

OPENPOPGRID: AN OPEN GRIDDED POPULATION DATASET FOR ENGLAND AND WALES

Data Product Manual

Murdock, A.P., Harfoot, A.J.P., Martin, D., Cockings, S. and Hill, C. (2015) OpenPopGrid: an open gridded population dataset for England and Wales. GeoData, University of Southampton

OpenPopGrid - An Open Gridded Population dataset for England and Wales

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OpenPopGrid - An Open Gridded Population Dataset for England and Wales

1. Introduction

This document describes OpenPopGrid - an Open Gridded Population level Dataset for England and Wales developed by GeoData, University of Southampton under the Open Source Geospatial Laboratory, Southampton¹ and based on datasets from the Office for National Statistics (ONS) 2011 Census and Ordnance Survey OpenData.

1.1. Why do we need an Open Gridded Population dataset?

The smallest geographical areas for which ONS provides population estimates and a broad range of attribute data for the 2011 Census are Census Output Areas (OAs). OAs are generated through the aggregation of adjacent unit postcodes and were designed to have similar population sizes and be as socially homogenous as possible based on tenure of household and dwelling type (Cockings et al, 2013). Urban/rural mixes are avoided where possible and OAs preferably consist entirely of urban postcodes or entirely of rural postcodes (ONS 20132).

A residential population count is published and an enormous range of economic and social data are available for every OA. But in the majority of cases, a single OA will usually include both populated (housing) and unpopulated regions for example non-residential public buildings and open spaces (see Figure 1, on next page), yet when displayed as a choropleth map, or analysed as a single value to represent the entire area, the population density is assumed to be homogeneous within the area.

However, the fact that the population from multiple households is aggregated to a single unit postcode (e.g. SO17 1BJ) means that the finest spatial detail of the actual population distribution, down to the individual address or property, is not preserved. Spatial analysis of such data often uses the data as point aggregations, leading to an all or nothing result, and placing strong emphasis on the location chosen to represent the aggregated postcode unit population. This imprecision causes inaccuracy when postcode data (or OA centroids) are used to map link or transfer data between different units (e.g. point in polygon methods).

Unit postcodes can be georeferenced using the National Statistics Postcode Directory (ONSPD)³. This provides an Ordnance Survey grid reference to the nearest metre for every postcode, determined by choosing the location of the address in the postcode closest to the mean of the coordinates of the constituent address locations. No figures have been published to describe the magnitude of the offsets between the published postcode centroids and the mean centre of the constituent address points.

An indication was obtained from some exploratory review of the distances between unit postcode centroids and residential addresses with the same postcode (based on the OS sample data for Exeter.

¹ Open Source Geospatial Laboratory, Southampton is an OSGeo initiative. The laboratory engages in open source geospatial research and training for geospatial software and data.

² ONS 2013 RUC2011 user Guide_v1.0_Aug 2013.pdf - this was not enforced in 2011 maintenance, however it was in 2001, and therefore OAs may still honour it

³ ONSPD Metadata

Ordnance Survey 2014) which revealed that distances could be as much as 3.7km from the centroid and were on average 59m. This preliminary analysis illustrates the potential displacement but requires further study.



Figure 1 Output Areas (OAs), Unit Postcode Centroids and Topographic Map detail

Due to the issue described above, there is a need for a population dataset that better represents where people are actually living, for use in GIS overlay analysis and which is also freely available as OpenData, in order to permit wider access to this information.

2. Improving upon point based aggregated population counts

There are several methods to improve the spatial representation of population from point data. These approaches *redistribute the population* into the surrounding space based on interpolation, density per unit area or some form of structured redistribution. In the case of densities these typically rely on coarse cells to give values per kilometre etc. Existing population products that use simple redistribution, such as CACI populated postcodes (CACI, 2014⁴) rely on additional commercial data such as address points and simply allocate an even share of the population total for the postcode onto the building centroid, assuming an even household size.

The goal of OpenPopGrid is to improve the spatial representation of the published population dataset, without having to rely on any commercial products; OpenPopGrid achieves this using a dasymetric mapping approach.

