
Monograph:
Leith, A.L. (2007) Travel to Work in Nottingham: An Analysis of Environmental Impacts and Mitigating Policies. Working Paper. The School of Geography, The University of Leeds

School of Geography Working Paper 07/7

(Working Paper 07/07)

Travel to Work in Nottingham: An Analysis of Environmental Impacts and Mitigating Policies

Allan Leith

Version 1.0
November 2007

School of Geography, University of Leeds,
Leeds, LS2 9JT, United Kingdom

This Working Paper is an online publication and may be revised.

The Author's full contact details are:

Mail address:

School of Geography
University of Leeds
Leeds
LS2 9JT
United Kingdom

Email:

geo5ajl@leeds.ac.uk

Acknowledgements

The Census data used in this paper are Crown Copyright and are produced by the Office of National Statistics (ONS). All of the Census data was accessed through CASWEB online, provided by the Census Dissemination Unit (CDU) through the Manchester Information and Associated Services (MIMAS), supported by Manchester Computing, University of Manchester. Data concerning the geodemographic segmentation system Mosaic was sourced from Experian, along with mapping data showing road and rail networks.

Abstract

This study uses Census data to look at travel to work patterns in Nottingham. Spatial trends are identified by analysing how number of journeys to work, distance travelled, commuter flows, method of travel, type of job and type of neighbourhood vary across the study area. Affluent commuters working in managerial and professional roles travelling long distances by car from the rural hinterland to the city centre contrast with people with routine jobs travelling short distances to work from deprived urban neighbourhoods using public transport. Temporal trends are revealed through the comparison of 1991 and 2001 Census data. The number of journeys to work is increasing, whilst flow patterns are becoming more complex. The environmental impact of travel to work in Nottingham is quantified through the application of a simple model that estimates the carbon dioxide emissions produced by commuting in each area. The Nottingham Express Transit tram network has been introduced in the city with the aim of reducing congestion and reliance on the car through the provision of an environmentally friendly alternative. The possible environmental benefits of this solution are highlighted by exploring several what-if scenarios. It is concluded that the tram network has the potential to significantly reduce carbon dioxide emissions.

Top left photo: Nottingham park and ride bus.
Source: Nottingham City Transport.

Top right photo: Traffic congestion.
Source: Google Images.

Bottom left photo: Nottingham Express Transit tram in central Nottingham.
Source: Nottingham Express Transit.

Contents

List of tables

List of figures

1 Introduction

This report looks at travel to work in Nottingham. The main issues relating to commuting are traffic congestion and the associated adverse environmental impact. Government policy aims to reduce dependency on the car by providing viable public transport alternatives. There are many facets of travel to work in Nottingham that can be explored. Figure 1 presents the aims of this study in the form of a series of questions that the analysis intends to answer.

- Has the number of journeys to work in Nottingham increased over time and how does this vary across the city?
- Has the distance travelled to work in Nottingham increased over time and how does this vary across the city?
- Which areas of Nottingham do people commute from and to and how has this changed over time?
- How do people in Nottingham travel to work? What is the spatial pattern of each method of travel and how has this changed over time?
- Is there a link in Nottingham between type of job and method of travel of travel to work?
- What is the environmental impact of commuting in Nottingham? What are the spatial patterns of this and how has it changed over time?
- Does the new tram network in Nottingham have the potential to reduce the environmental impact of travel to work?
- How does this analysis compare to previous academic study on travel to work?
- What are the implications for government policy?

Figure 1: Aims of study.

Figure 2 outlines the objectives of this project, which will enable the aims to be successfully achieved.

- Define a suitable level of geography at which to analyse data.
- Define a suitable study area.
- Measure the total number of journeys to work within the study area for both 2001 and 1991 and calculate this for each zone of the study area.
- Calculate average distance travelled for each zone of the study area for both 2001 and 1991.
- Look at commuting flows within the study area for both 2001 and 1991 and calculate change in each zone.
- Calculate the number of people in each zone travelling to work by each mode of transport. Do this for both 2001 and 1991.
- Look at the spatial distribution of different types of jobs within the study area. See if there is a statistically significant link between this and method of travel.
- Calculate total emissions of carbon dioxide for each zone in the study area for both 2001 and 1991 and look at changes over time.
- Analyse the existing and proposed routes of the new tram network in Nottingham. Implement various ‘what if’ scenarios to look at the possible environmental benefits of the tram.
- Undertake a literature review of academic studies regarding travel to work and compare the results of the analysis to these.
- Summarise the problems facing travel to work in Nottingham and the government policies put in place to deal with them.

Figure 2: Objectives of study.

The paper structure is as follows.

Section 2 provides the background to the report through a literature review of academic studies on the subject of travel to work. This is followed by Section 3 which outlines the data used in each analysis

section, and discusses the accuracy and time context of this data. Next comes Section 4 which is the largest part of the report. It presents the results of the analysis that has been undertaken using tables, maps and graphs, and outlines the methodologies that have been employed. It is divided into eight sub-parts, each of which seeks to achieve one of the objectives outlined in Figure 2, and thus answer the questions posed in Figure 1. The sub-parts are as follows:

Section 4.1: Study area
Section 4.2: Number of journeys
Section 4.3: Distance travelled
Section 4.4: Commuting flows
Section 4.5: Method of travel
Section 4.6: Type of job
Section 4.7: Environmental impact
Section 4.8: Tram network

Section 5 presents a discussion which summarises the results of the analysis, draws out the most significant points and relates the findings back to the literature. Concluding remarks are then made with regards to possible improvements that could be made to this study along with areas for future development.

Finally the References section lists all the sources cited in the report.

2 Background

Many previous academic studies have looked at issues surrounding travel to work. Cole et al (2002) discuss how census data can be used to assess the environmental impacts of work journeys and changes over time. Frost et al (1997) use 1981 and 1991 census data to help calculate the energy consumption of changing work travel in major English cities. They find that the number and length of trips to work are increasing, and that there is a continuing dominance of the car over public transport with adverse implications in terms of energy consumption. Research by the Department of Trade and Industry (2002) reaches similar conclusions. Frost et al (1998) follow up this work by looking at how increasing commuting distances are being influenced by the changing form of urban areas, and conclude that excess or wasteful commuting is a major problem.

Shuttleworth et al (2000) use 1991 census data look at travel to work patterns in Belfast. This data is used to propose urban employment policies such as locating jobs in areas of high unemployment. Shuttleworth and Lloyd (2005) use 1991 census data to look at distance travelled to work in Northern Ireland. They find that distance travelled is higher in rural areas, lower in urban areas, and is influenced by type of job.

Noland and Lem (2002) consider transport and environmental policy in the UK and US. They acknowledge the need to reduce reliance on the car by improving public transport. Kingham et al (2001) find that there is a willingness in the UK to switch from the car, but that public transport is often not a viable alternative in terms of lack of provision and attractiveness. Mann and Abraham (2006) consider the psychology of travel to work. They conclude that many people will continue to use cars

even if there is a good public transport alternative, owing to issues regarding personal space and control.

Rye (2002) looks at government policy aimed at solving travel to work problems in the UK. Travel plans implemented by employers have the potential to reduce the proportion of commuters travelling to work alone in cars. Coleman (2000) similarly explores how employers can help reduce traffic congestion. The Department for Transport (2002) focus on the need to reduce the adverse environmental impact of car-based travel to work, a solution being to provide incentives to travel by public transport. Dickinson et al (2003) investigate how cycling could potentially become a more-utilised method of travel to work in the UK. Kumar (1990) discusses technological developments facilitating the possibility of working from home and reducing the need to commute in the first place.

3 Data and methods

The analysis in this report is predominantly undertaken using data from the UK 2001 Census and UK 1991 Census. Where appropriate this is supplemented by data from additional sources. Table 1 outlines the data to be used in each section of analysis.

The census is the most comprehensive data source available for this study, however there are issues regarding the timeliness and accuracy of the data. Census data from 2001 is 6 years old and major changes related to travel to work in Nottingham have taken place since then, such as the opening of the tram network in 2004. Travel to work census data from 1991 is based on a 10% sample, it remains to be seen how representative this sample is. Censuses in general have a problem with undercounting, it is estimated that the UK 1991 census achieved only 98% coverage (Rees et al, 2002).

The methodologies employed and indicators calculated will be explained in further detail within each individual section of analysis.

Table 1: Summary of data used in each analysis section.

Analysis section	Data used
4.1 Study area	• UK 2001 Census: Commuting flows data in the form of an origin-destination matrix • Ward boundaries • Experian-sourced data showing roads, railways, rivers, urban zones
4.2 Number of journeys	• UK 2001 Census: Table KS15 – counts of total commuting journeys in each ward • UK 1991 Census: Table 82 – counts of total commuting journeys in each ward • Ward boundaries
4.3 Distance travelled	• UK 2001 Census: Table KS15 – average commuting distance from each ward • UK 1991 Census: distance data for Nottingham sourced from Frost et al (1997) • Ward boundaries
4.4 Commuting flows	• UK 2001 Census: Commuting flows data in the form of an origin-destination matrix • UK 1991 Census: Commuting flows data in the form of an origin-destination matrix • Ward boundaries
4.5 Method of travel	• UK 2001 Census: Table CAS122 – counts of people travelling to work by each method • UK 1991 Census: Table 82 – counts of people travelling to work by each method • Ward boundaries
4.6 Type of job	• UK 2001 Census: Table CAS122 – counts of people working in each type of job • UK 1991 Census: Table 82 – counts of people working in each type of job • Experian-sourced data showing dominant Mosaic UK group in each ward • Ward boundaries
4.7 Environmental impact	• European Environmental Agency-sourced data showing emissions for each method of travel over time • UK 2001 Census: Table KS15 - counts of people and distance travelled for each method of travel to work • UK 1991 Census: Table 82 - counts of people and distance travelled for each method of travel to work • Experian-sourced data showing dominant Mosaic Automotive group in each ward • Ward boundaries
4.8 Tram network	• Tram network map sourced from Nottingham Express Transit • Experian-sourced data showing roads, railways, rivers, urban zones • Ward boundaries • Estimates of carbon dioxide emissions for each ward as calculated in section 4.7

4 Analysis

4.1 Study area

In order to include the full commuting area for Nottingham it was decided that the study area should include all wards that send 5% or more of their resident working population to work within Nottingham Unitary Authority. Wards were chosen as the level of geography for this analysis because they provide a suitable level of detail and have good data availability. The study area comprises 171 wards. Figure 4 shows that the percentage of workers who travel to work in Nottingham UA is at its highest in and around the city centre.

