Origin-destination geodemographics for analysis of travel to work flows

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Abstract

This paper introduces a novel approach to the analysis of travel to work flows by combining separate geodemographic classifications of origins and destinations. A new classification of workplace areas is used in combination with an established official classification of residential areas. The approach is demonstrated using an empirical analysis of 26 million commuting flows in England and Wales, measured between the smallest residential and workplace areas in the 2011 census. The analysis demonstrates potential insights to be gained by this approach, revealing clear patterns in the structure of travel to work flows between geodemographic clusters. Our broad approach is not limited to use in specific countries and has potential application for use with data from non-census sources.

Key words

Travel to work, workplace zones, area classification, census, geodemographics, England and Wales

1. Introduction

In this paper we demonstrate a novel method for the analysis of spatially detailed, aggregate travel to work data by combining separate geodemographic classifications of trip origins and destinations and explore the flows between the clusters in these classifications. The generation and use of a separate, workplace-based, classification is, in itself, new. We apply this origin-destination approach to the 26 million travel to work flows recorded in 2011 census data for England and Wales. The representation and analysis of travel to work is important for understanding local labour markets, economic development, transport planning, daytime service delivery and more general insight into the factors underlying population mobility. Traditional sources such as censuses provide enormously powerful and complex travel to work data (Stillwell et al., 2010) which present challenges for analysis. These types of interaction data are available in many countries where censuses include a question about place of work, thereby providing a second georeferencing frame, additional to the place of usual residence which forms the basis for most small area census statistics. Sources of travel to work data range from long-established travel surveys and census microdata to new forms of real-time data with exciting potential, but none of these presently offer the combination of open access with full population coverage and detailed socioeconomic and spatial characteristics provided by census interaction data.

Complexity in travel to work data from all sources arises primarily from the large number of interactions, set within a very sparse origin-destination matrix. Rae (2016) presents an overview of the geography of travel to work using 2011 census data, focusing on the geovisualization of around 2.4 million small area interactions in England and Wales. The key challenge is one of data reduction, and spatial visualizations are constructed which allow important features of the data to be more readily seen and understood. The results powerfully present the geometry and magnitude of interactions but do not capture the social characteristics of the origin and destination areas. Geodemographic classification is a form of area classification and a powerful data reduction tool (Leventhal, 2016) which has found many applications, including market analysis and service planning. In this case, complexity arises primarily from the large pool of variables which are available to describe each small area. The use of geodemographic classification has become widespread but it has almost always been applied only to data for residential neighbourhoods.

Some previous studies (Debenham et al., 2003; Manaugh et al., 2010) have attempted to characterise travel to work flows by geodemographic classification of origin and destination areas. These have however been limited to classifications that are based on the same source data and spatial units for the locations of both residence and employment. The novelty of the approach proposed here is to combine separate classifications of places of work and residence, each based on the most appropriate geographical units and variables. We use outputs from the 2011 Census of England and Wales, which include separate small area geographies optimised for residential and workplace-based data products. We have used the official geodemographic classification of residential areas and undertaken an additional classification of workplace zones and here, for the first time, use the two classifications in combination.

The following section provides a brief review of geodemographic classification and analysis of travel to work, with particular reference to combination of relevant methods. The third section describes a new Classification of Workplace Zones for England and Wales (COWZ-EW), and the data and methods to be used here. We then present a series of analyses made possible by combining both residential and workplace-based classifications. The aim is not a comprehensive analysis of travel to work patterns, but demonstration of a new way to present and understand travel to work using origin-destination geodemographics.

2. Geodemographics and travel to work

Geodemographics refers to the classification of small areas based on reduction of multivariate aggregate data, typically involving a series of data preparation steps such as transformation and standardization, prior to application of some form of cluster analysis (Leventhal, 2016). Use of the term can be traced from the 1970s (Gale and Longley, 2013). The classifications seek to group areas based on their similarities and emerged as a methodological solution for handling highly dimensional census data (Webber, 1977). These classifications are conventionally applied to data representing the characteristics of residential populations, reflecting the fact that most geographical referencing is to residential addresses, whether from censuses, commercial or administrative sources. Geodemographics systems are internationally widespread and Poppie and Miller (2016) review the contemporary US scene, identifying a similar development trajectory to that in the UK. Output Area Classifications (OAC) for 2001 and 2011 covering the entire UK were developed entirely from small area census data and published as open data by the Office for National Statistics (ONS), the national statistical organisation for England and Wales, (Vickers and Rees, 2007; Gale et al., 2016). In addition to these official statistics, many classifications have been produced as commercial data products incorporating non-census sources, such as electoral registers, vehicle registrations, county court judgements, credit reference agency and lifestyle data (Leventhal, 2016), often in conjunction with census data. There are many data-informed but subjective design decisions required for any such classification, and the detailed methods and source datasets are not usually published for the commercial classification products.

The 2011 OAC is a geodemographic classification of residential areas created using 2011 census data for the smallest available output areas (OAs). Detailed accounts are provided in ONS (2015) and Gale et al. (2016), describing a similar methodology to that used for the 2001 OAC (Vickers and Rees, 2007). For the 2011 OAC, greater emphasis was placed upon reported user requirements, data selection and transformation issues, computational methods and new approaches to online visualisation and dissemination. Multiple methodological approaches were tested and evaluated, with particular emphasis on exploring how interactions between different methods and techniques influenced the final cluster solutions. Predicating this was a decision to use only open source software and the open release of all outputs and code through the website http://www.opengeodemographics.com. In total, 60 variables covering demographic, household composition, housing, socio-economic and employment domains were used. These were standardized, normalised and clustered using a *k*-means algorithm to create a three-tiered hierarchical classification comprising 8 Supergroups, 26 Groups and 76 Subgroups. The 2011 OAC is a key input to the analysis presented here.

Interest in analysis of commuting patterns to better understand aspects of, for example, urban spatial structure, employment and gender imbalances, home and work locations, commuting distances or excess commuting is internationally widespread. Recent studies employing a range of approaches to these issues include Sohn (2005), Kim et al. (2012) and Niedzielski et al. (2015) in the USA, Manaugh et al. (2010) in Canada, Novak et al. (2013) in Estonia, O'Kelly et al. (2012) in Ireland and Hincks (2012) in England. All pursue, in different ways, the description and analysis of travel to work flows between residential and business districts. Further, while many residential areas host very little work activity, in other areas work activity can reach enormously high concentrations, with many thousands of workers and sometimes quite different work activities occupying the same spatial units. A common challenge when using aggregate data is the inherently different spatial characteristics of places of residence and work. Data which differentiate residential areas well, including for example housing and household characteristics, are not the most appropriate for characterisation of workplaces. Most studies have used census residential geographical units to analyse variables for both origins and destinations of work trips, limiting the ways in which workplace destinations are demarcated.

