included incorrectly. Figure 6 shows the Address Points selected, also in yellow.

Figure 6 Selected address points



The last stage of the process was to identify which of the selected Address Points correspond to residential buildings. This was performed using the assumption that non-residential buildings have some sort of business or organisation name in the Address Point database (in the 'On' column in the table below). The residential building count therefore only includes address points that have no name.

Where the road width is variable along the route two selections have been made: at a minimum distance from the road centre and a maximum. This provides a range of possible exposed households. On some roads where lots of residential buildings were found, this range was examined to determine which estimate is most accurate.

Table 1 Address Point data showing residential and non-residential addresses

<i>On</i>	<i>En</i>	<i>Sb</i>	<i>Ed</i>	<i>Tn</i>	<i>Ft</i>	<i>Fc</i>	<i>Xcoord</i>	<i>Ycoord</i>
	27			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129518	2918861
	29			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129518	2918861
	31			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129448	2918816
	33			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129448	2918816
	35			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129395	2918769
	37			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129395	2918769
	39			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129637	2918567
	41			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129599	2918544
	43			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129555	2918516
	45			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129767	2918181
	47			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129811	2918213
	49			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129855	2918241
	51			SOWERBY MARCH	BIRMINGHAM	B24 DLH	4129905	2918271
RICKS PLACE	1			WOODLANDS FARM ROAD	BIRMINGHAM	B24 DPJ	4135220	2919399
INDIA GARDEN RESTAURANT	992			TYBURN ROAD	BIRMINGHAM	B24 OTL	4124127	2911112
SPRINGTHORPE SUPERMARKE	156			SPRINGTHORPE ROAD	BIRMINGHAM	B24 OSP	4125414	2918861
ST. AGNES REST HOME	33		31-33	SILVER BIRCH ROAD	BIRMINGHAM	B24 OAR	4117474	2925731
C A SAGAR & CO LTD			4A	WOOD END ROAD	BIRMINGHAM	B24 8AA	4107033	2915231
UNDERARM PRODUCTIONS					BIRMINGHAM	B24 8QF	4106764	2905456
	60			LYNDHURST ROAD	BIRMINGHAM	B24 8QS	4106884	2907046
ROLLASON WOOD HOTEL			126-130	WOOD END ROAD	BIRMINGHAM	B24 8BJ	4109622	2911306
BETHEL UNITED CHURCH					BIRMINGHAM	B24 8LQ	4106764	2905456
THE SYNTHESIS CENTRE					BIRMINGHAM	B24 8PF	4106764	2905456
ENERGY LTD	57			GRAVELLY INDUSTRIAL PAR	BIRMINGHAM	B24 8TQ	4101377	2896390

3 Results

A summary of the results is shown below in Table 2. A comparison is also made with the results of the site visits in the pilot study. Detailed results for each road link are shown in Appendix 1. The figures in Table 2 are estimated numbers of residential buildings, based on the assumption that residential buildings are those address points with no building name. This does however conceal some uncertainty because there may be buildings of non-residential use that also do not have names. This issue is considered further in the next section on sources of uncertainty.

Table 2 Summary of results

City	Number of links analysed	Number of households found in site visits in pilot study	Number of households estimated in this study (range based on varying road width assumptions)		Comments
Birmingham	16	59	260	453	The current analysis has identified more houses than found in the pilot survey. A large number of addresses suspected to be non-residential especially on city centre links.
Bristol	7	0	17	20	All links are in commercial areas, therefore most addresses likely to be non-residential.
Doncaster	2	0	2	2	Good correspondence.
Glasgow	3	0	6	13	Good correspondence.
Hull	3	0	66	76	Houses identified very near to end of road, may have been missed in the pilot survey. Also houses in adjacent roads are very near this road.
Leeds	9	50+	41	41	Good correspondence.
Leicester	6	6	54	55	This total includes a block of 24 flats. The links are all on a city centre ring road identified as commercial land use. Many of the points selected are therefore thought to be non-residential..
Liverpool	16	860+	485	642	Roads with large numbers of houses correspond well with previous results.
London (A406)	18	215+	373	497	Large numbers of flats included in this total. Also one link were houses were found to be within 10m in this study but not included in pilot. Otherwise good correspondence.
Manchester	12	95+	103	152	The current analysis has identified houses within 10m that were not included in the pilot survey.
Newcastle	4	0	344	378	A large block of flats is included
Portsmouth / Fareham	3	6	10	13	Good correspondence.
Sheffield	3	0	22	23	Possibly non-residential buildings.
TOTAL	102	2000+	1783	2365	

The analysis of the aerial photos provided some additional information. Figure 7 shows the photograph of the centre of Birmingham with the OSCAR data overlaid. Link 57191 is highlighted in yellow. The photo shows that large commercial and industrial buildings

dominate the area. In contrast, Figure 8 (link 16365 on Tyburn Road) shows mainly residential buildings with gardens. The south side of the link is commercial.

