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An analysis of modes of commuting in urban and rural areas

Xiangwu Tao*[1], Zongtang Fu[1], Alexis J Comber[2]

[1] School of Land Science and Technology, China University of Geosciences, Beijing, 100083, China

[2] School of Geography, University of Leeds, Leeds LS2 9JT, UK

*Email: xiangwutao@hotmail.com

*Tel: 0086 13810892120

*ORCID iD:0000-0001-5604-5759

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Abstract This study compares global and local analyses of non-car commuting modes and the probability of increasing modes use in different urban and rural areas for a case study in Yorkshire, UK, with commuter residence areas used as the response variable. The analyses compared Generalized Linear Models of commuting by bus, cycling and walking to estimate the probability of increasing sustainable modes use in commuters in urban areas, relative to rural areas. The three variables were found to be significant predictors for the models and indicate differential odds of commuting from urban areas relative to rural ones. An analysis of the non-stationarity of was undertaken using a Geographically Weighted Regression analysis, which showed how the probability of residing in a particular type of urban and rural area, as described by commuting patterns, varied spatially within the study region. The local analyses provide a critical information able to support and guide local policy in its ambition to increase sustainable transport modes and to reduce car dependence in both rural and urban areas.

Keywords: Commuting mode, Generalized Linear Model, Spatial variation, Geographically Weighted Regression.

1. Introduction

In recent years, governments have encouraged people to use active and public modes of transport instead of private transports for their daily trips such as commuting to work, with the aim of reducing the consumption of energy, environmental pollution, traffic congestion etc (Katz et al. 1994; Greene and Wegener 1997; Champion 2009;Travisi et al. 2010;Buehler and Pucher 2012). Transport policy-makers have identified commuting as a key area of intervention because of the high number of people traveling to work (Mann and Abraham 2006; Litman 2011; Kim et al. 2012). In the United Kingdom commuting accounts for 16% of all travel and is highly dependent on car use (Beck and Hess 2016). Walking and cycling are the most sustainable modes for the daily commute with greater benefits than travel by car or bus with no noise and air pollution and consuming far fewer nonrenewable resources (Buehler and Pucher 2012). If people travel to work by walking and cycling instead of using a car for such a short trip, there are additional important personal health benefits including a reduction of cardiovascular risk, physical fitness, and weight control (Woodcock et al. 2009; Yang et al. 2015; Fan et al. 2017).

Commuting by active transport (cycling walking, etc) and public transports is not widely practiced in the UK and people are highly car-dependent. According to the 2011 English and Welsh census, 67.1% of commuters traveled to work by private motorized transport, followed by public transport (17.8%), walking and cycling (14.0%), and other modes accounting for 1.1% (Goodman 2013). Furthermore, there is a large difference in the commuting modal shares amongst urban and rural areas, primarily because bus, cycling, and walking are easier in urban settings with well-established networks (cycle routes), public transport services, shorter travel distances and generally with a more compact form than rural area (Susilo and Kitamura 2008). It is important for transport planners to consider the impact of urban and rural settings on decisions to commute by bus, walking, and cycling when considering planning options to promote sustainable modes transport modes and to reduce car use.

The purpose of this research is to globally examine the impact of urban and rural settings on patterns of commuting, specifically around decisions to travel by bus, walking and cycling (sustainable modes), and a geographical approach was used to identify spatial variations in the association across the study region. Thus, the study could aid transport policymakers to target initiatives in areas where they are most needed or could have the most impact. The analysis examines commuting patterns in urban and rural areas (Bibby and Brindley 2013), using odds ratios to compare the modal shares of different types of commuting in different areas, generalized linear models to examine the probability of different types of commuting in different areas, and geographically weighted logistic regression (Brunsdon et al. 1996) to examine the spatial non-stationarity in these relationships.