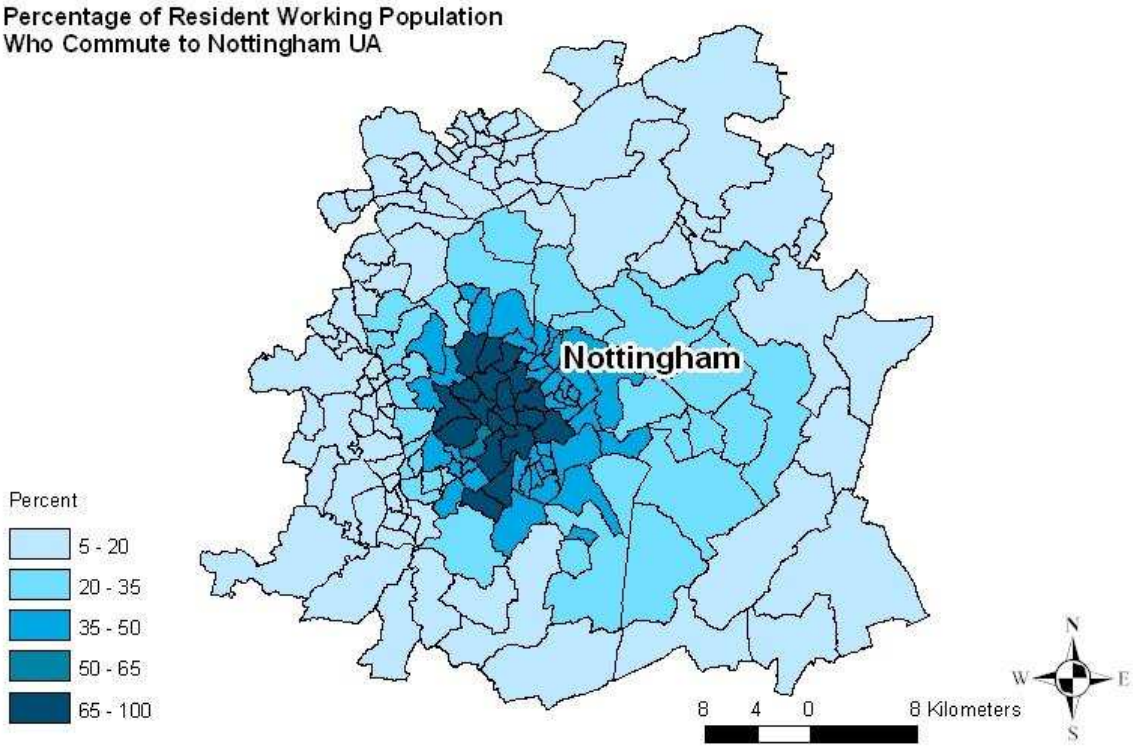


Figure 4: Percentage of resident working population who commute to Nottingham UA. Data source: UK 2001 Census.

Figure 5 shows the urban areas located within the study area, along with major roads and the rail network. The study area is dominated by Nottingham city. To the north and west are traditional industrial towns located in former coalfield areas. To the south and east are small rural villages located in extensive agricultural land.

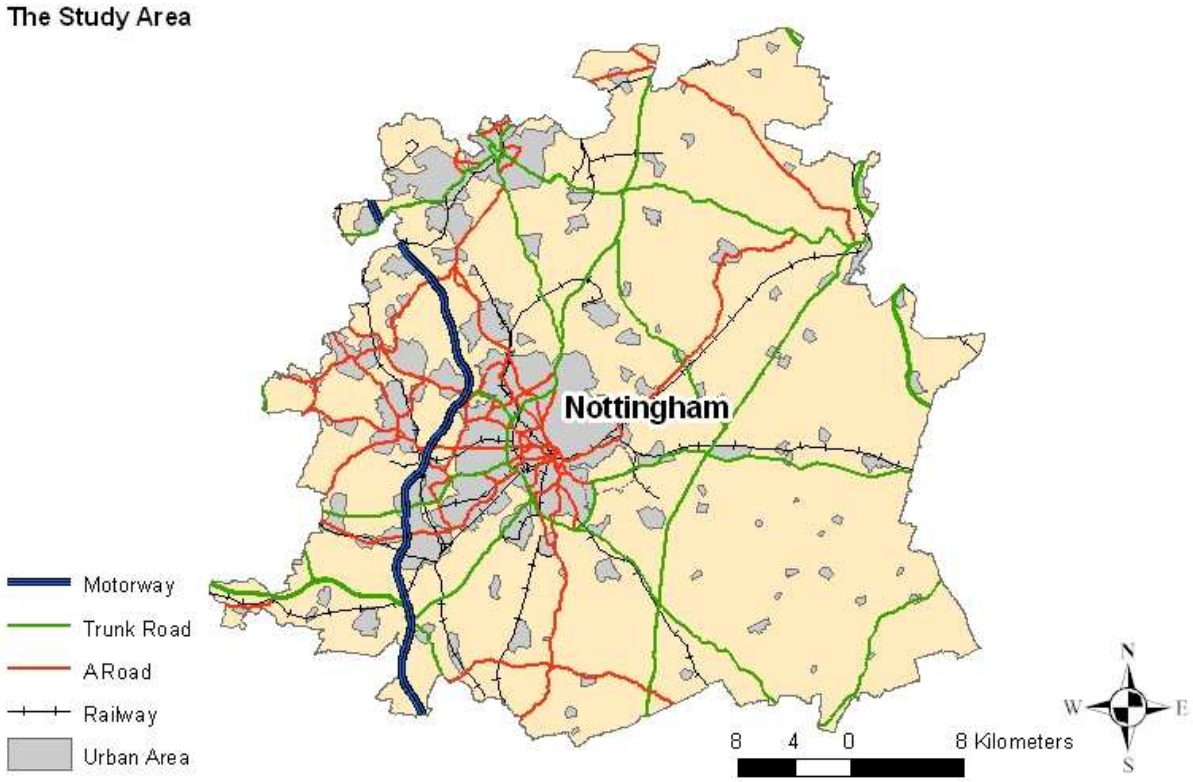


Figure 5: The study area.

4.2 Number of journeys

The journeys to work included in this analysis are those that both begin and end within the study area. Those that begin or end outside the study area are not considered. Table 2 shows that the number of journeys to work within the study area has increased considerably over time. There has been a 12% increase between 1991 and 2001.

Year	2001	1991
Total journeys to work	444501	396040

Table 2: Total number of journeys to work 2001 and 1991. Data source: UK 2001 Census and UK 1991 Census.

Figure 6 shows ward level maps for 2001 and 1991. The increase is clearly visible throughout the study area, particularly in peripheral wards.

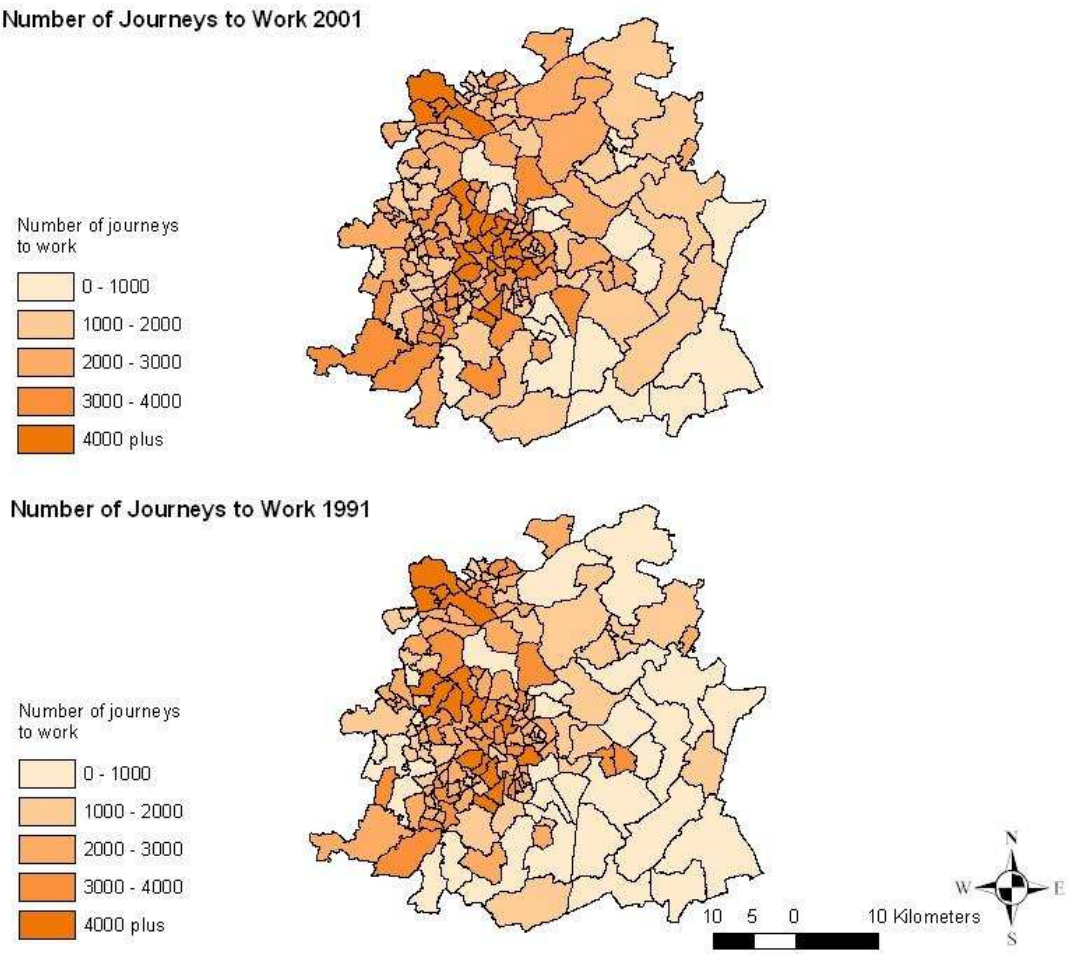


Figure 6: Number of journeys to work 2001 and 1991. Data source: UK 2001 Census and UK 1991 Census.

