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Delivering Census Interaction Data to the User: Data Provision and Software Development

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ABSTRACT

The Census Interaction Data Service (CIDS) is a Data Support Unit providing access for researchers in the UK to the interaction data sets that are produced by the Census Offices. These migration and commuting data sets are large and complex, differing from the area statistics by virtue of the fact that they involve two geographies – one of origin and the other of destination.

WICID, the web-based software system developed to provide the user interface to the Special Migration Statistics (SMS) and the Special Workplace Statistics (SWS) from the 1991 Census, has now been upgraded to allow registered users of census data to extract subsets of the 2001 interaction data sets. These include 2001 SMS and SWS as well as a new set of Special Travel Statistics (STS) for flows in Scotland. The data sets are different from those in 1991, not least because aggregate flow counts are available at the scale of output areas, as well as wards and districts, and because the method of data adjustment to eliminate the risk of disclosure is different from that used in 1991.

This paper is in three sections. Firstly, the 2001 interaction data sets are outlined and compared with what was produced in 1991. Work on the re-estimation of 1981 and 1991 data consistent with 2001 geographical boundaries is summarised and the effects of the small cell adjustment method (SCAM) are examined using migration data at three different spatial scales. Secondly, we illustrate the developments of the WICID user interface that have been made to incorporate 2001 data and to add some analytical functionality. Finally, we exemplify the type of analysis that the WICID system can be used to support choosing selected data sets from the 2001 Census.

Keywords: census, interaction, data, migration, commuting, interface, query, analysis

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1 Introduction

The decadal Census of Population is the most reliable and comprehensive source of information on migration and commuting in Great Britain and Northern Ireland, providing counts of flows of individuals, households or moving groups between origins and destinations. These extensive data sets, often referred to as the Origin-Destination Statistics or interaction data sets, provide information about the composition and pattern of migration in the 12 month period prior to the census as well as details of journey to work flows at the time when the census was carried out. During 2004, the interaction data collected by the 2001 'one-number' Census in the UK were released by the census agencies through a phased programme of delivery.

As with 1981 and 1991, there are two major interaction data sets for 2001, the Special Migration Statistics (SMS) and the Special Workplace Statistics (SWS). However, in Scotland, the SWS are replaced with a new set of Special Travel Statistics (STS) that include journeys to place of study and well as place of work. Various sets of SMS/SWS/STS were released at different times during 2004 by the census agencies according to spatial scale and also type of migration flow. Origin-destination data covering the UK as a whole were initially made available for flows between census output areas and flows between wards. Data on local authority level flows and on migration flows for moving groups were released subsequently, followed by the flows between postcode sectors covering people living in Scotland.

The initial aim of this paper is to explain the structure and content of the interaction data sets that are currently accessible via the Census Interaction Data Service (CIDS), an ESRC/JISC-funded Data Support Unit enabling members of the academic community and data suppliers registered with the Census Registration Service, to extract and download data for research and teaching. This process is undertaken using WICID, the web-based system that is used to store the data sets and to provide user-friendly query facilities so that extraction can be achieved with the minimum of difficulty (Stillwell and Duke-Williams, 2003). Since the 2001 data sets have been added to the existing database, the data are compared with those available in 1991, the deficiencies in the data sets are considered and the 1991 data sets that have been re-estimated for 2001 geographical areas are outlined. The second aim of the paper is to demonstrate some of the new features of the WICID system that have been incorporated to facilitate query construction but also to enable some online analysis with extracted data prior to downloading. Finally, in the last part of the paper, some examples are presented of the analysis of migration and commuting data using flows for the boroughs of Greater London extracted from the SMS and SWS.

2 Data sets and characteristics

2.1 Primary interaction data sets for 2001

The 2001 SMS and SWS are larger and more complex data sets than those that preceded them in 1991 or in 1981. They are larger partly because the 2001 Census results were the first to include data for Northern Ireland alongside the rest of the UK, but primarily because flows are provided between spatial units at a new scale below that of wards. Whilst data were collected in the 2001 Census by enumeration district as in previous censuses, these collection units have not been used for output. Instead, data are released for a set of output areas (OAs) at the smallest scale, areas that are built from postcode units that tend to have around 125 households within each of them. The OA is the building block for geographies based on either of the two postcodes collected on the census form in the migration and commuting questions, i.e. address one year ago and destination of travel to work (or study in Scotland).

The primary 2001 migration and commuting data come in three sets, where each set refers to a particular level or set of spatial units (Table 1). Level 1 contains the local authority districts across Great Britain, together with parliamentary constituencies in Northern Ireland. Level 2 is referred to as the ward level and contains and amalgamation of Census Area Statistics (CAS) wards in England and Wales and Standard Table (ST) wards in Scotland. Wards used in the CAS are slightly different from those used in the Standard Tables. This arises because there were some instances (about 50) where CAS ward counts were below the permitted threshold and therefore these units had to be merged with neighbours. There are no differences between the CAS and ST wards in Northern Ireland. Thus, since there is a mixture of wards at level 2, the spatial units are referred to collectively as ‘interaction wards’. The spatial units at level 3 across the UK are output areas.

Table 1: The geographical units used for 2001 SMS/SWS/STS at different levels

Country	Level 1	Level 2	Level 3
England	London Boroughs (33), Metropolitan Districts (36), Unitary Authorities (46), other Local Authorities (239)	CAS wards (7,969)	Output areas (165,665)
Wales	Unitary Authorities (22)	CAS wards (881)	Output areas (9,769)
Scotland	Council Areas (32)	ST wards (1,176)	Output areas (42,604)
Northern Ireland	Parliamentary Constituencies (18)	CAS wards (582)	Output areas (5,022)
Total	Districts (426)	Interaction wards (10,608)	Output areas (223,060)

There is one further set of primary data not shown in Table 1. This data set relates only to Scotland and contains postcode versions of SMS and STS originally issued at ST ward level. The geography is awkward because some 'postcode ward' areas include more than one postcode sector whereas in other cases, a single postcode sector can stretch across more than one ST ward.

2.2 Data tables and counts in 2001 compared with 1991

The 2001 interaction data sets are prepared as counts contained within series of tables at each of the three levels. There may be some confusion when comparing between 1991 and 2001 SMS because 1991 SMS Set 2 refers to the district level whilst 1991 SMS Set 1 refers to the ward scale. The interaction data tables and counts available from both censuses are shown in Table 2 and this summary indicates that whilst the number of tables is much the same, the number of counts available in 2001 is much greater; there is more disaggregation in the counts compared with 1991. There are more STS that SWS counts in 2001 because the former contain counts for children aged under 16 and therefore require additional categories in certain tables. No SWS Set C primary data were produced at district level in 1991.

Table 2: Tables and counts in the 2001 and 1991interaction data sets

Data sets	Level 1	Level 2	Level 3
2001 SMS	10 tables, 996 counts	5 tables, 96 counts	1 table, 12 counts
1991 SMS	Set 2: 11 tables, 94 counts	Set 1: 2 tables, 12 counts	-
2001 SWS	7 tables, 936 counts	6 tables, 354 counts	1 table, 36 counts
2001 STS	7 tables, 1,176 counts	6 tables, 478 counts	1 table, 50 counts
1991 SWS*	-	Set C: 9 tables, 274 counts	-

** 10% sample*

One major difference between the migration data sets in 2001 and 1991 is the treatment of students. In 1991, most students were recorded at their place of parental domicile rather than at their term-time address, unless they were living away from the parental home. In order to address concerns about the poor recording of students in 1991, the Office of Population Censuses and Surveys (OPCS) produced an additional table, Table 100, as part of the SAS/LBS series of tables, giving counts of resident students for every local authority district (LAD) by LAD of term-time address[1]. In the 2001 Census, students were counted at their term-time address where appropriate and, consequently, students migrating from the parental home to term-time location, from one term-time location to another or from term-time location to another area (after graduation) in the 12 months prior to the Census are included in the data. This may cause some problems when interpreting migration data classified by occupation, for example, because migrant status refers to that at the time of the 2001 Census. A student living in Leeds who graduated in the summer of 2001 and moved to London to take a new job working for a finance company would be classified as a higher professional rather than a student; consequently, places exporting graduates would be seen to be losing human capital. In order to facilitate comparison between 1991 and 2001, it is our intention to create a set of data which amalgamates counts in Table 100 with 1991 SMS Table 3.

The inclusion of student migrants in 2001 relates to another new dimension of the composition of the migration data which is the introduction of an entirely new unit of measurement in 2001, the 'moving group'. The concept of a moving group refers to a single person or a group of people within a household or communal establishment who have moved together from the same usual address one year before census day. Thus, a single 'migrant' who moves alone actually constitutes a moving group as does a 'wholly moving household', a household in which all members of the household are migrants and have moved from the same address, as used in 1991. To provide some clarification and indication of the relative volumes of counts in different categories, Table 3 indicates, for flows within the UK, the numbers in wholly moving households and other moving groups by size of group. Note that the one person counts for wholly moving households and other moving groups are the same for groups and migrants. Other moving groups include migrants into households that contain residents at census date who were non-migrants.

[1] Within WICID, the student's residential (i.e. parental) address for Table 100 data is considered to be the origin, whilst the term-time address is considered to be the destination.

Table 3: Numbers of moving groups within UK, 2000-01

	Number of persons			
	1 person	2 persons	3+ persons	All
Groups	Wholly moving households			
Number	719,379	500,461	486,356	1,706,196
%	42.2	29.3	28.5	100
	Other moving groups			
Number	1,545,286	178,041	104,753	1,828080
%	84.5	9.7	5.7	100
Migrants	Wholly moving households			
Number	719,379	1,000,922	1,821,914	3,542,215
%	20.3	28.3	51.4	100
	Other moving groups			
Number	1,545,286	356,082	367,029	2,268,397
%	68.1	15.7	16.2	100

Source: 2001 Census SMS level 1, Table 6

This table indicates that there were approximately 5.8 million migrants within the UK in 2000-01, moving in 3.5 million moving groups, of which 48% were wholly moving households and 52% were other moving groups, a high proportion of which were individual movers. Amongst the 3.5 million persons in wholly moving households, over half involve three or more persons moving together, with 28.3% in two person households and one fifth as single persons. In contrast, over two thirds of migrants in other moving groups were single persons, with similar numbers split between two person and three or more person groups. Where there is only one person in the moving group, that person is the moving group reference person (MGRP). For a group of students moving from one house to another, for example, the MGRP would be the eldest of the group. If each of the students had moved from a different address one year previously, then they would each be recorded as a separate household. A household is described as partly moving if one or more members of the household is a migrant but not all members of the household have moved from the same usual address.

What is different about the interaction tables and counts of flows in 2001 compared with 1991? In what follows, we initially consider migration and, thereafter, commuting. In Table 4, we compare the different tables from the two censuses at level 1 (district) scale, using the categories of age, status, ethnicity, illness, economic activity, moving groups, tenure, occupation and language. Thus, for example, in 2001 SMS Table 1, migrants are disaggregated into 24 age groups and 3 sex categories, whereas in the 1991 SMS, there are two tables containing age and sex counts with five and 19 age categories respectively.

Table 4: Tables and counts available from 2001 SMS Level 1 and 1991 SMS Set 2

2001 Census SMS Level 1 tables (459 spatial units)	Counts	1991 Census SMS Set 2 tables (426 spatial units)	Counts
Age			
Table 1: Age (24 categories) by sex (3 categories) plus totals	75	Table 1: Age (5 categories) by sex (2 categories) Table 3: Age (19 categories) by sex (2 categories)	10 38
Family status			
Table 2: Family status (17 categories) by sex (3 categories) plus totals	54		
Ethnicity			
Table 3: Ethnic group (7 categories) by sex (3 categories) plus totals (GB destinations) Table 3N: Ethnic group (2 categories) by sex (3 categories) plus totals (NI destinations)	24 9	Table 5: Ethnic group (4 categories)	4
Limiting long term illness			
Table 4: Whether suffering illness or not by sex (20 categories) by age (4 categories) plus totals	84	Table 6: Whether suffering illness or not (2 categories) by resident in household or not (2 categories)	4
Economic activity			
Table 5: Migrants by economic activity (13 categories) by sex (3 categories) Table 8: Moving groups (8 categories) by sex and economic activity (42 categories)	42 336	Table 7: Migrants aged 16+ by economic position (7 categories) Table 9: Wholly moving households by sex (2 categories) and by economic position of household head (5 categories) Table 10: Residents in wholly moving households by sex (2 categories) and by economic position of household head (5 categories)	7 7 7
Moving groups			
Table 6: Moving groups (8 categories) by groups and migrants	16	Table 2: Wholly moving households and residents in wholly moving households	2
Tenure			
Table 7: Moving groups (8 categories) by tenure (3 categories) plus totals	32	Table 8: Wholly moving households by tenure (3 categories) (excluding Scotland) Table 8S: Wholly moving households by tenure (4 categories) (Scotland)	3 4
Occupation			
Table 9: Moving groups (8 categories) by sex and NS-SEC of group reference person (36 categories)	288		
Some knowledge of Gaelic/Welsh/Irish			
Table 10: Age (11 categories) by sex (3 categories) plus totals	36	Table 11S: Gaelic speakers in Scotland Table 11W: Welsh speakers in Wales	1 1
Marital status			
		Table 4: Marital status (3 categories) by sex (2 categories)	6

Unlike 1991, where infants aged less that one were excluded altogether (since they were not born 12 months before the census), the 2001 migrant status for children aged under one in households is determined by the migrant status of their 'next of kin' (defined as in order of preference, mother, father, sibling (with nearest age), other related person, household reference person). There were no family status or occupation tables for the district migration data in 1991, whereas the marital status table used in 1991 has been discontinued in 2001. Important changes introduced in 2001 are the increased disaggregation of counts in the ethnicity table, the addition of age and sex categories in the illness, economic activity and language tables, and the introduction of an occupation table based on the new National Statistics Socioeconomic Classification (NS-SeC) that replaced the classification of social class based on occupation and socio-economic group.