2. Background

Motorized transportation has become an indispensable part of people's daily life. Car ownership and use have increased the levels of mobility in all European countries but it has also made people more dependent on the car (Kitamura 1989; Anable 2005; Beirão and Cabral 2007; Wilding et al. 2016). Although cars are convenient for regular daily travel, their use is accompanied by a number of problems, such as non-renewable energy consumption, environmental pollution and traffic accidents (Greene et al. 1997). Greenhouse gas emissions caused by cars become one of the main factors of climate change and mitigating greenhouse gas emissions have become a major societal and environmental challenge (Dujardin et al. 2012). These problems are exacerbated by population increases and increases in wealth generally and in previously less developed countries resulting increased demand for private motorized transport and consumption of non-renewable resources (Jakob et al. 2006). Transport policy-makers have made great efforts to encourage drivers to move out of the car and into sustainable modes of transport in order to achieve more sustainable everyday patterns of transport (Kingham et al. 2001). Much research and policy have focused on commuting because of the high numbers and dependency of commuters on the car.

A number of studies have examined the modal share of commuting choices at different geographical levels, from the national level (Goodman 2013) to individual level (Mann and Abraham 2006), and have analyzed the relationship between modal choice against a number of different factors including such as individual affect, transport infrastructure, and service efficiency etc. Goodman (2013) examined the distribution of commute modal share of cycling, walking, public transport and private motorized transport using the 2011 UK census at national and regional levels and compared historical trends with census data 1971–2011. There was evidence that commuting share by car has declined, after decades of growth, suggesting space to increase active and public transport modes. Titheridge and Hall (2006) examined the relationships between patterns of commuting mode choice with socio-economic and land-use characteristics (residential and workplace) in South East England using regression models. They found that traveling to work by public transport, cycling and walking were promoted in dense, urban areas, with and shorter journey distances. Kingham et al. (2001) analyzed factors influencing commuting choice and the potential for drivers to change to more sustainable transport modes such as cycling and bus, using the journey to work surveys from two large companies in Hertfordshire, England. The findings show that people comprehend the issues relating to air pollution and traffic congestion arising from car use and are willing to change their mode of travel, given certain changes: living closer to the workplace, more efficient public transport services and reduced ticket prices. Mann and Abraham (2006) examined the relationship between affect (that is their feelings or emotions) and traveling to work by car or public transport modes in the UK. Although considerations such as feelings of control and freedom easily achieved by car use are dominant in transport decisions, these feelings were not additive and were found to depend on respondents' perception of their circumstances and other considerations related to utility such as time, cost and reliability were perceived to be more important.

Some studies have shown that urban and rural residential environment has an impact on patterns of commuting. Clark et al.（2016）examine individual change in commute mode from year to year using the UK Household Longitudinal Study (UKHLS) data and globally analyzed the relationship between residential context and active transport using logistic regression models. The study shows that walking, cycling, and bus commuting are more unstable options than car commuting. The odds of travel to work by active transport for people living in large urban (250k+), medium urban (25k-250k), small urban (10-25k) and very small urban (3k-10k) are greater compared to rural area. Fan et al. (2017) investigated the differences between the urban and rural areas of three commuting modes: walking, cycling and public transport, and globally examined the relationship between built environment features and the three commuting modes, using the 2010 Decennial Census and the 2007–2011 American Community Survey data. The findings show that built environment factors explained more variances than socio-demographic factors for public transport in urban area, compared to the other two modes. Rurality is an important moderator in the relationship between built environment features and the three commuting modes.

Less research has focused on sustainable modes of commuting (sustainable modal choice) at the small area level in urban and rural environment and identified spatial variations in the relationship. This study evaluates these relationships at Middle Layer Super Output Area (MSOA) level. It does this, firstly, by examining the global distribution of all commuting modal shares (commuting choice) comparing urban and rural residential areas, and then comparing the odds in urban and rural areas for bus, cycling, and walking modes. Secondly, it identifies which type of area increasing these modes use of commuting is possible, using global generalized linear models (GLM). Thirdly, it examines the spatially non-stationary of these relationships using geographically weighted logistic regression.