Although there has been an overall rise in commuting journeys over time, some wards have experienced a decline. Figure 7 shows change in number of commuting journeys over time at ward level.

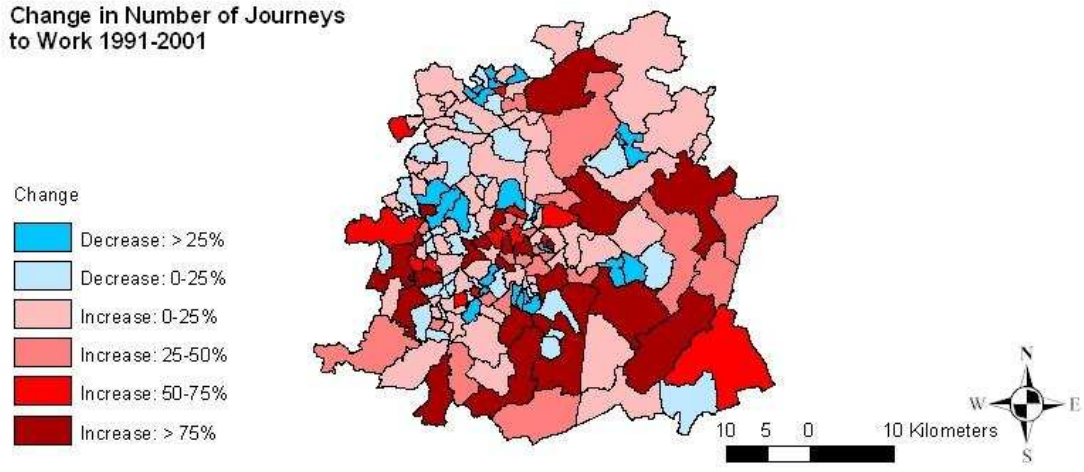


Figure 7: Change in the number of journeys to work 1991-2001. Data source: UK 2001 Census and UK 1991 Census.

Wards with a decrease in commuting journeys tend to be located to the northwest of Nottingham city centre. These areas are located in a former coalfield region with declining heavy industry. Perhaps increased unemployment has resulted in less commuting. The biggest increases are generally found in rural areas to the southeast of the city. This could be evidence of affluent workers moving out to villages in the countryside in search of a better quality of life, and commuting from there to jobs in central Nottingham.

4.3 Distance travelled

All journeys to work originating from within the study area are considered here. Average commuting distance from within the study area is 10.95km, which is lower than the UK average of 15.43km. This is to be expected because the study area is dominated by urban areas where commuting distances are shorter. Figure 8 shows the average distance travelled from each ward.

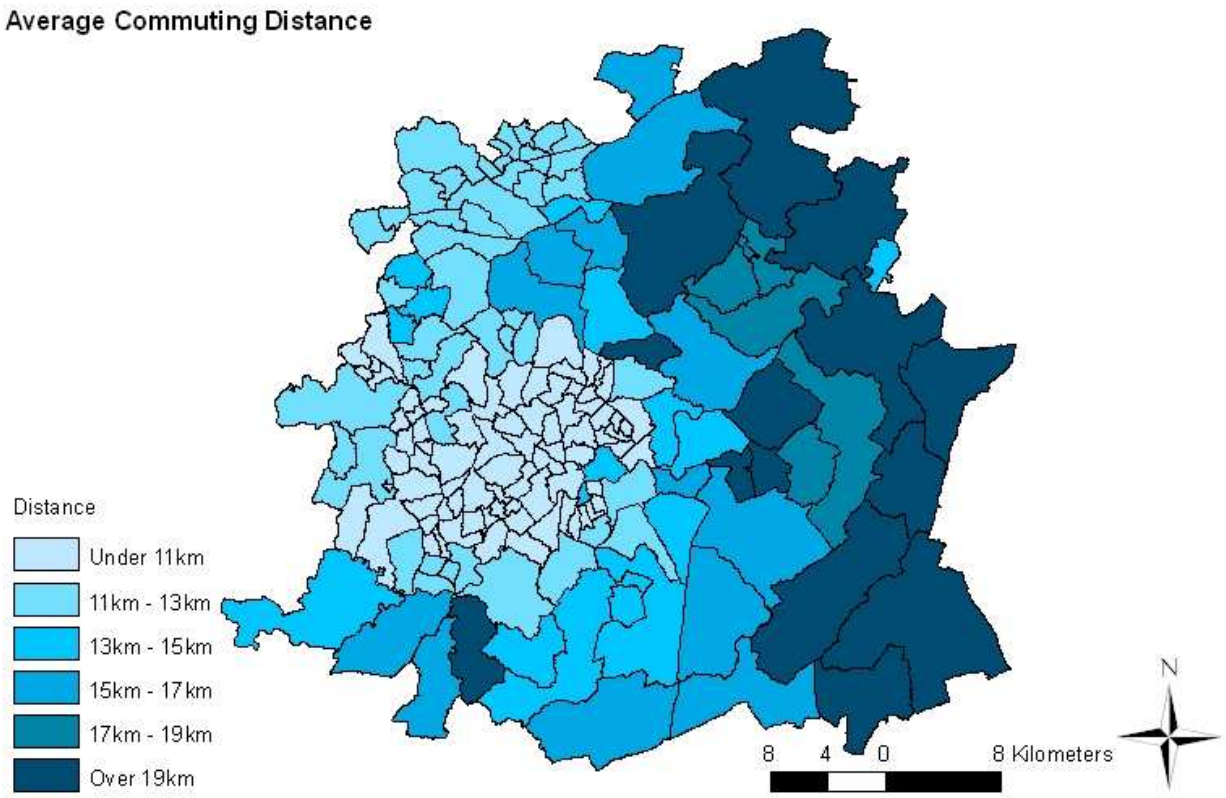


Figure 8: Average commuting distance. Data source: UK 2001 Census.

Shortest commuting distances are found around Nottingham city centre, longest commuting distances are found in the rural hinterland. People living in sparsely populated rural areas with poor accessibility have to travel further to get to work. This trend could also be explained by increased car ownership and affluent workers moving to the countryside then undertaking long distance commutes into the city.

Commuting distances are increasing over time. Frost et al (1998) report that the average commuting distance in Nottingham was 6.6km in 1981 and 7.6km in 1991. The 1981-1991 increase was therefore 15%, and the 1991-2001 increase around 30%.

4.4 Commuting flows

This section looks at where people commute to and from. Commuting flows can be summarised by comparing total number of incoming commuters with total number of outgoing commuters. The difference between these figures indicates whether an area is predominantly a place where people work or a place where people live. This analysis considers only those journeys to work that both begin and end within the study area.

Figure 9 presents this information at ward level for 2001 and 1991. Red-coloured wards have more incoming commuters than outgoing commuters implying that these are areas people commute to. Blue-coloured wards have more outgoing commuters than incoming commuters suggesting that these are areas people commute from. The general trend is that people commute to Nottingham city from the surrounding suburbs and rural hinterland. Smaller towns in the study area also attract commuters such as Mansfield to the north and Long Eaton to the west.

Commuting flows are becoming more complex over time. In 1991 there are more wards coloured either dark blue or dark red indicating a strong flow from the suburbs to the city. In 2001 this flow is far less pronounced suggesting that more people are commuting to the suburbs and outlying areas. This perhaps provides evidence of trends such as working at home and the decentralization of offices away from the city.