At level 2, there are five tables for ward migration data in 2001 compared with two in 1991 as shown in Table 5. This provision contains important new information on ethnicity (although only for whites and non-whites), on occupation and on tenure, as well as a more disaggregated age groups in SMS Table 1. The new data counts of migration by ethnic group at district and ward level are useful in providing insights into the internal migration behaviour of ethnic minority groups, although the disaggregation at ward scale is only between whites and non-whites.

Table 5: **Tables and counts available from 2001 SMS Level 2 and 1991 SMS Set 1**

2001 Census SMS Level 2 tables (10,608* spatial units)	Counts	1991 Census SMS Set 1 tables (10,933 spatial units)	Counts
Age			
Table 1: Age (16 categories) by sex (3 categories) plus totals	51	Table 1: Age (5 categories) by sex (2 categories)	10
Moving groups			
Table 2: Moving groups and migrants by wholly moving households and other moving groups	4	Table 2: Wholly moving households and residents in wholly moving households	2
Ethnicity			
Table 3: Ethnic group (2 categories) by sex (3 categories) plus totals	9		
Occupation			
Table 4: Moving groups (2 categories) by sex and NS-SEC of group reference person (36 categories)	24 9		
Tenure			
Table 5: Moving groups (2 categories) by tenure (3 categories) plus totals	8		

** These are interaction wards for the UK.*

However, it is disappointing that the flows of immigrants in 2001 are confined only to one count of those migrants with origin outside the UK. This is a retrograde development from the 98 foreign origins that were specified in 1991 and prevents separation of white from non-white immigrants, let alone analysis of non-white immigrants from different world regions. As in 1991, the 2001 SMS do contain counts of those whose address 12 months prior to the census was unknown. In 2001, the number of those migrating within or into the UK with no prior address was 456,736 compared with 325,630 migrants within or into GB with origin unknown in 1991.

At level 3, the 2001 Census SMS data for output areas consist of one table with counts for four age groups (all age, 0-15, 16-pensionable age, pensionable age+) for three sex groups (person, male, female) plus totals, giving 12 counts altogether. Since there are over 223,000 OAs in the United Kingdom, the matrices of flows for these 12 counts are enormous in theory, In practice, of course, the matrices will be relatively sparsely populated with most cells containing non-zero values being close to the diagonal.

The 2001 commuting data are divided into the journey to work or SWS data sets in England, Wales and Northern Ireland and the travel to work or study (STS) in Scotland. The destination location in the SWS refers to the place where a person works in their ‘main job’ or the depot address for people who report to a depot, whereas the destination in the STS is the place a person travels to for their main job or course of study (including school). Like the SMS, the 2001 SWS/STS have been produced at three levels, whereas the 1991 SWS Set C were produced only for wards. Moreover, the 2001 SWS/STS are 100% counts whereas the 1991 SWS are a 10% sample of the population and need to be scaled up when used for analysis.

Tables and counts for the two SWS data sets at this spatial scale are compared in Table 6. There are similarities in the tables on age, family status and mode of travel, but the main differences are the counts for the new NS-SeC classification of occupation that are included in 2001 SWS Table 4 and the discontinuation in 2001 of counts relating to hours worked, distance travelled and cars available, all of which were included in the 1991 SWS.

Table 6: Tables and counts available from 2001 SWS Level 2 and 1991 SWS Set C

2001 Census SWS Level 2 tables (10,608* spatial units)	Counts	1991 Census SWS Set C tables (10,933 spatial units)	Counts
Age			
Table 1: Age (5 categories) by sex (3 categories) and by employment type (9 categories) plus totals	72	Table 1: Age (8 categories) by sex (2 categories) and by economic position (4 categories) plus totals	54
Family status			
Table 2: Family status categories (9 categories) by sex (3 categories) and employment type (9 categories) plus totals	108	Table 3: Family position (5 categories) by sex (2 categories) plus totals	12
Mode of travel			
Table 3: Mode of travel (13 categories) by employment type (4 categories) plus totals	52	Table 5: Mode of travel (10 categories) by sex (2 categories) plus totals	22
Occupation			
Table 4: NS-SEC groups (12) by employment type (4 categories) and totals	46	Table 7: Occupation (23 categories) by sex (2 categories) plus totals	48
Table 5: Occupations (10 categories) by employment type (4 categories) plus totals	40	Table 8: Social class (6 categories and SEG (20 categories) by sex (2 categories) plus totals	54
Employment			
Table 6: Employment status (23 categories by sex (3 categories) and employment type (9 categories) plus totals	36	Table 9: Industry divisions (23 categories) by sex (2 categories) plus totals	48
Hours worked			
		Table 3: Hours worked (4 categories) by sex (2 categories) plus totals	10
Distance to work			
		Table 4: Distance (7 categories) by sex (two categories) plus totals	16
Cars available			
		Table 6: Cars (4 categories) by sex (2 categories) plus totals	10

A similar set of SWS tables to the 2001 level 2 suite have been provided at level 1 with the addition of one further table on ethnic groups (7 categories) by employment type (all persons, full-time student, in full-time employment, in part-time employment) by sex (2 categories). This table is available for Parliamentary Constituencies in Northern Ireland except that the ethnic group categories are restricted to white and non-white. At level 3, one table is available providing 36 counts of commuters by mode of travel to work for all persons, students and non-students. The STS data sets for Scotland at all three levels are very similar to those of the SWS for the rest of the UK except that the age categories extend to ages below 16 and cells are masked out that refer to counts of those aged 16-74 in employment.

2.3 Shortcomings and derived data sets

It is very important to acknowledge and understand the deficiencies associated with interaction data sets derived from successive censuses. In this section, we summarise briefly the problems associated with 1991 data and report on the new sets of derived data that have been estimated to enable comparisons to be made between the last three censuses. The implications of the small cell adjustment methodology (SCAM) used to control the risk of disclosure in 2001 are discussed in the subsequent section.

Whilst the 1991 SMS have been reviewed by Flowerdew and Green (1993) and critiqued by Rees *et al*. (2002), Cole *et al.* (2002) have highlighted how the quality of the SWS was compromised by the postcode processing problem. One key problem with the 1991 SMS Set 2 resulted from the methodology adopted by the Census Offices of suppressing flows of fewer than 10 individuals or wholly moving households in order to preserve confidentiality. Rees and Duke-Williams (1997) developed a methodology to re-estimate suppressed flows in Tables 4-10 of SMS Set 2 and these derived data are available in WICID in a data set called SMSGAPS. The problem of under-enumeration was investigated by Simpson and Middleton (1999) whose research led to further corrections to SMS Set 2 Table 3 (Migrants by five year age group and sex) now included as the MIGPOP data set in WICID.

One of the main objectives in creating the WICID system has been to enable users to compare patterns of migration or commuting over time. This task is confounded by changing definitions of variables measured in the census (such as flows by occupation) and by changes in the definitions of spatial units. Local government re-organisation during the 1990s, particularly associated with the creation of unitary authorities in Wales, Yorkshire and the Humber and the South West, as well as the redrawing of ward boundaries, poses huge problems for those seeking to compare census data in 2001 with similar data in 1991 and 1981 in a consistent way. This challenge has been approached within the CIDS project in two ways. Firstly, zone systems have been designed using lookup tables (LUTs) to produce geographical areas above the level 1 (district) scale that are approximately consistent between 1991 and 2001. The hierarchy of zones (known as CIDS common 1991/2001 geographies) for the UK that have been constructed from the initial set of 459 districts in 1991 and 426 districts in 2001 is as follows:

- ‘district’ geography with 417 zones;
- ‘intermediate’ geography with 219 zones;
- ‘100 zone’ geography has 99 zones in GB corresponding to the previously established ’99 zone DETR geography’ plus Northern Ireland;
- ‘city region’ geography with 47 zones; and
- ‘Government Office Region’ geography of 12 zones based on 1999 definition of GORs.

The second approach used by the CIDS team has been to re-estimate 1991 and 1981 interaction data for 2001 geographies to create a full set of time-series data from 1981, 1991 to 2001 using a methodology spelt out in Boyle and Feng (2002) whose initial work has produced 1981 migration and commuting counts based on 1991 geographical areas.

The transfer of socio-economic data from one geography to another incompatible geography is a problem of areal interpolation. We can refer to the reporting zones for which data are collected as ‘source zones’ and the reporting zones for which data are to be estimated as ‘target zones’. One popular method of interpolation is to assume that the attribute of interest distributes evenly over space and thus we can use ‘area of zone’ as a weight to estimate the attribute for intersection zones. These intermediate results are then aggregated into target zones. However, this method is not suitable for the interpolation of flow data. Suppose that in 1991 there is a flow from origin ward A to destination ward B and that in 2001, the ward B splits into two equal-area wards B_1 and B_2. It is inadequate to simply divide the flow from the origin ward into two equal-volume flows due to the same size of their area in the destination wards. First, this approach would ignore the fact that migration decays with distance and, if the two new destination zones are not equidistant from the origin zone, it is more likely that more of the migrants to terminate in the destination that is closer to the origin. Second, the method assumes that the population is evenly distributed across the zone, an assumption that is likely to be unrealistic. In fact, the half with the largest population would probably attract more migrants. Interpolating flow data is therefore more difficult than interpolating static data and some form of innovative strategy and modelling is required to solve these problems.

The methodology that we have developed to tackle the problem can be divided into a number of steps. Let us consider the re-estimation of 1991 interaction data for 2001 ward geography. The first step is to construct a gravity model for the 1991 flows at ward level and then apply the calibrated parameters derived from the ward-level model for predicting 1991 flows at the enumeration district (ED) scale. Thus, the second step is to disaggregate ward-level flows in 1991 into flows between EDs. The ED-level model uses ED populations, the distance between origin and destination EDs, and parameters which are derived from the ward-level model. The flows between EDs are estimated to be randomly proportional to the flows estimated using the gravity model. If a pair of EDs have a larger flow value estimated from the model then the pair tend to share more flows disaggregated from the inter-ward flows. The third step is to construct a lookup table between 1991 EDs and 2001 ST wards. In the fourth step the lookup table is then employed to aggregate the 1991 inter-ED flows to 2001 inter-ward flows. Table 7 indicates the SMS Set 1 and the SWS Set C tables in 1991 that have been re-estimated for 2001 geographies using the above method.

Table 7: 1991 interaction datasets re-estimated for 2001 at ward level

1991 data set	2001 origin geography	2001 destination geography	Number of tables	Number of counts
1991 SMS Set 1	2001 ST ward; 1991 foreign origin; unstated origin	2001 ST ward	2	12
1991 SWS Set C	2001 ST ward	2001 ST ward; workplace at home; no fixed workplace; workplace unstated; workplace outside UK	9	274

One problem that arose in constructing the 1981 EDs to 2001 ST wards lookup table was that 17 ST wards did not have any 1981 EDs falling within their boundaries. This could be due to genuine change taking place in the last twenty years; the new development simply does not exist in 1981. However, this might also be due to some errors in the centroids of the 1981 EDs. Because there are no 1981 ED boundaries, we cannot identify which is the correct answer. We have assumed that since 2001 ST wards are quite large (with an population average about 5,000), there may be small communities there since 1981. Therefore we have overlaid 1981 ED centres over 2001 ST ward boundaries using ArcMap and manually assigned each 1981 ED to each of 17 ST wards if the 1981 EDs on the basis of proximity. If it was difficulty to distinguish which ST ward was the closest when two EDs were both close to the ST ward, the two 1981 EDs were allocated to the same ST ward. The 1981 data sets that have been re-estimated for 2001 ST wards are summarized in Table 8. Additional sets of tables have been produced that contain counts of 1981 data re-estimated for 1991 geographical areas, and of further counts in which flows with origin unknown have been allocated origins pro rata.

