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## **Statistical Disclosure Control for Communal Establishments in the UK 2011 Census**

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# Statistical Disclosure Control for Communal Establishments in the UK 2011 Census

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**Abstract:** In this paper we will describe the targeted record swapping methodology that has been developed by the Office for National Statistics (ONS) as a statistical disclosure control strategy for 2011 UK Census tabular outputs relating to communal establishments. We discuss the household methodology from which the communal establishment methodology has been adapted and provide the reasons behind the requirement for change. We will describe the protection score process which is used to set the swap rates for different types of communal establishments before looking at the need for a detailed matching process to limit the damage to utility.

## 1 Introduction

The 2011 UK Census was conducted on the 27<sup>th</sup> March 2011. With detailed information on the socio-economic characteristics of the UK population, the data gathered from the census will allow Governmental departments and other organisations to better understand how to allocate their resources for public services such as transport, health services and education. Census outputs will be released in different formats; pre-planned tables, user requested commissioned tables and census sample microdata. With the release of aggregate and individual data through these outputs there comes a risk of identification of an individual and discovery of confidential information about them. With the production of official statistics dependent on the cooperation and trust of the population, individuals' information must remain protected to maintain this trust. The UK Census Offices of England and Wales, Scotland and Northern Ireland must also ensure that the confidentiality of the census respondents is upheld for all outputs to comply with their legal requirement. With an increased number of outputs to be released and with a constant demand from users for greater detail and accuracy, Statistical Disclosure Control (SDC) plays an important part in the success of this, potentially the last, UK Census. SDC aims to ensure the confidentiality of respondents is protected and is achieved either through the treatment of the microdata (pre-tabular), the output tables (post-tabular) or a combination of both. There will inevitably be some damage to the utility of the output and it is a key objective for the chosen SDC method to minimise this utility loss whilst maximising the protection against disclosure. This paper will outline the proposed SDC method for persons living in managed residential accommodation

known as Communal Establishments (CEs). Examples of CEs include prisons, hospitals, hotels and university halls.

The disclosure risks inherent in frequency tables surround cells of low counts such as 1s, 2s and 3s. It is, however, the position of 0s in a table that may lead to information about an individual or group of individuals being learnt. It is therefore important for the census SDC method to add ambiguity to both small cells and zero cells in tabular outputs. A common pre-tabular SDC method is record (data) swapping between households matched on control variables (Willenborg & de Waal, 2001). Random record swapping was selected as the SDC method for the 2001 UK Census, however, concerns were raised that the public would not perceive that the data had been properly protected. In light of this, a late decision was made by the Office for National Statistics (ONS) and Northern Ireland Statistics and Records Agency (NISRA) to employ the post-tabular method of Small Cell Adjustment (SCA) which rounded small cells either up or down to a base number. Because the General Register Office of Scotland (which has since been renamed the National Records of Scotland (NRS)) decided against SCA there was a lack of harmonisation across the UK. Furthermore, there was considerable criticism from users because of the damage to the utility of small cells and the inconsistency of totals between different tables. In some circumstances the SCA was found to be possible to unpick or provided little protection against disclosure by differencing (Shlomo, 2005).

In November 2006, the Registrars General of England and Wales, Scotland and Northern Ireland agreed upon the key aims of the UK Census Outputs including a “[c]ommon UK SDC methodology for Census 2011 outputs that minimises disclosure risk whilst maximising utility” (ONS, 2006). The agreement on the SDC UK Policy was based on the principle of protecting confidentiality as set out by the National Statistics Code of Practice, which has since been superseded by the Code of Practice for Official Statistics following the introduction of the Statistics and Registration Service Act (SRSA) 2007. The UK SDC Policy is still valid as it is in line with Section 39 of the SRSA. Given the lack of harmonisation and the criticism caused by SCA in the 2001 Census, an important step taken through the Registrars General was the definition of what constitutes as a disclosure risk. Given the impracticality to entirely remove risk caused by small cells, they concluded that the Code of Practice would be met if no outputs were produced that would allow the identification of an individual (or information about them) with a high degree of confidence. With this in mind, small counts (0s, 1s and 2s) could be included in publicly disseminated Census tables provided there is uncertainty as to whether the small cell is a true value and that creating this uncertainty does not cause significant damage to the data. The Registrars General acknowledged that discovering new information about an individual through outputs (attribute disclosure) is the key disclosure risk, rather than just the identification of an individual. An initial review of a wide range of SDC methods was completed in 2007 to create a short-list of methods for the 2011 Census. With an emphasis on selecting a method which would