3. Methods

3.1. Data and study region

The present study uses census commuting flow data for the Yorkshire and Humber region in the UK (Figure 1) extracted from the 2011 census, available through UK Data Service. This includes counts of who lives and travels to work by public transport in the region, the location of their usual residence, their place of work and their usual commute modes. In order to prevent individual information with unique characteristics from being identified in the 2011 Census data, a swapping technique has been used at MSOA level or below (ONS 2011). This makes unusual commuting modes data such as traveling to work by cycling and bus unreliable at Output Areas (OA) level and Lower Layer Super Output Areas (LSOA) level (Lovelace et al. 2014; Sapiro 2016). Lloyd (2016) examined spatial variation in population sub-groups (demographic and socio-economic) and the amount of spatial information contained at different spatial scales including OAs, LSOAs, MSOAs and LA for England and Wales. The results indicate that MSOAs would be more appropriate for many analyses of (No)Car and van travel where MSOAs could capture more variation than OAs. The data use the Middle Layer Super Output Area (MSOA) level of geographical aggregation which is designed to include an average population of 7000 (Baiocchi et al. 2015) to describe locations of commuting start and end points. The 2011 Rural-Urban Classification (Bibby and Brindley 2013) classifies MSOAs into a typology of Urban and Rural areas.

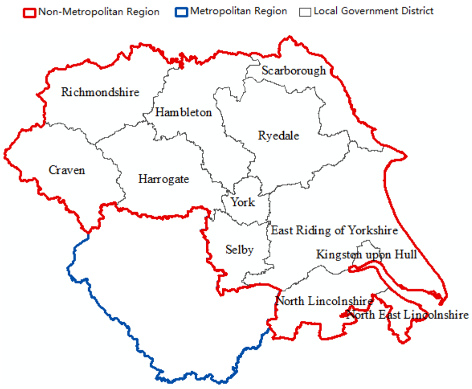

Fig.1 The Yorkshire and Humber region (UK) with the non-metropolitan study area in red.

This analysis examined the non-metropolitan part of the Yorkshire and Humber region as a case study, which includes 12 local government districts and 221 MSOAs which comprised of 142 urban areas (classified in Bibby and Brindley (2013) as City and Town and City and Town in a Sparse Setting) and 79 rural areas (classified as Town and Fringe, Town and Fringe in a Sparse Setting, Village, Village in a Sparse Setting). The average area of urban areas is about 9.0 square kilometers and the average area of rural areas is about 135 square kilometers. Because MSOA is designed to have the almost common population, population density in urban area is higher than that in rural area. If commuters move home from rural area to urban area, they are more likely to switch to no-car commuting (Limtanakool et al. 2006; Clark et al. 2016). A total of 0.63 million people aged 16–74 were recorded as being employed, of whom 0.43 million lived in the urban area, 0.20 million lived in rural areas. Average commuters in urban MSOAs is about 3017 and average commuters rural MSOAs is about 2562. The analyses compared commuting by bus, cycling and walking in these areas.

3.2. Analysis

Odds ratio of commute modes use

Commute modal share m as a result of commute mode choice is the proportion of commuters traveling to work by a particular mode. Here, m indicates the probability of choosing that mode of travel relative to all other modes for commuters to travel to work. We move the probability m to α:

$$\alpha = \frac{m}{1-m}$$

Equation 1

where α is the odds of using the particular mode among commuters. To compare the odds of using any particular between urban and rural commuters, we calculate the odds ratio:

$$\beta = \frac{\alpha_u}{\alpha_r}$$

Equation 2

where β is the ratio of the odds α_u of using the mode in urban area compared to the odds α_r in rural areas.

Global Trend Analysis

A global analysis was undertaken using Generalized Linear Models (GLMs) to model the probability of increasing sustainable modes of commuters in urban areas, relative to rural areas. The urban and rural classification of MSOA residential areas of the commuter was set as the response variables and bus, cycling and walking commuting shares were determined for each residential area as predictor variables. Note that the response has two categories: urban area which was given a value of 1 and rural area which was given a value of 0. The first independent variable to be considered was bus share, with cycling share and walking share added sequentially to GLM. Thus three models were considered:

$$pr(y = 1) = logit(b_0 + b_1 m_1) \quad \text{Model 1}$$
$$pr(y = 1) = logit(b_0 + b_1 m_1 + b_2 m_2) \quad \text{Model 2}$$
$$pr(y = 1) = logit(b_0 + b_1 m_1 + b_2 m_2 + b_3 m_3) \quad \text{Model 3}$$

where y is a 0/1 indicator showing whether the category of residence area is urban, m_1, m_2 and m_3 respectively indicate bus share, cycling share and walking share in respondent residence area.