GeoData, University of Southampton / Open Source Geospatial Laboratory, 2015

⁴ CACI (2014) Acorn Technical Documentation 2014

2.1. Dasymetric Mapping

Dasymetric mapping involves using additional data to restrict the redistribution of the population to specific areas. The original technique used by Semenov-Tian-Shansky in 1911 (Petrov, 2012) produced a population map showing discrete areas and their population densities and it was a similar technique subsequently used by Wright (1936). This approach has since been refined using various techniques to produce a population surface grid layer at various scales, from local scale (Langford, 2006, Langford, 2013, Mennis, 2003) to continental and global scales (Bhaduri *et al.*, 2005, Bhaduri *et al.*, 2007, Batista E Silva *et al.*, 2013).

Essentially, the number of people in each grid cell can be calculated by restricting the areas into which they can be distributed, and may use the information provided in the additional data layer to proportionally distribute individuals, such as in multiclass dasymetric mapping (Mennis, 2003). All methods of dasymetric mapping work on the assumption that the additional data indicates where people do and do not reside, and in what densities. In the case of LandScan USA (Bhaduri *et al.*, 2007), many additional data layers are used.

Binary dasymetric mapping uses an ancillary layer such as a classified remotely sensed image which indicates residential/non-residential areas to restrict the distribution of population (Langford *et al.*, 1994). In its simplest form, this method would exclude open spaces from the target zones (ie candidate areas to receive population), meaning that population could only be distributed amongst the built up areas. If a residential/non-residential classification (i.e. land *use*) is used, then the population should not be distributed into the non-residential buildings either and this should produce a more representative residential population map.

Having evaluated a range of options, this project has adopted a dasymetric mapping approach which makes use of two additional layers to restrict the redistribution and takes advantage of open data published through the *Making Public Data Public* initiative and made available under the Open Government Licence. This approach and datasets are described below, together with a description of the pre-processing needed.

3. Methodology

3.1. Overview

The approach to generating this dataset is summarised in Figure 2.



Figure 2 Flowchart of the dataset generation process

The 2011 census postcode headcounts data are used as the population source and the population is redistributed over a grid of candidate cells based primarily on buildings.

The building polygons have been filtered to remove those which fall in non-residential areas as identified by the postcode centroids not assigned a population. The remaining set of residential building polygons are candidates for receiving population from the postcode centroid that they are nearest to.

The algorithm then uses an even distribution approach to allocate the population to the candidate cells within the postcode area.

3.2. Data preparation

The following datasets were used:

- 2011 Census Postcode headcounts
- May 2011 National Statistics Postcode Directory (NSPD) Postcode centroids
- November 2013 National Statistics Postcode Directory (NSPD) Postcode centroids
- 2011 Census Output Areas (OA) boundaries
- ONS Postcode to 2011 Census Output Area lookup
- OS VectorMap District (OSVMD) (March 2013)

3.2.1. Georeferencing the Census Postcode Headcounts

The 2011 Census Postcode headcount table (table 1) was joined with the May 2011 NSPD to associate coordinates to the population data. 97 of the Headcount Postcodes were not present and 181 Headcount Postcodes were flagged as terminated (withdrawn from use by Royal Mail) in the May 2011 NSPD. These mismatches are likely to be due to the NSPD and Headcounts datasets not being exactly concurrent, postcodes having been terminated shortly after Census day, and new postcodes being in use at Census day, but not yet being reported in the NSPD.

The terminated postcodes had their terminated status ignored and were used to provide a georeference to the 181 matching headcount postcodes. The 97 headcount postcodes not present were matched to the November 2013 NSPD, within which they did exist.

3.2.2. 2011 Census Postcode headcounts

The postcode geography is such that in unusual cases, a postcode's constituent addresses are not contiguous, being split by another postcode. This has the consequence that despite the construction of OAs from unit postcode polygons, some postcodes are split between OAs. The 2011 Census postcode headcounts record the split of the population (but not gender and household counts) between OAs in these situations in an additional data table (ONS Postcode to 2011 Census Lookup).

By joining the split and unsplit postcode headcounts tables with the ONS postcode to OA lookup table, and then merging the two headcounts tables and removing duplicated counts in the process, a single table was generated that identified for each OA, all the contributing unit postcode populations, and their centroids. If a postcode was split, it was listed multiple times in the table, once against each of the OA codes over which its population was subdivided. A split postcode's centroid only fell within one of the OA boundaries that it was split across, and for all the other OAs, the centroid fell outside the OA boundary.

3.2.3. Unpopulated Postcode Directories

Unpopulated Postcode Directory points were added to the headcount postcode table described in the previous section in order to gain a complete picture of Postcode Directory coverage.