be accepted by users and assured additivity and consistency across tables, the three methods short-listed for further evaluation were record swapping, over-imputation and the ABS Cell Perturbation Method. Spicer & Tudor (2009) describe the quantitative and qualitative evaluation process that led to the decision to use record swapping across the UK for the 2011 Census. The weaknesses of the method were expected to be how to deal with population uniques and special populations such as CE residents. Importantly, the key strengths of record swapping are that a) no person or data items are removed ensuring that outputs for national and high level geographies are unaffected, and b) that the method has been used before.

## 2 Targeted Record Swapping for Households in the 2011 UK Census

Record swapping is a pre-tabular method of perturbation where the geographical variables of a percentage of households are swapped with those of other households matched on a set of key variables. The sample of households can either be selected randomly or by targeting households that pose a greater risk of disclosure. Using 2001 data, Shlomo *et al.* (2010) compared the affects of targeted and random record swapping methods. Their analysis showed targeted records swapping to be as effective as random record swapping with double the swap rate, whilst generally conserving higher levels of utility.

The 2011 UK Census record swapping methodology will be carried out in large geographic blocks called Delivery Groups (DGs). Within these DGs are three levels of nested geographies; Local Authority Districts (LADs), Middle Super Output Area (MSOAs) and Output Area (OAs), where OAs are the smallest geography for which detailed outputs are produced, consisting of roughly 300 persons and 120 households. Because the majority of Census tables consist of individuals, households are identified as high risk dependent on the individuals residing there. Individuals are given a risk score reliant on frequency counts on univariate distributions on a set of risk variables. A risk score, as described by Shlomo *et al.* (2010) is calculated at all three geographical levels for each individual record (not including imputed records), as follows:

- For  $M$  risk variables with  $k_m$ , ( $m = 1, \dots, M$ ) categories at the geographical level  $g$ , the frequency  $N_{k_m}^g$  is calculated.
- For every individual with values of categories  $k = (k_1, k_2, \dots, k_M)$ , a risk score ( $HR$ ) is calculated at geography level  $g$  by taking the average of the reciprocals of the counts:

$$HR_k^g = \left( \sum_{m=1}^M 1 / N_{k_m}^g \right) / M \cdot$$

A threshold level is set for each of the three geographies, whereby all records with a risk score higher than the threshold at that geography is deemed to be high risk. Any

household containing a high risk individual is then flagged as a high risk household. If an individual is unique at geography  $g$ , on any one of the risk variables, the individual and subsequently the household is flagged as unique at that geography. If then selected for swapping, the household would be swapped outside of the geography in which it is unique. A unique flag does not necessarily imply that the household will also be flagged as high risk.

Prior to the application of the SDC methodology, there will invariably be error in the data creating uncertainty around the counts in the output tables. One of the most impacting procedures to the data is the imputation of records to account for non-response. Non-response rates, and concurrently, imputation levels will vary between delivery groups. In areas where there are high levels of uncertainty gained through imputation, there is less of a need for SDC than areas with lower levels of imputation. Therefore, the percentage of households selected to be swapped within the delivery group will have an inverse relationship to the imputation rate. Whilst the sample size is set for each DG, it is allocated across the OAs dependent on a) the number of non-imputed households in the OA, and b) the percentage of high risk households in the OA, though a threshold percentage of households selected in any one OA is employed. The high risk households have a higher probability of being selected for swapping, though all non-imputed households will have a non-zero probability. No imputed households will be selected.

With the sample households selected, each sample household will be matched with one outside of the sample. To ensure counts of households and individuals remain correct for each geography, households will be matched on household size as well as a set of matching variables, selected to preserve certain characteristics. Initially, households are attempted to be paired with a match within the MSOA to restrict the damage to the data at higher level outputs. If however, the household is unique at a particular geography, it will be paired with a house so it is swapped outside of the geography in which it is unique. It will not be uncommon for some sampled households not to be matched at a low geography and with the matching variable. If this occurs, we initially relax the detail in the matching variables before looking at swapping at a higher geography.