Figure 7 Bull Ring (link 57191) in Birmingham



Figure 8 Tyburn Road (link 16365) in Birmingham

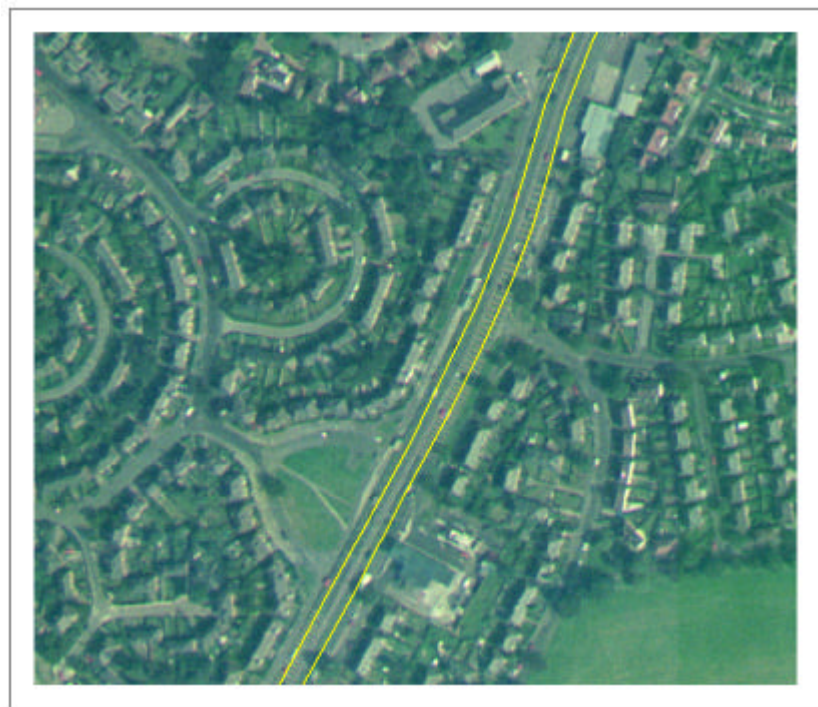


Figure 9 shows the large number of houses close to the North Circular Road on link 37113. Although the picture is not very clear, the variable road and pavement widths can be seen. Figure 10 shows part of link 37809, where no houses were found within 10m of the road in the pilot study, but between 27 and 43 have been found in this study.

Figure 9 London, North Circular Road (link 37113)



Figure 10 Manchester, A5103 near junction of M63 (link 37809)



3.1 SOURCES OF UNCERTAINTY

The description of the method included some discussion of the problems encountered with the digital maps and address point data. These problems may account for some of the disparity between the results of these two studies. Brief explanations of the possible sources of uncertainty in the new method are listed below. Appendix 1 also includes comments on individual road links.

- *Selection of buildings within 10m of the kerb:*

OS Landline data does not represent buildings as polygons and therefore it is not always possible to select individual buildings within the 10m zone. For example, whole terraces of houses may be selected. As far as possible this was corrected for by visual inspection of the selection in the GIS.

Variations in road width, slip roads and access roads caused problems in the calculation of the distance of the houses from the kerb. A range of values for the road width was used and this provided a range of possible households exposed. The aerial photographs did not provide any additional data that can improve this method. A possible solution would be to make individual measurements from the landline data between each house and to the road. This would clearly be very time consuming.

The OS Landline data provides no vertical distance information. For example the road could be a flyover or underpass and therefore the actual distance of buildings close to the road is greater than is shown on the map. No solution has been implemented for this problem.

