Statistical disclosure control for 2011 Census
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Statistical Disclosure Control for the 2011 Census

Summary
- Disclosure control is provided mainly through targeted record swapping, targeted towards ‘risky’ records.
- The swap rate is linked with the non-response rate in each area.
- Attribute disclosure (AD) is considered the main disclosure risk, rather than small cells; all univariate tables will be released.
- There will be small cells and apparent attribute disclosures but it will not be possible to interpret these as real individuals or households in the area with a high degree of confidence.
- The population and household thresholds for output areas (OAs) are the same as in 2001.
- There will be some restrictions on the level of detail.
- Communal establishments’ (CEs’) outputs are protected by swapping individuals.
- Workplace zones (WPZs) have been developed to facilitate a better geography for workplace information.
- Origin-destination (flow) data protection is provided primarily through licencing/access conditions.

1. Introduction
1.1. UK Census
Every 10 years since 1801, apart from 1941, the UK has set aside one day for the census, whereby information is obtained on every member of the population. It is the most complete source of information about the population that we have with details of family composition, health, employment and other socio-economic characteristics. The information provided allows central and local government, health authorities and many other organisations to target their resources more effectively and to plan housing, education, health and transport services for years to come.

1.2. The need for statistical disclosure control
Census data are released in a number of different formats; standard pre-planned tables, commissioned tables requested by users and census sample microdata. Publishing either aggregate or individual data carries a risk that individuals or other entities (e.g. households, families, businesses) could be identified and confidential information about them could be released. The UK census offices need to protect the confidentiality of census respondents for a number of reasons. The production and use of official statistics depend on the cooperation and trust of citizens. Such trust cannot be maintained unless the privacy of individuals' information is protected. There are also legal and policy obligations that must be respected. The Census Act 1920 as amended by the Census (Confidentiality) Act 1991 and the Census Act (Northern Ireland) 1969 as amended by the Census (Confidentiality) (Northern Ireland) Order 1991, make it an offence for the national statistician, registrars general (or any person under their control or a supplier of any services to them) to disclose any personal
census information to another person without lawful authority. The Statistics and Registration Service Act 2007 places a legal obligation on the UK Statistics Authority to protect the confidentiality of personal information. The National Statistics Code of Practice\(^1\) Protocol on Data Access and Confidentiality set out principles for protecting confidentiality. These include the principle that:

'The national statistician will set standards for protecting confidentiality, including a guarantee that no statistics will be produced that are likely to identify an individual unless specifically agreed with them.'

### 1.3. The aim of statistical disclosure control

The aim is to ensure that statistical outputs provide as much value as possible to the users while protecting the confidentiality of information concerning individuals or entities. For example, the main concern for disclosure risk in census tables arises from small cell counts, i.e. ones and twos, since these can lead to identity disclosure (where a user can identify themselves or someone else in a table) and potential attribute disclosure (where a user is able to deduce something about an individual that they did not already know) depending on the number and placement of zero cells in the rows/columns of the table. Statistical disclosure control (SDC) methods for census tabular data should not only protect small cells in the tables but also introduce ambiguity and uncertainty into the zero cells. SDC methods modify, summarise or perturb the data and there are a range of different methods that can be used to protect different census outputs. SDC methods can be pre-tabular (applied to the underlying microdata) or post-tabular (applied to tables).

### 2. SDC methods applied to 2001 Census outputs

A number of measures were applied to all 2001 Census output for England and Wales\(^2\) to prevent the inadvertent disclosure of information about identifiable individuals. These included:

- factors involved in the design of output tables
- record swapping in the output database
- application of thresholds to determine which areas could have certain results produced for them
- application of a small cell adjustment procedure to final tables to modify the values contained in small count cells
- conditions of use applied to all output products.

These methods are described in more detail below.

#### 2.1. Design of tables

A general principle of making the average cell count in a table greater than or equal to one was applied to the design of all 2001 Census outputs.

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1 The National Statistics Code of Practice was superseded by the UK Statistics Authority Code of Practice for Official Statistics in January 2009.
2 In 2001 there were different disclosure control methodologies across the UK because of differing views about the level of acceptable risk and the perception of what constitutes disclosure. Northern Ireland also employed small cell adjustment but Scotland did not. The methods used in Northern Ireland and Scotland are summarised here:
   [http://www.nisranew.nisra.gov.uk/census/censusmethodology/disclosure.html](http://www.nisranew.nisra.gov.uk/census/censusmethodology/disclosure.html)
2.2. Record swapping

The individual records on the output database were slightly modified by random record swapping. This means that a sample of records was 'swapped' with similar records in other geographical areas. The proportion of records swapped was the same in all areas. No account was taken of the protection provided through differential data quality (differences in data quality between areas due to, e.g. different levels of non-response imputation). Information about the proportion of records swapped cannot be provided as this might compromise confidentiality protection.

2.3. Thresholds

Minimum numbers of residents and households in an area were required for the publication of some sets of 2001 Census data. Areas with counts which fell below these threshold values either had some less detailed summary statistics produced, or were amalgamated with other areas to allow the release of more detailed sets of results for the combined area. All threshold values applied to population and household values on census day, 29 April 2001.

These measures were applied to predefined areas, such as parishes, wards or postal sectors, for which a particular set of results was generally available, but which might have had populations below the thresholds. All output areas were above the threshold for census area statistics (CAS) and key statistics.

There were three sets of threshold values applied to the different series of data produced. The thresholds were:

- 1,000 residents and 400 households for standard tables
- 100 residents and 40 households for CAS and key statistics
- 50 residents and 20 households for parish/community profiles

Where civil parishes in England, communities in Wales, or wards fell below either of the thresholds for CAS, but contained more than 50 people and 20 households, summary statistics profiles were released. The 1991 Census equivalent for this threshold was 50 people and 16 households, and the increase in the threshold of households to 20 reflected the change in average household size between 1991 and 2001.

Where civil parishes or communities had fewer than 50 people and fewer than 20 households, counts of the total numbers of residents, males, females and resident households were released. These were known as 'headcounts' in census products. There were no thresholds for headcounts, but small counts were still adjusted as part of disclosure protection.

Where areas were amalgamated, they were amalgamated with adjoining areas, and areas of the same type wherever possible. This was done in consultation with the local authorities of the areas concerned. The few postcode sectors which fell below thresholds were not amalgamated with other sectors as there was no definitive information on which sectors were adjacent.

2.4. Small cell adjustment

Random record-swapping had some limitations and the Office for National Statistics (ONS) became increasingly concerned about these. It was felt that it would not be apparent to a person using the census data that any method of disclosure protection
had been implemented. There would be a perception that persons and households were identifiable (particularly for a single count) and the observer might act upon the information as if it were true.

Small cell adjustment (SCA) is a technique applied to data after they have been tabulated. It involves adjusting the values of small cells up or down according to rules that say a proportion of the cells with that small value will be adjusted up, while the rest of the cells with that value will be adjusted down. SCA was applied after random record swapping had been carried out on the microdata.

During the process of small cell adjustment:

- a small count appearing in a table cell was adjusted (information on what constitutes a small cell count could not be provided as this may have compromised confidentiality protection)
- totals and sub totals in tables were each calculated as the sum of the adjusted counts so that all tables were internally additive (within tables, totals and sub totals are the sum of the adjusted constituent counts)
- tables were independently adjusted (this means that counts of the same population in two different tables were not necessarily the same)
- tables for higher geographical levels were independently adjusted, and, therefore, were not necessarily the sum of the lower component geographical units
- output was produced from one database, adjusted for estimated undercount, and the tables from this one database provided a consistent picture of this one population.

2.5. Conditions of use
Conditions of use were included with all outputs. These stated that census material shall not be used to attempt to derive information relating to an identified person or household nor shall a claim be made that such information has been obtained or derived.

3. Evaluation of SDC measures used in the 2001 Census
The disclosure measures implemented for the 2001 Census tabular outputs were a combined approach that was based upon a set of judgements. Each method alone did not offer adequate protection, but ONS concluded that the combination of the chosen methods offered the protection that was needed.

3.1. Issues arising from methods used
Random record swapping was initially planned for the 2001 UK census tables. This method of disclosure control was supplemented by applying population thresholds to the tables. The General Register Office for Scotland (GROS) adopted smaller thresholds than ONS and the Northern Ireland Research Agency (NISRA). However, concerns were raised that the public would perceive that no disclosure control method had been applied. Small cell adjustment added more uncertainty and removed small cells from tabular outputs. ONS and NISRA applied this additional method but GROS did not. This late change in SDC methodology and the lack of UK harmonisation had implications for users.

Applying small cell adjustment to 2001 Census tabular outputs resulted in:-
• small cells in tables not necessarily being ‘true’ figures.
• each table being internally additive, but cell counts and totals often appeared inconsistent between different tables.
• a time consuming process for ONS to check each set of tables produced – particularly for commissioned output, for small areas, since in particular some risk of disclosure by differencing remained.
• where totals were inconsistent, ONS advising users to use the highest level of geography with fewest breakdowns and fewest number of cells summed.

A more detailed evaluation of the methods can be found in ‘Census 2001 Review and Evaluation – Disclosure Control’

3.2. Lessons learnt
The main lessons from the project were that some elements of the disclosure risk assessment should have been carried out much earlier. It was less than one year before census day, in 2000, that ONS concluded it would need to take extra precautions to protect information as a result of the increased risk since 1991. ONS had to reassess the risks for census confidentiality from the increased amount of small area statistics that were to be published by the neighbourhood statistics project.

Consultation should have been carried out earlier and more time allowed to research and develop different options of disclosure control. The consultation regarding the options of rounding and small cell adjustment was considered to be too late in 2001 and 2002. ONS recognised that it could have made users explicitly aware that the disclosure procedures were under a further review and prepared users for the real possibility of further changes.

The consultation highlighted that many users were concerned about the impact of small cell adjustment on data quality. These concerns emphasised a need to provide users with information about the uncertainty that exists within census data introduced by many of the processes aimed at improving data quality such as the One Number Census and edit and imputation.

ONS and the other UK Census Offices were determined to learn from the outcomes of 2001 and there has been a large programme of SDC work in preparation for the 2011 Census.

4. 2011 Census – Registrars General statement and policy position on disclosure control
In February 2005, the national statistician and the registrars general for Scotland and Northern Ireland released a statement of agreement on the conduct of the 2011 UK censuses. This included a commitment to reach agreement wherever possible on points that would facilitate harmonisation where this was in the interest of census users. Disclosure control was one of the aspects where harmonisation was the aim. This was to be achieved through evaluation, testing and agreement on a common methodology in advance of the census.

The UK Statistical Disclosure Control Policy for 2011 Census output published in November 2006 was added as an annex to the registrars’ general statement. This was agreed by the registrars general of Scotland, England and Wales and Northern Ireland, based on the principle of protecting confidentiality set out in the National Statistics Code of Practice. The registrars general concluded that the code of practice statement can be met in relation to census outputs if no statistics are produced that allow the
identification of an individual (or information about an individual) with a high degree of confidence. The registrars general considered that, as long as there has been systematic perturbation of the data, the guarantee in the code of practice would be met. It was therefore agreed that small counts (0s, 1s, and 2s) could be included in publicly disseminated census tables provided that

a) sufficient uncertainty as to whether the small cell is a true value had been systematically created; and
b) creating that uncertainty did not significantly damage the data.

5. Evaluation of candidate methods for 2011

A full account of the evaluation and selection of the final method is provided in the document Evaluating a Statistical Control Strategy for Census 2011 Tabular Outputs on the ONS website.

5.1. Evaluation criteria

The advantages and disadvantages of thirteen SDC methods were compared to discount methods that would not be able to satisfy the disclosure control requirements for 2011 Census outputs. Discounted methods were excluded from further consideration and the short-listed SDC methods were assessed using a risk-utility framework. The final short-list was agreed in October 2007.

The following methods were originally considered for short-listing:

1. Record swapping
2. Over-imputation
3. Data switching
4. Post randomisation method (PRAM)
5. Sampling
6. Conventional rounding
7. Random rounding
8. Small cell adjustment
9. Controlled rounding
10. Semi-controlled rounding
11. Suppression
12. Barnardisation
13. ABS cell perturbation

Each method was assessed on whether they met, partly met, or did not meet the seven criteria listed. The criteria were split into primary and secondary qualitative criteria and an additional requirement was that any method that did not meet one of the primary criteria would not be considered further. The criteria were:

Primary criteria

i. Will the method provide additive and consistent tables which are a priority for users?
ii. Overall, will users accept the method?
iii. Does the method protect against differencing? (both geographical and categorical differencing)
iv. Is the method practical, feasible to implement and has it been used for protecting similar outputs to date?
Secondary criteria

i. Method should not restrict microdata releases.
ii. Method should be simple to understand.
iii. Method should be easy to account for in analyses.

For each of the seven criteria listed, the SDC method was assigned a score from zero to two; zero if the method did not meet the criterion, two if it met the criterion and one if it partly met the criterion. The criteria identified to be of primary importance were given double the weight of criteria which were of secondary importance. This enabled an overall score to be assigned to each method to inform the short-listing process. It was also agreed that if any method scored zero on any of the primary criteria then the method should be discounted from the short-list since it would have failed to meet the most important objectives.

In summary, the majority of SDC methods failed one or more of the primary criteria and were discounted from the short-list. For example, data switching was thought to be too complex a method, PRAM was difficult to implement and user acceptance for rounding, barnardisation and sampling was known to be low. Suppression would have also been difficult to implement and provided no protection against differencing in addition to being unpopular with many users. It should be noted that small cell adjustment on its own would have failed as it did not protect against disclosure by differencing. It was agreed to include it (with record swapping) in the final short-list to ensure that the first three methods could be compared against the 2001 method. Combinations of methods were also considered for the quantitative evaluation.

5.2. Description of the final short-listed SDC methods

Two of the short-listed methods were pre-tabular and one post-tabular. Pre-tabular methods are implemented on the microdata prior to the tabulation whereas post-tabular methods are applied directly to the tables. Both random and targeted pre-tabular methods were considered; random refers to the records being selected from the population at random whereas targeted refers to the record selection being based on the degree of disclosure risk associated with each record.

5.3. Record swapping

Record swapping involves exchanging variables between selected pairs of households within the census data. This method has been used for protecting census tables at the US Census Bureau (in 1991 random record swapping was used whereas targeted record swapping was used in 2001) and for the 2001 UK Census.

In order to minimise bias, pairs of households are determined which match on some control variables (Willenborg and de Waal, 2001), such as a large geographical area and the sex and broad age group of household members. Record swapping can be targeted to high-risk households ensuring that households most at risk of disclosure are likely to be swapped. Record swapping can also be modified to take into account imputation rates, i.e. by only swapping those records with no imputation, and by reducing swap rates in areas where imputation is high (and conversely by increasing rates in areas with high imputation). In a census context, geography variables are often swapped between households because this results in fewer edit inconsistencies due to the assumption that other census variables are more independent of geography.

5.4. Over-imputation

Imputation is a commonly used method for replacing missing values in census data due to item non-response. For this evaluation, we removed additional values of a
variable so that these would also be imputed and thus provide disclosure control, i.e. over-imputation. A new method of over-imputation had to be devised for this evaluation as it is not known to have been used before for protecting census data. Imputation in general is a very complex procedure, one reason being the need to establish the relationships that exist between variables. For example, imputing ethnicity is not straightforward as this could potentially lead to inconsistencies with other variables associated with ethnicity such as country of birth.

5.5. ABS cell perturbation
For the protection of their 2006 Census outputs, the Australian Bureau of Statistics (ABS) conducted research into a new cell perturbation algorithm (Fraser and Wooton, 2006). In the past they have released static tables of data, however flexible table generation was used for 2006. This enables users to design and populate their own tables. The new perturbation algorithm is designed to protect these tables by potentially altering every cell in every table by a small amount – the method is referred to on their website as ‘introduced random error’. In doing so it adds sufficient ‘noise’ to each cell to protect the data. The algorithm always randomises the same table in exactly the same way. It also preserves higher level totals between tables with common geographies.

5.6. Selection of method for implementation
Even after communication and consultation with representatives from the UK census offices, it was clear that the criteria, both on their inclusion and whether mandatory, and their respective weights, were quite subjective. Due to this subjectivity, the decision on SDC strategy was not made solely on the method with the highest score, but the scoring did give an indication as to the overall effectiveness of each method. It was also a useful way of summarizing the large amount of analysis and of highlighting relative differences between methods. Hence the assessment criteria can be seen as just one of a number of tools which contributed to a final decision. Both record swapping and over-imputation were capable of managing the risk of disclosure and disclosure by differencing. Hence the choice between them could be made on the impact of each method on the data utility. The weaknesses of over-imputation were that, at the levels of perturbation assessed, the method:

(i) distorted associations between variables,
(ii) impacted on totals and sub-totals within tables at all geographies (though it does not affect the total number of individuals in any geographical area)
(iii) has not been implemented satisfactorily in tests.

There was no accepted methodology for over-imputation for carrying out disclosure control, which could have made it difficult to sell this method to users. Additionally the fact that legitimate data items would be removed and replaced with imputed values was likely to be unpopular. There would also be some outputs, including those at small geographies, where over-imputation would not have been applied, since not every variable would have been imputed on, e.g. sex, marital status, ethnic group, religion – these would either have created difficulties in maintaining consistency with other variables or been very likely to have the real value imputed.

The weaknesses of record swapping are that:

i. it could be possible to match high level tables against samples of individual records and determine and locate households or individuals who are unique in the population
ii. it would be more difficult to protect special populations such as people living in communal establishments and people in workplaces

However, it would be possible to address these issues (i) predominantly through licensing arrangements and (ii) through careful design of the record swapping methods. It is also more difficult for record swapping to take into account the data quality of different variables but it could consider the data quality related to response rates and non-response imputation. The key strength of record swapping is that no persons or data items are removed from the census data and therefore outputs at national level and high geographies will be unaffected by record swapping. Record swapping has also been used before (in the UK and USA) to protect census tables, whereas over-imputation had not.

Record swapping was therefore recommended as the primary disclosure control method for 2011 Census. This recommendation was accepted by the ONS Statistical Policy Committee, and signed off by the UK Census Committee.

6. Implementation of targeted record swapping for 2011 UK Census

6.1. Targeting, probability of selection

Every individual and household are assessed for uniqueness or rarity on the basis of a small number of characteristics and every household given a household risk score. A sample of households is selected for swapping. The chance of being selected in the sample is based largely on the household risk score, so that households with unique or rare characteristics are much more likely to be sampled. However every household has a chance of being swapped. Once selected, another ‘similar’ household is found, from another area with which to swap.

6.2. Matching

The household and its swap are matched on some basic characteristics in order to preserve data quality. These characteristics include household size, so that the numbers of persons and numbers of households in each area will be preserved. Households are only swapped within local authorities (LAs) or, in the case of households with very unusual characteristics, with matches in nearby authorities. So you will not have a household, say, in Cornwall swapped with one in Birmingham.

6.3. Uncertainty and doubt

Every household has a chance of being selected for swapping. Therefore, there is a level of doubt as to whether the value of one in any cell is real. It may be that a person has been imputed or swapped so as to appear in that cell, or indeed there may have been another person or persons swapped out so as to move from that cell, thus creating the value of one. So no one can ever be absolutely sure that a value of one that they see in a table is really the true value.

Doubt relates to the uncertainty that cell values and apparent attribute disclosures in census tables represent real respondents or real attribute disclosures. Published cell counts may not represent the true number of respondents for a variety of reasons, some of which cannot be quantified easily (e.g. address register error, respondent or data capture error), and some that can be quantified (e.g. non-response and edit imputation, individuals and households swapped as part of disclosure control). We concentrate on the quantifiable elements as described below, though appreciate this
approach gives rise to a lower bound on the total uncertainty due to the unquantifiable elements and also the time lag between data collection and publication, where respondents may have moved in or out of the area. In any one area the level of imputation will partly drive the level of record swapping that is required to protect the confidentiality of individuals and households since, in areas with high numbers of imputed records and items, there may already be considerable 'doubt' present in cell counts and attribute disclosures (ADs) that are in the tables.

Record swapping involves swapping (between different geographical areas) of a small proportion of households and also individuals between communal establishments. The methodology for these processes is designed so that statistical tables will still provide a high quality of estimates relating to the population and its attributes at all geographies of the UK, though there will be uncertainty added to all cell values, particularly in detailed tables at the lowest geography.

The level of doubt introduced by imputation and swapping can be quantified. This is based on real AD cases that have been protected, and apparent AD cases that are not real because there are records that have been swapped in. The level of doubt increases as the number of protected real AD cases increases, and also as the number of apparent AD cases that are not real increases. The measure of doubt is based on these as proportions:

- The proportion of real AD cases that imputation and swapping have protected, and
- the proportion of apparent AD cases (i.e. in the swapped data) that are not real.

These proportions are combined to produce a measure of doubt.

### 6.4. Measures of disclosure control success

The calculation of 'doubt' relies on two measures:

- Success measure 1 (M1) represents the proportion of real attribute disclosures removed by imputation and swapping
- Success measure 2 (M2) represents the proportion of apparent attribute disclosures that are not real
- Doubt is then calculated as doubt = 1 - (1-M1)(1-M2) and has a value between 0 and 1. This measure is often referred to by a percentage

A raw table with no imputation or swapping has 0 per cent doubt, since all cell values and attribute disclosures are real (discounting unquantifiable elements) and therefore likely to be unsafe. As the levels of imputation and swapping increase, the doubt increases.

The national statistician and registrars general from the other UK census offices set the level of doubt that is required for tables to be sufficiently safe to be published. The precise value of this level will not be released, in order to retain the required level of protection in tables as this could compromise the data protection.

An outline of the diagnostic measures used to evaluate the performance of the record swapping and impact this has had on data utility are given in the appendix.

### 6.5. Level of swapping used

The precise level of swapping will not be disclosed to the public since this will compromise the level of protection that swapping provides. The level of swapping
will be lower in areas where non-response and imputation are higher and already provide a degree of protection against disclosure, so the swapping level will vary across the UK.

6.6. Areas with high levels of imputation
If the level of imputation in an area is high, the level of swapping required will be lower than in other areas. We still have to protect the very unusual and more identifiable persons who have completed and returned their census forms, even in the areas with lots of imputed records, so some record swapping will have been carried out in every area.

6.7. Apparent attribute disclosures
The swapping methodology is such that every household and every person does have a chance of being swapped, so all cell counts have a level of uncertainty. Indeed, given that some persons do not respond to the census and some questions are not answered by all, there are also imputed records appearing in the census database and therefore in the cell counts. The combination of imputation and swapping will produce some apparent attribute disclosures that are not real, and some cell counts which include imputed and/or swapped records.

6.8. Self identification
People or households with rare or unique characteristics might reasonably expect to be able to identify themselves or their household in the data. Identification disclosure occurs when an individual can be identified in the data, but no new information about the individual is learnt. However, there may be a number of reasons why such a person or their household may not be apparent in the data. There is a very small chance that the information may not have been captured properly, but more likely their household was selected for swapping with a household in another area, or that it may have been matched with a different household selected for swapping.

6.9. Impact of record swapping on data analysis
No persons or data items are removed from the census data and therefore outputs at national level and high geographies are unaffected by record swapping. At all geographical levels table totals reflect the sum of the cells and there are no differences between cell counts in different tables. Swapped households have been matched on basic characteristics to preserve data quality, and most swapping has been done within the same local authority or middle layer super output area (MSOA). The level of non-response and imputation will actually have a far greater effect on any counts seen in the tables than record swapping. Care has been taken to achieve a balance between disclosure risk and data utility. Because we are targeting records where the risk of disclosure is greatest, especially people with unusual characteristics who could be recognised in small areas, any analyses based on larger numbers will not be greatly affected.

6.10. Limits on the number of variables/cells provided in a table
The basis of the level of doubt is that a sufficient proportion of 'real attribute disclosures' are removed by imputation or swapping, and of 'apparent attribute disclosures' that are introduced by imputation or swapping. The targeting means that the records with the highest degree of disclosure risk are much more likely to be swapped. However, where tables are very detailed, they would consequently have many cells with low counts and a large percentage of records that cause attribute disclosures. The level of swapping must be kept low enough not to cause significant
loss of utility, but it would need a much higher swap rate than would be desirable in order to sufficiently protect the very high numbers of attribute disclosures. The trade off in maintaining the utility of outputs is therefore to restrict the breakdowns of variables and/or the numbers of cells.

6.11. Sparse tables – minimum average cell size
For every table a minimum average cell size has been imposed over the whole table. Where there are small numbers of people in tables with large numbers of cells, the numbers of real attribute disclosures are likely to be high and more difficult to protect using record swapping. In tables where the average cell size is higher, there will be fewer attribute disclosures and these are likely to be cells of a larger size (contain more cases). These are likely to be from records that have been swapped because of their unique or rare characteristics.

This type of rule was used during 2001 UK Census for commissioned tables, with a minimum average cell size of one. So where tables had a greater number of cells than records, table design was employed to reduce the number of cells, or a higher geography used with greater numbers of cases. Within ONS, an average cell size rule is used for many outputs including births and deaths.

7. Communal establishments

7.1. Implementation of disclosure control for communal establishments
One of the weaknesses of record swapping was thought to be the protection given to persons living in communal establishments (CEs). However, to provide consistency with the methodology used to protect individuals in households it was decided to use an adaptation of the household record swapping methodology to protect the 2011 Census communal establishment data. The response rates and data quality of the communal establishment population in the 2001 UK Census were significantly lower than for the household population. However there are types of communal establishments with significantly higher or lower response rates and these also vary across the UK. The locations of a large number of communal establishments, such as prisons or general hospitals, are very much public knowledge. Hotels and care homes are also likely to be well known within the local area. Given this, it is difficult, and in many cases pointless, to protect the actual establishments from identity disclosure.

Where a communal establishment is identified within an output, it essentially provides data at a detailed geographical level and subsequently would lead to a greater disclosure risk for the individuals living there (referred to from now as residents). The primary difference between the household record swapping method and the communal establishment method is that, rather than swapping whole communal establishments, individual person records are swapped. This ensures that the emphasis is placed on protecting the information of the residents and it also preserves both the counts of communal establishments and residents at all geographies.

Communal establishment residents have been classified into three types:

- **Clients**: non-staff residents for which the communal establishment caters (e.g. patients of a hospital, clients of a hotel).
- **Staff**: staff and owners who live in the communal establishment. This does not include staff from the communal establishment who live elsewhere.
- **Family**: family members or partners who live in the communal establishment with either a member of staff or a client.
In the same way that we wished to preserve the characteristics of the communal establishment type\(^3\) when swapping records, maintaining the characteristics of the different resident groups was also a key aim. It was also clear that there were some communal establishment types which had a greater risk of disclosure than others, and some which were of a more sensitive nature. The swap rate therefore varies with the risk of attribute disclosure for a communal establishment type within a particular geography. As with households the swapping of records occurs only within the local authority district or nearby local authority districts.

### 7.2. Communal establishment protection scores

The communal establishment methodology varies the swap rate based on a calculated protection score (PS). This is taken as the sum of different risk factors and is calculated for every communal establishment type in each MSOA.

Another important influence on disclosure risks in a communal establishment is the count of residents. Since the counts of the three resident groups will vary, we require different swap rates for clients, staff and family. We therefore calculate separate protection scores for clients (CPS) and staff (SPS). A final factor affecting the CPS is whether the communal establishment has a high or low client turnover\(^4\). Because the detailed outputs will be released over a year and a half after the day the census was conducted, many communal establishments with a high client turnover will naturally have higher uncertainty around apparent attribute disclosures. Less statistical disclosure control protection will therefore be needed.

### 7.3. Selecting the sample

The sample selection process is similar to that of households whereby a risk score is calculated for each individual record. However, whilst unique records will be flagged at each geography, the risk score will only be calculated at MSOA level and in relation to the other records within the resident group and communal establishment type. Those records with a higher risk score then have a greater chance of being sampled for swapping.

### 7.4. Family residents

Unlike families in households, there is no family composition matrix to connect the family members either to each other, or to any of the staff or client residents. This enables us to swap the family residents individually rather than as a whole family. Because the number of family residents living in communal establishments is very low we set one single swap rate and select the sample from across all communal establishment types in the local authority.

### 7.5. The matching process

Because the characteristics of clients may differ from those of staff within communal establishment types, it is important to ensure that swapping is carried out within resident groups. In the same way, the amount of matching on communal establishment type is to be maximised. The aim is to keep swapping within CE type.

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\(^3\) CE type relates to the category in which the communal establishment will appear as in the census output tables.

\(^4\) If the usual length of stay of clients is less than a year, the CE type is considered to have a high client turnover. Otherwise, the CE type has a low client turnover.
However census processing requirements constrain the grouping of areas within which records can be swapped. As a consequence there will be many circumstances where swapping within communal establishment type will not be possible (e.g. there is only one prison establishment in the grouping that includes Bristol). Therefore, the matching variables play a crucial role in ensuring that where swapping does occur between CE types, the key variables that define the communal establishment type populations are preserved as much as possible.

8. Disclosure control for origin-destination tables
These tables are matrices that provide counts of persons (or households) having two geographical areas of reference. Examples of these are tables of area-to-area counts of people who

- migrated in the year before the census
- travel from their area of residence to their area of work

These are counts of every area-to-area flow (each cell in the matrix) and provide breakdowns of the characteristics of the people in the flow at various geographical levels, with more detail for the higher geographical levels. The protection of the most detailed origin-destination tables comes from the licensing/access conditions. Similar outputs from 2001 Census were protected by the post-tabular small cell adjustment which still allowed wide and easy access but which also adversely affected the utility of the outputs.

9. Workplace zones
9.1. Workplace zone geography
The primary geography for 2011 Census outputs will be the output area (OA) hierarchy that has been designed on the basis of household and resident populations. This can cause problems for users who are interested in data collected based on workplace, since the distributions of workplaces and workers by OAs are not even. To improve outputs provision for workplaces, there was a call for the creation of a geography based on workplace by aggregating or splitting OAs, and to which would allow more detailed and more consistent statistics on workplace to be released. A geography of workplace zones (WPZ) has been developed to disseminate those statistics. Note that workplace zones have complete coverage across England and Wales, including those who work at home, but the total population in all workplace zones will be different to the total resident in all OAs. The set of workplace zones will cover those working 'outside England and Wales/ UK’ but the workplace zone statistics will not include those resident outside England and Wales who work in England and Wales.

There is a legal obligation to protect the identity of an individual business or organisation. Section 39 of the Statistics and Registration Service Act 2007 (SRSA) requires the protection of data referring to any persons, legal and natural. This includes reference to the 'body corporate' which brings into scope the protection of any entity that is able in law to take action - to sue or be sued. A business or enterprise, living or dead, is in scope and therefore must be protected by law. The SRSA prevents the release of data which allow the attributes of a particular individual (in the case of workplace statistics, this is an organisation) from being successfully connected to the identity of that organisation, where identity is taken to mean the value used by a particular person to separate them from their peers. For example, if an
employer is the only one in a particular industry in an area where there are several workplaces, the aggregated statistics of workers by industry would immediately allow information about employees to be attributed to that employer. Moreover, we must also consider the requirements of the Data Protection Act 1998 to consider the potential risk of harm or distress to an individual where the data could be used along with privately held information.

Confidentiality protection has to be provided for the workplace statistics just as it is provided for statistics based on residents. Even though it is not the businesses themselves that have provided the information, but individuals who work for them, the aggregation of the individual statistics generates a set of business statistics and as much protection should be afforded to individual businesses as individual persons. The design of the workplace zones will help here but issues may still occur, for instance, a table broken down by a detailed industry variable at the local authority level could result in detailed statistics in one industry category covering just one business.

Protection of workplace statistics is achieved predominantly through WPZ design, masking statistics on large employers by grouping them together with other neighbouring smaller employers, while still providing detail for small areas that was not available in 2001.

9.2. Workplace zone design

Workplace zones:

- comprise a whole number of (at least two) postcode building blocks
- do not split postcode building blocks, except where this has already occurred due to the splitting of residential postcodes
- contain a workforce of at least 100 persons (this is comparable to the resident threshold of 100 persons for an output area)
- have a total workforce population which exceeds the workforce of any large single workplace postcode population by at least 99. This would add, as a minimum, a non-disclosive number of employees to any single large workplace, where a large workplace postcode population would be defined as 625 or greater, in line with the upper output area resident population threshold.

This has the merits of

- allowing no statistics that could pertain directly to an individual business or workplace
- adapting the output geography to the size of the workplace population
- allowing much greater detail to users at sub-local authority geographies than was available in 2001
- allowing statistics for higher geographies (workplace zones are nested within MSOAs)

Appendix

Diagnostics and utility of protected data

The main diagnostic measures produced by the swapping process are listed below for each area processed.
- **High-risk records**
  Count for each category of each risk variable
  Count and percentage of real (i.e. non-imputed) individuals flagged as high-risk
  Count and percentage of households flagged as high-risk in each.
  Counts of individuals who are high-risk/not high-risk at each and multiple geographic levels

- **Sampling**
  Summary of sampling in each LA
  Count of times individual households have been sampled
  Size of adjustment to the sample size of each OA where the sample size was capped
  Counts and percentages of sampled/non-sampled high-risk/not high-risk households

- **Swapping**
  Output area distribution of number of swapped records
  Count of households swapped at each geographic level
  Overall swapping rate achieved, swap counts and rates in OAs with high swapping rates
  Counts and percentages of swapped/non-swapped high-risk/not high-risk households

After record swapping has been run for each area, any measures that are found to lie outside acceptable ranges are investigated. Input parameters can be adjusted and the process re-run until a result which provides adequate disclosure control while maximising data utility is achieved.

Data utility is a broad concept describing the usefulness of data or the satisfaction of users. Almost all SDC techniques reduce the utility of data for users compared with the raw unprotected data and our aim is to minimise this information loss. A particular user’s utility depends on which variables they are most interested in and what analysis they want to perform, but there are also some general principles which apply to all users. To evaluate the general loss of utility from targeted record swapping we use quantitative measures such as the number and proportion of cells changing values and the amount by which the values of cells have changed.

Software to measure information loss was used to compare protected tables against the original data for selected swapping rates and sample areas. As expected we saw an increasing impact on utility with higher swapping rates. There are differences between the tables produced at OA and higher level geographies. This is because swapping has been designed to occur more intensely at the smaller geographies.