Several families of purpose-specific geographical units such as Travel to Work Areas (TTWAs) in the UK (Coombes and Bond, 2008; ONS, 2015), POWCAR commuting catchments in Ireland (O'Kelly et al., 2012) and Metropolitan and Micropolitan Statistical Areas in the USA (Adams et al., 1999; Office of Management and Budget, 2010) have been developed to capture the structure of travel to work, using statistical measures to demarcate regions in which there is a degree of self-containment between resident and workforce populations. The increasing length of travel to work journeys is evidenced by the latest release of Travel to Work Areas (ONS, 2015) which continues the trend of reduction in the number of TTWAs defined by self-containment. Australian Bureau of Statistics (2011) and Federal Highway Administration (2010) describe additional geographical units (destination zones and traffic analysis zones, in Australia and US, respectively) created as more appropriate destination zones for transportation modelling than the standard residence-based census output units. However, these areas are all intended to encompass local commuting systems and therefore are designed at a scale too coarse to characterise differences between very small origin and destination areas.

It is attractive to use data which directly describe commuters, rather than the areas to and from which they are travelling. Kim et al. (2012) and Niedzielski et al. (2015) make use of US 2000 Census Transportation Planning Package (CTPP) data allowing commuting patterns to be broken down by occupation and gender or race/ethnicity and income respectively. Debenham et al. (2003) employ UK Special Workplace Statistics (SWS) and limited non-census workplace data but focus on a single set of medium-sized spatial units, in this case postcode sectors (mean population approximately 5100). CTPP and SWS-type products are effectively the richest of the aggregate datasets available from conventional census-based sources but do not contain the full range of census characteristics found in small area aggregate data. Where data about individual commuters are available in census microdata files such as the Irish POWCAR data (O'Kelly et al. 2012) or ONS controlled access microdata samples these are subject to tightly controlled access conditions and can rarely be used at the most detailed spatial scales. We propose that there is much still to be learned from further analysis of the rich aggregate data about flows between small areas.

Duke-Williams (2010) and Dennett and Stillwell (2011) describe a bespoke area classification for the study of migration flows, while Singleton et al. (2016) address the challenge of comparing geodemographic classifications between two censuses. In both of these cases, the focus is on understanding interactions between classifications of residential areas. Travel to work is subtly different, in that it relates to flows from residential areas, typically characterised by housing and family characteristics, to workplace areas, characterised by employee and business characteristics and it is with these flows that our interest lies here. Very few studies have attempted to employ geodemographic classification as a means of describing the origins and destinations of travel to work flows.

Hincks (2012) aggregates census travel to work data from the 2001 census in North West England to sub-regional housing market areas and TTWAs. He develops a six-way urban-rural classification of wards which is then applied to describe both origins and destinations. Analysis proceeds by looking at the pattern of the dominant, then second and third order flows into each TTWA, the latter tending to capture the longer commuting patterns. This is an interesting approach, allowing the strength of association between different area types to be measured, but is limited by the relatively large areal units and the same residential-based area classification being applied to places of both residence and employment. Nevertheless, the analysis reveals insights into the structure of the regional labour market. Area classification as a means of interpreting travel to work flows is most fully implemented by Manaugh et al. (2010) whose Montreal study uses a combination of travel survey and census data. They apply a factor-cluster analysis using a range of variables covering both socioeconomic characteristics and measures of urban form. They achieve a fine spatial scale, applying the classification to 150 x150m grid cells and undertake separate factor and cluster analyses on home and work locations, albeit using the same pool of input variables. However, the locations classified are limited to those cells containing home or workplace of individuals in the travel survey. The specific objective of their analysis is to model trip length using regression methods. We here propose a more generally applicable approach to the analysis of travel to work flows by combination of a residential classification of travel to work origin areas and a new classification of workplace destination areas, implemented at a national scale using the smallest available areal units for each.

3. Methodology and data

Our empirical study is based on the 2011 Census of England and Wales. It exploits the 2011 OAC and a new family of data products for a second sets of small areas known as workplace zones (WZs), developed specifically for the reporting of census workplace data (Martin et al., 2013). Using these workplace data, we have developed, in collaboration with ONS, a new geodemographic classification of workplace zones, known as the Classification of Workplace Zones – England and Wales (COWZ-EW). COWZ-EW comprises one half of the data input for our origin-destination geodemographic analysis. In this section we set out the data used and methods employed, including some necessary explanation of areal units.

OAs are the smallest units for which residential census data are published in England and Wales. They were originally generated in 2001 using an automated zone design procedure, and updated where necessary for 2011 (Cockings et al., 2011) to reflect changes in local government boundaries or underlying population distribution, although 97.4% were unchanged. They were explicitly designed to exceed residential thresholds of 100 persons and 40 households and the resulting zones have a mean residential population of 325. For the 2011 census, a second, entirely new, set of 53,578 WZs (compared with 181,408 OAs) was created, based on respondents' reported places of work, as described in Martin et al. (2013) and Mitchell (2014). Some WZs are the same as OAs but many OAs have been aggregated or subdivided to produce WZs with minimum thresholds of 200 workers and three workplace postal codes.

Although place of work questions have been included in previous censuses (and used to generate travel to work flow matrices), the very small workplace populations in many 2001 OAs constrained the publication of OA-level statistics and just four univariate tables were produced relating to workplace population, insufficient for any meaningful small area classification. The introduction of WZs in 2011 ensured sufficiently sized workplace populations to permit publication of 25 data tables relating to workplace population, covering a broad range of individual demographic and socioeconomic characteristics, as well as Standard Industrial Classification of workplaces and journey to work characteristics such as mode and distance travelled. These data provided the opportunity to undertake a new classification of WZs to create COWZ-EW. In order to provide consistency between the two classifications of small area census outputs, COWZ-EW adopted the same methodological approach as the official 2011 OAC, adopting a sequence of standardization, normalisation and *k*-means clustering of 48 variables into a two-tiered classification comprising 7 Supergroups and 29 Groups. Details of variable selection and calculation stages are provided in Cockings et al. (2015). Both classifications include personal demographic variables, but COWZ-EW excludes variables relating to residential characteristics such as housing and household composition, focusing instead on variables from the workplace tables and georeferenced to workplace locations. The classification highlights distinct workplace types such as industrial estates, business and retail parks and town centres. Berry et al. (2016) is the first study to utilise the COWZ-EW classification, focusing on retail store performance in relation to the characteristics of work-time catchment population characteristics, but their analysis employs the workplace data independently of interaction flows.

Our intention in the following analysis is to explore the structure of travel to work in England and Wales in terms of travel between the clusters of the residential 2011 OAC and the workplace COWZ-EW. These effectively represent the types of residential and workplace neighbourhoods between which commuters travel. 2011 SWS data (ONS, 2014a) provide counts of persons travelling to work from each OA of residence (origin) to WZ of primary employment (destination). Some initial processing is required to allocate all journeys to OA-WZ pairs. For the vast majority of journeys the origin OA and destination WZ reported in the SWS may be used directly. However, individuals who work from home or have no fixed place of work are deemed by ONS to both live and work at the same location (their residential OA) and home-working is itself an important characteristic of some neighbourhood types. Where these OAs and WZs have identical boundaries, allocation is straightforward but where they partially overlap, it is necessary to impute a WZ to be associated with the OA for analysis. There are several possible ways to do this, for example the OA may be assigned to the nearest WZ based on the distance between their population-weighted centroids, or on the basis of the greatest overlap of geographical area or cluster assignment. We have assessed all three options and found little difference in terms of the overall relationship between 2011 OAC and COWZ-EW clusters, hence the nearest centroid method has been used here. COWZ-EW does not include individuals who live in England and Wales but work offshore or outside the two countries, as these destinations necessarily fall outside the geographical scope of the classification.