- *Selection of Address Points within selected buildings:*

Because of the nature of the Landline data described above, address points could not be selected on the basis of being 'inside' a building. Therefore all Address Points within a distance of 5m of selected building outlines were selected.

- *Residential Address Points:*

It was assumed that Address Points without a building name are residential. This assumption may have provided an over-estimate where there are non-residential buildings that are empty or where no name is given in the database. In some cases such errors could be identified and corrected, such as where surrounding buildings were obviously commercial rather than residential, but in others it was not possible to make the distinction.

- *Blocks of flats:*

Address points with flats or apartments are often represented by a series of points all at the same grid reference. The exposed households are those at ground level and possibly first floor level, but it is not possible to determine how many of the flats are at these levels. In these cases, all addresses are included.

- *Inaccuracy in the original survey:*

Inaccurate distance measurements in the pilot study may have resulted in uncertainty in the exposures. For example, overestimates of distances would have resulted in buildings not being counted in the pilot.

4 Conclusions

Compared with the pilot study, the results of this analysis provide a more accurate estimate of the numbers of buildings along the road links with the highest predicted NO₂ concentrations. A large amount of data has been used and although the method developed is partly automated, the results at each stage are checked carefully to ensure that the results are as accurate as possible based on the information available.

The method can be applied to assess exposure at any distance from the road for any pollutant for which concentration data is available. The NO₂ exposure results provided here can also be updated as the NO₂ modelling is improved, which may result in a different set of road links requiring analysis.

In this study, the households exposed to NO₂ have been assumed to be those within 10m of the kerbside. This distance is chosen somewhat arbitrarily, based on the knowledge that NO₂ concentrations decrease from the kerbside towards the buildings, although the rate of this decline is not known. Also the predictive model of air concentrations is only valid for roads where there is a canyon effect caused by buildings close to the roads. It is thought that this model is not reliable where the buildings are greater than 10m from the kerb.

The actual number of residential houses exposed to exceedances of the NO₂ objectives are likely to be considerably higher than stated here, as only 102 links have been considered compared with 761 which were predicted to exceed the NO₂ objective in 2005. The links considered were those with the highest predicted NO₂ concentrations. However, those with lower traffic flows, and hence lower predicted concentrations, are more likely to be residential roads, and therefore may represent higher risks in terms of exposure.

The results of this report may be of use to Local Authorities as a check against locally derived estimates of exposure or as a starting point in the analysis of likely areas requiring action.

5 References

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Appendices

CONTENTS

Appendix 1 Detailed results by road link

Draft

Appendix 1 Details of individual roads links analysed

Road details					Pilot survey results				New analysis				
Census ID	City	Name of road	Road No. e.g. A40	Length (m)	Houses within 10 m? Y/N	Aspect? Buildings both sides?	Continue survey? Y/N	No. of houses at < 10m	Min distance tested	Max distance tested	Number of residential buildings (min)	Number of residential buildings (max)	Comment
6390	Birmingham	Kingsbury Road	A38	1273	y	wide road, housing and commercial both sides	y	20	13	16	13	63	Variable width road/pavements make it difficult to accurately measure houses. 13m is the most accurate
6391	Birmingham	James Watt Queensway	A4400	800	n	commercial offices, open road	n		13		31	63	Ring road, few buildings close to main road
7676	Birmingham	Dartmouth Middleway	A4540	419	n	all commercial, open road	n						Results combined with 57193
7928	Birmingham	St Chads Queensway	A4400	800	n	mainly commercial, 1 block flats at ~25m	n						No houses
16365	Birmingham	Tyburn Road	A38	1742	y	houses one side, commercial on the other	y	15	13	14	15	66	Lots of semi detached houses on N side of the road, lots just on or within 10m. Offices and industry opposite.
27736	Birmingham	Watery Lane Middleway	A4540	1558	n	no housing within 30m	n		15		2	2	unlikely to be residential - more likely empty or unnamed buildings
36400	Birmingham	Moor Street Queensway	A4400	500	n	high office blocks	n		15		0		
46398	Birmingham	Lichfield Road	A5127	2731	n	wide road, mixed low commercial	n		13	16	19	39	lots of 'residential' buildings but they don't look like houses - large blocks of flats or empty office / industry buildings?
46399	Birmingham	Bristol Road	A38	847	n	wide road, mixed commercial	n		13		33	33	looks like a commercial area but has buildings with no name
47202	Birmingham	Chester Road	A452	1400	n	wide road, some commercial	n						no houses
47999	Birmingham	Bristol Road	A4400	650	n	wide road, small shops, offices above	n		13		30	30	looks like a commercial area but has buildings with no name
56394	Birmingham	St Chads Queensway	A38	782	n	wide road, some shops	n		13	16	4	4	unlikely to be residential - more likely empty or unnamed buildings
56399	Birmingham	Tyburn Road	A38	1201	y	wide open road, housing one side, commercial on the other	y	10-15	14	16	57	129	Looks like 14m is the most accurate. Some terraces with all addresses selected may represent an over estimate.
57191	Birmingham	Bull Ring Digbeth	A41	405	n	built up high shops / offices	n		15		33	33	looks like a commercial area but has buildings with no name
57193	Birmingham	Dartmouth Middleway	A4540	393	n	open area, mainly large commercial	n		13		2	2	commercial area (these results include link 7676)