All unmatched and unterminated postcodes were extracted from the May 2011 NSPD. These were then spatially joined to the 2011 OA boundaries in order to assign an OA code and then appended to the populated headcount data.

Unpopulated postcodes which were spatially coincident with populated postcodes were removed.

3.2.4. OS VectorMap District Buildings

Ordnance Survey Vector Map District (OSVMD) was selected because it is open data and provides a vector representation of building outlines. The OSVMD building polygons are simplified from more detailed features and adjacent buildings are aggregated in many cases.

As supplied, OSVMD polygons, including buildings, which straddle the boundary of a 100km Ordnance Survey grid square are split at the boundary. Such cases were identified and the polygons were therefore, joined back together in a preparatory step.

3.3. Processing Workflow

Processing was undertaken on an OA by OA basis, and was performed in FME (Safe Software). The OA used to illustrate the processing steps in this section is E00086859 in Freemantle, Southampton.

3.3.1. Initial extraction of data

The populated and unpopulated postcode points are queried for the OA being processed, and the OA polygon is used to clip the OSVMD buildings dataset to extract just the portion falling within the OA. A shape index is calculated and used to exclude very thin slivers of building polygons generated at the edges of the OA (Figure 3).



Figure 3 Input datasets to the processing (purple line – OA boundary, purple fill – all OSVMD buildings, orange fill – OSVMD buildings clipped to OA, red points – Postcode headcount centroids with count of associated population, background mapping – OS Streetview, shows more detailed building outlines for illustration purposes).

3.3.2. Assigning Postcode Centroids to OSVMD Buildings

Postcode points that do not already fall within an OSVMD building polygon are moved to the nearest OSVMD building polygon. Due to the methods used in their generation most postcode centroids do not need adjusting in this manner, however split postcodes will result in postcode centroids that fall outside the OA boundary, and these will be adjusted. In certain circumstances, this adjustment will result in multiple postcodes being moved to the same location, creating a stack. In this case, the stacked populations will be summed and treated as a single point.

Using the adjusted positions, OSVMD building polygons are assigned to a postcode point, be it populated or not in order to create a full coverage, although unpopulated buildings are not carried forward to the final product. For OSVMD polygons that contain a single postcode point the

assignment is straightforward, for those that contain multiple postcode points, the OSVMD polygon is divided between the points using the Thiessen polygon boundaries which were created for this project from the postcode point set. Building polygons not containing a postcode point are assigned to the nearest postcode point.



Figure 4 Assignment of OSVMD building polygons to Postcode Headcount centroids (green points – adjusted Postcode headcount centroid locations, red lines – Thiessen polygon based subdivision of OSVMD polygon.

3.3.3. Generation of the output grid

A mesh of gridded points at 10m intervals are generated from the OSVMD building polygons and assigned to the associated postcode centroid. It was felt that 10m spacing was sufficient to capture the indicative shapes of the buildings to which the population would be assigned.

OSVMD polygons associated with unpopulated postcode centroids do not have any grid points generated for them. The population associated with each postcode centroid is distributed evenly across its associated grid points.



Figure 5 The regular grid of points that receive population from the postcode centroids (grid points at 10m spacing). For example, the pink grid points in the lower centre of the OA are each allocated the value of 3 which is the population of 66 at the centroid divided evenly over 22 grid points.

Due to the processing running on a single OA at a time in isolation, there is the possibility that a grid cell straddling the boundary between two adjacent OAs will have population assigned to it from both. This outcome would result in over counting of the population in these cells. A check is made for this and all but one of the duplicate cell assignments are removed. The gridded points are then converted into a raster dataset to form the final product.



Figure 6 The final output (yellow - low population per cell, red - high population per cell).

3.3.4. QA and known issues

The 10m cells are aligned to the British National Grid, and for one OA, E00175716 (not shown here), this alignment means that no cell centre falls within the OA as it is too narrow. This OA is thus unable to be assigned population using the grid system adopted, and its population has been displaced into cells in the adjacent OAs E00175647 and E00046379.

3.4. The final dataset



Figure 7 Example of OpenPopGrid - Southampton

3.5. Data format

Data are currently supplied in ASCII grid format by 100km OS grid tiles on a 10m grid.

We hope to have a more flexible selection and web download services available soon.