### **3 Targeted Record Swapping for Communal Establishments in the 2011 UK Census**

As previously mentioned, one of the weaknesses of the record swapping methodology was thought to surround persons living in communal establishments. However, rather than use a different SDC method, to provide consistency in SDC methodology it was decided to use an adaptation of the household record swapping code to protect the Census 2011 CE data. The location of a large number of CEs, such as prisons or general hospitals, are very much public knowledge. Hotels and

care homes are also likely to be known of within the local area. Given this, it is difficult, and in many cases pointless, to protect the actual establishments from identity disclosure, especially given that to do so would either mean perturbing the CE counts or the counts of persons in CEs, neither of which are suitable in a record swapping methodology. Regardless, it is not a priority to protect the identity of a CE given the limited amount of information the census outputs produce for the CE itself. However, if a CE is identified within an output, it can essentially be viewed as a smaller geography and subsequently would lead to a greater disclosure risk for the individuals living within the establishment (referred to from now as residents). The primary difference between the household record swapping method and the CE method is that, rather than swapping whole CEs, individual records are swapped. Whilst this is mostly out of necessity (in the majority of cases, there will not be a suitable match to swap whole CEs without greatly damaging the data), it ensures that the emphasis of record swapping is placed on protecting the information of the residents and also preserves both the counts of CEs and persons at all geographies.

The unique problem that is posed when adapting the household record swapping methodology is not the transition from swapping whole households to swapping individuals, but the aim to maximise utility. At the heart of this difficulty is the homogenous nature of the residents of particular CEs and the impact on utility that a distortion of particular characteristics will cause. A prison, for example, will have different resident characteristics to those in university halls. Within the resident CE population, there is a separation into three resident groups:

- **Clients:** Non-staff residents for which the CE caters (eg. patients of a hospital, clients of a hotel).
- **Staff:** Staff and owners who live in the CE. This does not include staff of the CE who live elsewhere.
- **Family:** Family members or partners that live in the CE with either a member of staff or a client.

In the same way that we wish to preserve the characteristics of the CE Type<sup>1</sup>, maintaining the characteristics of the different resident groups is also a key aim. Whilst the preservation of characteristics is dependent on the matching process of record swapping, it is also possible to maximise utility by minimising the amount of swapping. Because of the variety of establishments falling under the definition of CEs, it is clear that there are some CE Types which have a greater risk of disclosure than others. We therefore can look towards varying the swap rate dependent on how great the risk of attribute disclosure is for a CE Type within a particular geography. A final restriction on the record swapping methodology for CEs is the logistical requirement to limit the swapping of records to within the DG. The three aims of the CE record swapping methodology are therefore a) to keep record swapping within

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<sup>1</sup> CE Type relates to the category in which the CE will appear as in the Census output tables.

delivery groups, b) to ensure a greater proportion of individuals are swapped in CE Types which would have a higher impact attribute disclosure, and c) to develop the matching process to minimise utility loss.

### 3.1 Communal Establishment Protection Scores

It was observed in the 2001 UK Census that the response rates and data quality for the CE population were significantly worse than for the household population but we cannot assume the response rates and data quality of every CE will be poor. There will be CE Types with significantly higher or lower response rates and much like with household response rates, these rates will also vary across the UK. Because we cannot assume low response rates for all CE Types, we are not using the imputation rates to vary the swap rates. The CE methodology will instead vary the swap rate based on a calculated protection score (PS), which is taken as the sum of different risk factors and is calculated for every CE Type in each MSOA. MSOAs have been the geography chosen at which to calculate the scores because this is a geography at which tabular outputs are produced which combine CE Type with other variables, besides counts of staff, clients and family residents. The first three risk factor scores are solely dependent on the CE Type and its rarity within the area:

- **Counts of CE Type in MSOA:** As stated in *Section 3*, if a CE is identified, it can essentially be viewed as a smaller geography, in which an individual may be identified. A single establishment of a particular type is easier to identify and therefore the risk of attribute disclosure is increased.
- **Uniqueness of the CE Type in the LAD:** Because the higher geography has outputs of more detail, a unique CE Type within the LAD requires greater protection.
- **Impact of identity disclosure in a CE Type:** Although the emphasis of SDC for the 2011 UK Census is placed on protecting against attribute disclosure, identifying an individual as living in a particular CE is in itself an attribute disclosure. Identity disclosure of an individual that lives in a ‘high impact’ CE (such as a prison) will be more damaging than that of identity disclosure of an individual in a ‘low impact’ CE (such as a hotel).