Road details					Pilot survey results				New analysis				
Census ID	City	Name of road	Road No. e.g. A40	Length (m)	Houses within 10 m? Y/N	Aspect? Buildings both sides?	Continue survey? Y/N	No. of houses at < 10m	Min distance tested	Max distance tested	Number of residential buildings (min)	Number of residential buildings (max)	Comment
57194	Birmingham	Belgrave Middleway	A4540	812	y	open wide road, housing	y	6	13		21	21	block of flats and a terrace of houses
36409	Bristol	Bond Street	A4044	500	n	Offices 1 side	n		15		0		
37053	Bristol	Western Inner Ring Road	A4044	1100	n	offices and shops both sides	n		14	17	12	14	some flats (above shops?) and possibly some empty offices
48003	Bristol	Brunel Way	A370	500	n	no buildings close	n				0		no houses
48459	Bristol	Temple Gate Bath Bridge	A4	347	n	station / hotel	n		15	18	0	0	
56375	Bristol	Temple Way	A4044	706	n	wide road with offices both sides	n		15	18	4	4	
56400	Bristol	Bond Street	A4044	347	n	high office blocks both sides	n		15		0		
57291	Bristol	Newfoundland Street	A4032	1100	n	wide open road, shops at one end	n		13	17	1	2	
7397	Doncaster	?	A638	685	n	commercial	n		17	20	1	1	
8747	Doncaster	?	A638	853	n	offices and commercial	n		17	20	1	1	
16270	Fareham	A27/A32	A27/A32	780	n	open	n		15		0		very few buildings near, no houses
20922	Glasgow	Stobcross Street	A814	700	n	underneath flyover and high hotels	n		15	18	4	4	
40924	Glasgow	Clydeside Expressway	A814	3500	n	open area, commercial both sides	n		14	16	0	0	
50974	Glasgow	Clyde Tunnel	A739	2009	n	it's a tunnel!	n		14	16	2	9	
7913	Hull	Garrison Road	A63	805	n	wide open road, some commercial	n						no buildings within 15m of road centre
27932	Hull	Castle Street	A63	658	y	wide road	y	6 in 1 block	14	17	42	52	a couple of block of terraces. Trinity Court and Fish Street
48331	Hull	Hessle Road	A63	965	n	wide road and commercial offices	no		13		24	24	Some houses near slip road (do these count?), and others near main part of road
8554	Leeds	York Road	A64	500	n	open, offices both sides	n					0	
16593	Leeds	York Road	A64	2800	y	housing and shops both sides	y	50+	16		38	38	lots of houses just over 10m
18451	Leeds	West Street	A58	476	n	all offices	n				0		3 large buildings, don't look like houses
28003	Leeds	Wellington Road	A58	600	n	open area	n					0	
28005	Leeds	A643 in Holbeck	A643	1200	n	open area, some commercial	n					0	
46633	Leeds	York Road	A64	2800	n	wide open road, some houses at 20-25m	n		15		3	3	
48049	Leeds	Wellington Road	A58	500	n	no buildings	n					0	
48535	Leeds	West Street	A58	300	n	open road, elevated	n					0	
57696	Leeds	Geldard Street	A58	300	n	open road, commercial both sides	n					0	