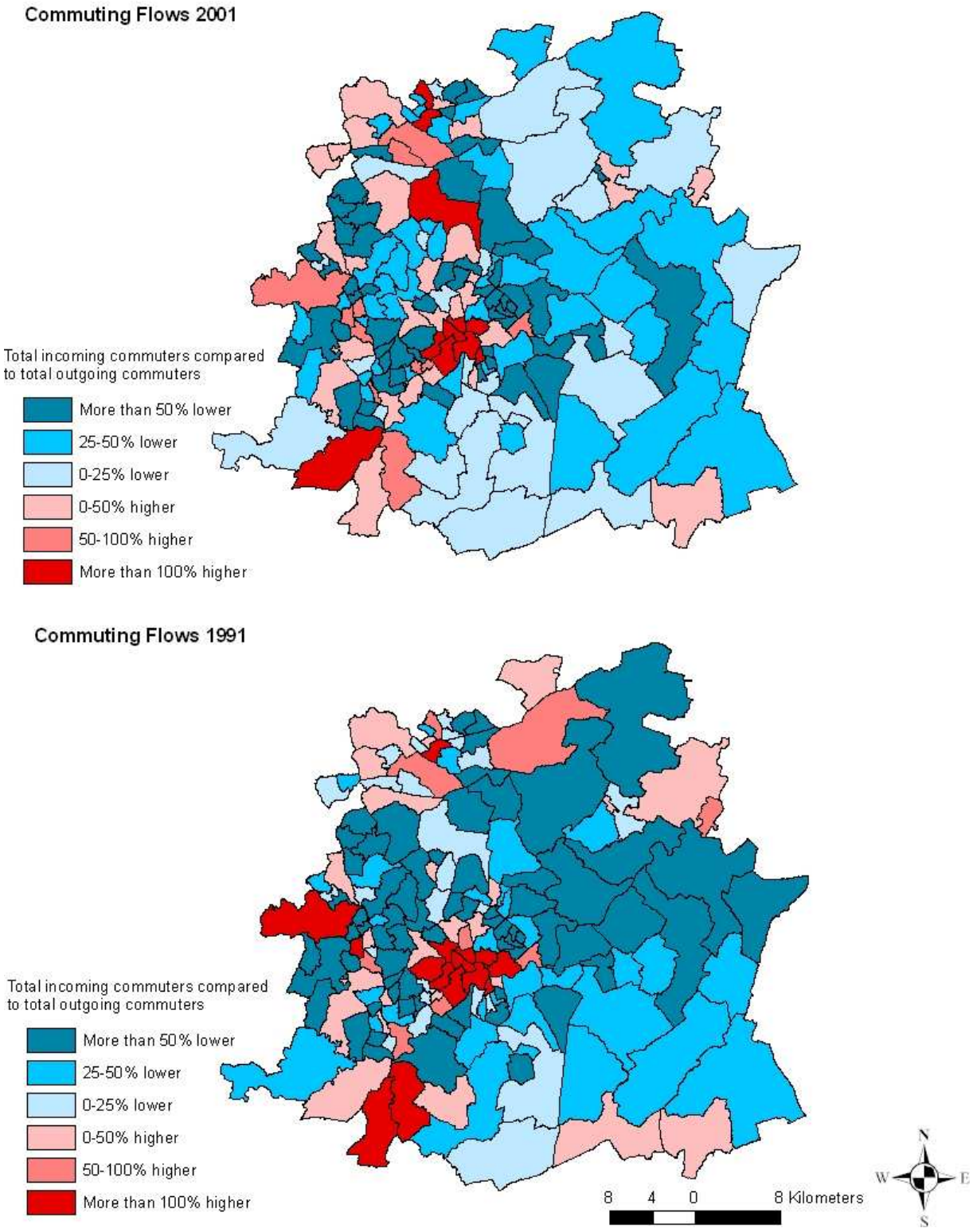


Figure 9: Commuting flows 2001 and 1991. Data source: UK 2001 Census and UK 1991 Census.

4.5 Method of travel

This section of analysis considers only those journeys to work that both begin and end within the study area. Travel to work in Nottingham is dominated by the car. Table 3 compares the percentage of people in the study area who travel to work by each method of transport to the equivalent figures for the UK.

Table 3: Comparing mode of transport used in the study area to the UK as a whole. Data source: UK 2001 Census.

Method	United Kingdom	Percent	Study Area	Percent	Index
Work mainly at home	2857516	8.07	36315	8.17	101
Underground, metro, light rail	1397348	3.95	184	0.04	1
Train	1618842	4.57	3915	0.88	19
Bus, minibus or coach	3071208	8.68	51820	11.66	134
Motorcycle, scooter or moped	393585	1.11	4814	1.08	97
Car or van	21261125	60.07	286647	64.49	107
Bicycle	990469	2.80	13917	3.13	112
On foot	3654751	10.33	45395	10.21	99
Other	151218	0.43	1494	0.34	79
Total	35396062	100	444501	100	100

The study area has above average usage of cars, buses and bicycles, and lower than average usage of trains. The bus network within Nottingham is extensive whereas the rail network is comparatively limited, concentrating on intercity services as opposed to local commuter routes. Figure 10 maps the percentage of commuters using each main method in each ward.

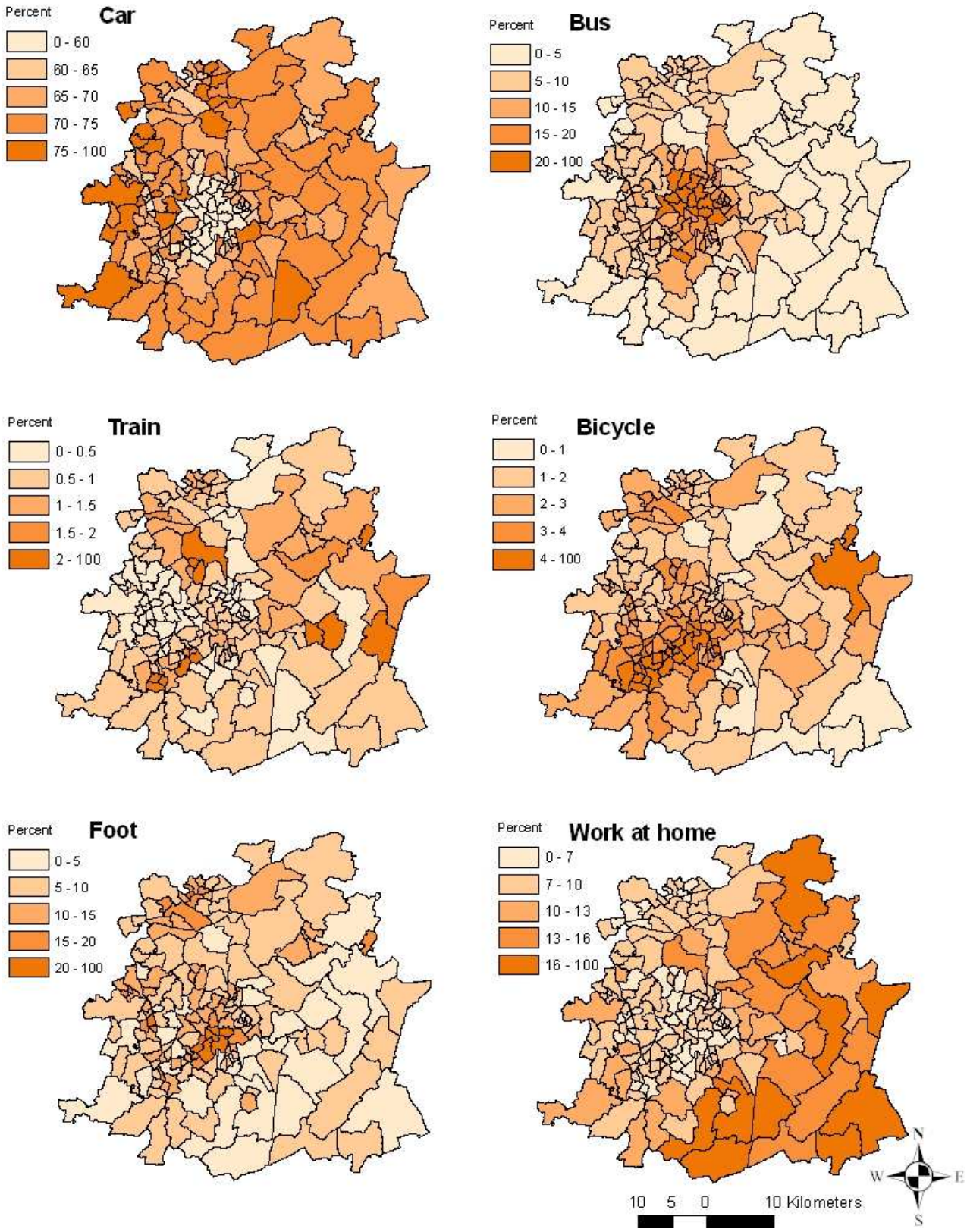


Figure 10: Percentage of commuters using each main method of travel to work. Data source: UK 2001 Census.

Car usage is highest in outlying areas where commutes are longer and public transport is less developed. Bus usage is highest in central Nottingham where journeys to work are shorter and the

network is extensive. The train network in the study area is limited, however significant numbers of commuters travel to the city from surrounding towns including Beeston and Long Eaton. Commuting by bicycle or on foot is predictably at its highest close to the city centre where journeys to work are shortest. Working from home is most common in outlying rural areas, perhaps this pattern is influenced by the agricultural sector where people live close to their place of work.

Table 4 compares mode of transport data for 2001 with the equivalent figures from the 1991 census.

Table 4: Changes in mode of transport between 1991 and 2001. Data source: UK 2001 Census and UK 1991 Census.

Method	2001	Percent	1991	Percent	Index
Work mainly at home	36315	8.17	15950	4.03	203
Underground, metro, light rail	184	0.04	230	0.06	71
Train	3915	0.88	2470	0.62	141
Bus, minibus or coach	51820	11.66	49580	12.52	93
Motorcycle, scooter or moped	4814	1.08	6150	1.55	70
Car or van	284870	64.09	255160	64.43	99
Bicycle	13917	3.13	12680	3.20	98
On foot	45395	10.21	46380	11.71	87
Other	3271	0.74	7440	1.88	39
Total	444501	100	396040	100	100

The most obvious change over time is the rise of working from home. This is perhaps evidence of technological advances making the location of work less important. The limited local rail service has increased in popularity, whilst the car has remained the dominant mode of transport.

Commuting distance has increased significantly between 1991 and 2001. Table 5 shows how much distance has increased for each main method of travel.

Table 5: Total km travelled by each method 2001 and 1991. Data source: UK 2001 Census and UK 1991 Census.