4. Limitations

4.1. Lack of residential / non-residential building attributes.

The main limitation of OpenPopGrid is the lack of an open source buildings dataset that is classified into residential and non-residential uses with which to refine the redistribution.

Currently, we can exclude many buildings if they are in proximity to a non-residential postcode. However, in several areas non-residential buildings will share a postcode with residential ones, and in these situations OpenPopGrid will have incorrectly placed people into these buildings. Schools are a particular example of this issue as shown in Figure 8. This effect will be greatest where there is a mixture of residential and non-residential properties in close proximity to one another.

It would also have been possible to use more detailed building objects extracted from the OS StreetView dataset but it was felt that the OSVMD data provided the indicative shapes of the buildings and would be more suitable for mapping and analysis over larger areas.



Figure 8 The consequences of mixed residential and workplace postcodes. The schools circled in green share a postcode with residences, and as the school buildings cannot be differentiated from dwellings in the OSVMD dataset, they have been assigned population.

In rural areas the issue of mixed residential and non-residential postcodes is more prevalent, due to the typical interspersal of non-residential properties such as agricultural buildings with dispersed residential properties.

The OpenPopGrid team is working on refinements to the modelling which will allow some of these non-residential buildings to be removed as candidates for receipt of population. However, this will never be totally resolved without improved open building level information / classification which is currently only available within commercial products.

5. Accuracy

5.1. Overview

Given the limitations described above, an assessment of accuracy is provided. The population totals from the OpenPopGrid gridded dataset were compared to summary OA values as published by the Office for National Statistics. The processing was undertaken within GIS and used *Zonal Statistics* functions to sum OpenPopGrid cell values within (intersecting) the OA boundary polygons. The statistics in this section ignore the OA described in 3.2 that was too small to contain any grid cells, and therefore was not populated.

5.2. Absolute difference

The absolute difference between OpenPopGrid and the OA totals were calculated (i.e. all values are expressed as positive values) but indicating a departure from the ONS value.

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Statistic	Value
Min	0.00
Max	43.00
Sum	1925.93
Mean	0.01
% of OAs with zero difference	26.51
% of OAs with difference >0 and <=	72.62
0.001	
% of OAs with difference > 0.001	0.87

Table 1 Absolute Difference summary

The largest differences were explored in more detail: the 32 instances with an absolute difference exceeding five people were individually investigated, and in all cases the difference was due to grid cell centres falling on the boundary between OAs resulting in the population in those cells being assigned to an adjacent OA to that intended. The majority of OAs have an absolute difference of between 0 and 0.001, these are the result of rounding errors accruing between the disaggregation of the integer postcode populations on to grid cells and subsequent re-aggregation back to OA totals.

6. Support

Further details of the OpenPopGrid dataset can be obtained from: <u>http://www.openpopgrid.geodata.soton.ac.uk</u>

7. Licence Acknowledgements

The development of OpenPopGrid has utilised the following datasets supplied under the <u>Open</u> <u>Government Licence</u> and Ordnance Survey <u>OpenData Licence</u>.

Provider	Products	Copyright statement
Ordnance Survey	VectorMap District	© Crown copyright and database right 2014
	StreetView	
Office for National	2011 Census Output Area boundaries	© Crown copyright and database right 2014
Statistics	2011 Census Postcode headcounts	
Office for National	ONS Postcode Directory (Open) May	© Crown copyright and database right 2014
Statistics	2011 and November 2013	© Royal Mail copyright and database right 2014

Table 2 -3rd Party data products used in OpenPopGrid

OpenPopGrid is made available under the Open Database License: http://opendatacommons.org/licenses/odbl/1.0/. Any rights in individual contents of the database are licensed under the Database Contents License.

8. Citation

OpenPopGrid is an open dataset which you are free to use under the terms of the OdBL licence above and provided that data are cited as follows:

8.1. Text Citation:

Murdock, A.P., Harfoot, A.J.P., Martin, D., Cockings, S. and Hill, C. (2015) OpenPopGrid: an open gridded population dataset for England and Wales. GeoData, University of Southampton.