Road details					Pilot survey results				New analysis				
Census ID	City	Name of road	Road No. e.g. A40	Length (m)	Houses within 10 m? Y/N	Aspect? Buildings both sides?	Continue survey? Y/N	No. of houses at < 10m	Min distance tested	Max distance tested	Number of residential buildings (min)	Number of residential buildings (max)	Comment
36502	Leicester	Burleys Way	A46	500	no	commercial area	n		15		5	5	one is an Arts Centre, others look like businesses but no names
36524	Leicester	St Mathews Way	A47	585	n	open, some commercial	no		13		8	8	6 look like residential; 2 are 'empty' units; business units that look like houses
48489	Leicester	Vaughn Way	A46	400	no	commercial area	n		15		5	5	the 'residential' look like commercial
48677	Leicester	Humberstone Rd	A47	472	n	all commercial	no		14		9	9	mixture of building sizes, looks all commercial
56435	Leicester	A47 west of ring road	A47	430	y	wide split road	y	6 flats	15	17	25	26	one large block of 24 flats, the other two buildings look too large for residential
56464	Leicester	Vaughn Way	A46	600	no	commercial area	n		15		2	2	don't look like residential buildings
7274	Liverpool	Breaze Hill	A5058	690	y	few houses 1 side	y	10	15	17	62	65	Buildings with multiple APs which appear to be residential (flats?)
7862	Liverpool	Brunswick Street	A580	500	n	wide road	n		16	18	7	16	
17657	Liverpool	Strand Street	A5036	621	n	wide road, commercial	n		17	19	2	26	
17661	Liverpool	Rocky Lane	A5049	1347	y	half domestic, half commercial	y	300+	16	18	146	174	
18508	Liverpool	M62 link	A580	372	y	open road	y	20	17	19	9	9	
28563	Liverpool	Islington	A580	214	N	commercial	n		15	17	3	4	
37334	Liverpool	Queens Drive	A5058	751	y	wide road, housing both sides	y	300+	14	16	112	112	
37794	Liverpool	Erskine Street	A580	800	n	wide open road	n		16	18	1	1	
38350	Liverpool	Lime Street	A5038	341	n	all commercial	n		15	17	4	10	
47911	Liverpool	Near University	A59	1300	n	open road	n		15	17	19	19	
47917	Liverpool	Edge Lane	A5047	2085	y	mainly commercial, wide road	y	30	14	16	87	89	All APs appear to be residential
47919	Liverpool	Edge Lane	A5080	1105	y	wide road	y	200+	14	16	33	117	All APs appear to be residential
48332	Liverpool	Near University	A59	300	n	open road	n		16	18	0	0	
56612	Liverpool	Near University	A59	638	n	wide open road	n		16	18	0	0	
57715	Liverpool	Liver Street	A5041	109	n	empty road	n		15	17	0	0	
58222	Liverpool	New Islington	A5080	227	n	open road	n		15	17	0	0	
6076	London	North Circular Road	A1	500	n	wide road, some buildings set back	n		15		2	2	houses at end of terraces on side roads
7055	London	North Circular Road	A406	2100	y	housing at one end of link, rest is wide dual carriageway	y	20	15	16	20	31	terrace close to Hanger Lane Junction
8468	London	North Circular Road	A406	300	n	flyover, commercial nearby	n				0		no houses