Method of travel	Total km travelled 2001	Total km travelled 1991	Percentage increase
Train	48648	22481	116.40
Bus	594520	398567	49.16
Motorbike	57808	51792	11.62
Car	3528205	2191796	60.97
Bike	164145	106873	53.59
Foot	535803	384174	39.47

The total distance travelled to work by people in cars has increased by 61% in 10 years. This reinforces trends regarding long distance commutes originating from the rural hinterland around Nottingham.

4.6 Type of Job

There is a strong link between type of job and method of travel. This section of analysis considers only those journeys to work that both begin and end within the study area. As figure 11 shows, workers who have managerial jobs generally live in rural areas to the south and east of Nottingham where people mostly commute by car. Routine workers inhabit inner city districts and industrial small towns northwest of the city where buses are commonly used to travel to work.

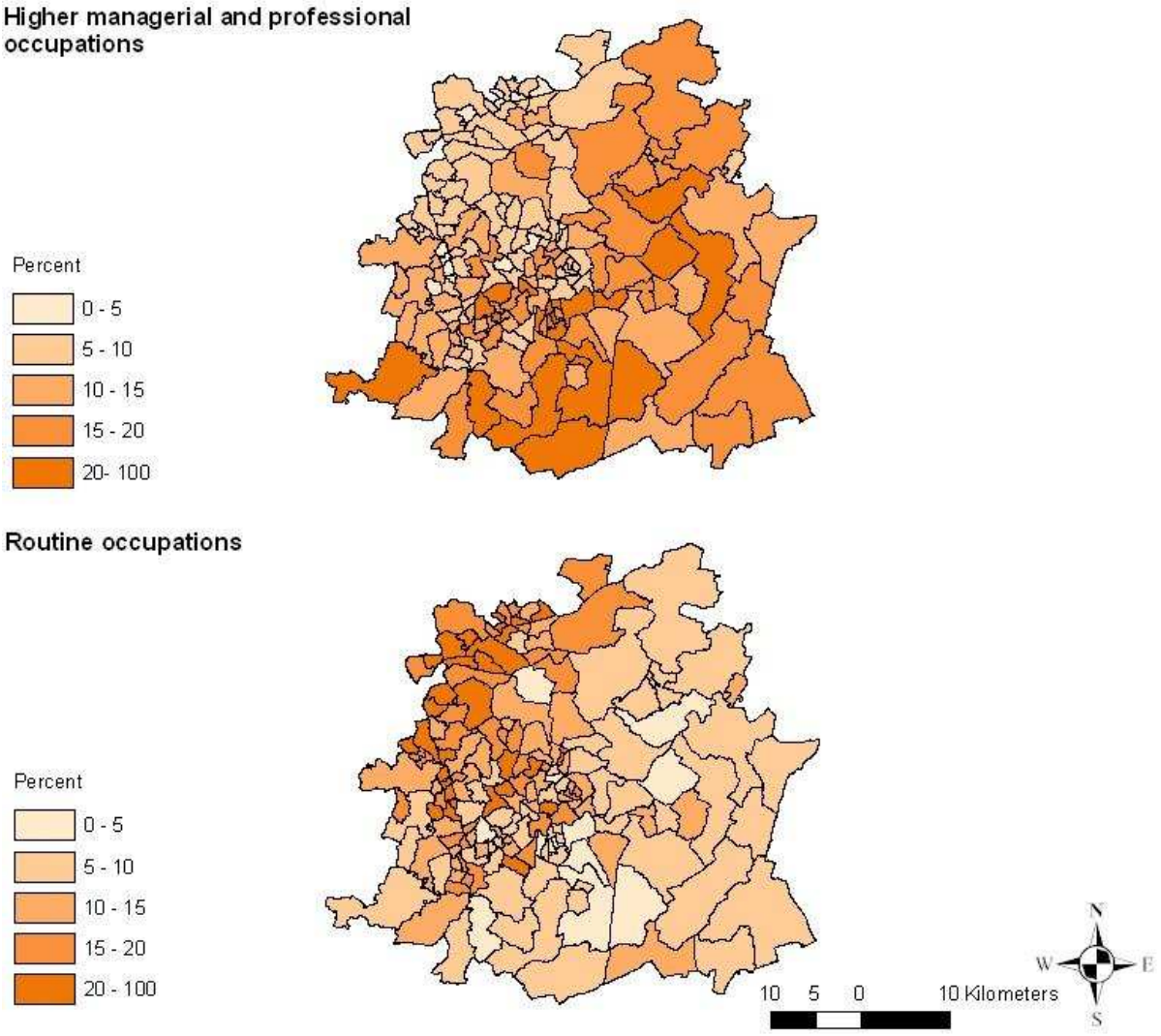


Figure 11: Spatial distribution of higher managerial occupations and routine occupations. Data source: UK 2001 Census.

The strength of the relationship between occupation and mode of transport can be analysed statistically by measuring the correlation between these variables, as shown in table 6.

Table 6: Correlation between type of job and method of travel to work. Data source: UK 2001 Census.

Occupation	Home	Light rail	Train	Bus	Motorbike	Car	Bicycle	Foot	Other
Higher managerial & professional	0.56	0.24	0.14	-0.20	-0.53	0.13	0.06	-0.34	0.08
Lower managerial & professional	0.52	0.12	0.14	-0.25	-0.47	0.33	-0.09	-0.52	-0.03
Intermediate	-0.38	-0.01	0.02	-0.30	0.10	0.04	-0.01	-0.16	-0.35
Small employers & own account workers	0.91	0.05	-0.04	-0.56	-0.24	0.47	-0.48	-0.51	0.34
Lower supervisory and technical	-0.57	-0.28	-0.09	0.10	0.65	-0.03	0.02	0.24	-0.11
Semi-routine	-0.63	-0.22	-0.14	0.30	0.53	-0.26	0.06	0.42	-0.13
Routine	-0.59	-0.24	-0.11	0.21	0.49	-0.23	0.06	0.46	-0.03
Not classified	-0.17	0.34	-0.01	0.33	-0.31	-0.54	0.33	0.51	0.09

Key: Not significant; Negative significant 0.05; Positive significant 0.01; Negative significant 0.01

People working in managerial roles are likely to commute by car or work from home, whereas routine workers are likely to commute by bus or on foot.

A geodemographic segmentation system can give further insight into the types of neighbourhoods found within the study area. Figure 12 shows the dominant Mosaic UK group in each ward. This was calculated by looking at the number of households belonging to each Mosaic UK group in each ward.

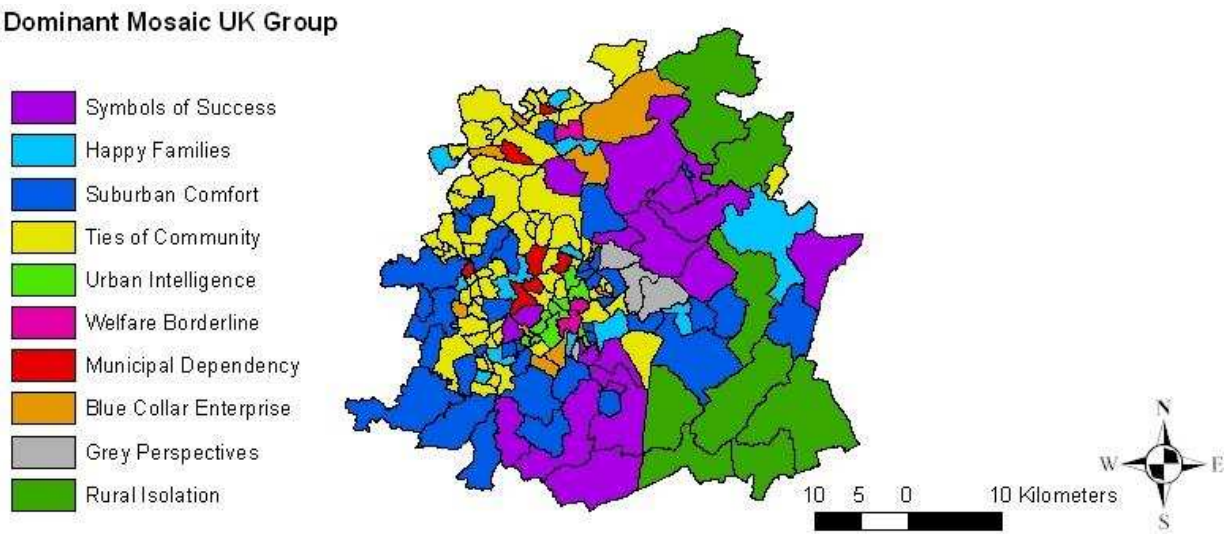


Figure 12: Dominant Mosaic UK group. Data source: Experian.

This map reinforces trends outlined earlier in the study. Symbols of Success are found in rural villages to the south and east of Nottingham, from where people commute long distances by car to managerial jobs in the city. Ties of Community are found in the traditional industrial areas northwest of Nottingham, from where people commute short distances by bus to work in routine jobs.

4.7 Environmental impact

Environmental impact can be quantified by estimating carbon dioxide emissions. This section of analysis considers only those journeys to work that both begin and end within the study area. Table 7 shows carbon dioxide emissions for different modes of transport over time. Emissions for cars and buses have decreased over time as technology has improved.

Table 7: Carbon dioxide emissions for different methods of travel to work. Data source: European Environmental Agency (2004).

Method of travel to work	Grams of carbon dioxide emitted per passenger-km: 2001	Grams of carbon dioxide emitted per passenger-km: 1991
Work mainly at home	0	0
Underground, metro, light rail	43.7	42.1
Train	43.7	42.1
Bus, minibus or coach	66.1	67.1
Motorcycle, scooter or moped	83.5	85.9
Car or van	126.2	131.3
Bicycle	0	0
On foot	0	0
Other	118.4	121.5

Passenger-km travelled by each mode of transport in each ward can be calculated using census data. A simple estimate of carbon dioxide emissions can therefore be calculated by multiplying the emissions figures for each method by passenger-km travelled.