Another important influence on disclosure risks in a CE depends on the counts of residents. Since the counts between the three resident groups will vary, we require different swap rates for clients, staff and family residents. We calculate both a Client Protection Score (CPS) and a Staff Protection Score (SPS). Family residents will be discussed in *Section 3.4*. A final factor affecting the SPS is whether the CE has a high or low client turnover<sup>2</sup>. Because the detailed outputs will be released over a year and a half after the day the Census was conducted, many CEs with a high client turnover will naturally have higher uncertainty around apparent attribute disclosures.

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<sup>2</sup> 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.

Less SDC protection will therefore be needed. The protection scores are calculated by multiplying together the relevant scores from the risk factors affecting the disclosure risks. The factors and respective scores used in calculating the CPS and SPS are shown in *Tables 1* and *2*.

Score	A CE Type count in MSOA	B Is the CE unique within the LAD?	C Is the CE Type high impact?	D1 Number of clients within the CE Type	E Client Turnover
4	-	-	-	1-15	-
3	1-2	-	-	16-40	-
2	3-5	Yes	Yes	41-100	Low
1	6+	No	No	101+	High
0	-	-	-	0	-

**Table 1:** Scores for each of the factors affecting the Client Protection Score (CPS).

Score	A CE Type count in MSOA	B Is the CE unique within the LAD?	C Is the CE Type high impact?	D2 Number of staff within the CE Type
3	1-2	-	-	-
2	3-5	Yes	Yes	1-10
1	6+	No	No	11+
0	-	-	-	0

**Table 2:** Scores for each of the factors affecting the Staff Protection Score (SPS).

For example, the CE Type ‘Prison Service establishment’, considered to be a high impact CE with a low client turnover, with a count of 1 in the MSOA and the LAD, containing a total of 250 clients and 12 staff, would have a CPS and SPS calculated as follows:

- A = 3, B = 2, C = 2, D1 = 1, D2 = 1, E = 2
- CPS = 3 x 2 x 2 x 1 x 2 = 24                      SPS = 3 x 2 x 2 x 1 = 12

By contrast, the CE Type ‘University’, considered to be a low impact CE with a high client turnover, with a count of 6 in the MSOA, containing a total of 24 clients and 1 staff, would have a CPS and SPS calculated as:

- A = 1, B = 1, C = 1, D1 = 3, D2 = 2, E = 1
- CPS = 1 x 1 x 1 x 3 x 1 = 3                      SPS = 1 x 1 x 1 x 2 = 2

### 3.2 Communal Establishment Swap Rates

With the protection score calculated for both staff and clients of a CE Type in an MSOA, a swap rate is assigned based on CPS and SPS, as shown in *Tables 3* and *4*,



where A% is the lowest percentage swap rate and C% is the highest<sup>3</sup>. Regardless of what swap rates are chosen for the Census, if we were to round to the nearest integer the number of records to be sampled for each CE Type population, it would more than likely result in cases of CE Types having no records swapped. To ensure that swapping occurs for every CE Type for each MSOA, the number of records to be swapped will always be rounded up to the next integer. However, this will imply that no matter how risky a CE is, if there is only one staff or client record, it will always be sampled. Whilst this should not occur too regularly for client records, it may be a relatively common occurrence for staff records. To overcome this and avoid significant damage to the staff resident data we will attach a probability to the record being sampled which will depend on the SPS score.