**Glossary**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address register</td>
<td>A comprehensive list of residential addresses in England and Wales at the time of the 2011 Census used to provide addresses for the post-out of census questionnaires.</td>
</tr>
<tr>
<td>Attribute disclosure</td>
<td>This occurs where a data user is able to deduce something</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
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<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Barnardisation</td>
<td>A method of disclosure control for tables of counts that involves randomly adding or subtracting 1 from the values in some cells in the table.</td>
</tr>
<tr>
<td>Bias</td>
<td>A systemic inaccuracy in data due to the characteristics of the way the data were produced.</td>
</tr>
<tr>
<td>Census area statistics</td>
<td>A series of tables which provide detailed information down to output area level. They comprise CAS tables, CAS Theme Tables that provide information on a particular population such as dependent children, and Univariate tables.</td>
</tr>
<tr>
<td>Commissioned tables</td>
<td>Where users’ requirements are not met by standard outputs, they may commission customised census outputs from ONS. Charges are made for commissioned tables.</td>
</tr>
<tr>
<td>Communal establishments</td>
<td>Communal establishments are residential establishments. These include prisons, hotels, nursing homes, military barracks, halls of residence and children’s homes.</td>
</tr>
<tr>
<td>Community</td>
<td>The smallest administrative area in Wales, equivalent to parish in England.</td>
</tr>
<tr>
<td>Conventional rounding</td>
<td>Cell values are converted to the nearest multiple of a rounding base; e.g. base 10 rounding converts cell values to the nearest multiple of 10.</td>
</tr>
<tr>
<td>Data capture error</td>
<td>Any error occurring during the process of converting collected data into a machine-readable form. Such errors include mis-reading of hand written characters.</td>
</tr>
<tr>
<td>Data switching</td>
<td>Swapping the values of one or more variables in one record with the values for the same variables in another record.</td>
</tr>
<tr>
<td>Data utility</td>
<td>The value of any particular set of data as a resource for analytical purposes.</td>
</tr>
<tr>
<td>Disclosure by differencing</td>
<td>Users may compare statistical tables for, e.g. two sets of geographical areas, and produce new statistics for the areas formed by the difference between these two areas. These may have populations below confidentiality thresholds.</td>
</tr>
<tr>
<td>Edit and imputation</td>
<td>Inconsistent responses and omissions on questionnaires are resolved during processing. These are instances where a question has not been completed with a response consistent with other answers on the form, or where responses to the same question by people living in adjoining properties are not consistent (e.g. where the response to ‘type of dwelling’ in an address where neighbouring addresses are in a block of flats). A response is edited if the answer is incompatible with the rest of responses on the same form. This ensures the results of the census are complete and consistent.</td>
</tr>
<tr>
<td>Key statistics</td>
<td>The Key Statistics dataset consists of a series of tables which provide a summary of the complete results of the census. They are designed to enable easy comparison between areas across</td>
</tr>
<tr>
<td>about an individual in the data that they did not already know.</td>
<td></td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<td>------------------------------</td>
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</tr>
<tr>
<td>Local authorities</td>
<td>A generic term covering London boroughs, non-metropolitan districts, and unitary authorities.</td>
</tr>
<tr>
<td>Microdata</td>
<td>Individual-level data on persons, households, businesses or other statistical units.</td>
</tr>
<tr>
<td>One Number Census</td>
<td>The One Number Census project provides an accurate national estimate of the population by adjusting the results of the census data collection to take account of those individuals who were missed.</td>
</tr>
<tr>
<td>Output area hierarchy</td>
<td>Output areas are the smallest geographical area for which census outputs are published. They consist of clusters of adjacent unit postcodes. Statistics may also be published for lower super output areas (LSOAs), which are aggregation of output areas, and middle super output areas, which are aggregations of LSOAs.</td>
</tr>
<tr>
<td>Parish</td>
<td>The smallest type of administrative area in England (also known as civil parish). Parishes are equivalent to Welsh communities.</td>
</tr>
<tr>
<td>Parish/community profiles</td>
<td>Condensed summary results on a particular topic are released for all parishes/communities with at least 50 residents and 20 households for which Key Statistics are not produced.</td>
</tr>
<tr>
<td>Perturbation</td>
<td>For cells containing numerical values this is the addition of a small random value, either positive or negative. Perturbation for categorical variables such as occupation is the modification of the occupation of a respondent.</td>
</tr>
<tr>
<td>Population/sample uniques</td>
<td>An individual, household, or business that has unique characteristics in the population/sample.</td>
</tr>
<tr>
<td>Post randomisation method</td>
<td>A perturbative microdata disclosure control technique applied to categorical variables. The values of some categorical variables for certain records are changed to a new value according to a prescribed probability mechanism. Each new value may or may not be different from the original value.</td>
</tr>
<tr>
<td>Postcode sector</td>
<td>Postcodes consist of an outward code followed, usually after a space, by the inward code. The postcode sector is given by the outward code and the first (i.e. the numeric) character of the inward code</td>
</tr>
<tr>
<td>Post-tabular method</td>
<td>Refers to a method applied after data have been summarised in a table.</td>
</tr>
<tr>
<td>Pre-tabular method</td>
<td>Refers to a method applied to data before they have been summarised in a table.</td>
</tr>
<tr>
<td>Random rounding</td>
<td>A perturbation method in which a random decision is made as to whether a cell value is rounded up or down. The rounding mechanism can be set up to produce unbiased rounded results.</td>
</tr>
<tr>
<td>Risk-utility</td>
<td>The trade-off between the contradictory goals of reducing disclosure risk and increasing data utility.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rounding</td>
<td>Approximating a number by restricting its expression to a fixed number of significant digits or decimal places.</td>
</tr>
<tr>
<td>Sampling</td>
<td>The process of selecting a number of units from all the units in a population.</td>
</tr>
<tr>
<td>Standard tables</td>
<td>Standard tables provide detailed results for selected areas – wards and higher administrative areas and health administration areas (UK) and postcode sectors (Scotland only).</td>
</tr>
<tr>
<td>Suppression</td>
<td>Replacing a cell value with a symbol or a blank to prevent disclosure.</td>
</tr>
<tr>
<td>Ward</td>
<td>Electoral wards/divisions are the key building block of UK administrative geography, being the spatial units used to elect local government councillors in metropolitan and non-metropolitan districts, unitary authorities and the London boroughs in England; unitary authorities in Wales; council areas in Scotland; and district council areas in Northern Ireland.</td>
</tr>
</tbody>
</table>