More accurate estimates can be calculated by taking into account the types of car in each area. Table 8 shows how Mosaic Automotive has been used to decide how carbon dioxide emissions should be weighted for different types of car. Size and age of cars was taken into account when devising weights, for example it is assumed that large old cars emit more carbon dioxide than small new cars.

Table 8: Weighting of car carbon dioxide emissions according to Mosaic Automotive group. Data source: Experian (2007).

Mosaic Automotive Group	Typical Cars	Size	Age	Weight
Symbols of Success	BMW, Mercedes, Porsche	Very large	Very new	1.3
Happy Families	Renault, Vauxhall, Fiat	Large	New	0.9
Suburban Comfort	Nissan, Honda, Toyota	Medium	New	0.8
Ties of Community	Vauxhall, Fiat, Ford	Medium	Quite old	1.1
Urban Intelligence	Volkswagen, Audi, Saab	Small	Quite new	0.9
Welfare Borderline	Vauxhall, Ford, Rover	Medium	Very old	1.2
Municipal Dependency	Ford, Proton, Daewoo	Medium	Old	1.1
Blue Collar Enterprise	Ford, Vauxhall, Fiat	Large	Quite old	1.2
Grey Perspectives	Rover, Honda, Skoda	Small	Quite new	0.8
Rural Isolation	Land Rover, Subaru, Mitsubishi	Very large	Quite old	1.3

Table 9 exemplifies how carbon dioxide emissions have been calculated for each ward.

Table 9: Example of emissions calculation. Data source: UK 2001 Census.

Carbon dioxide emissions produced by cars commuting from Arboretum ward in 2001		
Number of people commuting by car from Arboretum ward in 2001		1128
Average commuting distance from Arboretum ward in 2001		10.95
Passenger-km travelled by cars commuting from Arboretum ward in 2001	(1128*10.95)	12351.6
Grams of carbon dioxide per passenger-km emitted by cars in 2001		126.2
Weight (dominant Mosaic Automotive group in Arboretum ward is Urban Intelligence)		0.9
Weighted emissions	(126.2*0.9)	113.58
Grams of carbon dioxide emitted by cars commuting from Arboretum ward in 2001	(12351.6*113.58)	1402895

Emissions are calculated for each mode of transport then added together to provide a final estimate for each ward. Figure 13 displays ward-level carbon dioxide emissions maps for both 2001 and 1991. It is clear to see that emissions are increasing over time.

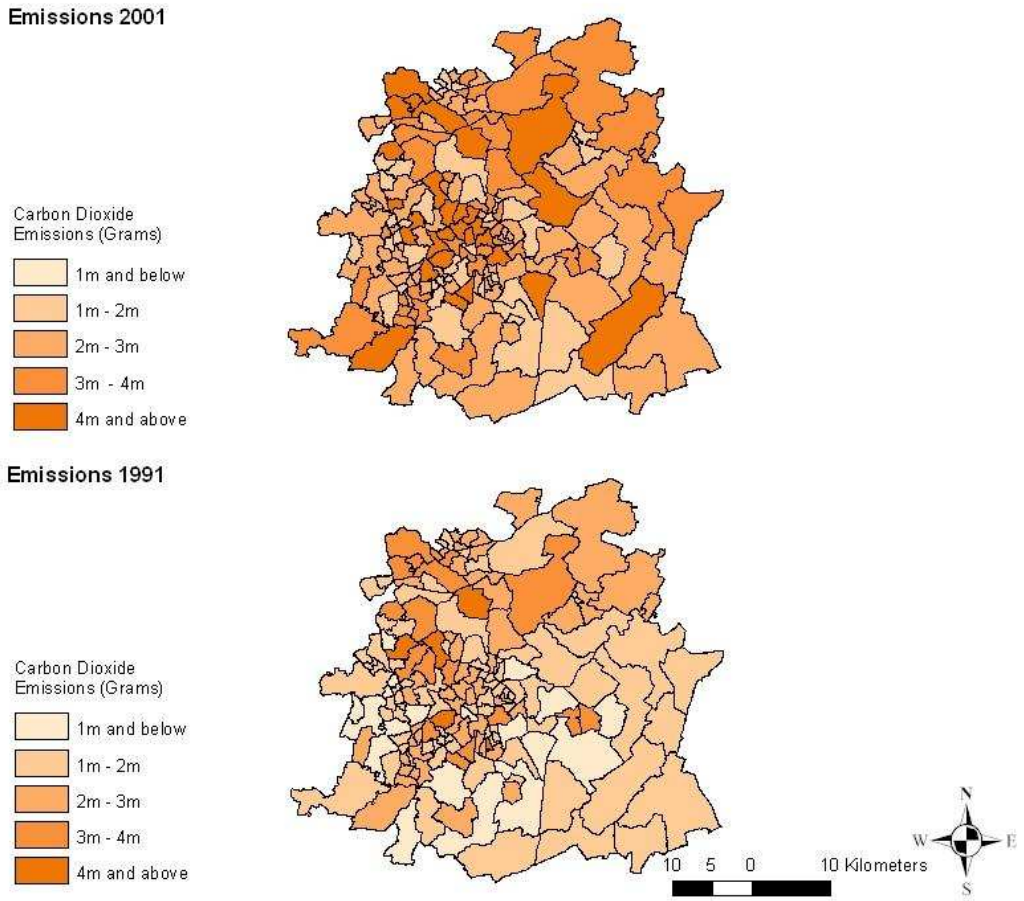


Figure 13: Carbon dioxide emissions 2001 and 1991. Data source: UK 2001 Census and UK 1991 Census.

Overall emissions of carbon dioxide attributed to commuting within the study area have increased by 51% between 1991 and 2001. The number of commuting journeys has increased by 12% over the same time period. This means that each journey is now producing more emissions, as highlighted in table 10. This is perhaps caused by long distance commutes by car.

Table 10: Change in emissions per journey over time. Data source: UK 2001 Census and UK 1991 Census.

	2001	1991
Total carbon dioxide emissions	508903202	336793035
Total number of commuting journeys	444501	396040
Grams of carbon dioxide emitted per journey	1145	850

The underlying trends are not easily identifiable. This is because high emissions could in theory be caused by a small number of people travelling a long distance by car, or a large number of people travelling a short distance by bus. Figure 14 shows change in emissions between 1991 and 2001.

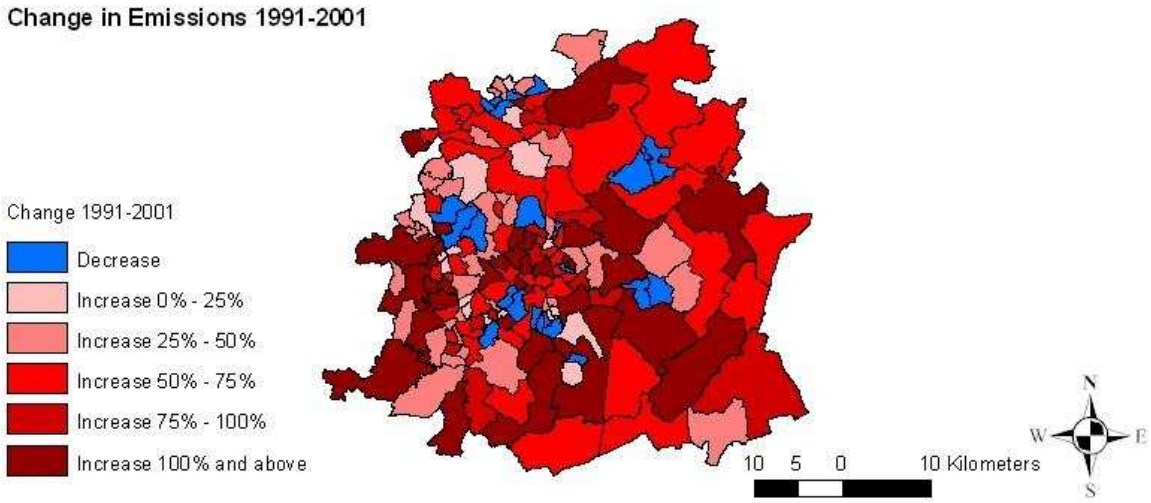


Figure 14: Change in emissions between 1991 and 2001. Data source: UK 2001 Census and UK 1991 Census.

The highest increases are spread across the city. These areas include rural villages to the southeast of Nottingham, giving further credence to the theory regarding affluent commuters travelling long distances to work, driving from the countryside to city centre in luxurious cars. It is interesting to note that some wards have experienced a decrease in emissions. This could perhaps be the result of high unemployment or successful public transport schemes.

Table 11 looks at the emissions produced in the study area by each mode of transport in both 2001 and 1991.

Table 11: Emissions produced by each method of travel 2001 and 1991. Data source: UK Census 2001 and 1991.

Method of travel to work	2001 Emissions	2001%	1991 Emissions	1991%	Change in %
Work mainly at home	0	0.00	0	0.00	0.00
Underground, metro, light rail	98893	0.02	77273	0.02	0.00
Train	2125901	0.42	946441	0.28	0.14
Bus, minibus or coach	39297773	7.72	26743863	7.94	-0.22
Motorcycle, scooter or moped	4826971	0.95	4448959	1.32	-0.37
Car or van	460337621	90.46	297021929	88.19	2.27
Bicycle	0	0.00	0	0.00	0.00
On foot	0	0.00	0	0.00	0.00
Other	2216043	0.44	7554570	2.24	-1.81
Total	508903202	100	336793035	100	0

It is unsurprising to discover that cars account for the vast majority of emissions produced in the study area. The percentage of emissions attributed to cars has increased from 88.19% in 1991 to 90.46% in 2001. This is likely to be the result of an increased number of long distance commutes.

4.8 Tram network

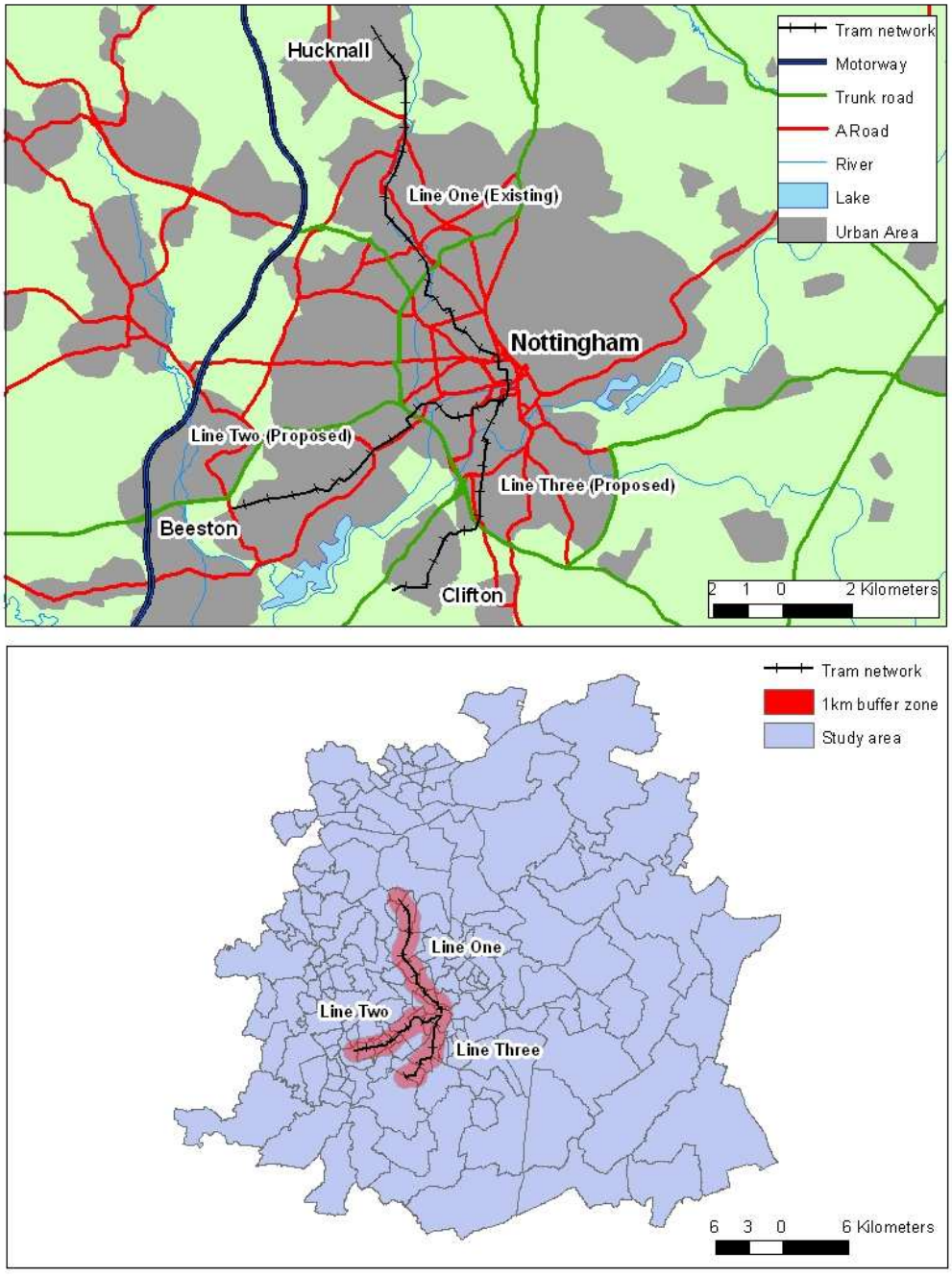
The Nottingham Express Transit tram network aims to reduce car dependency by improving the provision of public transport (Nottingham Express Transit, 2007a). Anticipated benefits include more transport choice, better accessibility, opportunities for regeneration and reduced congestion and pollution (Nottingham Express Transit, 2007b). Figure 15 shows a tram travelling through Nottingham city centre.

Figure 15: A Nottingham Express Transit tram in central Nottingham. Source: Nottingham Express Transit.

The inaugural 14km line opened in 2004. Two further extensions have been proposed, which will add a further 17.5km to the network (Nottinghamshire County Council, 2007). Table 12 provides a summary of the three lines.

Table 12: Summary of Nottingham Express Transit tram network.

Line	Route	Status	Opening date
One	Nottingham-Hucknall	Existing	2004
Two	Nottingham-Beeston	Proposed	2013
Three	Nottingham-Clifton	Proposed	2013



.

Figure 16: Nottingham Express Transit tram network.

Figure 16 shows existing and proposed routes of the Nottingham Express Transit tram network. A 1km buffer zone has been placed around the tramlines. All wards partially or fully covered by this buffer zone have a 'near tram' variable set to 1, for all other wards this variable is set to 0. The purpose of this is to assess how well the network might fare in terms of reducing carbon dioxide emissions caused by commuting in Nottingham. Figure 17 shows the relationship between the near tram variable and 2001 carbon dioxide emissions for each ward.

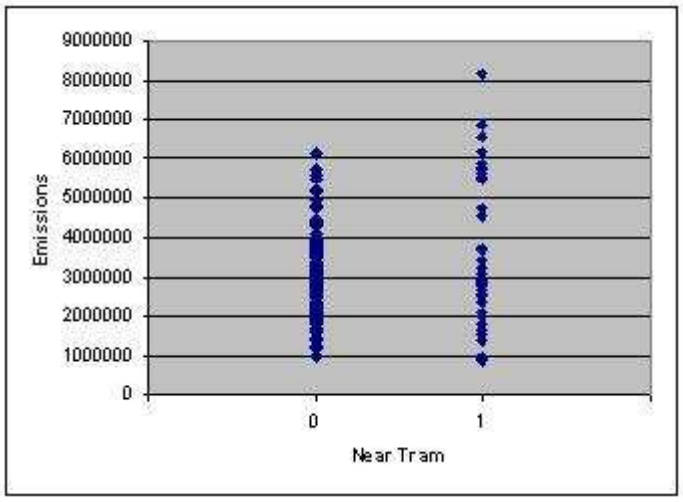


Figure 17: The relationship between emissions and near tram variable.

Many of the most polluting wards are located near existing or proposed tram routes. The correlation figure between the near tram variable and emissions is 0.217, which is significant at the 0.01 level. This indicates that the tram is being targeted at areas of high emissions.

Table 13 presents passenger statistics for the opening years of the tram network. Usage of the network has steadily increased.

Table 13: Nottingham Express Transit passenger statistics. Data source: Department for Transport (2005, 2006).

	2004/05	2005/06
Passenger boardings	8 million	10 million
Passenger-km travelled	37 million	42 million

Given that the tram extensions have yet to be built, it is difficult to fully assess the environmental impact of the completed network. This can however be estimated through the implementation of various 'what if' scenarios. Table 14 presents three possible scenarios.

Table 14: Tram scenarios.

Scenario	Impact of tram
One	50% of people who commute by bus from near tram wards switch to the tram
Two	75% of people who commute by bus and 25% of people who commute by car from near tram wards switch to the tram
Three	100% of people who commute by bus and 50% of people who commute by car from near tram wards switch to the tram

Each scenario has been modelled under the assumption that the complete extended network was open in 2001. Carbon dioxide emissions for the near tram wards have been re-calculated according to the changes in method of travel set out in each scenario. The results are presented in table 15. In all cases there is a reduction in emissions which is to be expected given that trams are less polluting than cars and buses.

Table 15: Impact of each scenario on carbon dioxide emissions.

Area	Scenario One	Scenario Two	Scenario Three
Near tram wards	-2.20%	-17.4%	-32.61%
Whole study area	-0.63%	-5.01%	-9.39%

Figure 18 maps the impact on emissions of scenario three which presents the most optimistic possible future impact of the tram network.

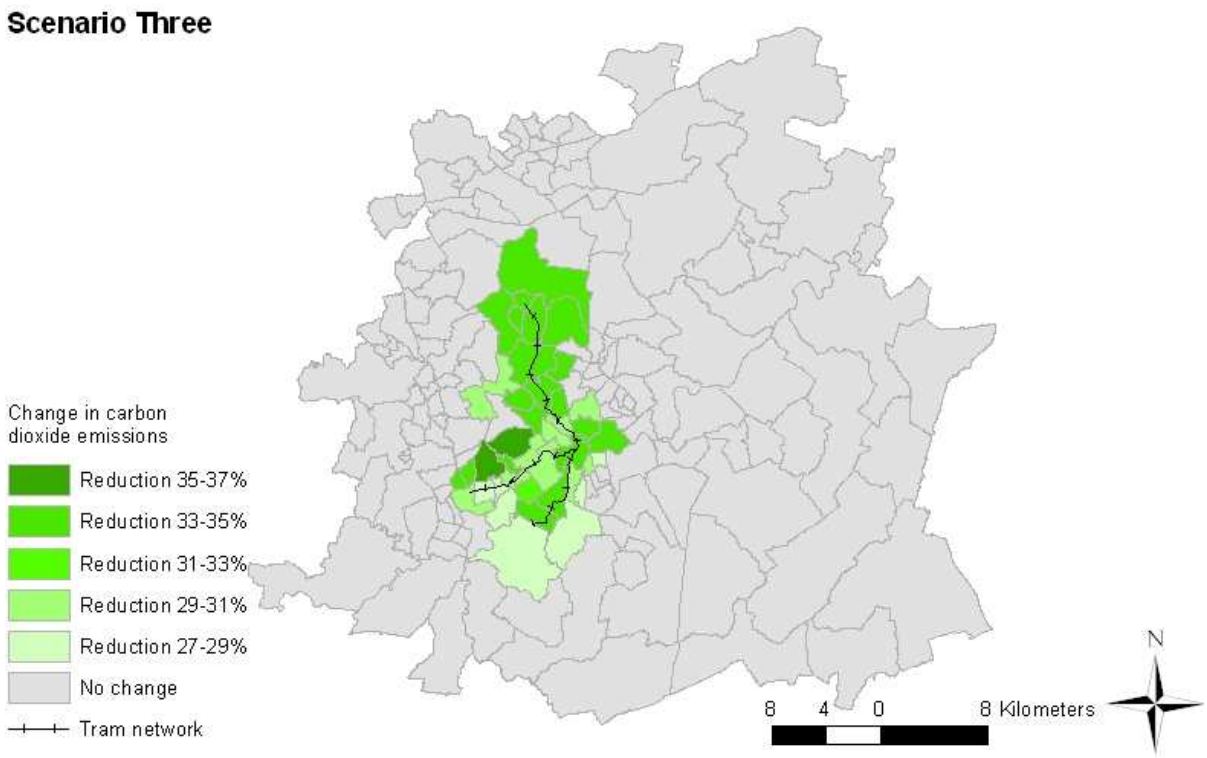


Figure 18: Impact of scenario three on carbon dioxide emissions.

The analysis shows that the tram has the potential to significantly reduce emissions within the study area. If scenario three became a reality then emissions would be reduced by 9% across the whole study area and by 33% in near tram wards. However for this to occur then a significant proportion of car users would have to be persuaded to switch to the tram, it remains to be seen if this is a realistically achievable objective.

5 Discussion and conclusion

Figure 19 presents a summary of the results of the analysis.

- The number of journeys to work within the study area has increased by 12% between 1991 and 2001. The majority of journeys to work originate from wards close to the city of Nottingham, although there has been a rapid increase in journeys originating from the surrounding countryside.
- The average distance travelled to work in Nottingham has increased by around 30% between 1991 and 2001. Distances to work are short in the city centre and long in the surrounding rural hinterland.
- Generally people travel to work in Nottingham city from the surrounding suburbs and rural villages although commuting flows are becoming more complex over time.
- Travel to work in the study area is dominated by the car, especially away from the city centre. Within central Nottingham, a significant minority of commuters travel by bus, bicycle or on foot. Over time there has been a significant increase in working from home.
- There is a strong link between type of job and method of travel. Typical examples include people in managerial roles living in the countryside and commuting by car, and workers with routine jobs living close to city and commuting by bus.
- There has been a considerable increase in the estimated carbon dioxide emissions produced by travel to work in the study area. Emissions have increased by 51% between 1991 and 2001. Long distance commutes by car are largely responsible for this increase.
- The Nottingham Express Transit tram network has the potential to significantly reduce carbon dioxide emissions within the study area, but only if it succeeds in persuading a large proportion of car users to switch to the tram.

Figure 19: Summary of the results of the analysis.

Many of the findings are linked together. There is a rise in commuting from rural villages surrounding Nottingham. This leads to a continued reliance on the car and an increase in commuting distances. People who undertake these commutes tend to work in managerial jobs in central Nottingham and own large luxurious cars, which contribute to increased traffic congestion and carbon dioxide emissions.

The results agree with the findings of previous academic study. Frost et al (1997) similarly found that the number and length of journeys to work are increasing, with adverse environmental implications. Shuttleworth and Lloyd (2005) make similar findings with regards to distance and the influence that type of job has on commuting. Many other studies mentioned in Section 2 acknowledge the growing problems caused by commuting and the need for public transport to improve in order to provide a viable alternative to cars.

Nottinghamshire County Council (2006) intend to reduce congestion and pollution caused by commuting. In addition to extending the tram network, bus links are to be improved, roads are to be widened and integration between different modes of transport is to be improved. Congestion charging and taxing workplace car parking are being considered in order to dissuade people from commuting by car (Jowit, 2004). Figure 20 shows an example of one of the improved bus services that have been introduced in Nottingham. These are targeted specifically at commuters, students or airport passengers and aim to reduce congestion along key commuting routes (Nottingham City Council, 2007).

Figure 20: An example of improved bus services in Nottingham. Source: Nottingham City Transport.

If this study had not been limited in terms of time and resources it may have proved useful to compare Nottingham with other cities in the UK or abroad. Analysing data at a lower level of geography such as Output Area may reveal more specific spatial trends, whilst using UK 1981 census data could give further understanding of temporal trends. The calculations used to estimate carbon dioxide emissions are somewhat simplistic, it would certainly be possible to devise a more sophisticated and more accurate model.

Looking to the future, it would be worthwhile repeating this analysis once UK 2011 census data is available. This will include information on method of travel to study, which when used in addition to travel to work data would enable a more comprehensive overview of traffic-related issues to be ascertained (Office for National Statistics, 2005).

References

Cole K., Frost M. and Thomas F. (2002) Workplace Data from the Census. In: Rees P., Martin D. and Williamson P. (Eds.) *The Census Data System.* John Wiley & Sons Ltd., Chichester.

Coleman C. (2000) Green commuter plans and the small employer: an investigation into the attitudes and policy of the small employer towards staff travel and green commuter plans. *Transport Policy,* Vol. 7, pp. 139-148.

Department of Trade and Industry (2002) *Energy Consumption in the United Kingdom.* Department of Trade and Industry, London.

Department for Transport (2006) *Transport Statistics for Great Britain: 2006 Edition.* Department for Transport, London.

Department for Transport (2005) *Light Rail Statistics: England: Key Facts.* Department for Transport, London.

Department for Transport (2002) *Making travel plans work: Lessons from UK case studies.* Department for Transport, London.

Dickinson J., Kingham S., Copsey S. and Pearlman-Hougie D. (2003) Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D,* Vol. 8, pp. 53-67.

European Environment Agency (2004) *Indicator factsheet: TERM 2003 27 EEA31 – Overall energy efficiency and specific CO2 emissions for passenger and freight transport.* http://themes.eea.europa.eu/Sectors_and_activities/transport/indicators/technology/TERM27%2C2003.09/TERM2003_27_EEA31_Overall_energy_efficiency_and_specific_CO2_emissions_for_passenger_and_freight_transportfinal.pdf, accessed 9th June 2007.

Experian (2007) *Mosaic Automotive: E-Handbook.* Experian Limited, Nottingham.

Frost M., Linneker B. and Spence N. (1998) Excess or Wasteful Commuting in a Selection of British Cities. *Transportation Research A,* Vol. 32, No. 7, pp. 529-538.

Frost M., Linneker B. and Spence N. (1997) The Energy Consumption Implications of Changing Worktravel in London, Birmingham and Manchester: 1981 and 1991. *Transportation Research A,* Vol. 31, No. 1, pp. 1-19.

Jowit J. (2004) *Congestion charging sweeps the world.* http://www.guardian.co.uk/congestion/story/0,12768,1148714,00.html, accessed 2nd July 2007.

Kingham S., Dickinson J. and Copsey (2001) Travelling to work: will people move out of their cars. *Transport Policy,* Vol. 8, pp. 151-160.

Kumar A. (1990) Impact of Technological Developments on Urban Form and Travel Behaviour. *Regional Studies,* Vol. 24, No. 2, pp. 137-148.

Mann E. and Abraham C. (2006) The role of affect in UK commuters' travel mode choices: An interpretative phenomenological analysis. *British Journal of Psychology,* Vol. 97, pp. 155-176.

Noland R. and Lem L. (2002) A review of the evidence for induced travel and changes in transportation and environmental policy in the US and the UK. *Transportation Research Part D,* Vol. 7, pp. 1-26.

Nottingham City Council (2007) *Link bus strategy.* http://www.nottinghamcity.gov.uk/sitemap/link_bus_strategy, accessed 27th April 2007.

Nottinghamshire County Council (2007) *Nottingham Express Transit (NET) Phase 2: Submission of an order under the Transport and Works Act 1992 to authorise construction and operation of two extensions to the system.* Nottinghamshire County Council, Nottingham.

Nottinghamshire County Council (2006) *Local Transport Plan for Greater Nottingham: Final Plan 2006/7.* Nottinghamshire County Council, Nottingham.

Nottingham Express Transit (2007a) *Integrated transport vision…* http://nottinghamexpresstransit.com, accessed June 9th 2007.

Nottingham Express Transit (2007b) *Why NET Phase Two?* http://www.netphasetwo.com, accessed June 9th 2007.

Office for National Statistics (2005) *The 2011Census: Initial view on content for England and Wales.* Office for National Statistics, London.

Rees P., Thomas F. and Duke-Williams O. (2002) Migration Data from the Census. In: Rees P., Martin D. and Williamson P. (Eds.) *The Census Data System.* John Wiley & Sons Ltd., Chichester.

Rye T. (2002) Travel plans: do they work? *Transport Policy,* Vol. 9, pp. 287-298.

Shuttleworth I. and Lloyd C. (2005) Analysing Average Travel-to-Work Distances in Northern Ireland Using the 1991 Census of Population: The Effects of Locality, Social Composition, and Religion. *Regional Studies,* Vol. 39, No.7, pp. 909-921.

Shuttleworth I., Power J. and McKinstry D. (2000) Examining 1991 travel-to-work patterns in the Belfast Urban Area as a context for urban employment policy. *Applied Geography,* Vol. 20, pp. 177-202.