Geographic Variation

Geographically Weighted Regression (GWR) analysis as a sample-point-based technique(Brunsdon et al. 1996) treats points as the basic spatial unit of observation (Francisco et al. 2008). Although geometric centroid which was widely used in many GWR analyses for zonal system data (Brunsdon et al. 1996; Mennis 2006; Chasco et al. 2007; Li et al. 2009; Shoff et al. 2012) is the simplest way to proceed in this study, the geometric centroids cannot accurately represent the center of the population in the northern part of the study area where rural areas are larger than urban areas. Therefore, we choose the population-weighted centroid in an MSOA available through ONS to represent the population center of the MSOA to improve the spatial regression performance (Sharkey et al. 2008). Although in the analysis the population-weighted centroids of MSOAs in rural area are sparser than that in urban area, GWR is beneficial to this situation and can reduce variation in results from different zonal systems by using the smoothing technique (Lloyd 2014). In order to examine non-stationary relationships (Comber et al. 2011) between the probability of being in the urban area and the independent variables, Model 3 was extended to a Geographically Weighted Regression (GWR) analysis as follows:

$$pr(y = 1) = logit(b_{0(u_i,v_i)} + b_{1(u_i,v_i)} m_1 + b_{2(u_i,v_i)} m_2 + b_{3(u_i,v_i)} m_3) \quad \text{Model 4}$$

Where (u_i, v_i) are the coordinates of *i*th residence area location in two-dimensional geographical space, the coefficients including b_0, b_1, b_2, *and* b_3 can be considered as functions of these coordinates. The coefficients estimated for each residence area location will be assigned to the relevant residence area.

Determining the bandwidth is a critical step in any geographically weighted approach. There are two types of bandwidth including fixed bandwidth which is suitable for regular data and adaptive bandwidth which is suitable for irregular data and was adopted in the study. For the aim of prediction, adaptive bandwidth in the study is selected by cross-validation method (Bowman 1984). The weighting function used to weight local subsets of the data in this study was Gaussian kernel function (Charlton et al. 2009; Gollini et al. 2013) that calculates geographical weight w_{ij} for observation point *j*:

$$w_{ij} = \exp\left(-\frac{1}{2}\left(\frac{d_{ij}}{b}\right)^2\right) \quad \text{Equation 3}$$

Where d_{ij} is the Euclidean distance in meters between observation point *i* and calibration point *j*, *b* is the bandwidth. In this case, all the spatial analyses were implemented using the x and y coordinates of the population-weighted centroids of MSOAs. The bandwidth of the Gaussian kernel was determined to be 10% which means about 23 MSOAs for each estimation for the GWR with bus, cycling and walking shares as independent variables. Although in the analysis centroids in rural area are more sparser than that in urban area, GWR is beneficial to this situation by assigning weights to observation point using continuous function of distance from the calibration point.

4. Results

4.1. Commuting modes comparison between urban and rural commuters at regional level

Distribution of global levels of modal shares

Of the 0.63 million residents who were recorded as employed and aged 16–74 (not including people working at or from home) in the 2011 census in the study region, 0.43 million lived in urban areas and 0.20 million lived in rural areas. Table 1 shows the distribution of their usual main commute modes and the difference between urban and rural residents. In general, the modal share of commuting for residents was dominated by private motorized transport (71.13%, 63.63% from car), which is 4.00% higher than that nationally (Goodman 2013). This was followed by active transport (20.81%, 14.93% from walking, 5.88% from cycling), public transport (7.35%, 6.02% from bus), and finally by taxi and other (0.71%). Car, walking, and bus were the main modes of private motorized transport, active transport, and public transport respectively.

Difference in modal shares between urban and rural commuters

The data in Table 1 shows that Urban residents are more likely to travel to work by walking, cycling, and bus than rural residents, and the difference in walking share between urban and rural residents is bigger than that in cycling and bus shares that have almost same difference value. Specifically, when urban residents are compared to rural residents show greater levels of active transport (12.16% greater), with walking contributing 7.52% and cycling 4.64% and public transport (4.84%) most of which is accounted for by bus travel (4.71%). Urban commuters are less likely to use private motorized transport (17.49% less) with a difference of 18.95% less car use in Urban areas. The odds ratios β in Table 1 support the following statements:

- The odds of commuters using a bus to commute in urban areas is 2.8 times greater than in rural area;
- The odds of commuters walking to commute to work in urban areas is 1.9 times than in rural areas;
- The odds of commuters cycling to work in urban area is 2.8 times than in rural areas.