Road details					Pilot survey results				New analysis				
Census ID	City	Name of road	Road No. e.g. A40	Length (m)	Houses within 10 m? Y/N	Aspect? Buildings both sides?	Continue survey? Y/N	No. of houses at < 10m	Min distance tested	Max distance tested	Number of residential buildings (min)	Number of residential buildings (max)	Comment
17018	London	Gunnersbury Avenue	A406	1300	n	residential, set back from road	n		15		14	14	a few houses close to junction
17019	London	North Circular Road	A406	1939	y	commercial and residential, dual carriageway	y	50	15	16	28	68	various blocks of terraced houses and individual houses
17020	London	North Circular Road	A406	900	n	some residential set back from road, then underpass	n				0		no houses
26080	London	North Circular Road	A1	206	n	open road, one apartment block	n		16	17	32	32	block of flats and one house
27086	London	Hanger Lane	A406	200	n	no houses noted in survey, picture shows some close to road	n		18		9	9	wide road, one block of flats
27087	London	North Circular Road	A406	900	n	commercial buildings and flyover	n				0		no houses
37112	London	Gunnersbury Avenue	A406	1100	y	some houses set back, some close; open road with wide central area	y	35			0		no houses, must have underestimated distance in pilot survey
37113	London	North Circular Road	A406	2400	y	houses close to road, often both sides	y	100+	15	18	209	269	variable road width, difficult to accurately quantify. Lots of houses close to road
37114	London	North Circular Road	A406	940	n	open road, few buildings	n		15.2		16	16	two blocks of flats
38366	London	Hanger Lane	A406	1992	n	some commercial, some open	n		15	16	38	49	a few houses at the south end of the link
38601	London	Hanger Lane Roundabout	A406	200	n	shops set back from large roundabout,	n				0		no houses
56758	London	North Circular Road	A406	1200	n	no buildings, underpass	n		15				no houses
56982	London	Forty Lane	A4088	822	n	residential, houses set back from road	n		16	17	5	7	one house has a part near the road, and a couple of other buildings
57056	London	North Circular Road	A406	721	y	2 storey houses both sides	y	10	14	15	33	44	lots of houses close to Northern side of A406, some on opposite side at ends of side roads
57656	London	Blackbird Hill / Neasdon Lane	A4088	1100	n	commercial and residential, houses at > 10m	n		15	16.5	112	143	lots of flats (in divided houses?); disparity between findings - likely over-estimate of distance in pilot survey
6161	Manchester	Broad Street, Pendleton	A6	1000	n	mostly commercial, houses used as offices	n		17	25	0	10	
16537	Manchester	Old Trafford	A34	700	n	mainly low commercial, some houses on side roads close but not <10m			16	20	6	8	

Road details					Pilot survey results				New analysis				
Census ID	City	Name of road	Road No. e.g. A40	Length (m)	Houses within 10 m? Y/N	Aspect? Buildings both sides?	Continue survey? Y/N	No. of houses at < 10m	Min distance tested	Max distance tested	Number of residential buildings (min)	Number of residential buildings (max)	Comment
17675	Manchester	Princess Road	A5103	2169	n	some houses close according the photos, not quantified in survey	y	?	14	16	0	2	Much shorter road link than that quantified in the pilot study.
26352	Manchester	Kingsway	A56	792	y	wide road, some with open aspect, some houses close	y	20	16	18	12	14	
28684	Manchester	Chester Rd in Stretford,	A56	137	n	residential type buildings, not quantified	y	>25	15	20	2	3	Variable road and pavement widths make quantification difficult. See photograph.
36578	Manchester	Chester Rd in Stretford	A56	822	n	wide aspect, low buildings	n		15	20	33	34	
36585	Manchester	Regent Road	A57	895	n	housing set back from road on one side, mostly open aspect on other	n		15	20	0	8	
37809	Manchester	junction of M63	A5103	1400	n	housing set back from road	y	possibly	16	18	27	46	
48023	Manchester	Regent Road,	A57	495	n	commercial and residential, some blocks of flats very close	y	>50 flats	14	20	16	16	
56160	Manchester	Crescent Chapel	A6	748	n	commercial	n		16	20	3	3	
58022	Manchester	Old Trafford	A56	600	n	open aspect, block of flats set way back, commercial close to road	n		16	20	0	0	
58252	Manchester	Great Ancoats St	A665	127	n	commercial	n		15	20	4	8	
6090	Newcastle	Gateshead Highway	A184	450	n	wide road, offices	no		15	17	276	276	
18626	Newcastle	A1 in Lemmington	A1	1500	n	wide road, no buildings	n		16	20	2	5	
47829	Newcastle	Park Road	A184	3069	n	wide open, some commercial	n		14	16	34	43	
58151	Newcastle	A167	Tyne Bridge	800	n	river	n		16	18	32	54	
28437	Portsmouth	A228 in Hilsen	A228	2158	y	wide road some commercial	y	6	16	18	10	13	kerb width variable, some semis on one side
47078	Portsmouth	A3/M27 junction	A3	450	n	open junction	n		15				no houses, just a car dealer
18722	Sheffield	Sheaf Street	A61	800	n	open area, some commercial	n		16	18	6	6	
47839	Sheffield	Wicker	A6135	304	n	shops and offices built up	n		15	17	6	7	
48076	Sheffield	Sheaf Street	A61	379	n	built up area, commercial	n		16	18	10	10	