Client swap rate =	0%	if CPS is	0
	A%		1-5
	B%		6-25
	C%		26+

**Table 3:** The client swap rates vary depending on the Client Protection Scores.

Staff swap rate =	0%	if SPS is	0
	A%		1-5
	B%		6-11
	C%		12+

**Table 4:** The staff swap rates vary depending on the Staff Protection Scores.

Returning to our examples, the prison establishment with a CPS score of 24 and an SPS score of 12 would have B% of client records sampled and C% of staff sampled. With a CPS of 3, the ‘University’ CE Type would have the lowest percentage (A%) of client records selected for the swap sample. With only 1 staff record, there would be a non-zero probability of the record being sampled. With an SPS of 2, this probability will be lower than if the SPS was, for example, 12.

### 3.3 Selecting the Sample

The sample selection process will be 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 CE Type. Rather than setting a threshold and flagging high risk records, the risk scores are used as the weighting when selecting the sample of records to be swapped. Those records with a higher risk score will then have a greater chance of being sampled for swapping.

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<sup>3</sup> ONS will not release specifics of the SDC methodology such as swap rates, matching variables and risk variables, for the protection of the outputs.

### **3.4 Family Residents**

Unlike families in households, there is no family composition matrix to connect the family members either to each other, nor to any of the staff or client residents. This enables us to swap the family residents individually rather than as a whole family. The number of family residents living in CEs is very low; in the Census 2001 most LADs had between 0-15 family residents living in CEs. Because of this, we shall set one single swap rate and select the sample from across all CE Types in the LAD.

### **3.5 The Matching Process**

Because the characteristics of clients will differ from those of staff within CE Types, it is important to ensure that swapping is carried out within resident groups. In the same way, the amount of matching on CE Type is to be maximised. It is an aim to keep swapping within CE Type, however, because swapping must be kept within the DG, in many circumstances this will not be possible (eg. there is only one prison establishment in the Bristol DG). Therefore, the matching variables play a crucial role in ensuring that where swapping does occur between CE Types, the key variables that define the CE Type populations are preserved as much as possible. Because individuals aged under 16 do not answer particular questions on the census form, this has in turn forced the client records to be split between those aged 16 and over, and those under 16. We therefore have three matching groups, each with a unique set of matching variables. Because of the lack of records, it is required to swap family records with either staff or clients. Family records are therefore allocated out to one of the three matching groups depending on the age of the individual and whether they fit into a particular variable category associating them more with either staff records or client records. As with households, we may find that a match is not found using the specified matching variables in which case, we will use a coarser set of variable classifications before looking for matches at a higher geography and then outside of the CE Type. Imputed records will not be swapped.

## **4 Utility Loss and Further Work**

Striking the balance between utility and protection is at the heart of effective disclosure control. For both the household and CE record swapping methodologies this balance is dependent on the level of detail in the outputs and the swap rates. The future work for the SDC branch at the ONS for the CE methodology will be focussed on ensuring the swap levels are reduced to a minimum without compromising the protection of the tables. We shall be assessing the utility loss primarily using the Average Absolute Distance measure as detailed by Shlomo *et. al* (2010), whilst we will be assessing the protection offered by the SDC method using two success measures developed by the ONS. The first measure calculates the proportion of real cases (ie. not cases created by imputed records) of attribute disclosure in a given

table that have been removed through the record swapping methodology. We have recognised that levels of uncertainty are raised where false cases of attribute disclosures are created through record swapping. Therefore, our second success measure calculates the proportion of the apparent attribute disclosures that are actually false (ie. cases of attribute disclosure created by imputed or swapped records). With these success measures and a set threshold level, we are able to assess whether the uncertainty surrounding an output table is ‘sufficient’.

## 5 Summary

This paper has provided an overview of the SDC process for communal establishments for the 2011 UK Census. Having taken the fundamental steps of adapting the household methodology to swap individual records rather than whole households, the focus of the CE methodology has centred around minimising utility loss. We have developed a protection score method to reduce the swap rate for those CE Types that have less of a risk of disclosure. The matching process has been advanced to preserve specific population characteristics and to allow for swapping individuals between CE Types where required. Although further work is continuing to finalise the swap rates using utility measures and the two success measures, the best dataset to assess this methodology will be the trial data of the 2011 Census. Imputation rates are expected to be higher in CEs than in households and thus offer some natural uncertainty. However, we cannot rely on this assumption for the privacy of individuals in CEs and this methodology will provide the necessary further protection that the UK Census Offices are legally obliged to offer those who do respond, without significant damage of the data.

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