Table 8: 1981 interaction datasets re-estimated for 2001 at ward level

Data set	Origin geography	Destination geography	Number of tables	Number of variables
Special Migration Statistics (Set 2) re-estimated for 2001 geography	2001 ST ward; 1981 foreign origin; unstated origin	2001 ST ward	1	2
Special Workplace Statistics (Set C) re-estimated for 2001 geography	2001 ST ward	2001 ST ward; no fixed workplace; workplace unstated; workplace outside UK	5	170

One of the data sets missing in 1981 contains the interaction flows between postcode sectors in Scotland and the 1981 Scottish interaction data for 1991 geography re-estimated by GRO(S) were found to have errors in them. GRO(S) have expressed a willingness to recreate the 1981 flows in due course.

2.4 The effects of small cell adjustment

In 2001, following a consultation exercise and discussion on a number of alternatives, ONS decided to adopt a series of methods to prevent risk of disclosure. The first of these is the setting of 'minimum thresholds' of numbers of persons and households for the release of sets of output. These thresholds are 100 persons and 40 households for the CAS and 1,000 persons and 400 households for the Standard Tables. Secondly, a process of 'record-swapping' has been introduced in which a sample of records was swapped with similar records in other geographical areas. The proportion of records swapped is confidential. The third technique used to prevent disclosure has become known as 'small cell adjustment method' (SCAM) and involves the adjustment of small counts appearing in the tables. It is this adjustment which has caused most profound concern amongst the user community since it is fact that many of the cells of interaction matrices will contain small flows, particularly as the level of spatial resolution reduces.

Although the methodology has not been released, it is assumed that small counts refer to values of one or two and these have been adjusted to values of zero and three in such a way that there is a two thirds probability that a value of one will be adjusted to zero and one third probability that it will be adjusted to three, whilst the probabilities for adjusting the value of two to zero or three are the other way around. These assumptions are supported by the observation that the values 1 and 2 do not appear in tables which have been modified using SCAM. The graph in Figure 1 shows the frequency counts of observed values of interior cells (those which are not totals or sub-totals) in a set of flows in Table MG301 from the 2001 SMS. The counts are of flows between (and within) all OAs (origins) in the UK to all OAs (destinations) in the UK except those in Scotland. SMS flows to Scottish destinations were not subject to SCAM (neither were any of the STS data sets).

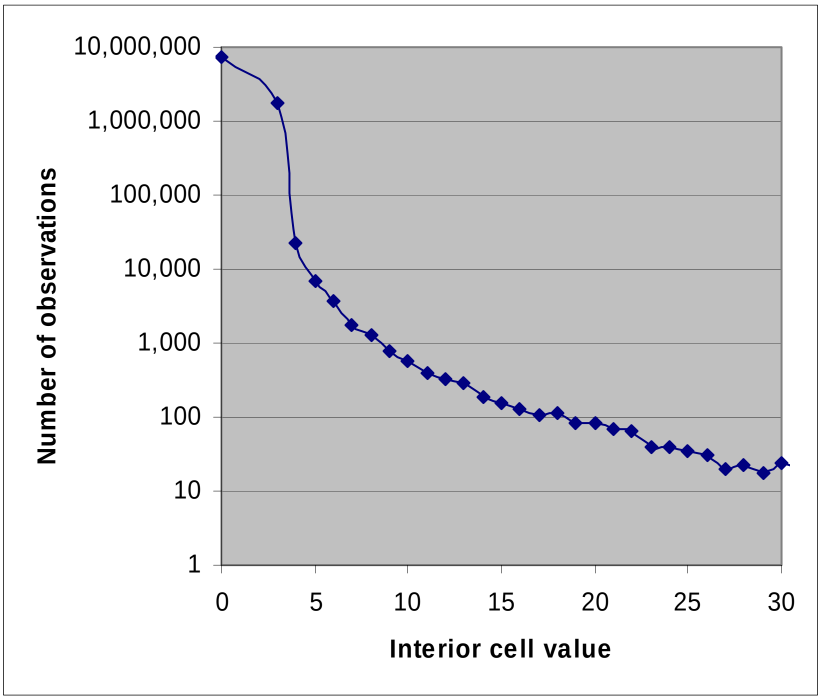


Figure 1: Distribution of interior cell values in 2001 SMS Table MG301

Figure 1 has a logarithmic y-axis because of the wide range of counts in the data, and the x-axis is truncated: there is a long tail of observed interior cell values going up to the largest observed value of 297. The logarithmic scale removes some emphasis of the distribution. The first two points plotted are for observed values of 0 and 3. There are nearly 10 million zero values in the tables and over 1 million values of 3. It can be seen from Figure 1 that values of 4 and above exhibit a steady rate of decline in frequency, whilst the value of 3 has a higher frequency than suggested by a linear extrapolation of the higher count values. In total, 99.6% of all interior cells in this set of OA-to-OA flows are either 0 or 3, and 95% of migrants in the flows are accounted for by these values. Of course, the majority of the zero cells will have been zero originally; only a proportion are ‘adjusted to zero’ cells. The assumptions we presume were made about the SCAM process dictate that had SCAM not taken place, 95% of migrants would still be in cells of value less than 4, but that these would be distributed across the values 1, 2 and 3 rather than all clustered on the values 0 and 3**.**

Turning to the SWS, we observe that although the interior cells of Table W301 (OA level journey-to-work flows) have been modified by SCAM in the same way, the clustering is not quite as extreme. The proportion of all interior cells that are either 0 or 3 is almost the same as is the case with MG301, at 99.5%. However, these account for a smaller proportion (77.5%) of all workers. The remaining 22.5% of workers are tabulated in un-modified cells of this table. The difference between the SMS and the SWS is explained by the spatial focusing of commuting flows: some OAs have very high numbers of workers traveling to them.

Thus, from the analyses reported above, SCAM has affected the interaction data by changing the distribution of values found in the data. In addition to this aggregate perspective, there are two noticeable ways in which the effects of SCAM will impact on users. Firstly, SCAM has caused varying conceptually equivalent counts within sets of tables for a single flow at the same scale; and secondly, SCAM has created varying conceptually equivalent values within the same count table across different spatial scales.

The variation in conceptually equivalent totals between sets of tables for a specific flow is most obvious when totals and sub-totals are studied. Totals and sub-totals in tables are calculated as the sum of the adjusted data so all tables are internally additive. However, different tables are independently adjusted and this means that counts of the same population in two or more different tables at the same scale may not necessarily be equivalent. The problem occurs in the SMS and SWS data sets at level 2 (ward) and level 1 (district); it is not relevant to any level 3 (OA) data sets, as those data sets only contain a single output table for each flow. There are two direct counts of total migrants in SMS level 2, and five in SMS level 1. SWS level 2 has five counts of total commuters, whilst SWS level 1 has six such counts.

The way in which SCAM introduces differences between equivalent totals can be examined by comparing the two available totals in SMS level 2. Of 1,156,804 flows to destinations outside Scotland, the two totals are different in 714,693 (61%) cases. However, the majority of these are cases where the total is taken from one cell, and is equal to 0 in one table and 3 in the other table. Excluding such cases, (that is, where the total number of commuters is reported as being greater than 0 in both tables), there are 235,498 flows (20%) for which the totals differ. The absolute differences are rarely large, with the most frequent difference (accounting for 44.6% of all cases) being 3. Figure 2 shows the distribution of all differences in flows to destinations excluding Scotland where the total is greater than 0 in both tables. The most extreme difference between the two totals is 21. In this case, the total taken from table MG201 is 60, whilst the total taken from table MG203 is 39. Clearly, using a value from one table as a denominator for a value taken from the other table could lead to very misleading results, yet it would be a mistake that would be easy to make.

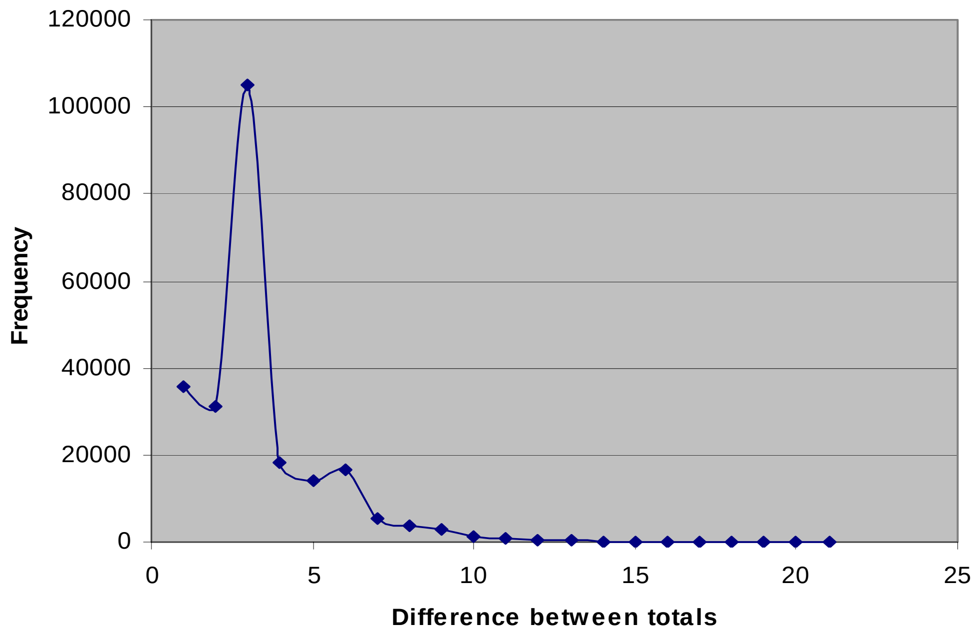


Figure 2: Distribution of differences between alternative totals in 2001 SMS Level 2

The other noticeable effect of SCAM – that conceptually equivalent totals may not be the same across spatial scales is similar to the effect discussed above. Since all tables for all flows and all data sets were processed independently, aggregation of flows to larger units will not always result in identical totals. For example, calculating the total flow of migrants within the Headingley ward of Leeds, West Yorkshire by aggregating relevant flows from the OA level information in SMS Level 3 gives a result of 4,651. Finding an equivalent value from SMS Level 2 with which to compare this re-introduces the second problem described above: that there are two alternative totals for migration within the ward. Of these two totals, one is 4,632 and the other is 4,635. The difference between these two alternatives is minor, and the aggregated total has a deviation of less than 0.5%. However, the differences may be large enough to introduce problems if the 'wrong' total is used as a denominator, and are certainly large enough to cause confusion and loss of confidence in users of the data.

We can use net migration rates for London boroughs to exemplify the effects of SCAM at different spatial scales. Table 9 shows net rates computed directly using data from SMS 104 for migration between London boroughs and all other local authorities in the country compared against net rates computed from data aggregated from level 2(SMS 204) and from Level 3 (SMS 304). These three sets of rates are presented for London boroughs, in descending rank, against an equivalent set of rates derived from TT37 of the Theme tables. As expected, the large majority of boroughs lose migrants in net terms, many at very high rates. Only the very central borough of City of London and the peripheral borough of Kingston upon Thames record positive rates of net migration across all four measures. The average net rates vary from -6.94 for SMS104 to -7.34 for SMS204 and the highest correlation is between data from the TT37 and from SMS 104. This is to be expected since the rates are based on data counts adjusted at the district level and likely to contain fewer adjusted values. The series of rate values for the City of London do vary more than those for other boroughs and this highlights the problem that will occur when dealing with smaller counts. The City of London is a relatively small area with a population of just under 7,200 and migration inflows and outflows in 2000-01 that are only around 1,000 in either direction.

Table 9: Net migration rates for London boroughs in 2000-01 derived from four different source tables

	Net migration rates per 1000			
Borough	TT 37	SMS 104	SMS 204	SMS 304
City of London	4.87	5.01	11.70	3.34
Kingston upon Thames	3.33	3.95	2.76	3.14
Lambeth	0.00	0.55	-0.69	0.76
Sutton	-0.15	1.39	0.66	1.30
Barking and Dagenham	-0.49	-0.16	-0.23	-0.16

Bromley	-1.99	-1.68	-2.67	-1.75
Havering	-2.43	-2.09	-1.38	-1.96
Hillingdon	-3.01	-1.43	-2.83	-2.13
Redbridge	-3.62	-3.60	-2.40	-3.57
Bexley	-3.78	-2.89	-4.14	-3.23
Tower Hamlets	-4.72	-3.26	-6.12	-4.02
Barnet	-5.51	-4.24	-5.96	-4.16
Greenwich	-5.65	-6.10	-5.70	-6.18
Wandsworth	-6.00	-3.81	-8.31	-3.14
Lewisham	-6.01	-5.65	-6.91	-5.66
Croydon	-6.34	-5.82	-7.71	-6.43
Southwark	-6.62	-7.58	-5.04	-7.56
Richmond upon Thames	-6.68	-5.33	-5.23	-5.94
Enfield	-6.98	-7.66	-8.61	-7.38
Merton	-8.40	-9.55	-7.93	-10.64
Hackney	-8.46	-9.21	-9.18	-10.17
Waltham Forest	-8.60	-9.95	-9.10	-10.38
Camden	-11.05	-9.50	-12.41	-9.51
Westminster	-12.36	-13.33	-15.30	-12.96
Haringey	-12.70	-13.26	-12.66	-13.03
Harrow	-12.81	-13.08	-13.91	-13.61
Islington	-12.83	-16.14	-14.21	-15.88
Hammersmith and Fulham	-12.96	-11.86	-14.47	-12.64
Brent	-13.33	-12.94	-13.47	-12.68
Kensington and Chelsea	-13.50	-13.70	-14.49	-14.37
Hounslow	-14.04	-13.12	-14.24	-13.49
Ealing	-14.64	-15.08	-14.70	-14.84
Newham	-16.73	-18.04	-17.30	-18.05
Mean net rate	-7.10	-6.94	-7.34	-7.18
Correlation with TT37 rate		0.985	0.975	0.980

The general advice that ONS has given (for all data products) is that users should generate counts that they intend to use from as few components as possible. Suppose that a user is interested in the total number of male migrants, at district scale. This is available from a variety of the 2001 SMS Level 1 tables. Naïvely, a user might assume that the correct table to use is table MG101, 'Age by Sex'. The number of males is available as a column total. This total is the sum of all other values in the 'Male' column: a total of 24 values, each of which may potentially have been affected by SCAM. The total number of males can also be calculated from tables MG102 (Family Status by sex), table MG103 (Ethnic group by sex), table MG104 (Whether suffering limiting long-term illness by whether in household by age by sex), and table MG105 (Economic activity by sex). Of these, it is table MG103 that allows the user to calculate the total number of males using the smallest number of components.

3 Interface developments

WICID has undergone considerable development over that last two years from the version that was reported in Stillwell and Duke-Williams (2003). In this section of the paper, we outline two of the new features of the system, the map selection tool developed to support query-building, and the analysis tool, designed to provide users with some additional insights into the data sets that they have extracted. Initially, however, we provide a short resumé of the basic query-building procedure for users of the system, because this has also undergone some modification.

3.1 Building queries in WICID

One of the fundamental aims of the Census Interaction Data Service (CIDS) has been to create a user-friendly interface to these complex data sets in order to enhance usage of the data. Consequently, a great deal of effort has been directed at building a flexible, yet simple query interface. Once logged into the system and running WICID, the user is confronted with the screen shown in Figure 3, containing a number of hotlinks that provide information about the data sets held in the system, details about the user's account and links to another useful web sites.

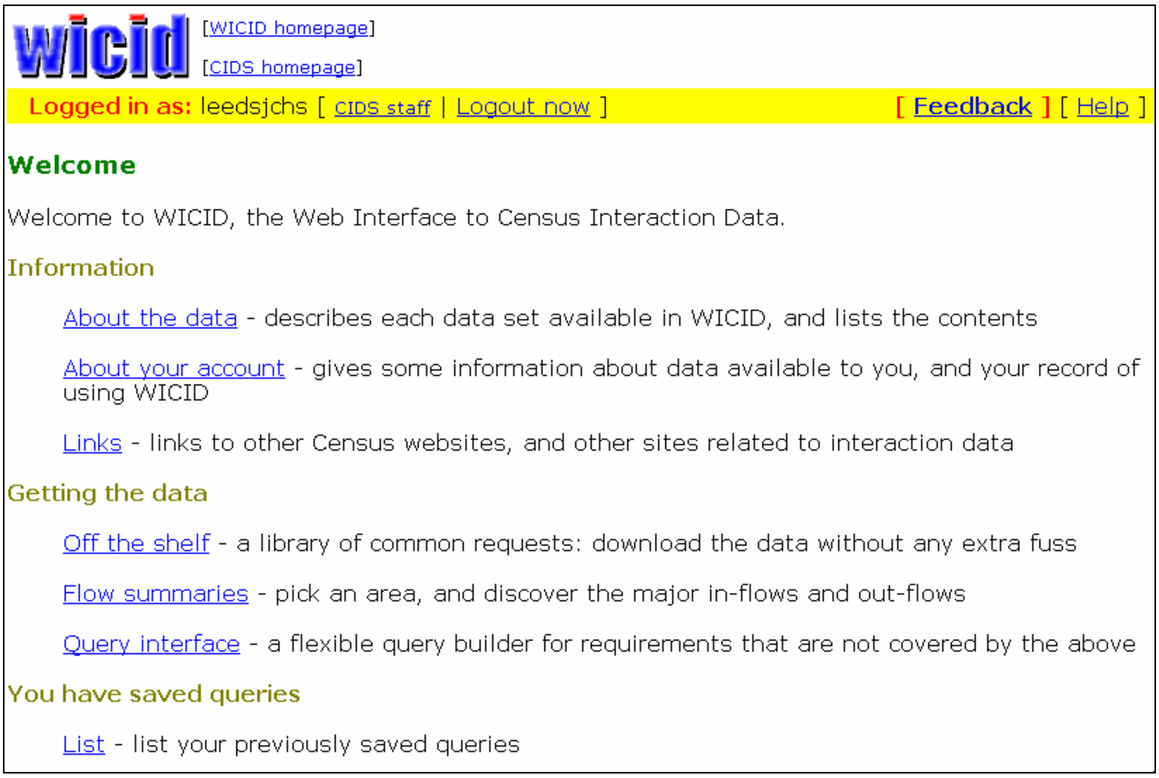


Figure 3: The Welcome screen in WICID

For users wanting to build queries and extract data, there are three mechanisms for 'Getting the data' from WICID. The first is through the 'Off-the-shelf' facility of downloading data from a library of prepared queries. The second allows users to generate 'Flow summaries' for individual areas that they can specify. Figure 4 is an example of a summary in which the user has asked for commuting flows to and from the City of London in 1991, including flows from within that borough. The data comes from the 1991 SWS Set C and has been aggregated to show the top ten districts of origin (London boroughs in this case) and of destination. The user can produce similar lists for other zones by clicking on any one of the other areas in either of the two lists; a flow pyramid can be generated by clicking on the pyramid icon in the left hand column of each list. Figure 5 illustrates an age-specific pyramid for commuters between Havering and the City of London.

Summary

[Start again]

Area: City Of London (from *GB Districts 1991*) (OPCS/ONS code: 01AA)

Data set: 1991 SWS Set C - Ward level journey-to-work data from the 1991 Census

Figures: Total employees and self-employed (10%)

Origin geographies GB Districts 1991		Destination geographies GB Districts 1991	
Origin	Flow *to* City Of London	Destination	Flow *from* City Of London
Havering	1001	City Of London	66
Bromley	929	Westminster, City of	25
Redbridge	870	Hackney	15
Wandsworth	804	Tower Hamlets	15
Bexley	702	Camden	14
Waltham Forest	624	Islington	9
Lewisham	610	Kensington and Chelsea	3
Basildon	561	Southwark	2
Barnet	551	Hammersmith and Fulham	2
Southwark	541	Lambeth	2

- Census output is Crown copyright and is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland
- Source: 1991 Census: Special Workplace Statistics (Set C)

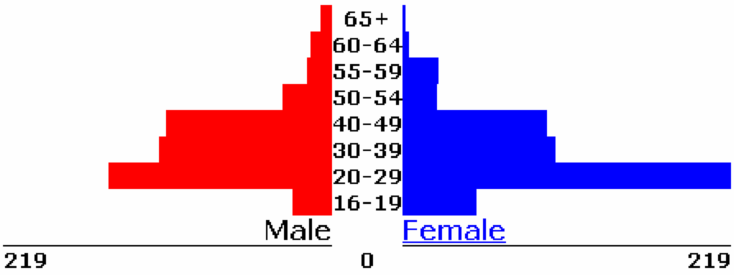
Figure 4: Summary of commuting flows to and from the City of London, 1991

Summary: flow pyramid

Flow from Havering (*GB Districts 1991*) to City Of London (*GB Districts 1991*)

Note Pyramids should be drawn as a formal histogram; thus a bar representing five years of age should be five times the height of a bar representing one year of age. These pyramids do not yet obey this convention, and thus care should be exercised in the interpretation of them.

Flow pyramid



Data table

Age	Male	Female
16-19	27	50
20-29	150	219
30-39	115	102
40-49	111	97
50-54	33	24
55-59	17	25
60-64	15	5
65+	8	3

-
- Source: 1991 Census: Special Workplace Statistics (Set C)

Figure 5: Age pyramid of commuters from Havering to the City of London, 1991

Building queries in WICID begins from the query interface (Figure 6) where the user is given the option of selecting ‘Geography’ or ‘Data’. Of course, the interaction data sets all require double geographies and consequently the user has to decide which origin and destinations are required. One of the most innovative features of WICID is the facility to build geography selections in which the origins and destinations are drawn from sets of areas at different spatial scales and are not required to be the same. Consequently, it is possible, for example, for the user to select a single destination (e.g. the City of London) and to extract flows originating from other London boroughs, from other districts adjacent in the South East GO region and from other GO regions in the rest of the country. If the flows required are commuters, then the user would make a selection of the appropriate variables from the table in the SWS. Figure 7 is an example of a query to extract data on flows of employees and self-employed persons from the 2001 SWS for 110 origins (100 districts and 10 regions). Once the traffic lights are green, the user can run the query or refine the query in some way (e.g. my merging some of the variables selected) before extraction.

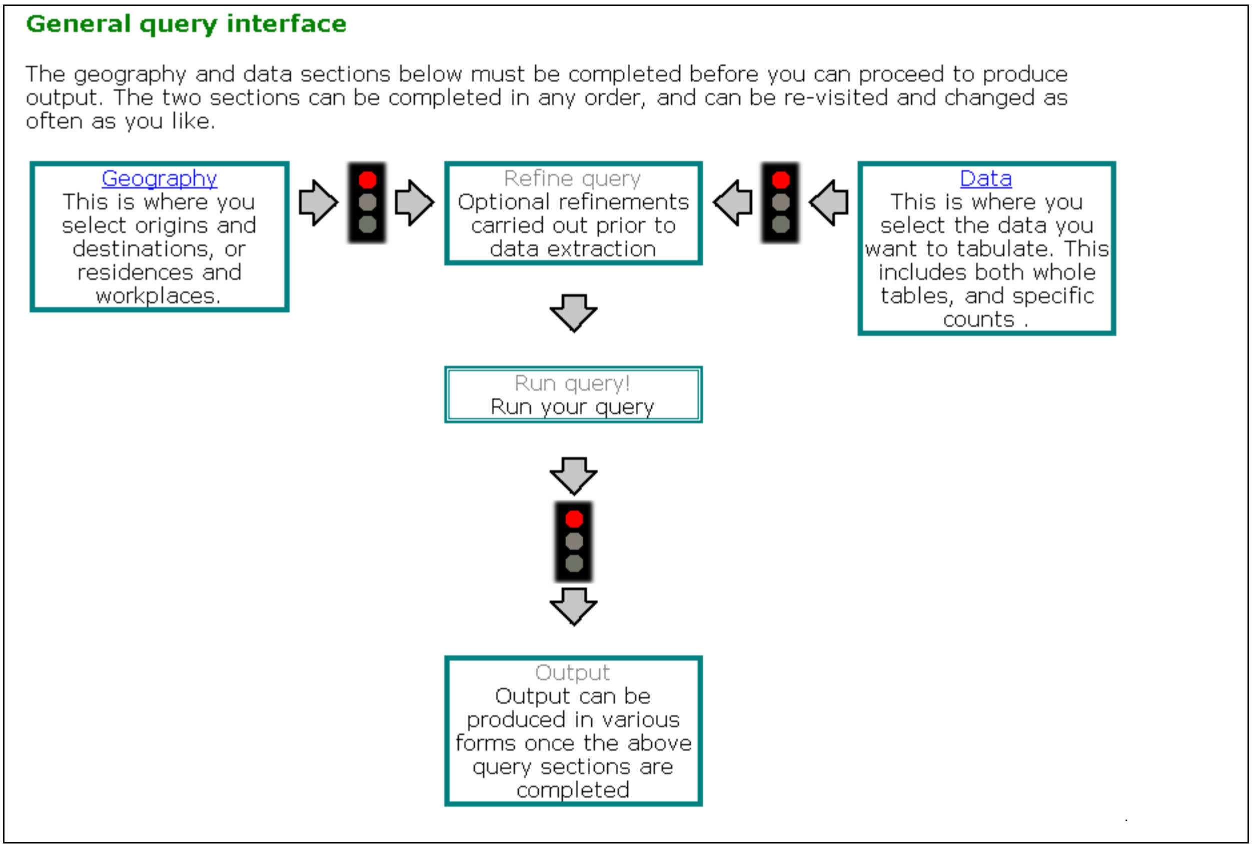


Figure 6: The general query interface in WICID prior to selection

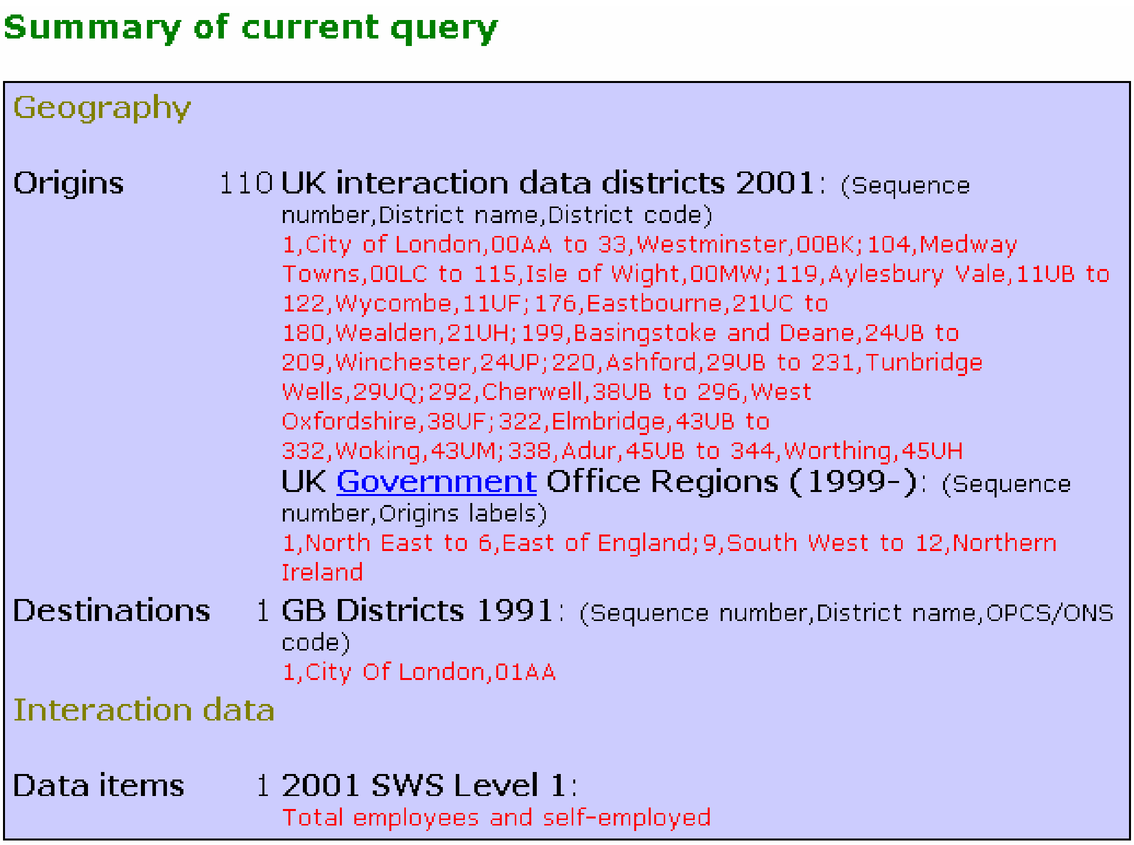


Figure 7: Query to select commuting data to City of London, 2001

There are various methods of selecting geographical areas: ‘Quick selection’ enables all areas at a certain scale to be selected; ‘List selection’ allows areas to be chosen from a list of all areas at each scale; ‘Type-in-box’ selection provides for one area to be selected at a time; and ‘Copy selection’ allows areas selected for origins to be copied into destinations or vice versa. One of the new developments in WICID using web-mapping software is that of ‘Map selection’, enabling users to pick their origins and destinations from a map on screen.

3.2 Map selection tool

The map selection tool for choosing origins and destinations is crucial when users are unfamiliar with the geographical areas that they need to extract data for. We have found that this facility is particularly important when users are students doing project work, especially for small areas like wards. The initial screen for map selection (Figure 8) contains one panel on the left hand side which is the map window and three panels on the right hand side, the topmost of which is where the user chooses to select either areas or elements of areas by clicking the cursor in the map window. There is a scroll down menu available to facilitate the selection of areas at more detailed spatial scales. The panel below enables the user to zoom in and out or to reposition the map in the window. Finally, the lower panel contains various links to other screens where the user can customise the map size, labelling and colour shading of the map if required and can reset the map to its original scale and view. As the user moves between of areas, the legend at the bottom of the screen will change to incorporate each level that has been specified. The example shown in Figure 9 illustrates the selection of the City of London at the district scale as a destination. Note that the status specification at the top of the figure changes as each destination is selected in the map window.

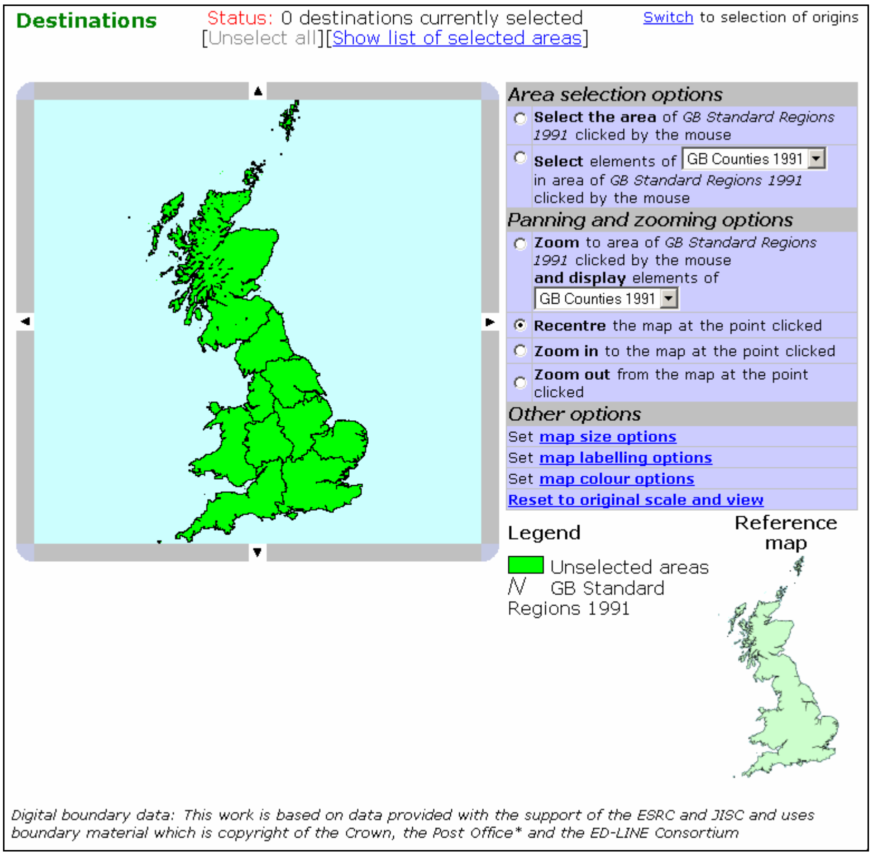


Figure 8: The map selection window in WICID

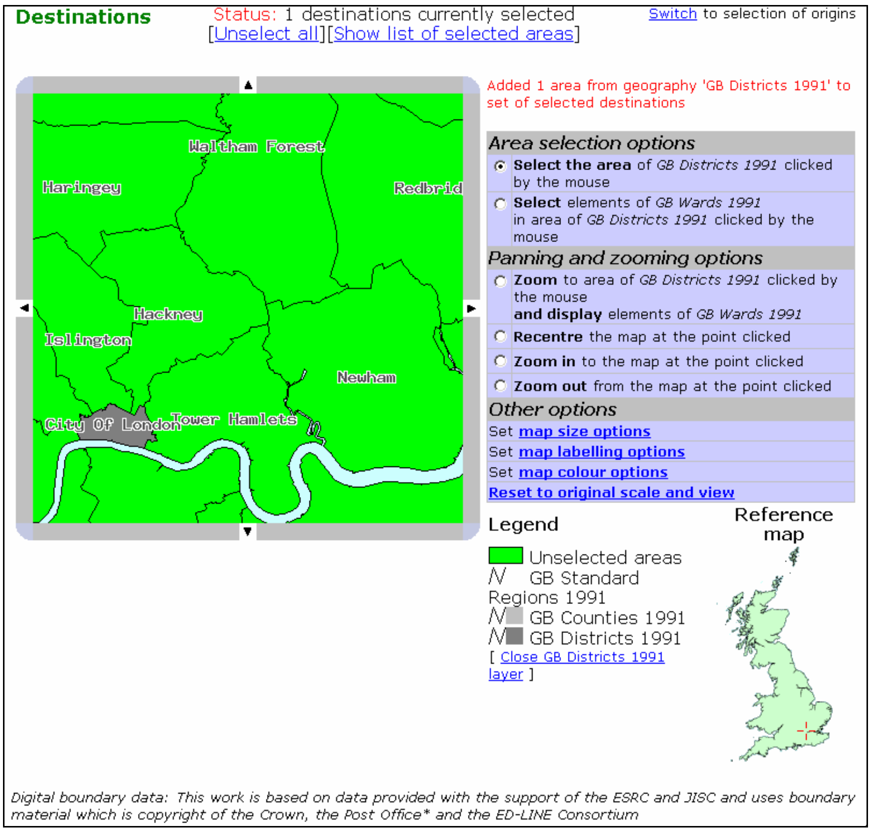


Figure 9: Example of map selection of City of London as destination area

3.3 Analytical functions

Once the selection has been made, the data can be extracted and downloaded. However, WICID also allows users to undertake some analysis of the data set extracted. The analytical facilities are comprised of a suite of five sets of indicators (Figure 10) that are computed for a selection of any five of the counts that have been selected in the query. This maximum of five is to allow easy output on a single screen. The general statistics consist of descriptive statistics for all the flows extracted together with correlation coefficients that indicate the strength of any statistical correlation between each pair of variables. The distance indicator is simply the average distance travelled and this measure relies on the availability of a additional data on distances between origins and destinations. The distance measure is not available when the origins and destination sets are drawn from different scales.

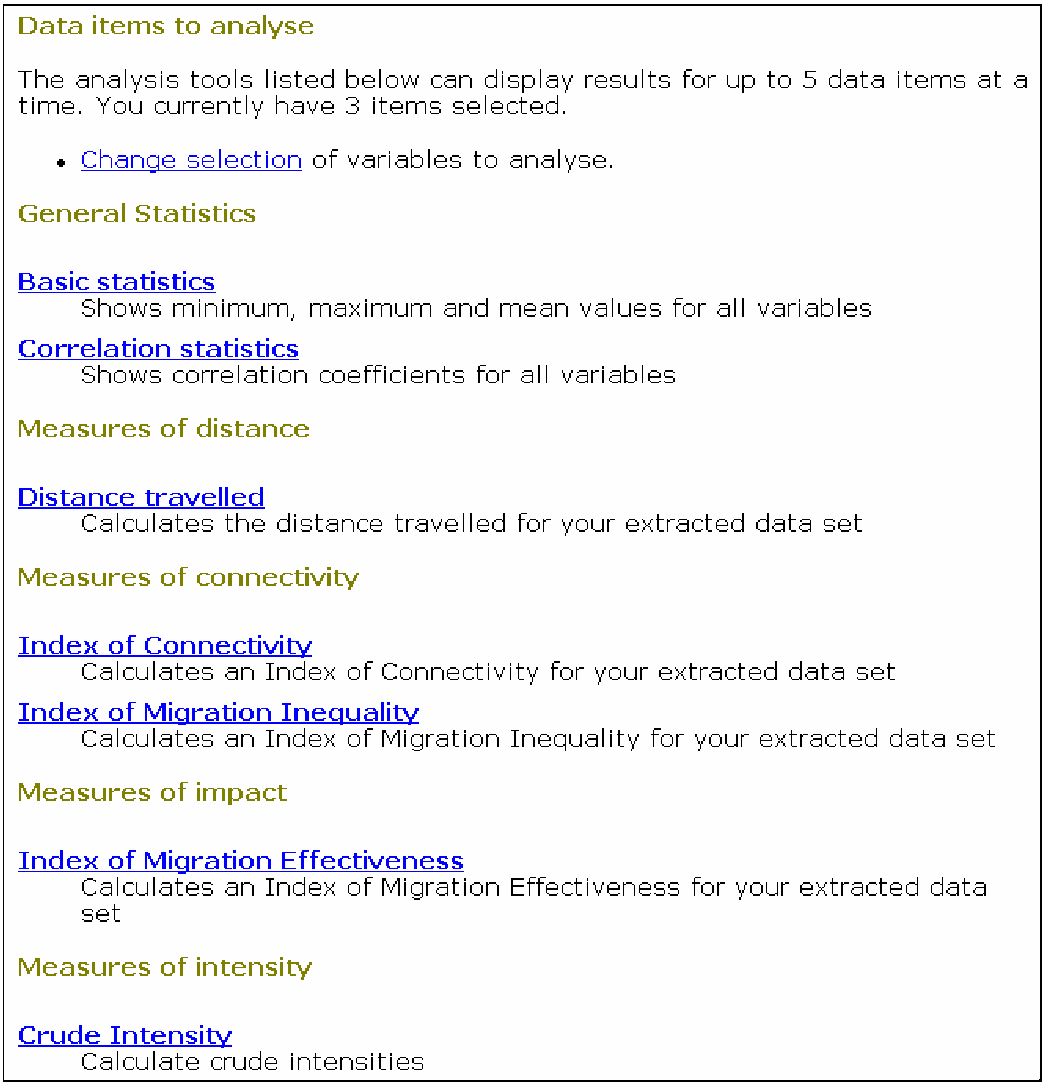


Figure 10: The analysis indicators available in WICID

Additional data are also required for computation of the crude intensities. In most cases, these intensities are commuting or migration rates whose computation requires that the flow is divided by the appropriate population at risk (PAR). For some variable counts, the PAR are straightforward (e.g. the PAR for migration outflows of those in age group 1-4 is the population of the area aged 1-4 on census date obtained from the area statistics) but for other variable counts, PAR are much less straightforward to define (e.g. PAR for outflows of moving groups) and may not be available from area statistics or standard tables. PAR counts for the 2001 interaction data sets are currently being prepared

Three further indicators are available in the current WICID system, none of which require additional information. These are indicators of connectivity, inequality and effectiveness. The latter two tend to be used for migration analysis whilst the *index of connectivity*, measured as the number of pairs of zones that have a flow between them divided by the total number of pairs of zones selected, can be used with commuting as well as migration data. The *index of migration inequality* is derived in two alternative ways. Users can choose to follow the method defined in Bell *et al.* (2002) which computes half the sum of the absolute differences between each observed flow and the observed mean value across all origins and destinations, except where the origin is the same as the destination. In fact, the index in WICID uses the observed and expected shares of total migration rather than the flow count and the index can be computed as a measure of out-migration inequality for each origin and of in-migration inequality for each destination, as well as an overall index for all flows in the system. Alternatively, the expected (mean) value can be replaced with another value (e.g. from another matrix). An index of inequality value of zero indicates that all origin-destination flows in the system are equal to the mean, whereas a value of unity would suggest only one positive flow in the system with all other flows being zero. The *index of migration effectiveness* computes net migration as a proportion of the total of its constituent inflows and outflows, giving a measure of how efficiently net migration redistributes the population in the category selected. Some of these analytical facilities are exemplified in the next section of the paper.

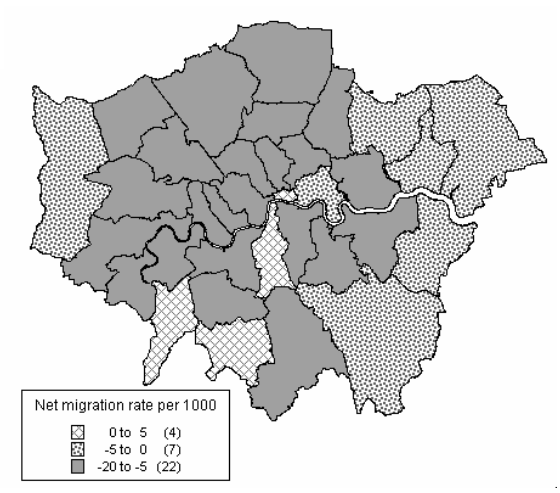
4 Using the 2001 data: some examples

Selected examples are used in this section to illustrate some analyses of 2001 Census data that have been extracted from WICID. In the first example, we compare patterns of aggregate net migration for boroughs and then investigate variations by ethnic group. In the second, we extract data to compute net migration balances by age for London as a whole and then use WICID to compute migration effectiveness scores. In the third example, SMS and SWS data are used to compute migration and commuting connectivity indices for different ethnic groups in London. Finally, we compare commuting patterns to the City of London using primary SWS data for 2001 and derived data for 1991.

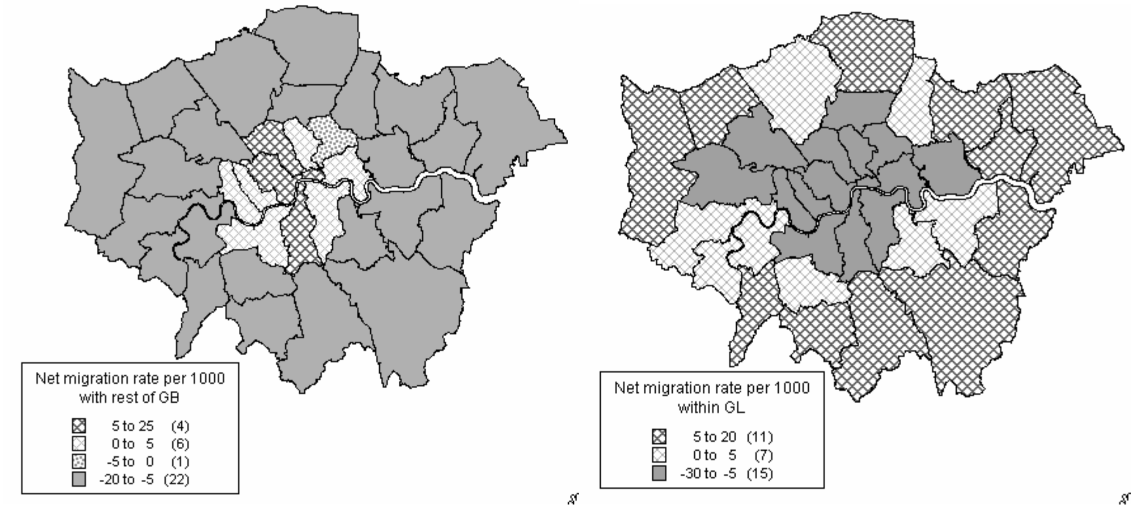
4.1 Internal migration and ethnicity in London in 2001

Greater London is the hub of the British internal migration system. In the 12 months before the 2001 Census, London lost, in net terms, over 50,000 people to the rest of Great Britain. In Figure 11, we contrast the pattern of overall net migration rates for the London boroughs with net rates for migration between London boroughs and the rest of Britain and net rates for migration occurring between boroughs of London. The patterns are very different suggesting that London has its own internal migration dynamics. Overall, all the boroughs except City (‘the square mile’), Kingston upon Thames, Sutton and Lambeth record let losses when data from SMS Table 104 is used. However, it is the boroughs that constitute the outer ring that are losing to the rest of Britain; the inner London boroughs, with the exception of Hackney, are all gaining from internal net migration from the rest of the Britain. On the other hand, the pattern of net migration rates for migration within London shows net migration gains in the outer band of boroughs and losses for a wider set of inner boroughs. In other words, people are leaving inner London for the outer suburbs, but these net gains are being offset by net out-movement from the outer suburbs to the rest of Britain.

(a) Location map of boroughs



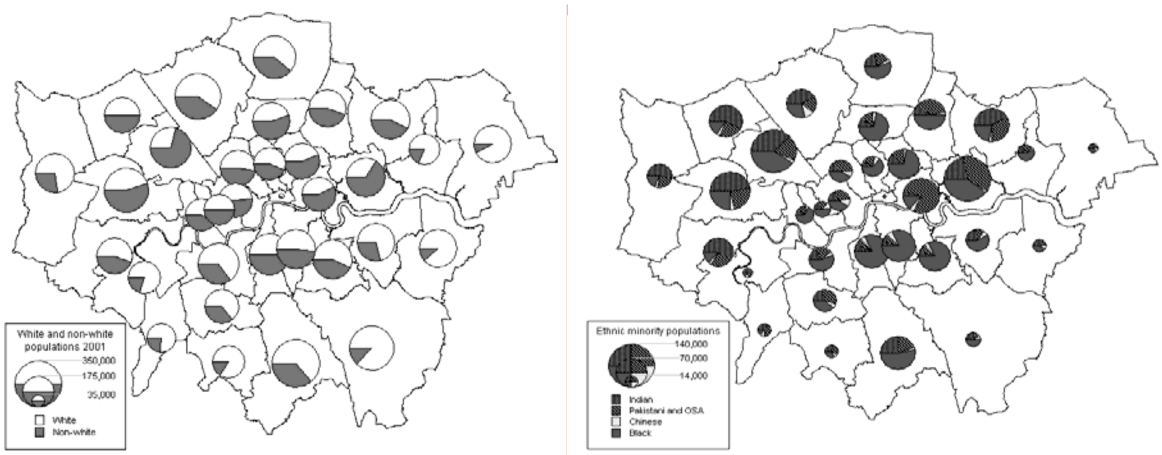
(b) Overall net rate



(c) Net rate with rest of GB (d) Net rate within London

Figure 11: Patterns of net migration for London boroughs, 2000-01

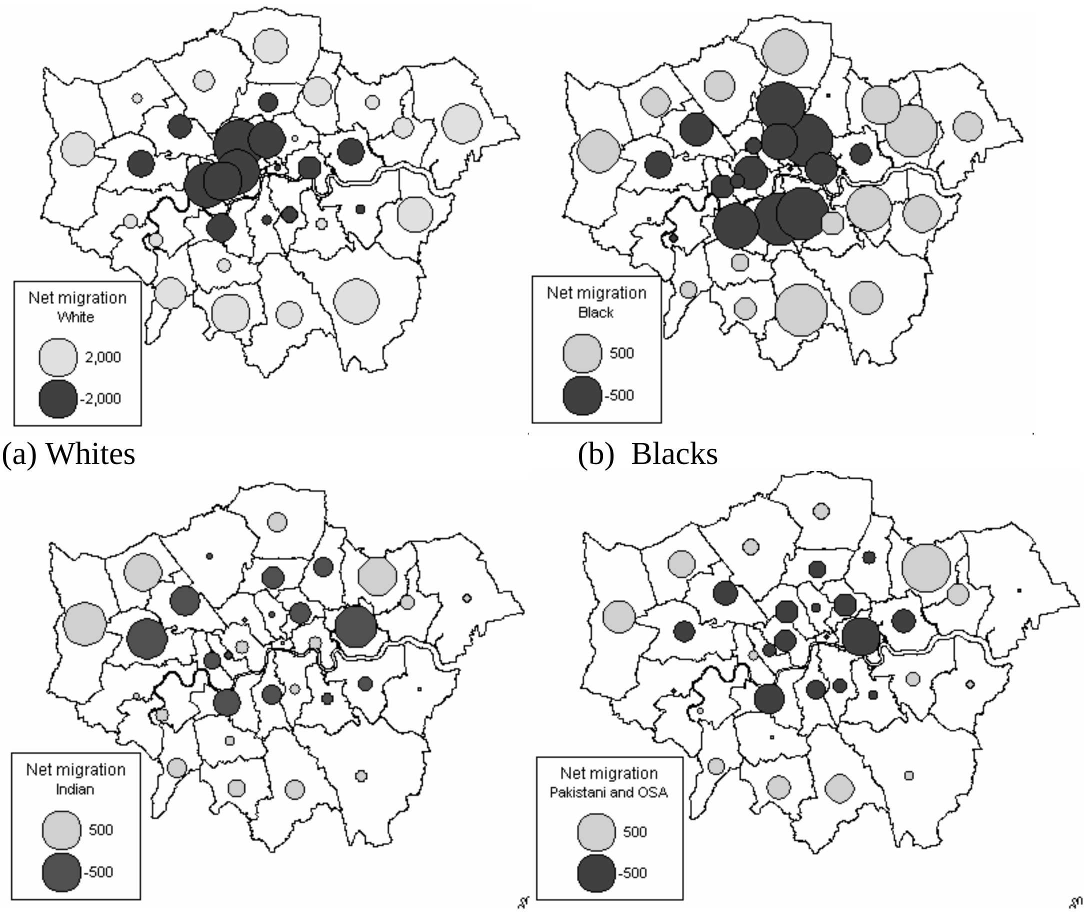
One question that emerges from these maps is whether the patterns of deconcentration within London are occurring for different ethnic groups, recognising that London has a huge proportion of ethnic minorities, many of whom are non-white (Figure 12) according to the 2001 Census Key Statistics.