Table 1 The modal share of main commute modes, differences in modal share between urban and rural commuters, and associated odds ratios between urban and rural commuters.

Commuting mode	All commuter	Urban commuter	Rural commuter	Difference	β
Public transport	7.35	8.91	4.07	4.84	
Bus	6.02	7.53	2.82	4.71	2.81
Train	1.31	1.35	1.23	0.12	
Underground (incl. light rail)	0.02	0.03	0.02	0.01	
Private motorized transport	71.13	65.52	83.01	-17.49	
Car(van)	63.63	57.56	76.51	-18.95	
Passenger	6.54	6.94	5.69	1.25	
Motorcycle (incl. scooter)	0.96	1.02	0.81	0.21	
Active transport	20.81	24.71	12.55	12.16	
Walking	14.93	17.34	9.82	7.52	1.93
Cycling	5.88	7.37	2.73	4.64	2.83
Taxi and Other	0.71	0.86	0.37	0.49	
Taxi	0.42	0.55	0.14	0.41	
Other	0.29	0.31	0.23	0.08	

Difference = Urban commuter- Rural commuter

4.2. Global statistical analysis

For the three variables, the average bus share is 5.95% for all MSOAs, with urban MSOAs having a higher share (7.76%) than rural MSOAs (2.70%). The average cycling share is 5.62% for all MSOAs, with urban MSOAs having a higher share (7.27%) than rural MSOAs (2.65%). The average bus share is 14.51% for all MSOAs, with urban MSOAs having a higher share (16.92%) than rural MSOAs (10.18%). Table 2 shows the effect of sequentially adding the three independent variables as in Models 1, 2 and 3 (bus, cycling, walking). The results indicate decreases in Akaike's Information Criterion (AIC) score with each additional variable, indicating significantly improved model fit as the cycling and walking variables are added. The Model 3 with the lowest AIC of 143.7 which means that the model is closer to the "true" model(Yang et al. 2017) compared to the other two models was selected. The result of deviance tests between Model 1, Model 2 and Model 3 are shown in Table 3 and all three variables were found to be significant. The odds ratios in Model 3 support the following statements:

- The odds of being in urban area increase 53% for every unit growth of bus modal share;
- The odds of being in urban area increase 72% for every unit growth of cycling modal share;
- The odds of being in urban area increase 12% for every unit growth of walking modal share.

Table 2 Results of the GLM analyses of the probability of increasing sustainable modes use in commuters in urban area, relative to rural area (Models 1 to 3), all variables significant at the 99.9% level

Model	Variable	Odds ratio	Lower 95% CI	Upper 95% CI	AIC
Model 1	Bus	1.75	1.49	2.11	200.3
Model 2	Bus	1.50	1.25	1.85	165.3
	Cycling	1.77	1.42	2.30	
Model 3	Bus	1.53	1.26	1.92	143.7
	Cycling	1.72	1.35	2.27	
	Walking	1.12	1.07	1.19	

Table 3 Analysis of deviance of the terms associated with the probability of increasing sustainable modes use in commuters in urban area, relative to rural area, significant at the 99.9% level.

Terms	Df	Residual Df	Residual Deviance	Deviance Reduction
NULL	NA	220	288.2	NA
Bus	1	219	196.3	91.8
Cycling	1	218	159.3	37.0
Walking	1	217	135.7	23.6

4.3. Local statistical analysis

The results of the GWR analysis are shown in Table 4. The inter-quartile ranges indicate the spatial variation in the odds ratios in Table 4 when they are determined using local analyses. From Table 4, little variation was found walking, ranging from 1.139 to 1.193. Considerable variation in the odds ratio was observed in cycling which ranged from 1.280 to 2.117.