All the census statistics, geographical references and the 2011 OAC are available as census outputs and COWZ-EW data have been published by the authors. All data used here may thus be freely downloaded under open data licences and relevant URLs are listed in Table 1.

Table 1: Download locations of input data sources

Dataset	Source URL (Accessed 22.09.16)

2011 OAC	http://www.ons.gov.uk/methodology/geography/geographicalproducts/areaclassifications/2011areaclassifications/datasets
2011 COWZ-EW	http://cowz.geodata.soton.ac.uk/download/
2011 OA boundaries	http://geoportal.statistics.gov.uk/datasets/09b8a48426e3482ebbc0b0c49985c0fb_0
2011 WZ boundaries	http://geoportal.statistics.gov.uk/datasets/a399c2a5922a4beaa080de63c0a218a3_0
2011 SWS	https://www.nomisweb.co.uk/census/2011/wf02ew

Journeys to work can be characterised in terms of the 2011 OAC residential cluster from which they originate and the COWZ-EW workplace cluster where they end. Based on the 8 2011 OAC and 7 COWZ-EW Supergroups we have a 56-way classification of journeys to work. At the Group level, flows between 26 2011 OAC Groups and 29 COWZ-EW Groups result in a 754-way classification, although there are small numbers in some of these combinations. Naming of geodemographic clusters is contentious but can provide intuitive shorthand labels for the area types, albeit not without risks of misrepresentation (Goss, 1995; Parker et al., 2007; Vickers and Rees, 2007). For consistency we here use the previously published 2011 OAC and COWZ-EW numbers and names. Full multivariate profiles, including textual and statistical description of each Supergroup and Group are available at: http://www.ons.gov.uk/methodology/geography/geographicalproducts/areaclassifications/2011areaclassifications/penportraitsandradialplots and http://cowz.geodata.soton.ac.uk/download/. Interactive mapping of both classifications is available at: http://oac.datashine.org.uk and http://cowz.datashine.org.uk respectively. In our mapping, we use colour palettes consistent with these sites in order to permit direct visual comparison.

Using this combination of a new workplace classification with existing official statistics, many substantive questions may be addressed and we are here only able to demonstrate the analytical potential rather than comprehensively explore travel to work patterns. In the following section we firstly compare the overall national distributions at the Supergroup level by independent mapping of the classifications. We then explore the pattern of flows between Supergroups by cross-tabulation, considering distances travelled and focusing particularly on flows which are much larger or smaller than expected. If there were no pattern to the relationship between the residential and workplace classifications, the flows would simply be proportional to the marginal population totals of the origin and destination Supergroups. To better understand the anatomy of the flow matrix, we calculate observed minus expected flows, divided by expected flows. Thus cells with positive values represent interactions larger than expected and negative values smaller than expected. The extreme low and high values are interesting because they indicate levels of strong separation and association in travel to work between neighbourhood types. We also calculate median distances for all the interactions in each cell. It is not feasible to represent all 754 interactions at the Group level in a conventional table, so we instead use a graphical table based on divergence from uniform interaction as calculated above. We then move to mapping the pattern of workplaces to which residents travel, revealing the ‘home geography’ of commuters over a large regional scale using the workplace classification to explore first, second and third order flows in the manner of Hincks (2012). Finally, we explore the spatial intersection of the two classifications and again use a graphical table to show the extent to which types of residential and workplace neighbourhoods are co-located.

4. Results

Figures 1 and 2 map the 2011 OAC and COWZ-EW at the Supergroup level, side by side, with insets showing Greater London. The detailed pattern of individual OAs and WZs is not visible at these scales and the Supergroups with the highest population densities cover very small land areas. Nevertheless, some important general observations are possible which help to introduce the key features of the two classifications. Firstly, the Supergroups labelled Rural in both classifications dominate the land surface. A greater proportion of WZs are classified as Rural in COWZ-EW than OAs in the 2011 OAC but the two are highly spatially overlapping. All other Supergroups in both classifications are essentially urban or suburban in nature. In both cases, Greater London is almost entirely accounted for by non-rural classifications but its internal subdivision is quite different. The 2011 OAC displays patterns of residential classification which are broadly similar to many other geodemographic classifiers. London displays a broadly concentric pattern, with the Cosmopolitans Supergroup in the centre, surrounded by Ethnicity Central and then a broad band of Multicultural Metropolitans. It is also apparent that across the east and south there is a swathe of more mixed classes including many Suburbanites. London has few OAs classified in the lower status Constrained City Dwellers and Hard-Pressed Living categories. The latter Supergroup is however much more clearly visible in areas of former heavy industry in the north and west of England and in Wales. The COWZ-EW, by contrast, displays a much closer relationship to recognized industrial structures, with the Top Jobs Supergroup appearing only in the innermost areas of London and the major metropolitan areas, whose outer areas are primarily classified as Metro Suburbs. The Suburban Services and Manufacturing Supergroups are mostly absent from core urban areas, but are found across industrial regions and the outer suburban areas of many cities. The Retail and Servants of Society COWZ-EW Supergroups (the latter containing much local administration, educational and healthcare employment) are widely dispersed but rarely account for large adjacent areas, retail activity often being concentrated in local high streets and centres with small spatial extents. There are thus frequently-repeated patterns across many towns and cities but with London and the major conurbations displaying extreme concentrations, particularly of those Supergroups reflecting ethnic diversity and higher status employment. Northern and western regions of the country are more heavily represented by lower status residential and workplace Supergroups, which appear only in small sectors of the major conurbations.

Table 2 and Figure 3 present for the first time the geodemographic structure of 26,681,568 individual journeys to work from 2011 OAC Supergroups to COWZ-EW Supergroups (Table 2) and 2011 OAC Groups to COWZ-EW Groups (Figure 3), reflecting the complex commuting patterns between and within the clusters mapped in Figures 1 and 2. Considering Table 2 first, the row and column headings show the Supergroup numbers and names. The first value in each cell contains the number of people in employment travelling from all OAs in one 2011 OAC Supergroup to all WZs in one COWZ-EW Supergroup, the second shows the (observed-expected)/expected value and the third is the median travel distance in km, with a mean of 474,442 journeys in each cell. At the Group level, it is not feasible to reproduce all the values (mean 35,387 per cell) in conventional table format, but the graphical table in Figure 3 provides a rich visualization of the flow structure, referenced by the Group level numbers and names. The symbol shading represents quintiles of divergence of (observed-expected)/observed, with the black icons representing the top quintile (values above +0.45) and the white ones the lowest quintile (values below -0.73). Any cells with expected flows of less than 3,538 (10% of mean) have been suppressed to reduce the visual impact of small numbers, which particularly affect 2011 OAC Groups 3c: Ethnic Dynamics and 7b: Constrained Flat Dwellers. These tabular and graphical representations are effectively new geodemographic classifications of journeys to work, with 56 and 754 clusters respectively.

Figure 1 2011 OAC Supergroups, England and Wales with London inset

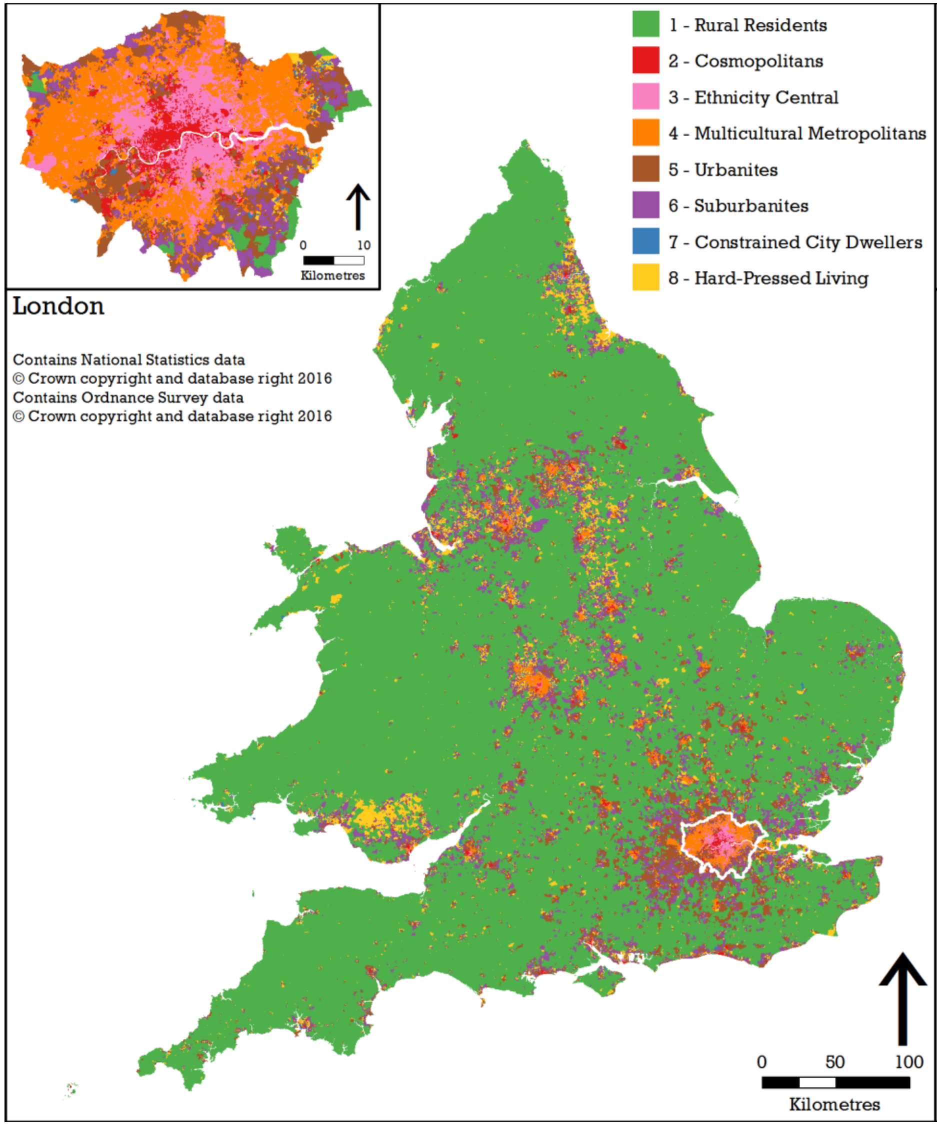


Figure 2 COWZ-EW Supergroups, England and Wales with London inset

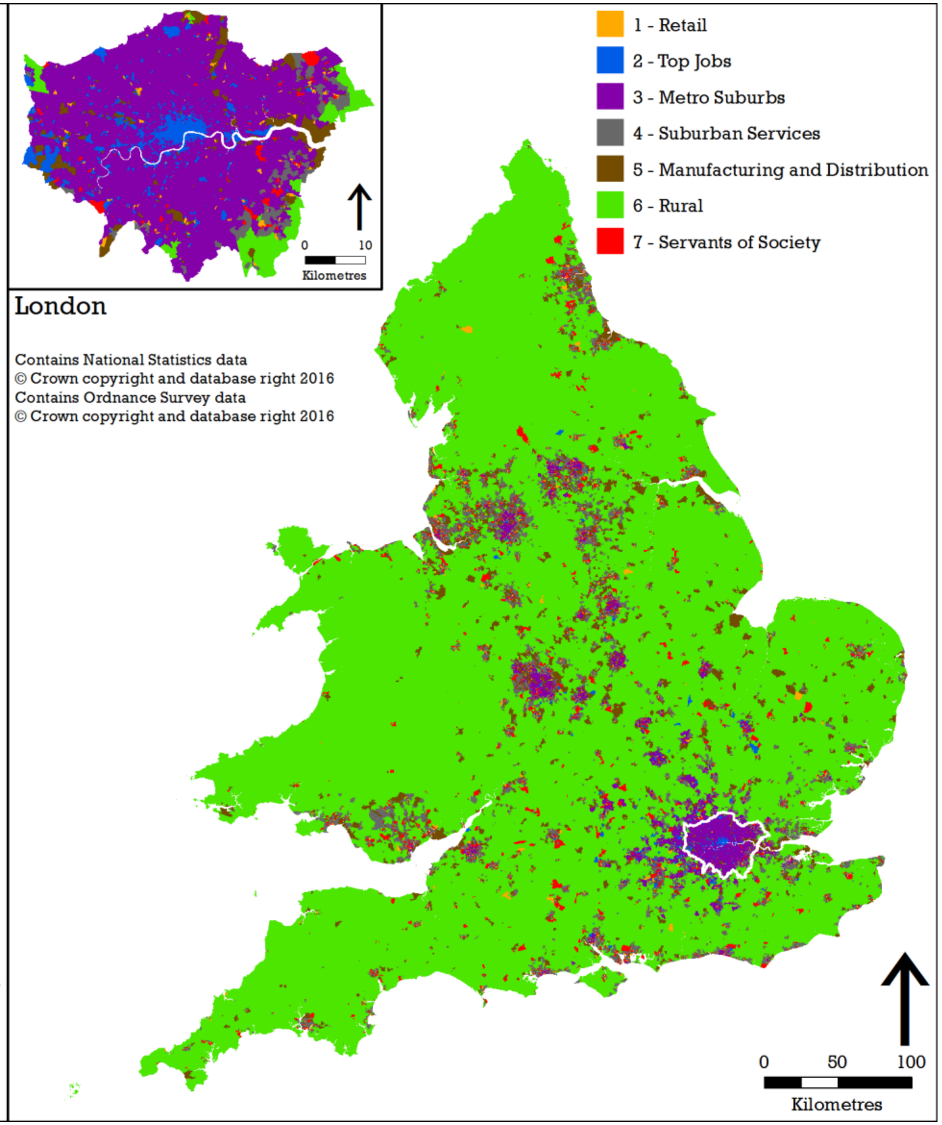
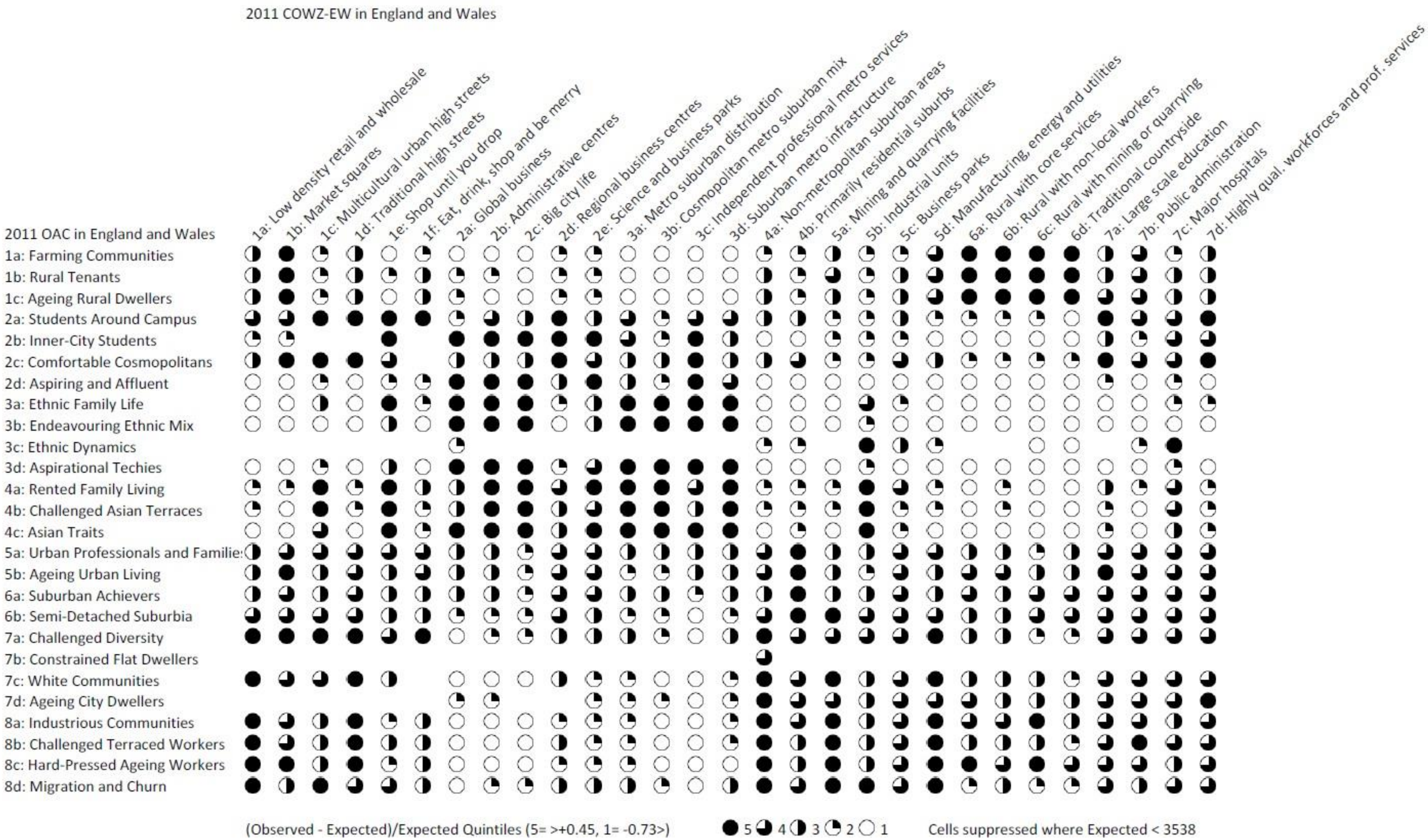


Table 2 Observed flows 2011 OAC to COWZ-EW Supergroups: count of flows, (divergence from expected), median distance (km)

2011 OAC (rows) and COWZ-EW (columns)	1: Retail	2: Top Jobs	3: Metro Suburbs	4: Suburban Services	5: Manufacturing and Distribution	6: Rural	7: Servants of Society	Total
1: Rural Residents	236,321 (-0.24) 9.63	**147,438** **(-0.67)** **36.76**	**49,501** **(-0.87)** **18.79**	254,100 (-0.43) 7.37	432,406 (-0.16) 11.48	**1,467,315** **(2.25)** **0.00**	429,776 (-0.09) 13.06	3,016,857 (-0.03)
2: Cosmopolitans	162,125 (0.09) 1.38	**590,897** **(1.76)** **5.19**	274,534 (0.49) 0.18	**83,889** **(-0.61)** **2.45**	**97,674** **(-0.61)** **6.80**	**42,827** **(-0.8)** **14.78**	200,909 (-0.11) 2.07	1,452,855 (0.03)
3: Ethnicity Central	**63,040** **(-0.62)** **3.18**	**726,986** **(2.09)** **6.30**	**633,787** **(2.13)** **0.91**	**20,789** **(-0.91)** **6.55**	**79,809** **(-0.71)** **6.09**	**12,154** **(-0.95)** **22.06**	**59,022** **(-0.76)** **3.27**	1,595,587 (0.04)
4: Multicultural Metropolitans	320,418 (-0.14) 3.06	**823,151** **(0.55)** **10.00**	**1,226,815** **(1.68)** **0.96**	194,758 (-0.63) 3.24	566,335 (-0.08) 4.66	**94,989** **(-0.82)** **12.01**	381,947 (-0.32) 3.10	3,608,413 (0.03)
5: Urbanites	588,729 (0.07) 2.98	748,044 (-0.05) 15.18	535,750 (-0.21) 2.33	943,624 (0.21) 0.60	867,347 (-0.05) 6.40	661,155 (-0.17) 3.57	987,326 (0.19) 4.46	5,331,975 (0)
6: Suburbanites	594,766 (0) 4.70	578,403 (-0.32) 18.06	380,406 (-0.48) 4.39	1,177,434 (0.39) 0.79	1,099,125 (0.11) 7.51	876,906 (0.01) 1.69	1,085,371 (0.2) 6.50	5,792,411 (-0.01)
7: Constrained City Dwellers	210,815 (0.5) 2.19	**87,213** **(-0.57)** **11.51**	88,406 (-0.49) 3.03	279,078 (0.4) 0.76	312,423 (0.34) 4.43	140,888 (-0.31) 5.45	245,127 (0.15) 3.42	1,363,950 (0)
8: Hard-Pressed Living	555,561 (0.23) 3.52	**211,293** **(-0.67)** **14.97**	**180,380** **(-0.68)** **4.85**	939,961 (0.46) 0.84	1,085,488 (0.44) 5.42	676,008 (0.03) 3.07	758,025 (0.10) 5.22	4,406716 (-0.01)
Total	2,731,775	3,913,425	3,369,579	3,893,633	4,540,607	3,972,242	4,147,503	26,568,764

Figure 3 2011 OAC Group to COWZ-UK Group flows: quintiles of relationship between observed and expected flows



As with the maps, a striking feature of Table 2 is the relative self-containment of rural areas (Rural-Rural flows 2.25 times greater than expected), with Rural Residents underrepresented in every other workplace type, especially Top Jobs and Metro Suburbs. These patterns are intuitively meaningful, with very few residents of most urban areas travelling to work in rural areas. Figure 3 reveals this even more starkly, with each individual Group level flow within the Rural residential and workplace Supergroup being in the top quintile. The only other COWZ-EW Group in the top quintile of destinations from Rural 2011 OAC Groups is 1b: Market Squares, reflecting work travel from rural areas into smaller towns and illustrating the sensitivity of the combined classifications to distinctive between-group flows.

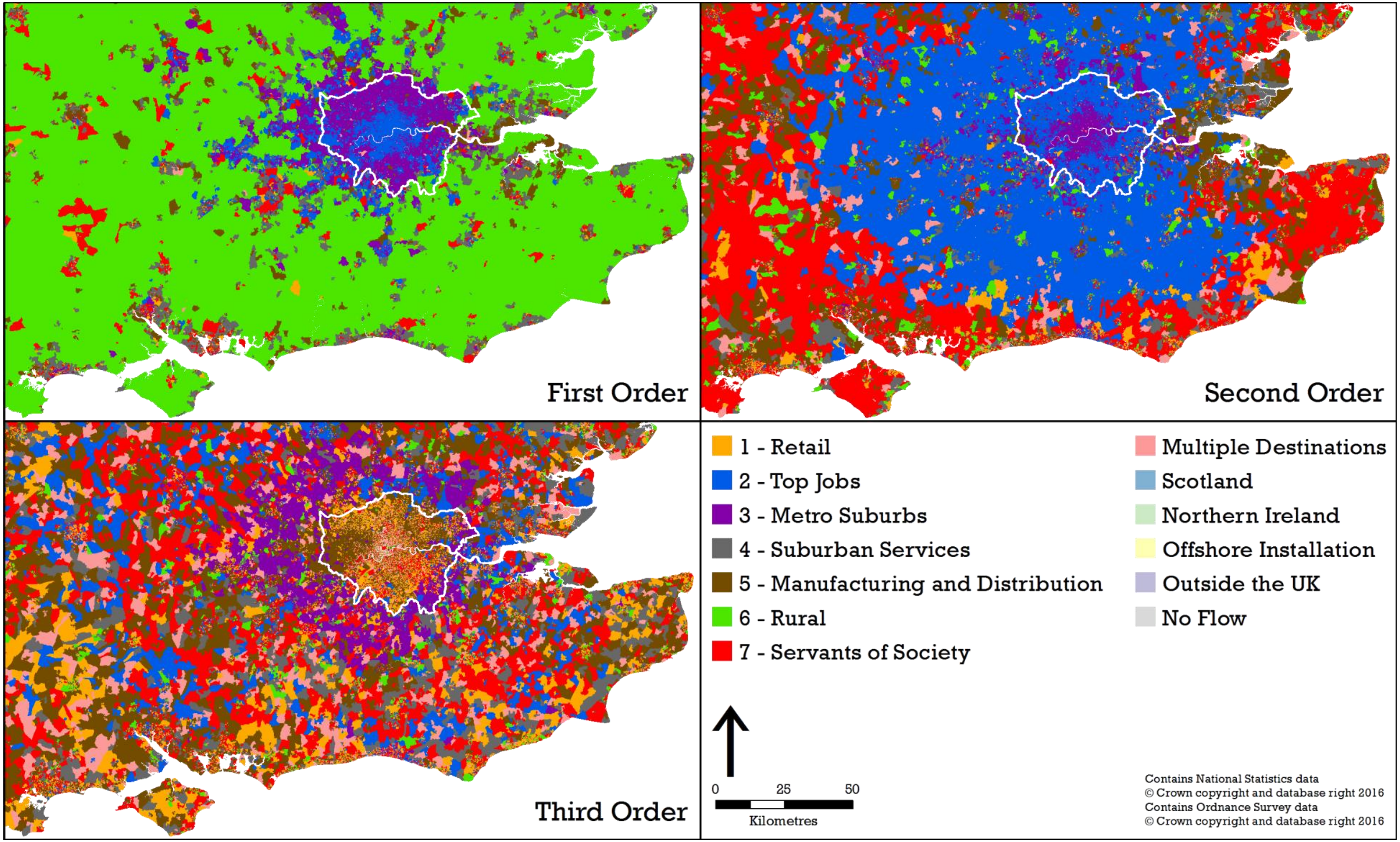
Three of the residential 2011 OAC Supergroups: Cosmopolitans, Ethnicity Central and Multicultural Metropolitans have very few rural workplace destinations but differ from one another in other respects. Numerically, the smallest flow in Table 2 is from the 2011 OAC Cosmopolitans to the COWZ-EW Rural, with 42,827 trips, but at the same time Cosmopolitans Supergroup residents are underrepresented in Suburban Services, Manufacturing and Distribution and very strongly overrepresented in Top Jobs (1.76). Again, the group level reveals additional structure, for example the striking overrepresentation of the 2011 OAC Group 2a: Students Around Campus in all types of Retail workplace, reflecting student employment particularly in large purpose-built retail and entertainment centres in 1e: Shop until you drop and 1f: Eat, drink, shop and be merry (5.34 times larger than expected). By contrast, 2011 OAC Group 2d: Aspiring and Affluent is underrepresented in all types of Retail workplace, but reflected in commuting from some of the highest status residential areas, with the group-level flow to the COWZ-EW Global Business Group (7.01 times larger than expected), being the largest value underlying Figure 3.

The Ethnicity Central 2011 OAC Supergroup, which is itself concentrated in London and major metropolitan areas with significant ethnic diversity, is the most starkly divided of the 2011 OAC Supergroups in terms of workplace destinations, with strong overrepresentation in Top Jobs (2.09) and Metro Suburbs (2.13) and underrepresentation across all other COWZ-EW Supergroups and this is also seen across most of its groups. Another notably large flow is that between Multicultural Metropolitans and Metro Suburbs, which represents complex urban commuting flows between suburban residential and business areas. The Urbanites and Suburbanites residential Supergroups are the least patterned in terms of workplace destinations, with flows the closest to expected values, demonstrating the diverse and complex trips undertaken by 11 million urban and suburban residents into all types of working neighbourhood. The last two rows of Table 2 represent the Constrained City Dwellers and Hard-Pressed Living residential Supergroups, which are notable for their relative absence from the highest status workplace Supergroups Top Jobs and Metro Suburbs. These origins serve primarily lower status workplaces including Retail, Suburban Services and Manufacturing and Distribution, with some overrepresented Groups such as 1a. Low Density Retail and Wholesale, 4a. Non-metropolitan Suburban Areas, 5a. Mining and Quarrying Facilities and 5d. Manufacturing, Energy and Utilities. The Constrained City Dwellers Supergroup is the smallest overall and the 2011 OAC Group 7b. Constrained Flat Dwellers is suppressed in Figure 3 where it intersects with the smallest COWZ-EW Groups, especially in Retail. It is notable that COWZ-EW Supergroup Servants of Society draws widely from across 2011 OAC Supergroups, reflecting the widespread range of occupations within public service employment such as education and health care.

Overall, we see a pattern of high self-containment of rural areas, complex self-contained mixing of lower status suburban areas and highly selective interactions between the more cosmopolitan and ethnically diverse suburban areas and central business districts. The underlying data permit all these patterns to be explored in far greater detail, for example in terms of the trip lengths shown in Table 2. At the Supergroup level the longest median flow distance is from the 2011 OAC Rural to COWZ-EW Top Jobs which, while less common than expected, still accounts for 147,438 journeys to work with a median journey length of 36.76km. In general, the high status Top Jobs COWZ-EW Supergroup commands consistently long commuting distances, while some of the lowest distances are found among the suburban clusters. Also notable is the median distance of zero between the 2011 OAC and COWZ-EW Rural Supergroups reflecting the prevalence of working from home or at no fixed address within these areas. Those travelling into Rural COWZ-EW Supergroups from Cosmopolitans and Ethnicity Central are among the smallest numbers, and the longest distances. At the group level we begin to see a pattern whereby some types of residential areas are almost entirely without interaction with some types of workplace, even when setting aside small absolute Group sizes. The wholly white symbols represent a dimension of population segregation not usually considered in conventional analyses of residential location.

Another way of considering the flows between places of residence and work is to map residential areas according to the workplace destinations of their principal flows. In Figure 4 we map OAs in terms of the COWZ-EW Supergroup destinations of their first, second and third largest commuting flows. The legend includes flows to destinations outside England and Wales and thus outside the scope of COWZ-EW although there are very few of these. Multiple destinations refers to OAs where more than one destination COWZ-EW Supergroup has the same value. We here concentrate on the south east of England, covering a much wider area than the Greater London inset in Figures 1 and 2. The first order flows reveal the spatial consequences of rural activities being the primary workplace destination in most rural areas, with workers in Top Jobs being drawn both from the very central residential areas and also from the outer urban fringes. For the remaining majority of London's built-up area, Metro Suburbs jobs are the primary destination. The importance of Servants of Society in urban areas outside London is apparent, as is the corridor to the east of London, where Suburban Services and Manufacturing and Distribution Supergroups dominate. The second order map is completely different, revealing the huge spatial range of high status commuters, with almost the entire mapped region contributing to Top Jobs workplaces, from up to 100km distant (made possible by an extensive suburban commuter rail network). In the very centre of London this is replaced with commuting out to Metro Suburbs. Beyond London commuting, the Servants of Society Supergroup is widely evident, but Manufacturing and Distribution and Retail begin to gain prominence in local areas. The third order map is very different again, reflecting the complex but localised flows of workers into generally lower status employment, with Retail and Manufacturing and Distribution evident across the map, now that the major effects of rural employment and long-distance commuting have been filtered out. In this map the capital city is surrounded by an almost unbroken outer belt of workers who commute into Metro Suburbs employment. Some residential areas (particularly in central London) are dominated by flows to a single type of workplace, while others reveal a wide dispersal of commuters across workplace types. Clearly, a fuller understanding would require more advanced analysis of the flow matrices, which is beyond the scope of this paper.

Figure 4 First, Second and Third order dominant COWZ-EW destination Supergroups by output areas