8.2. Mapping Citation:

© OpenPopGrid, 2015. This product contains information from several Information Providers under Open Government Licence and Ordnance Survey OpenData Licence (<u>http://openpopgrid.geodata.soton.ac.uk/Openpopgrid.xml</u>)

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Appendix A: Metadata

Open Gridded Population Dataset for England and Wales

Abstract: Gridded Population data for England and Wales based on the 2011 Census. This open dataset of population provides a more realistic spatial representation of where people are actually located than the current ONS census postcode headcounts but which does not rely on commercial products to achieve this. The dasymetric mapping approach adopted uses a number of other open source datasets to guide redistribution of the population from the postcode centroids into neighbouring building locations. Citation: Murdock, A.P., Harfoot, A.J.P., Martin, D, Cockings, S. and Hill, C. (2015) OpenPopGrid: an open gridded population dataset for England and Wales.

ISO 19115 - Metadata

- Metadata information
- Data information
- Data quality information
- Reference system information
- Distribution information

Metadata information

File identifier: http://openpopgrid.geodata.soton.ac.uk/Openpopgrid.xml Language: English Character set: MD_CharacterSetCode_utf8 Hierarchy level: Dataset Contact:

Organization name: GeoData, / Open Source Geospatial Laboratory Southampton (OSGL) **Contact information:**

Address:

Delivery point: University of Southampton City: Southampton Postal code: SO17 1BJ Country: United Kingdom Electronic mail address: <u>openpopgrid@geodata.soton.ac.uk</u> Role: Point of contact

Date stamp: 2015-06-16 Metadata standard name: ISO19115 Metadata standard version: 2003/Cor.1:2006

Data information

Citation:

Title: Open Gridded Population Dataset for England and Wales
Date: 2015-06-16 Date type: Publication
Date: 2014-07-07 Date type: Creation
Date: 2014-07-07 Date type: Revision
Identifier: http://openpopgrid.geodata.soton.ac.uk/Download/

Abstract: Gridded Population data for England and Wales based on the 2011 Census. This open dataset of population provides a more realistic spatial representation of where people are actually located than the current ONS census postcode headcounts but which does not rely on commercial products to achieve this. The dasymetric mapping approach adopted uses a number of other open source datasets to guide redistribution of the population from the postcode centroids into neighbouring building locations. Citation: Murdock, A.P., Harfoot, A.J.P., Martin, D, Cockings, S. and Hill, C. (2015) OpenPopGrid: an open gridded population dataset for England and Wales. GeoData, University of Southampton.

Point of contact:

Organization name: GeoData, University of Southampton / Open Source Geospatial Laboratory **Contact information:**

Address:

Delivery point: University of Southampton City: Southampton Postal code: SO17 1BJ Country: United Kingdom Electronic mail address: <u>openpopgrid@geodata.soton.ac.uk</u>

Role: Owner

Organization name: GeoData, University of Southampton / Open Source Geospatial Laboratory Southampton (OSGL) **Contact information:**

Address:

Delivery point: University of Southampton City: Southampton Postal code: SO17 1BJ Country: United Kingdom Electronic mail address: <u>openpopgrid@geodata.soton.ac.uk</u>

Role: Distributor

Descriptive keywords:

Keyword: Population distribution — demography . Type: Thesaurus name: GEMET - INSPIRE Themes

Date: 2008-06-01 Date type: Publication

Resource constraints:

Use limitation: © OpenPopGrid 2015, Open Database License: http://opendatacommons.org/licenses/odbl/1.0/ Licence acknowledgements: Ordnance Survey: VectorMap District, StreetView: © Crown copyright and database right 2015 Office for National Statistics: 2011 Census Output Area boundaries, 2011 Census Postcode headcounts: © Crown copyright and database right 2015 Office for National Statistics: ONS Postcode Directory (Open) May 2011 and November 2013: © Crown copyright and database right 2015, © Royal Mail copyright and database right 2015

Access constraints:

Other constraints: No restriction for public access with INSPIRE

Spatial resolution:

Distance: 10.0

Language: English Topic category: Society Extent:

Description: England and Wales Temporal extent:

Geographic bounding box:

West bound longitude: -6.37988 East bound longitude: 1.76896 South bound latitude: 49.871159 North bound latitude: 55.811741

Data quality information

Scope: Dataset Lineage:

Statement: The population data are derived from the Office For National Statistics 2011 Census postcode headcounts. Census Output Areas and Ordnance Survey Vector Map District Building Features are used to guide the redistribution of the population.

Reference system information

Reference system identifier: 27700

Distribution information

Distribution format:

OpenPopGrid - An Open Gridded Population dataset for England and Wales

Name: Arc/Info ASCII Grid Version: