

Using WICID (Web-based Interface to Census Interaction Data) in the Classroom

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ABSTRACT

The Census of Population is one of the key sources of data for social science research in the UK. Many census results appear in published reports, but most data are available directly from the Office of National Statistics or from web sites offering extraction services for registered users. Many Geography students use information from the census to undertake projects and to complete dissertations, frequently when studying small geographical areas. It is important that students learn the skills for downloading census data and understand what shortcomings are associated with the data as well as knowing how to incorporate the data into GIS and to analyse it effectively. This paper focuses on how students at the University of Leeds are taught to use one particular product of the census, the Origin-Destination Statistics, that are available from a web-based interface known as WICID. The paper briefly outlines the context and characteristics of the data before explaining the rudiments of building queries and extracting data. A typical class assignment is presented to demonstrate how a student learns how to build queries using WICID before analysing the results or mapping the data using an independent GIS. Experience indicates that students need to think hard about their requirements before using WICID for project work.

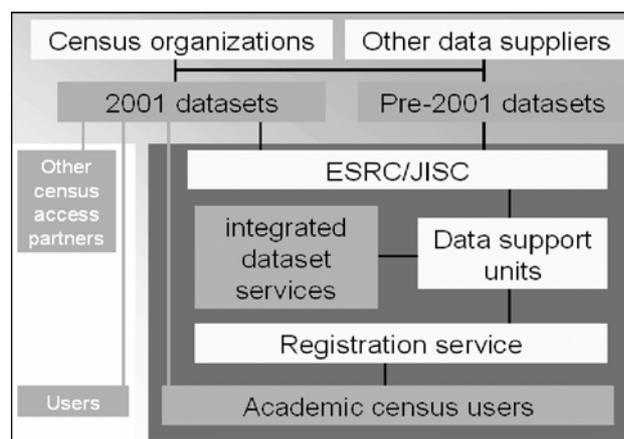
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1. DELIVERING UK CENSUS DATA FOR EDUCATION AND RESEARCH

In the absence of a population registration system, the Census of Population in the UK remains an extremely important source of data. Its relative reliability together with its comprehensive territorial coverage and small area detail mean that it is used widely in national, regional and local government, by health authorities and other service providers and by the private sector. It also represents a very important source of data for research and education. The spatial detail that is provided by the census ensures that it has particular value for students of Geography interested in the socio-demographic variations that occur in the population from place to place.

The provision of easy access to census data has been high on the agenda of the national census organisations (in England and Wales, Scotland and Northern Ireland) over the last few years, as the results of the 2001 'one number' census have been produced. On the academic front, the Economic and Social Research Council (ESRC) and the Joint Information Systems Committee (JISC) have purchased data from the Office of National Statistics (ONS) for use by the higher and further education community for teaching and research. ESRC/JISC also provide funding through the Census Programme (currently 2001-2006) to enable members of the academic community (staff and students) to access data from the 2001 and previous

censuses quickly and effectively. The framework of the Census Programme 2001-2006 is illustrated in Figure 1.



Source: Martin (2003)[2]

Figure 1: The UK Census Programme

At the heart of the Census Programme are the following six 'Data Support Units' (DSUs) which provide access to different types of information:

- the *Census Dissemination Unit* (CDU) at MIMAS, University of Manchester supporting the Census Area Statistics and postcode lookup tables;
- the *UKBORDERS* service at EDINA, University of Edinburgh, supporting digital boundary data sets;
- the *Census Interaction Data Service* (CIDS) at the Universities of Leeds and St Andrews supporting the Origin-Destination statistics;
- the *Cathie Marsh Centre for Census and Survey Research* at the University of Manchester supporting the Samples of Anonymised Records;
- the *Centre for Longitudinal Study Information and User Support* (CELSIUS) at the London School of Hygiene and Tropical Medicine supporting the Longitudinal Study; and
- the *Census Registration Unit* (CRU), based in the UK Data Archive at the University of Essex registering all users wishing to use any of the data held by the other support units.

Further details of the DSUs, their services and their data holdings are available from the portal maintained by the Census Programme Coordinator (<http://census.ac.uk/>) or from their respective web sites of the individual units. In this paper, we focus on one of these units, the Census Interaction Data Service (CIDS) which provides access to the so-called 'Origin-Destination Statistics' or interaction data sets through a system known as WICID, the Web-based Interface to Census Interaction Data, located on a server at the University of Manchester.

2. ORIGIN-DESTINATION STATISTICS

Among the lesser known but extremely useful products of the last three censuses of population in Britain (1981, 1991 and 2001) are the data sets known collectively as the Special Migration Statistics (SMS) and the Special Workplace Statistics (SWS). The various data that constitute the respective SMS and SWS are the flows of *migrants* (individuals, households or moving groups) and of *commuters* between origin and destination zones at census ward and local authority level, together with counts flows between very small areas known as 'output areas' in 2001. The migrant data refer to flows in the 12 month period prior to the census, whilst the commuting data refer to the journey between place of residence and main place of work in the week prior to the census.

These data sets are very large and complex because that they involve geographies of origin and destination zones as well as counts disaggregated by age, sex, ethnicity, economic position and so forth. In 2001 for example, there were 426 local authority districts in the UK, 10,608 census wards and over 223,000 output areas. Each matrix of origin-destination flows at the district level alone potentially contains 181,476 cells, although the majority of these will not have counts in them. Further data sets for 1991 and for 1981 are available as explained in Stillwell *et al.* (2005)[9], some of which have been derived from the raw counts. Access to flow data of this type has been a major problem in the past and this is one of the reasons why these products, produced at some cost to the census agencies, have not been used extensively in the past. In fact, the SMS/SWS data sets provide a huge resource for student projects. Further details of the tables and counts involved are available in Rees *et al.* (2002) [5] and in Stillwell and Duke-Williams (2003) [8].

In this paper, we consider access to the interaction data from a student user perspective, and demonstrate how a student would go about using WICID to build and refine queries, to extract and download data and also to carry out some online analysis based on the extracted data. WICID has been beta tested by students in the classroom and is used regularly by students to extract data for their projects and dissertations. This paper will demonstrate how students build queries to generate data that will help them to answer key migration or commuting questions.

3. USING WICID FOR QUERY-BUILDING AND DATA EXTRACTION

Although WICID has a guest function that allows anyone to logon and explore the system, those wishing to extract and download interaction data are required to do two things initially: to obtain an Athens userid and password and to become a registered census user.

The Census Registration Service facilitates access to the census data resources for UK higher and further education via Athens Single Sign On at <http://census.data-archive.ac.uk/>. Currently the system is only available to members of the academic community in the United Kingdom. Once registered, access to the CIDS homepage is at <http://cids.census.ac.uk/> as shown in Figure 2. Clicking on the WICID button on the homepage will start the system.



Figure 2: The CIDS homepage

In technical terms, one of the major challenges in developing WICID has been to allow users the flexibility of selecting zones from different geographical scales and allowing the origin zone set to be different from the destination zone set. In practice, this means that the system has to respond to the following type of query: extract all the commuting flows into the centre of a particular city (designated by a central ward) from other wards in the city, from surrounding districts, from other counties or regions and from the rest of the world. From a user perspective, this procedure is facilitated by using a traffic light metaphor (Figure 3) to ensure that the geographical settings and the variable selections have been completed satisfactorily before the query is allowed to run. Users (students) can refine the query prior to extraction e.g. to set the diagonal (intra-zone) flows to zero if required.

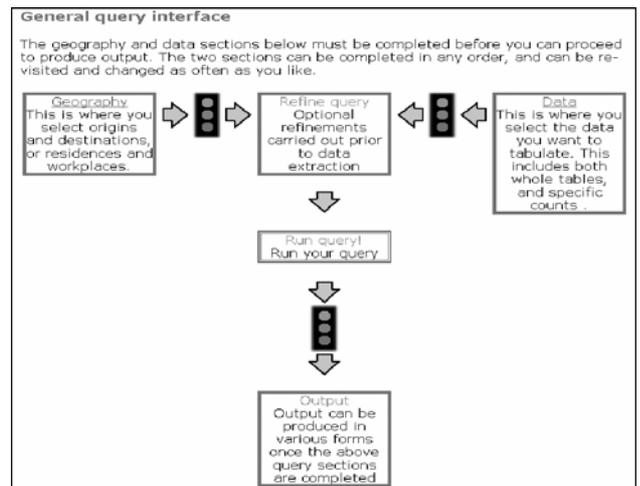


Figure 3: The WICID query interface

Geographical settings and variables can be selected in whichever order the user requires. By clicking Geography on the query interface, the user is transferred to a screen indicating the available selection tools. There are various methods of selecting geographical areas (Figure 4): '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; and 'Type-in-box' selection provides for one area to be selected at a time. One of the new developments in WICID using web-mapping software is that of 'Map selection', explained in more detail in Stillwell (2005)[7].

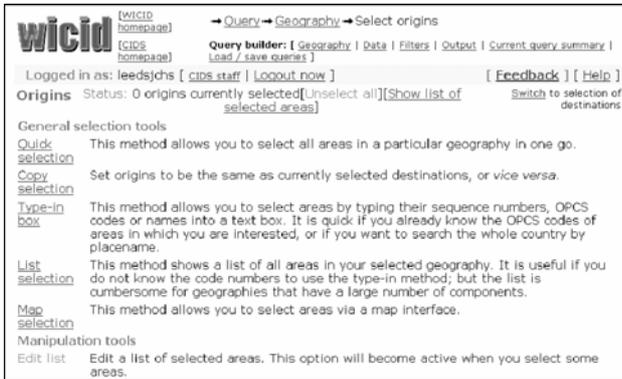


Figure 4: Area selection tools available

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 whose precise locations and names they will not be familiar with. All the area selection methods require that users initially choose the spatial scale or level of geography for which they wish to extract data in the first instance. The main geographies available currently for 1991 and 2001 are shown in Figure 5 and the user is required to click on whichever level is required. If a data variable has already been selected, those geographies for which no data is available will be greyed out. Note the different numbers of areas associated with different geography options and that icons before each geography can be clicked to show further information.

Geography	Number of areas
Main Geographies	
Great Britain	1
GB Countries 1991	3
GB Standard Regions 1991	10
GB Counties 1991	67
GB Districts 1991	459
GB Wards 1991	10933
1991SMS Foreign origins	98
1991SMS Misc. origin totals	4
1991SWSC Other residence categories	1
UK Output Areas 2001	223060
UK Interaction data wards 2001	10608
UK Interaction data districts 2001	426
UK Government Office Regions (1999-)	12
UK Standard Table Wards 2001	10558
CIDS 1991/2001 common geography - 'districts'	417
CIDS 1991/2001 common geography - 'intermediate'	219
CIDS 1991/2001 common geography - '100 zones'	100
CIDS 1991/2001 common geography - 'city regions'	47
United Kingdom - member countries	4
Great Britain and Northern Ireland	2

Figure 5: Main Geographies available in WICID

The most common method used for selecting areas tends to be the list selection method (Figure 5). If, for example, the user chooses 1991 GB Districts, the screen shown in Figure 6 will appear and the user can make the desired selection by checking the appropriate boxes and clicking on 'Add chosen areas'. A mechanism is available to allow users the option of using two levels of geography; i.e. to select all wards in one district by selecting that single district.

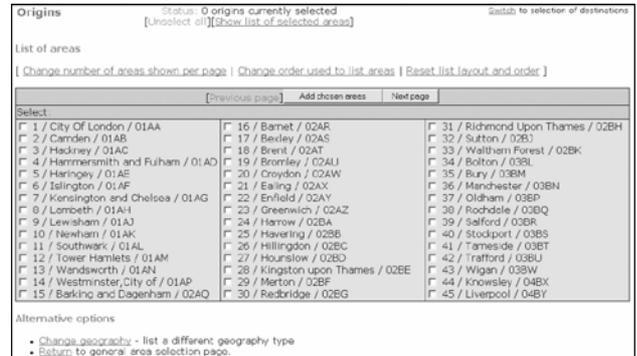


Figure 6: List selection of districts

Different sets of origins and destinations can be selected and each set may contain areas at different spatial scales so long as data exists in the database for this level. Consequently, results can be produced for asymmetric matrices in which the origin and destination areas are completely different, e.g. flows between boroughs of London and districts of the South West region of England.

Once origins and destinations have been selected, the next step is to select the variables by clicking on 'Data' in the query interface. A corresponding set of data selection methods are available: 'Query selection' allows the selection of pre-defined totals that are available with certain data sets; 'Select by variable' enables particular variables to be found quickly; 'Select by data set and table' allows the selection of cells in tables as described in published documentation and is the most commonly used method. Once a data set has been selected (Figure 7), the user chooses the table required (Figure 8) and finally the variable(s) from the selected table. Figure 9 indicates that four variables/cells are selected from 1991 SMS Set 2: Table 6, counts of flows of migrants who are either in households or not and who have a limiting illness or not.

Data period	Data set	Sample data sets
1990-91	Sample data	Sample dataset - blurred count of inter-district migrants from 1991 Census
Migration data		
2000-01	2001 SMS Level 1	District level migration data from the 2001 Census
	2001 SMS Level 2	Ward level migration data from the 2001 Census
	2001 SMS Level 3	Output area level migration data from the 2001 Census
1990-91	1991 SMS Set 1	Ward level migration data from the 1991 Census
	1991 SMS Set 1 (2001 geog)	Ward-level migration data from the 1991 Census, re-estimated for 2001 boundaries
	1991 SMS Set 2	District level migration data from the 1991 Census
	1991 SMS - MIGPOP	Simpson and Middleton MIGPOP data
	1991 SMS - SMSGAPS	Rees and Duke-Williams SMSGAPS data
	1991 Table 100(a)	District level place of residence by term-time address (resident students)
	1991 Table 100(b)	District level place of residence by term-time address (present students)
1980-81	1981 SMS Set 2 (1991 geog; inc. operate 'origin unstated')	Ward-level migration data from the 1981 Census, re-estimated for 1991 boundaries
	1981 SMS Set 2 (1991 geog)	Ward-level migration data from the 1981 Census, re-estimated for 1991 boundaries
	1981 SMS Set 2 (1981 geog; county/region level)	County/region level migration data from the 1981 census using 1981 geography
	1981 SMS Set 2 (2001 geog)	Ward-level migration data from the 1981 Census, re-estimated for 2001 boundaries

Figure 7: The data sets available on migration

1991 SMS Set 2: District level migration data from the 1991 Census		
Pre-defined totals	Total migrants	
Table 1	All migrants: age (5 broad age groups) by sex	
Table 2	Wholly Moving Households and residents in Wholly Moving Households: counts	
Table 3	All migrants: age (5 year groups) by sex	
Table 4	All migrants: marital status by sex	
Table 5	All migrants: ethnic group	
Table 6	All migrants: whether resident in households by whether suffering from limiting long term illness	
Table 7	All migrants aged 16+: economic position	
Table 8	Wholly Moving Households: tenure	
Table 8S	Wholly Moving Households: tenure	
Table 9	Wholly Moving Households: sex and economic position of head	
Table 10	Residents in Wholly Moving Households: sex and economic position of head	
Table 11S	All migrants: Gaelic speakers	
Table 11W	All migrants: Welsh speakers	

Figure 8: Tables available in 1991 SMS Set 2

Data Status: 0 data items currently selected
[Unselect all][Show list]

Select individual cells or totals and then click "Add selected cells". Checking the checkbox next to row or column labels will lead to all cells in that row or column being selected

All migrants: whether resident in households by whether suffering from limiting long term illness (1991 SMS Set 2 Table 6)

Add selected cells Select all Clear all

	<input type="checkbox"/> With limiting long term illness	<input type="checkbox"/> Without limiting long term illness	TOTAL
<input type="checkbox"/> In households	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> Σ
<input type="checkbox"/> Not in households	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> Σ
	<input type="checkbox"/> Σ	<input type="checkbox"/> Σ	

Figure 9: Cells of table 6 in 1991 SMS Set 2

Once the selection has been made, the data can be extracted and downloaded. It is appropriate to check that everything is in order by returning to the general query screen and ensuring that the lights are on green (Figure 3), producing a summary of the query and then extracting the data by clicking on 'Run query'. The time taken to perform the query will depend upon the amount of data to be extracted. When the extraction has been completed the user will be informed of the time taken to complete the procedure (Figure 10) and invited to continue, at which point the data can be shown on screen (if not too extensive), downloaded or analysed.

Run query



The data is now being extracted; this may take some time, especially if you have large numbers of origins or destinations.

Done!

Extraction took 0.88 seconds

Options

- Continue to output pages
- WICID homepage
- Query homepage

Figure 10: Screen indicating extraction has been completed

Data sets of reasonable size can be printed to the screen but if the data are to be downloaded, the user has the option of choosing various formatting, labelling and layout options. Flows can be downloaded in matrix format or as a list for each origin-destination pair. However, WICID also allows users to undertake some analysis of the data extracted and 'add value' to the raw counts. The analytical facilities comprise a set of basic descriptive statistics and suite of indicators that WICID will compute for a selection of any five of the counts that have been selected in the query, as indicated in Stillwell *et al.* (2005) [9]. Some of these indicators require additional information such as populations at risk or distances between areas.

4. EXAMPLE QUERIES AND OUTPUTS

Classroom practicals are designed to introduce students to census interaction data and to teach them how to construct

queries and to extract subsets of flow data. Class sizes may involve up to 50 students working on separate terminals. Practical sessions are therefore focused on questions that relate to different census interaction data sets and students are required to respond to questions by constructing queries, extracting the relevant data and presenting results in either tabular, graphic or map form. The following is an example of a class exercise involving two queries:

Question 1: What is the age breakdown of in-migrants to Leeds Metropolitan District in 1990-91?

Construct a query that provides the data you require. Use 5 year age groups and 85+. You will need to 'derive' the 15-19 age group because age 15 is tabulated separately. Distinguish two types of flow: (a) those in-migrants to Leeds District from elsewhere in GB, and (b) those immigrants to Leeds District from overseas. Leave flows from unstated origins unselected. Extract the data you require, transfer it into Excel, and produce a graph illustrating the data. What do you conclude from your this subset of data?

Question 2: How did the social structure of commuting flows in Leeds vary spatially in 1991?

Construct a query that gives you the journey to work flows to the two central wards of Leeds from the other wards of Leeds and from the six districts that surround Leeds. This might be a good opportunity to test out the map selection tool! The flows should be disaggregated by social class (six categories) but not by sex (although this might be interesting too!).

Extract the data and transfer the data to Excel. Add the flows into the two destinations (called central Leeds) together and compute the percentages of the flows from each origin to central Leeds in each of the 6 social classes. Rank the origins according to the percentage of the flow in the Professional category and plot the percentages in each social class for each origin area using a 100% Stacked Column graph which allows you to compare the percentage that each value contributes across total categories. Produce two maps of the proportion of commuters to central Leeds that are in social classes 1 (professional) and 5 (Unskilled). What do you conclude about the spatial variation in the social class of commuters in Leeds?

Evaluation

When you have finished constructing the queries and extracting the data, please provide some comments on your 'experience' using the Feedback facility in WICID. Did you find the system easy to use? What problems did you encounter? Have you got any suggestions to make about improving the screen pages or the procedures? Please copy these into a word file for handing in as part of the assignment.

The query associated with the first of these tasks is illustrated in Figure 11, and indicates that the two origins to be selected are available from the 1991 SMS Miscellaneous origin totals (see Figure 5) whereas the single destination district of Leeds is selected from the GB Districts 1991. There are 18 age group variables that are selected from the 1991 SMS Set 2: Table 3. The 15 and 16-19 age groups have been merged into a single 15-19 age group shown at the end of the variable list. The extracted data is graphed in Figure 12 to indicate the familiar age schedule of migration peaking in the early twenties.

Summary of current query

Geography	
Origins	2 1991SMS Misc. origin totals: (Sequence number,Origin label,OPCS/ONS code) 2,Total inflow from GB,222222 to 3,Total inflow from overseas,333333
Destinations	1 GB Districts 1991: (Sequence number,District name,OPCS/ONS code) 68,Leeds,08DA
Interaction data	
Data items	18 1991 SMS Set 2: Age (5 year groups) 1-4, Age (5 year groups) 5-9, Age (5 year groups) 10-14, Age (5 year groups) 20-24, Age (5 year groups) 25-29, Age (5 year groups) 30-34, Age (5 year groups) 35-39, Age (5 year groups) 40-44, Age (5 year groups) 45-49, Age (5 year groups) 50-54, Age (5 year groups) 55-59, Age (5 year groups) 60-64, Age (5 year groups) 65-69, Age (5 year groups) 70-74, Age (5 year groups) 75-79, Age (5 year groups) 80-84, Age (5 year groups) 85+, Age 15-19

Figure 11: Query to extract data for Question 1

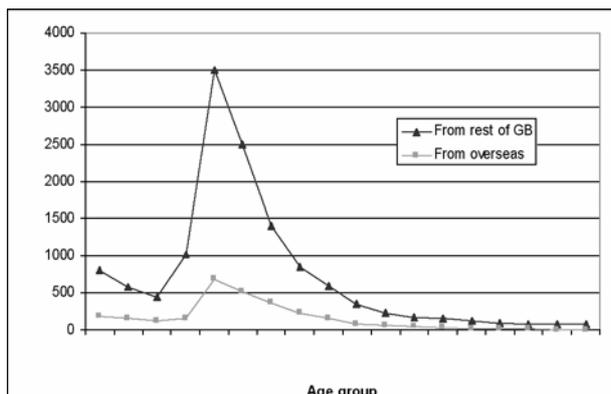


Figure 12: Results of query for Question 1

The second query requires a little more thought about the geographies of origin and destination since the question is focused on deriving commuting flows for the set of origins shown in Figure 13 that terminate in the two central city wards of Leeds (City and Holbeck and University wards). The origins are the 33 wards of Leeds plus the six local authority districts that surround the city (Harrogate, Selby, Wakefield, Calderdale, Kirklees and Bradford).

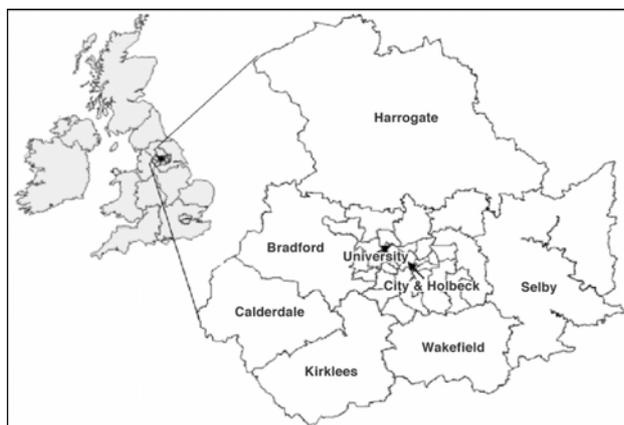


Figure 13: Ward and district origins required for Question 2

The 33 ward origins and two ward destinations are selected from the GB Wards 1991 whilst the six surrounding districts are selected from the GB Districts 1991 as shown in the first part of the query (Figure 14). The six variables refer to the counts of flows in each of the six social classes (I Professional; II Managerial; IIIN Skilled non-manual; IIIM Skilled manual; IV Partly skilled; and V Unskilled).

Summary of current query

Geography	
Origins	39 GB Wards 1991: (Sequence number,Ward name,OPCS/ONS code) 1623,Aireborough,08DAFA to 1655,Worley,06DAGK GB Districts 1991: (Sequence number,District name,OPCS/ONS code) 65,Bradford,08CX to 67,Kirklees,08CZ;69,Wakefield,08DB;293,Harrogate,37NZ;297,Selby,37PD
Destinations	2 GB Wards 1991: (Sequence number,Ward name,OPCS/ONS code) 1630, City and Holbeck,05DAFH;1651,University,08DAGF
Interaction data	
Data items	6 1991 SWS Set C: Social Class I Professional etc. occupations, Social Class II Managerial and technical, Social Class III(N) Skilled occupations - non-manual, Social Class III (M) Skilled occupations - manual, Social Class IV Partly Skilled occupations, Social Class V Unskilled occupations

Figure 14: Query for Question 2

Once the commuting flow data has been generated, students will need to work with the data in Excel to calculate the percentage of the flow from each origin into the destination zones that are of different social classes. Once this is done the origins are ranked on the basis of proportion in class 1 and a stacked column graph can be produced (Figure 15).

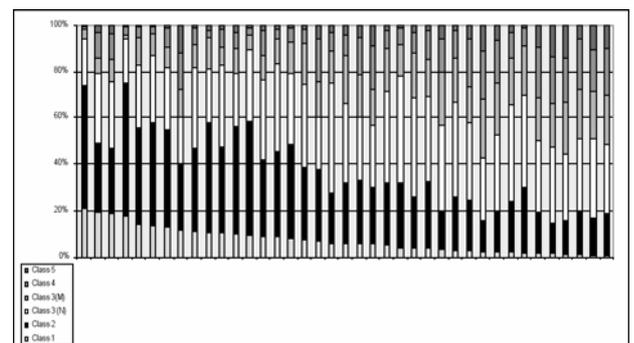


Figure 15: Stacked column graph

Data for the percentage professional and percentage unskilled would be input to MapInfo to generate maps (Figure 16) indicating how the higher social class commuters to the city centre tend to originate from the northern suburbs or from the inner city wards, whereas the highest proportions of unskilled commuters come from the south side or from the south side of the city.

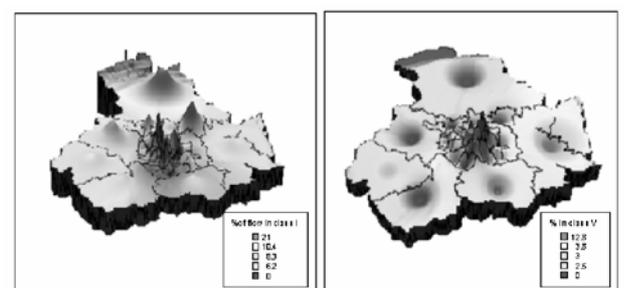


Figure 16: Results of query for Question 2

Successive cohorts of students has been used to test new versions of WICID since its inauguration in 2002. Comments are provided by students on what they like and what they find difficult through the feedback facilities that are available online. On many occasions these comments have led to the implementation of modifications and the simplification of procedures. In performing this function, students develop evaluation skills themselves.

5. USING WICID IN THE CLASSROOM

The examples shown in this paper are typical of the assignments that BA Geography students in their final undergraduate year at the University Leeds would be given when studying a third year module on 'GIS for Urban and Regional Planning'. These students would have already undertaken some training in the use of Excel and MapInfo desktop GIS in their second year and are preparing to improve their skills and develop their own applications by undertaking an independent project in the same module which would be based on using WICID to extract data that would be subsequently analysed and written up as a report. Our experience suggests that whilst the interface is relatively easy to use, students have to put considerable effort into thinking through exactly which data sets are required for which origins and destinations. This involves careful consideration of the phenomenon that they are studying and judgements about the spatial scale that is appropriate for analysis of that phenomenon before sitting in front of the computer. Thus, for example, a project on counterurbanisation might require the selection of a system or urban and rural spatial units whereas a project on immigration might be tackled at a national level or for whole cities of at a detailed level for one particular city.

It is very easy to generate large quantities of data and students learn quickly that it is often necessary to aggregate and summarise this information. Another key dimension of using census interaction data is to understand its characteristics so that any interpretation of results is made with recognition of the inherent shortcomings. The limitations of successive census data sets derive from underenumeration, origins being unstated, missing information, errors from sampling, and changes due to the methods used by census agencies to preserve anonymity and to reduce the risk of disclosure (see Flowerdew and Green, 1993[1]; Rees and Duke-Williams, 1997[4], Simpson and Middleton, 1999[6], Rees *et al.*, 2002[5], Stillwell and Duke-Williams, 2003[8]; and Stillwell *et al.*, 2005[9] for further information). These problems exist alongside the limitations associated with the definition, measurement and collection of census variables, as reviewed by Rees (1997)[3].