(a) White and non-white (b) Non-white groups

Figure 12: Distribution of white and non-white and selected non-white ethnic populations, 2001

In this instance we choose to show how the net migration balances vary across the London boroughs for four ethnic groups: whites; Indians; Pakistanis and other South Asians; and blacks (Figure 13). The general patterns are remarkably similar, with inner London boroughs losing through migration in all ethnic groups and outer boroughs gaining through net in-migration. There are, however, more detailed differences in the magnitude of loss from the inner city boroughs according to ethnic group. White losses are highest from the west end, whilst blacks and Pakistanis and other South Asians are leaving boroughs both on the north and south sides of the river in which they have a significant presence. The set of boroughs on the outskirts of London experiences net gains across all the ethnic categories. These maps suggest patterns of deconcentration of non-white populations that following those of whites.



(a) Whites

(b) Blacks

(c) Indians

(d) Pakistanis and other South Asians

Figure 13: Net migration balances for selected ethnic groups, 2000-01

4.2 Migration effectiveness by age

It is unfortunate that the Census interaction data tends to be uni-dimensional, allowing little cross-classification of variables. Thus, for example, there is no data available on migration by ethnic group and age or occupation and researchers requiring this type of data would have to use microdata from the Samples of Anonymised Records (SARs). Age is clearly an important influence on migration propensity in all systems of interest as shown in a number of studies, most notably by Rogers, Raquillet and Castro (1978) and

Rogers and Castro (1981) and. In this example, we have used WICID to extract data for 2000-01 for flows within London and between London and the rest of GB and to calculate the effectiveness of migration for different quinary age groups.

The graphs in Figure 14 show, in absolute volume terms, the size of the respective flows and the net balance for London as a whole. The peak of migration within London and from London to the rest of GB occurs for those aged 25-29. However, London attracts a peak inflow of migrants aged 20-24 and this creates an age schedule of negative net migration balances in all ages apart from 20-24 and 25-29. The peak gains at age 20-24 are likely to occur due to the influx of students and young workers to the capital. Students will be represented in this age group because many of those aged 19 on entry to HE will be aged 20 at the time of the 2001 Census.

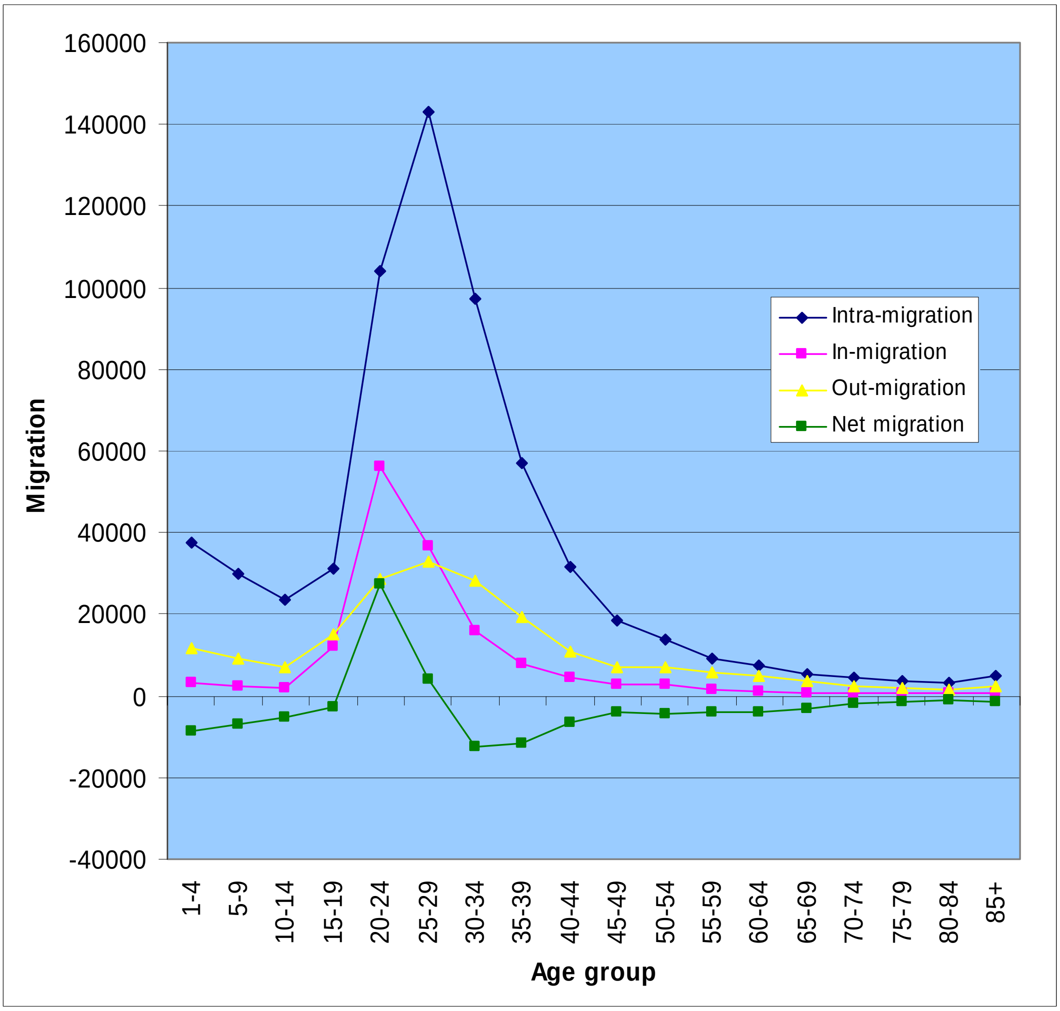


Figure 14: Migration flows and net migration balances by age group for London, 2000-01

The net migration balances shown in Figure 13 demonstrate the magnitude of the difference between inflows and outflows for London resulting in a net loss of around 50,000 persons during the 12 month period. It is interesting to note that no retirement peaks are evident from these data since they have not been standardised for population size. In order to assess the importance of these migration balances for each group, WICID has been used to compute the migration effectiveness scores for each age group (Figure 15). Migration effectiveness measures the net flow as a proportion of migration turnover (inflow plus outflow), demonstrating that although the net losses appear to be relatively small in magnitude for older age groups, it is in these age groups, where the impact of net out-migration is most important. The retirement age groups in particular, involving those in their 60s, have net migration losses that reach 68% of migration turnover, whereas the young adult net gains aged 20-24 in fact only involve 32% of the those arriving and leaving.

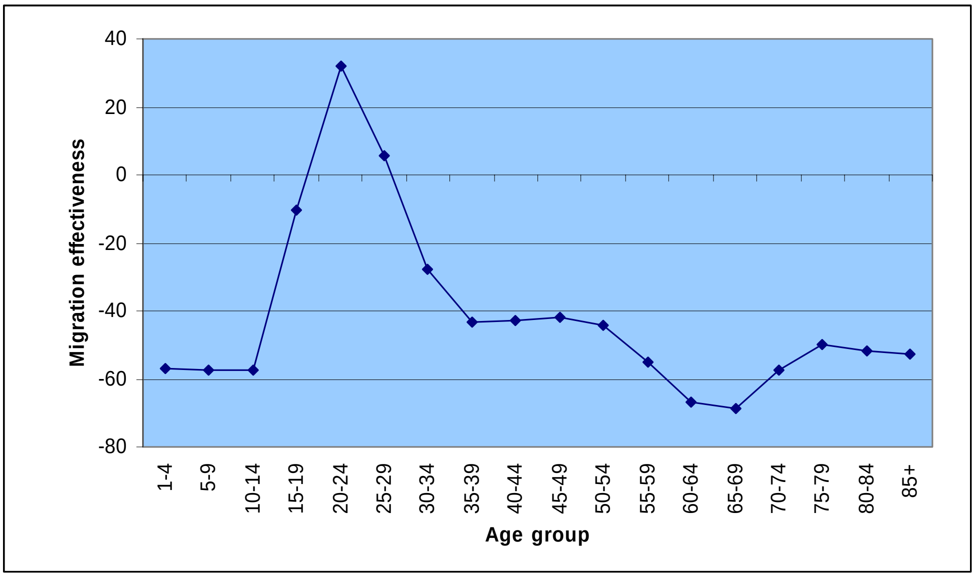


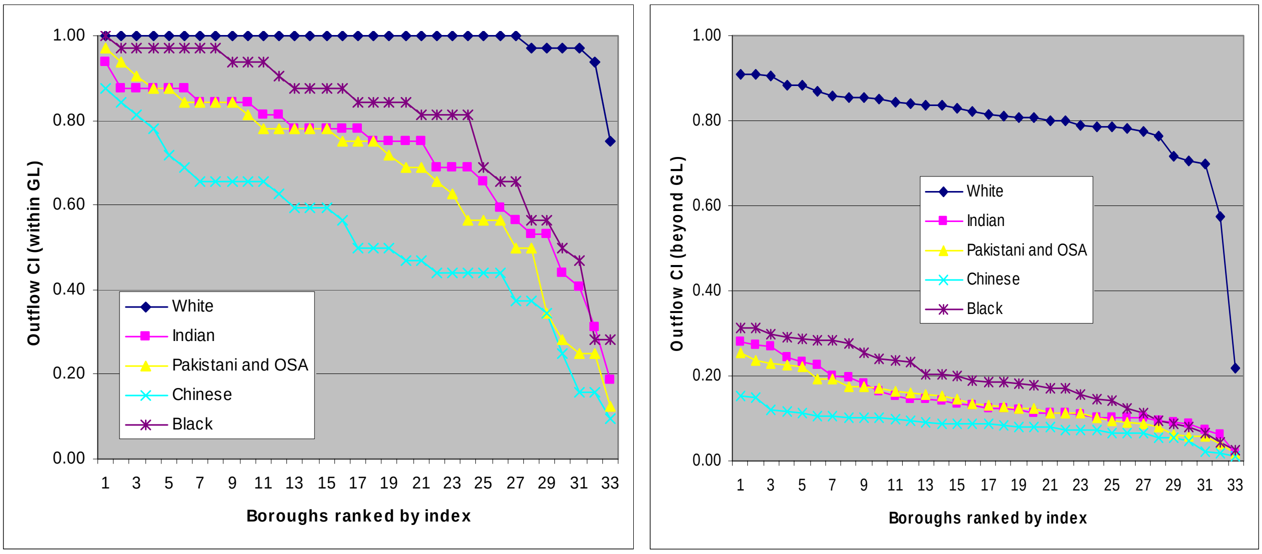
Figure 15: Net migration effectiveness by age group for London, 2000-01

4.3 Migration and commuting connectivity by ethnic group

In the third example, we have chosen to consider ethnic group variations in the extent to which London boroughs are connected with one another. Two dimensions of connectivity are considered here. The first involves flows of migrants from London boroughs to other London boroughs on the one hand, and to other local authorities in the rest of Britain on the other. The second involves those aged 16-64 who commute to work in each London borough from other London boroughs. Indices of connectivity have been computed in

WICID that indicate for any one borough, what proportion of the other boroughs in London or of local authorities in the rest of GB they have some connection with (i.e. where there at least three out-migrants from the origin borough to a destination).

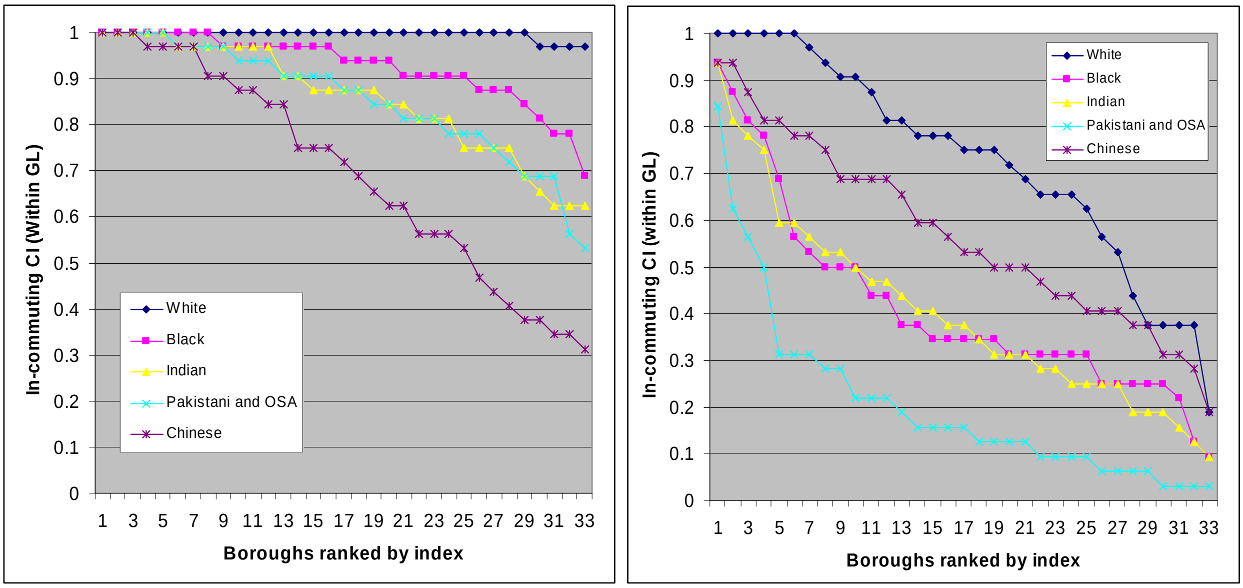
In Figure 16, boroughs have been ranked according to their connectivity index for each ethnic group, showing that as far as whites are concerned, virtually all boroughs are connected with one another within London. At the other end of the spectrum, least connectivity is exhibited by the Chinese. There is some evidence to suggest lower levels of connectivity for out-migrants belonging to the Pakistani and other South Asian group than the Indian group. When we consider migration between London boroughs and elsewhere in Britain, variations between whites and other ethnic groups are much more clearly defined. Half the London boroughs are connected by out-migration to 80% or more of the other local authorities in Britain, whereas most boroughs have out-migration connections with less than 20% of boroughs in the remainder of the country.



(a) Flows within London (b) Flows outside London

Figure 16: Out-migration connectivity by ethnic group for London boroughs, 2000-01

The second measure of connectivity is for in-commuters to each London borough from other London boroughs and, in this example, we distinguish between all flows and flows of full-time students in Figure 17. Commuting connectivity is greater within London than migration connectivity, but similar differences occur between white, black, Asian and Chinese ethnic groups.



(a) All in-commuters (b) Full-time student in-commuters

Figure 17: In-commuting connectivity by ethnic group for London boroughs, 2000-01

Much greater discrimination between ethnic groups is evident from the graphs for full-time student commuters. In this case, blacks and Indians exhibit similar levels of connectivity, and indices are lowest for the Pakistani and other South Asian group. Chinese students, on the other hand, although having the lowest levels of out-migration connectivity, experience higher levels of in-commuting connectivity than the other three ethnic groups.

4.4 Commuting to London

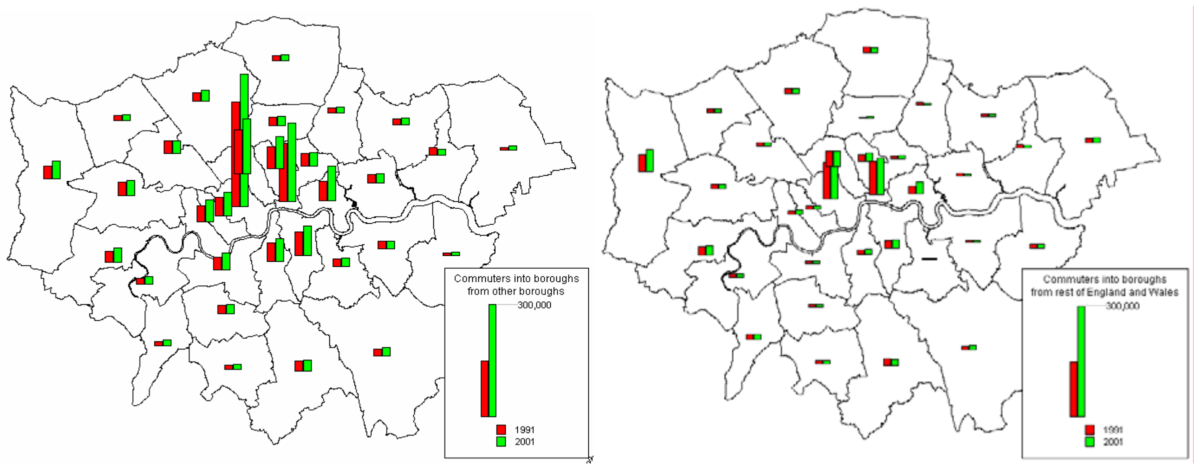
In this last example, we have chosen to examine how commuting flows to London boroughs have changed between 1991 and 2001, focusing in particular on the changes in flows within London and those arriving from the rest of England and Wales. In order to do this, we make use of the 2001 SWS and the 1991 SWS re-estimated for 2001 boundaries. The aggregate statistics (Table 10) suggest an increase of 20% in the commuting flows into London boroughs from 2.1 million to 2.5 million between the two census dates. However, the increase in flows from outside London (8.6%) is much smaller than the increase in inflows from other London boroughs (25.3%). In fact, the largest increase in commuting (nearly 60%) during the 1990s was taking place within boroughs, suggesting that more and more people in London and making shorter journey to work trips, and being primarily responsible for the 31% increase in total commuting flows.

Table 10: Commuting flows into London boroughs, 1991 and 2001

	1991*		2001		1991-01
	Number	%	Number	%	% change
Total flows	2,906,820	100.0	3,803,874	100.0	30.9
Flows within boroughs	806,300	27.7	1,282,529	33.7	59.1
Flows between boroughs	1,436,590	49.4	1,800,430	47.3	25.3
Flows from outside London	663,930	22.8	720,915	19.0	8.6
Flows entering boroughs	2,100,520	72.3	2,521,345	66.3	20.0

** 1991 data has been multiplied by 10*

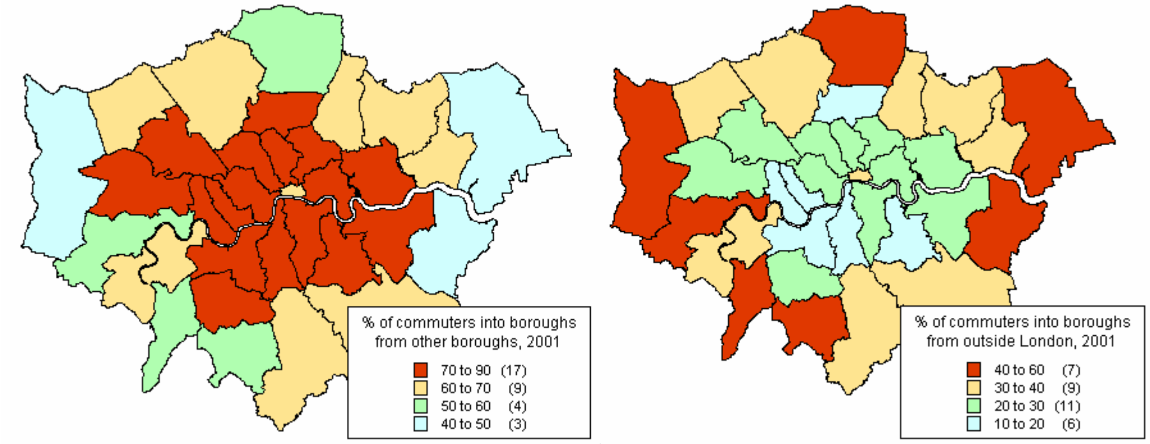
The variations across London between boroughs in terms of their commuting inflows are substantial (Figure 18) but remain consistent between 1991 and 2001. The Borough of Westminster records over 350,000 commuters in 2001 with origins elsewhere in London and a further 110,000 coming from the rest of the country. The City of London ranks in second place with over 210,000 commuters from within London and further 100,000 from outside the capital. Only in two boroughs, Bexley and Havering, were the inflows from London exceeded by the inflows from elsewhere in both periods.



(a) Inflows from elsewhere in London (b) Inflows from outside London

Figure 18: Commuting inflows to London boroughs, 1991 and 2001

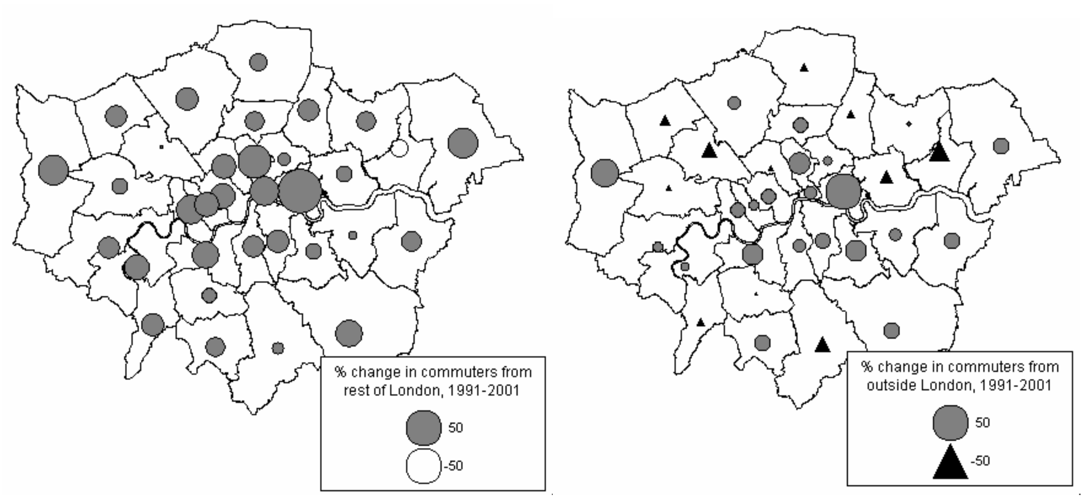
As we might expect, the geographical patterns of destinations for commuters depend to a large extent on where they originate. In Figure 19, two maps based on 2001 data are compared: the first illustrates that the inner London boroughs are the destinations for the large majority flows that originate within London, whilst the outer boroughs have much lower shares from within London. The second map is the mirror image of the former, demonstrating that for flows originating outside London, it is the outer boroughs (and the City of London) that have the higher shares of this category of commuters. The patterns were much the same in 1991.



(a) Inflows from elsewhere in London (b) Inflows from outside London

Figure 19: Percentage shares of commuting inflows to London boroughs, 2001

The increase in the overall volume of commuting between 1991 and 2001 conceals a range of experience for different boroughs (Figure 20). Commuting from within London to Tower Hamlets rose by over 70% whilst equivalent flows to Harrow declined by 14% between 1991 and 2001. Several boroughs experienced declines in their commuting inflows from outside London, particularly Brent, Croydon, Newham and Barking and Dagenham, whilst the largest increases occurred in Tower Hamlets and Hillingdon.



(a) Inflows from elsewhere in London (b) Inflows from outside London

Figure 20: Percentage changes in commuting inflows to London boroughs, 1991-2001

5 Conclusions

CIDS has now been in operation for users of census interaction data sets since 2002 and its web-interface (WICID) has been modified to incorporate new data sets. The Origin-

Destination Statistics from the 2001 Census were released by the Census Offices in 2004 and have been loaded successfully into WICID. In addition, data from the 1981 and 1991 Censuses has been re-estimated for spatial units defined in 2001 and this allows more consistent comparison over time. Whilst this is of considerable benefit, accurate comparisons between particular counts from one census to the next are frustrated by changes in the definition and tabulation of variables and in the nature of the adjustments that have been undertaken to prevent any risk of disclosure. One of the key messages to users of the system is the importance of obtaining a clear understanding of the data sets being used for the analysis being undertaken. The first part of the paper endeavours to assist the user in this respect by contrasting the tables and counts in 2001 with those in 1991 and demonstrating the extent to which the 2001 adjustment methodology (SCAM) has affected the interaction data sets.

As well as the inclusion of new data sets into the system, various functions or facilities within WICID have been developed to facilitate user access to the data prior to extraction and user analysis of the data following extraction. A new map selection tool has been constructed in response to feedback from users (particularly students) whose knowledge of the geographies of the UK is limited and who require some assistance in selecting sets of zones to build customised queries involving origins and/or destinations at different spatial scales. The map selection tool has yet to be operationalised for the 2001 data sets. The analysis facilities offered by WICID are useful because they add value to the raw counts extracted from the primary and derived data sets. Currently, a restricted set of indicators are available and considerable work remains to be done to assemble the count-specific populations at risk and the inter-area distances required to make the facilities fully functional with 2001 data. These tasks form part of the CIDS agenda over the next 12 months.

Finally, we have included in this paper a series of examples based on selected the migration and commuting data sets for Greater London and its boroughs that illustrate the importance of the data in helping us to understand human behaviour in a spatial manner. Several of the results have been generated through innovative disaggregation of counts of net migrants or in-commuters to London boroughs from within London or from outside. The results provide a number of fascinating insights confirming or extending our understanding of various processes that others have studies in detail. We have shown the extent to which net migration gains in the outer band of boroughs that arise due to net in-migrants from inner London have been cancelled out by the net out-movement from the outer suburbs to the rest of Britain. We have indicated how non-white ethnic groups in London are deconcentrating geographically to the outer suburbs through net migration in patterns that are similar to those of white migrants. We have demonstrated the importance of net migration losses from Greater London as a whole for the more elderly by using a migration effectiveness indicator. We have presented analyses on connectivity for both migration and commuting interaction that reveal the variations that are apparent by ethnic groups. Finally, we have provided some time series comparisons of commuter inflow patterns into London boroughs in 1991 and 2001 and identified those boroughs where changes have been most evident. These analyses provide evidence of the value of the interaction data sets collected by successive censuses in the past and add strength to the request for the continued generation of census interaction data sets in the future.

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