Table 4 The variation in the odds ratios of the independent variables from the GWR model(model 4), with the Inter-Quartile Range (IQR) providing a measure of the spatial variation.

Variable	Minimum	1st Quartile	Median	3 rd Quartile	Maximum	IQR	Global
Bus	1.102	1.431	1.567	1.736	16340	0.305	1.53
Cycling	0.733	1.280	1.460	2.117	115.1	0.837	1.72
Walking	0.437	1.139	1.167	1.193	34.48	0.054	1.12

Figure 2 maps the spatial variation in the odds ratios of urban to rural areas and commuting by cycling and by bus. They indicate that local variation in commuting by cycling is less than for bus commuting, which has more short-range variation and evident clusters. There are much greater probabilities of cycling commuting in urban residence in the South East of the study area and much less in the North West with the probability increasing evenly NW to SE towards Hull, the major urban center in this region. There is a cluster around York that was clearly defined as a mono-centric city in both of cycling and bus commuting. It is evident that the influence range of York is bigger for patterns of bus travel than for cycling. By contrast, the spatial distributions of odds ratios of urban to rural areas and commuting by bus shows a very different pattern, with clusters high ratios around Hull and York and in North West of the study area, with a swath of low odds ratio through the middle of the study area and around Beverley. The spatial distributions of odds ratios by bus is like a saddle shape where Beverley is the bottom part of the saddle with urban MSOAs having a little higher modal share (3.85%) than rural MSOAs (2.73%). These patterns may, of course, be indicative of variations in bus transport services.

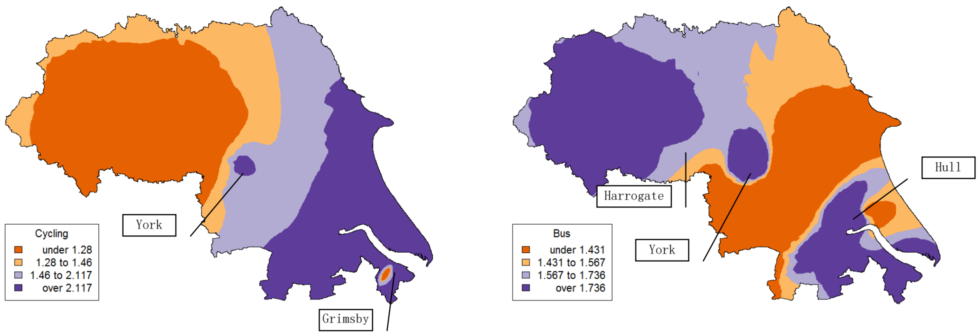

Fig. 2 Spatial variation in the odds ratios associated with cycling and bus.

5. Discussion

Urban versus rural variations in sustainable transport modes of commuting were found in this study. Urban commuters were found to travel to work more frequently by bus, walking, and cycling than rural commuters at the regional scale. The differences in walking share between urban and rural commuters were higher than the other two modes, with the odds ratios between urban and rural commuters using bus and cycling almost the same value but higher than that for walking. Cycling and bus modes for commuters are more dependent on public infrastructure or service than walking. One of the prerequisites about walking to work is that people lived close enough to the workplace and this prerequisite applies to people who could cycle to work. Kingham et al. (2001) found that better cycle routes, changing facilities and cycle security have more influence on potential cycling commuters and improvement of reliability, frequency and cost of services are important to potential bus commuters. It is obvious that these conditions needed by cycling and bus commuters are better in urban areas than rural areas, as Figure 3 shows that the average bus stops density in urban MSOAs(13.2 stops per square kilometer) was higher than in rural MSOAs(0.9 stops per square kilometer). Unlike the distribution of bus stops cycleway were mainly concentrated in major cities(Harrogate, York, Hull, Scunthorpe and Grimsby) and were very few outside major cities. Cycleway density and bus stop density in major cities was very higher than other areas.

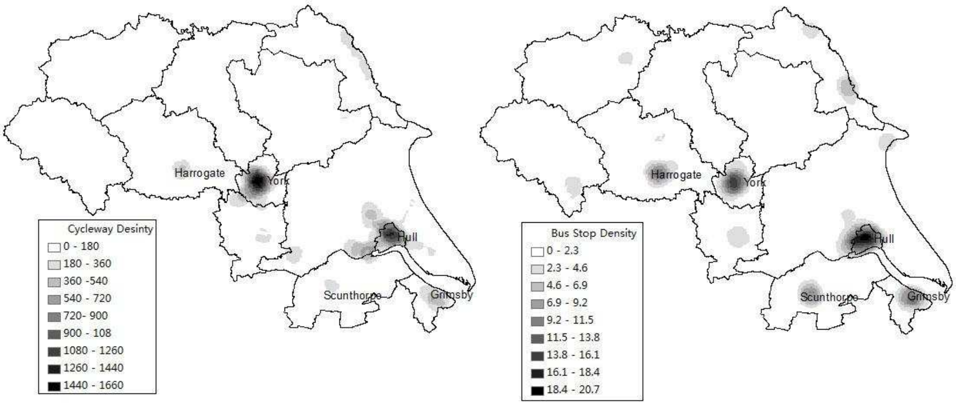

Fig. 3 Cycleway density (m/km^2) based on OpenStreetMap data and bus stop density(stops/ km^2) based on 2011 year data from Department for Transport.

There was evidence that commuting share by car has declined (Goodman 2013), and transport policy-makers should seize this opportunity to increase active and public transport modes. This study globally analyzed the possibility of growth of sustainable transport modes use in urban area compared to rural area, using GLM. Considering variation in the distribution of modes use in the study region, we calculated commuting modal shares within each MSOA which include a roughly equal number of households (Bibby and Brindley 2013) and MSOAs with very high levels of modal share were separated with those of low levels. The result showed that greater opportunities for increasing sustainable transport modes exist in urban areas than rural area, especially for bus and cycling modes that more depend on public infrastructure. In this way transport policy-makers can encourage and attract potential bus and cycling commuters to increase sustainable modes of commuting. Unless a more economical and effective way to cycling and bus commuting for rural areas is developed, the key points to promote these three modes in rural area should be walking. In urban areas, the three modes can be targeted.

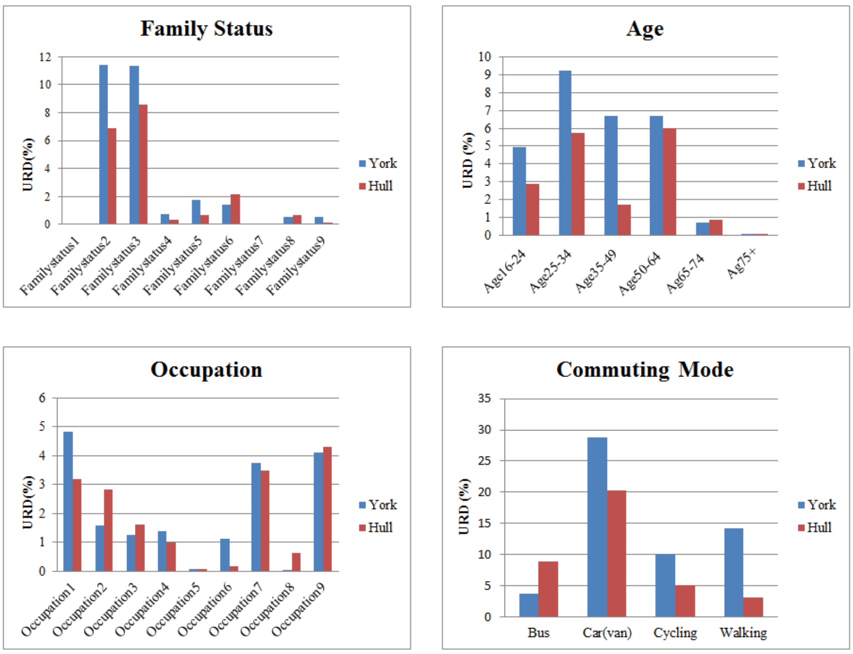

Fig. 4 Urban-rural difference(URD) in family status, age, occupation, commuting mode categories in York and Hull. For comparison of urban-rural commuters difference in selected socio-demographics, we selected 14 rural MSOAs which were adjacent to urban MSOAs for

York urban MSOAs(20) and 15 rural MSOAs which were adjacent to urban MSOAs for Hull urban MSOAs(48). We calculated the proportion of each category of MSOAs, then respectively calculated the average value of urban MSOAs and rural MSOAs, and finally calculated the absolute value of the urban-rural difference in the average value of each category. Family status categories include: not in a family:aged 65 and over;not in a family: aged under 65;in a couple family: member of couple;in a couple family: dependent child of one or both members of the couple;in a couple family: non-dependent child of one or both members of the couple;in a lone parent family: parent; in a lone parent family: dependent child of parent;in a lone parent family: non-dependent child of parent;not in a household. Occupation categories include: managers, directors and senior officials; professional occupations; associate professional and technical occupations; administrative and secretarial occupations; skilled trades occupations; caring, leisure and other service occupations; sales and customer service occupations; process, plant and machine operatives; elementary occupations.

Although at the global level opportunity to grow sustainable transport modes in urban area result was obvious, the relationship was found to vary spatially across the region. From the result of GWR analysis, the walking model was more spatially stationary than other two modes, although both bus and cycling are dependent on infrastructure or service. An outlier area with a cluster of lesser probability of being in urban areas by cycling commuter was obvious in the southwest of Grimsby. Cycling modal share of the outlier urban which was classified urban area was lower than the surrounding rural areas. Additionally, a mono-centric city (York) where total modal share of cycling, walking and bus in urban MSOAs accounted for 40% was identified in the study region and a cluster of greater probability of being in urban areas by bus and cycling commuter was obvious in areas around York. The influence range of York is evidently bigger for patterns of bus travel than for cycling. Commuting around Hull which had the higher bus stop density and the other major cities in the study did not show the same effect. Thus, although for people living in urban areas it may be easier and more advantageous to travel to work by cycling or bus (Titheridge and Hall 2006), relative to people living in rural areas, higher levels of bus and cycling infrastructure does not always result in more sustainable uses. This indicates that the right provision of infrastructure can lead to more use of cycling and bus in urban area for work trip (Schwanen et al. 2001).

We examined the socio-demographics including categories of age, occupation, family status and commuting mode and found that urban-rural differences in family status, age and commuting mode in York were larger than in Hull, except for urban-rural difference in occupation categories where York and Hull were very close, as Figure 4 shows. Many external and internal factors have an impact on commuting mode choices, such as land-use characteristics (Titheridge and Hall 2006), environmental awareness and company policy (Kingham et al. 2001), affective benefits (Mann and Abraham 2006), and perhaps critically the involvement of the local community in infrastructure planning. This study did not consider other factors due to data limitation. If resources or funds are limited, it may be a good choice for the transportation department to put resources or funds in the major cities which is in blue area (greater possibility area) for cycling or bus mode and with better public transport infrastructure or service and higher cycling or bus modal share in order to promote sustainable modes use.

6. Conclusions

It is obvious that urban residential environment is more advantageous for commuters to travel to work by sustainable modes than rural environment. Considering absolute measures such as the difference in commuting modal share or relative measures such as odds ratios of commuting modes between urban and rural commuters at regional level was able to quantify differences in commuting preference and environmental advantages associated with commuting by bus, cycling and walking. As infrastructure or service dependent modes, bus and cycling almost showed similar global and spatial patterns in this study and urban area was found to have a greater impact on the probability of bus and cycling than walking as a simple condition dependent commuting mode.

This study examined the impact of residential environment on the growth of sustainable modes use for the MSOA level work population flow data analysis. GLM was used to estimate the relationship between residential environment and growth of sustainable modes use and a GWR analysis was used to capture the spatially non-stationary relationships. The results showed that growth of sustainable modes use in urban area was globally more likely than that in rural area, especially for bus and cycling use, and local variation in commuting by walking is less than for bus and cycling commuting. However, some cities were found to have a significant impact on bus and cycling commuting modes, while others were not, suggesting differences in uptake, infrastructure and service. These analyses can provide transport policy-makers with both a microscopic picture of the global opportunities to increase sustainable modes of commuting between urban and rural area through spatial policy, and local detail of where the uptake and use of existing resources and infrastructure, especially in urban areas, could be increased.

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