Although WICID has been designed primarily with a view to facilitating access to and analysis of the census interaction data sets by researchers, it does provide a very useful example for classroom teaching of students about relational databases and metadata, as well as the software components required to build customised web-based databases with analytical and mapping facilities, planning support systems (Stillwell and Geertman, 2003)[10] or decision support systems more generally.

In order to encourage use of WICID in the classroom at other higher and further educational institutions, teaching resources have been produced under another ESRC/JISC funded project entitled 'Developing the Collection of Historical and Contemporary Census Data and Related Materials (CHCC) into a Major Learning and Teaching Resource' whose web site is found at <http://ahds.ac.uk/history/collections/chcc.htm>. Tutorial guidelines are available as CHCC Unit 15 at <http://www.chcc.ac.uk/CAS/unit15/unit15.html>. In addition, the following materials have been prepared to support the use of the migration and workplace statistics by teachers:

- guidance notes for teachers that outline how materials might be used in the classroom;
- A Unit 15 text document that can be distributed to students for self study;

- a series of practical exercises; and
- a set of powerpoint slides that can be downloaded and used to teach the material in the unit.

CIDS is a service that encourages use of the interaction data sets. 'Easy access' and 'user-friendliness' are key principles in delivering the service. Users are at liberty to phone the help line in emergency situations or to email the developers with questions or for advice on using certain data sets or building particular queries. The development of WICID is ongoing. All the raw migration and commuting counts from the 2001 Census are now available from the system and work is underway to improve the ability to make comparisons between censuses, to construct new geographies that users might find useful, to enable users to create their own geographies, to extend the analytical facilities and to introduce a facility allowing users to map their results online rather than downloading to their own mapping/GIS package. Funding has now been secured until 2011 and, from 1 August 2006, CIDS has been rebadged as the Centre for Interaction Data Estimation and Research (CIDER). Plans are being developed to incorporate non-census interaction data sets as well as the flow data from the 2011 Census.

Acknowledgement

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References

- [1] R. Flowerdew and A. Green, "Migration, transport and workplace statistics from the 1991 Census", in A. Dale and C. Marsh, (eds) **The 1991 Census User's Guide**, London: HMSO, pp. 269-294, 1993.
- [2] D. Martin, "The ESRC/JISC 2001 Census Programme", presentation at Census Programme Workshop, 2003.
- [3] P.H. Rees, "The measurement of migration from censuses and other sources", **Environment and Planning A**, Vol. 9, 1977, 63-75.
- [4] P.H. Rees and O.D. Duke-Williams, "Methods for estimating missing data on migrants in the 1991 British Census", **International Journal of Population Geography**, Vol. 3, 1997, pp. 323-368.
- [5] P.H. Rees., F. Thomas and O.D. Duke-Williams, "Migration data from the census", in P.H. Rees, D. Martin and P. Williamson, (eds.), **The Census Data System**, Chichester: Wiley, pp. 245-267, 2002.
- [6] L. Simpson and E. Middleton, "Undercount of migration in the UK 1991 Census and its impact on counterurbanisation and population projections", **International Journal of Population Geography**, Vol. 5, 1996, pp. 245-267.
- [7] J.C.H. Stillwell, "Providing access to census-based interaction data in the UK: that's WICID!", **Proceedings of the 3rd International Conference on Computing, Communications and Control Technologies (CCCT'05)**, Austin, Texas, 2005.
- [8] J.C.H. Stillwell and O.D. Duke-Williams, "A new web-based interface to British census of population origin-destination statistics", **Environment and Planning A**, Vol. 35, 2003, pp. 113-132.
- [9] J.C.H. Stillwell, O.D. Duke-Williams, Z. Feng and P. Boyle, "Delivering census interaction data to the user: data provision and software developments, **Working Paper**, Leeds: School of Geography, University of Leeds, 2005.
- [10] J.C.H. Stillwell and S. Geertman, (eds.), **Planning Support Systems in Practice**, Heidelberg: Springer, pp.578, 2003.