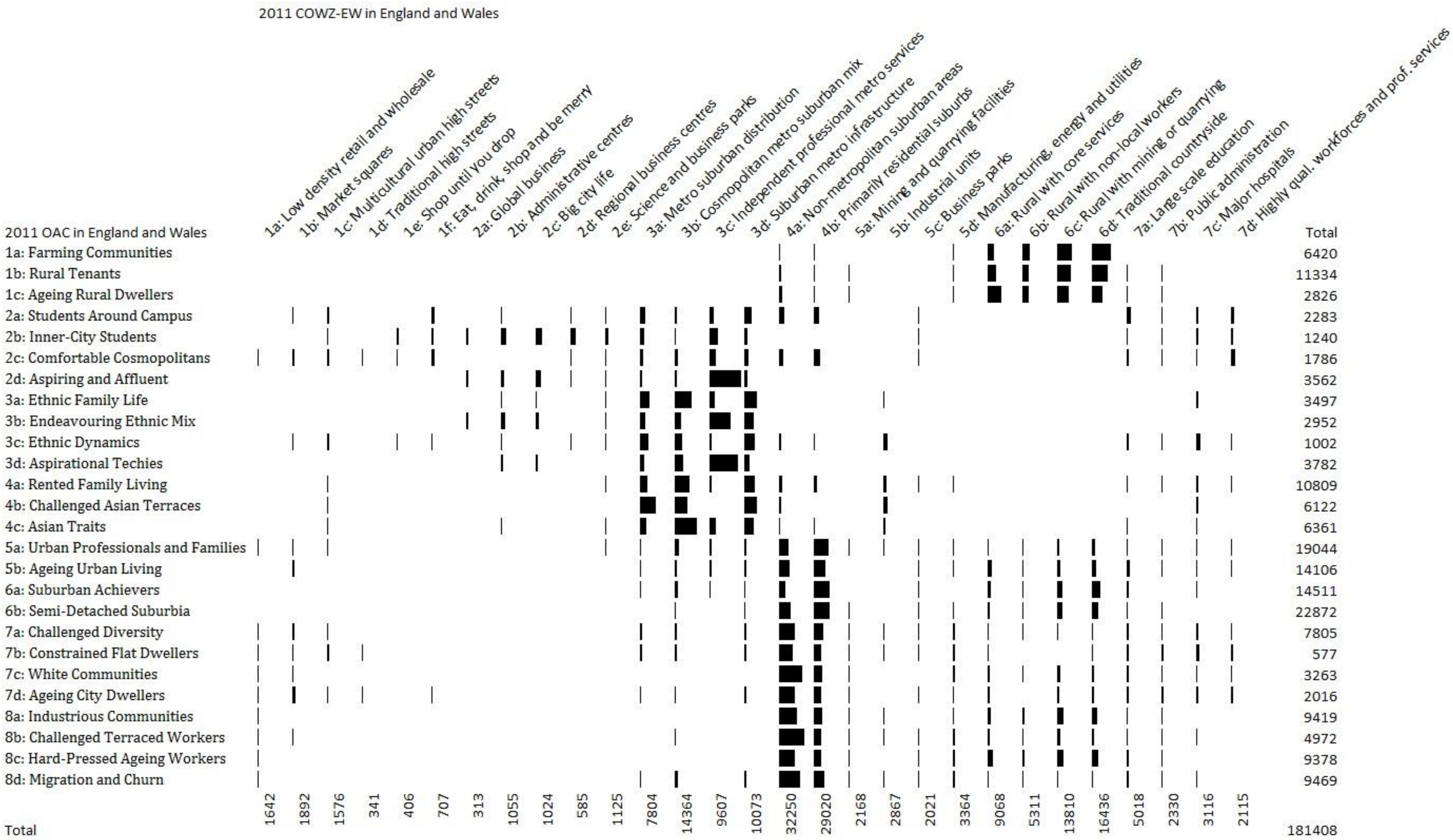


A further possibility for exploiting the combined classifications is to consider how COWZ-EW adds information to the 2011 OAC, already established as the official classification of residential areas. The graphical table in Figure 5 shows the proportions of OAs within each 2011 OAC Group (rows) that are spatially coincident with each COWZ-EW Group. As expected, where commuting distances are low, as in all the Rural Groups, the pattern is very similar to travel to work in Figure 3 as people are essentially living and working in the same places. However, different 2011 OAC Groups are related in quite different ways to workplace activity. 2c. Comfortable Cosmopolitans is broadly spread across many COWZ-EW Groups, but absent from a few such as 5a. Mining and quarrying facilities and 5d. Manufacturing and distribution, while others such as the 2011 OAC Group 3d. Aspirational Techies are heavily concentrated in very few COWZ-EW Groups, in this case dominated by 3c. Independent Professional Metro Services. The structures of Figures 3 and 5 are related, being similar where commuting distances are small, but quite different where longer-distance commuting leads to large transfers between distant residential and workplace Groups. It is visually striking how the four 2011 OAC Supergroups at the bottom of the table are strongly concentrated in the two Groups belonging to the COWZ-EW Supergroup Suburban services. These types of pattern offer important insights to those who would seek to use conventional residential classifications for example to target the delivery of services, as further differentiation is clearly possible based on those likely to be working as well as living within these areas. Further analysis would readily begin to identify those areas where daytime (working) and nighttime (residential) populations are broadly similar in social characteristics and others where they are largely different populations.

5. Discussion

Geodemographic classification is widely used as a means of multivariate data reduction for the differentiation of residential areas. Travel from home to work continues to be an important area of research and policy interest having many implications for transportation planning, social mixing and energy use. Although microdata are sometimes accessed by researchers these are generally sampled census or survey records, coded to large geographical areas due to their potentially disclosive nature. Even where researchers have made forays into classification of origin and destination areas (Debenham et al., 2003; Manaugh et al., 2010), the same geographical referencing frame and the same, mostly residential, characteristics have been used to classify both trip ends. These approaches fail to capture the very different dimensions that characterise places of residence and work: geodemographic classifications which are good at differentiating housing types are not well-suited to differentiating between retail parks and universities, for instance. In response, we have created an entirely new classification of small area workplace data and combined this with an existing official classification, to develop the concept of origin-destination geodemographic classification. It is worthy of note that these residential and workplace classifications are not entirely independent – in our application, both are sourced from the same census and have partially overlapping sets of input variables. No definitive validation is possible of a specific classification as it represents a data reduction rather than a directly measurable empirical reality. However, the stark clarity of some of the resulting patterns, for example in the structure of Table 2 and Figure 3, suggests that much important structural information has been captured through the intersection of these two classifications.

Figure 5 Spatial coincidence of 2011 OAC Groups with COWZ-UK Groups: proportions of 2011 OAC Groups



We have used these paired area classifications for a series of illustrative explorations of travel to work, but it is the underlying classification datasets rather than the specific empirical observations which are the most important feature of this paper. This method for classifying travel to work flows offers multiple avenues for investigation, exploring the characteristics of flows between residential clusters workplace types, identifying the varying levels of connection between the different groups and the distances travelled between them. There are many potential extensions, including investigation of the exclusivity of some of these relationships in terms of narratives on equality of access to employment, the structure of urban systems, modes and costs of travel and relationships between wages and housing costs in different areas. The 2011 England and Wales census did not include a question about travel times, but an application meriting further work would be to use the origin-destination classifications as a means of stratifying analyses of travel survey data, which might also be extended to consider provision and barriers to public and private transport between the 20111 OAC and COWZ-EW clusters.

The quality of the classifications is dependent on the original census data, and although questions relating to work and workplaces are found by quality surveys to be among the least accurately answered among census questions (ONS 2014b), they still offer a unique combination of high population coverage and rich socioeconomic detail compared to alternative sources. Further, there are many alternative classification methods, none of which can be considered definitive and our approach could be implemented using entirely different classifications of both origin and destination neighbourhoods. For example, non-census workplace data of the type used by Debenham et al. (2003) could be combined with a workplace geography to undertake analysis similar to that introduced here. Chow et al. (2014) undertake a multisource data analysis of urban traffic congestion in London, including Oyster public transport travel card data. By contrast Birkin et al. (2014) analyse spatial patterns of Twitter behaviour, providing some information on the likely activities in which users are engaged at different locations, but not specific to travel to work. Novak et al. (2013) are one of the few research teams to have explored commuting flows using mobile telephony data, focusing on studies of Tallinn, Estonia. In isolation, the new forms of data do not provide much detailed characterisation of either the commuters or the neighbourhoods of residence and employment, but could readily be used to measure the magnitudes of flows that may be characterised using the origin-destination geodemographics introduced here.

6. Conclusions

We have demonstrated an approach to the investigation of travel to work by using purpose-specific geographical units and geodemographic classifications for places of residence and employment. The availability of new workplace geographies and classifications overcomes recognised data limitations and analytical challenges, and potentially offers new dimensions to our understanding of the complexity of workplaces and travel to work. The COWZ-EW classification recasts the census datasets in terms of the working population at their places of work and thus provides a rich description of the small area geography of employment as a counterbalance to traditional geodemographic classifications of residential areas. Although demonstrated using England and Wales census data, there is nothing nationally specific about the proposed approach. The key innovations are the construction of a national small area workplace classification and particularly the combination of the origin and destination classifications as a basis for exploring the structure of commuting flows. We anticipate the publication of WZs and a workplace classification for the whole of the UK and comparable datasets could be constructed in many countries. More generally, origin-destination classifications have power for the reduction and visualization of travel to work data.

This paper comes at a time when there are major changes taking place in censuses globally, and increasing moves towards the replacement of census data with administrative information (Ralphs and Tutton, 2011). However, our approach will continue to have considerable merit in characterising trip origins and destinations: the key point is that the classifications need to reflect the different domains relevant to the characteristics of residential and workplace neighbourhoods. Rather than being limited to the analysis of census aggregate data, the approach proposed here has the potential to offer a common framework for the interpretation of trip magnitudes derived from many of these new forms of data.

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