Sustainable Urban Development Indicators in Great Britain from 2001 to 2016

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Summary

Current planning strategies promoting suburbanisation, land use zoning and low built-up density areas tend to increase the environmental footprint of cities. In the last decades, international and local government plans are increasingly targeted at making urban areas more sustainable. Urban structure has been proved to be an important factor guiding urban smart growth policies that promote sustainable urban environments and improve neighbourhood social cohesion. This paper draws on a series of unique historical datasets obtained from Ordnance Survey, covering the largest British urban areas over the last 15 years (2001-2016) to develop a set of twelve indicators and a composite Sustainable Urban Development Index to establish the spatial and temporal structure of changes in urban structure. The results show that there is a uniform increase in urban structure sustainability of areas in and around city centres and identify that the primary built environment feature driving these improvements was an increase in walkable spaces.

KEYWORDS: Urban structure; Spatial analysis; Composite index; Britain

1. Introduction

In 2018, urban areas accommodated more than half of global population (Brelsford *et al.*, 2018). The 2018 population projections forecasted that urban areas will concentrate more than two thirds of the global population by 2050 (United Nations, 2018). This worldwide trend of urbanisation is expected to trigger economic growth and development as well as changes in the spatial organisation of population and land use (Batty, 2008). However, the rapid urban expansion of cities across the globe is also expected to put populations and natural environment under pressure. Additionally, the unfolding COVID-19 pandemic may influence future housing choices away from city centres to less dense areas. Current planning strategies promoting suburbanisation, land use zoning and low built-up density areas tend to increase the environmental footprint of cities (Jones and Kammen, 2014). In the last decades, international and local government plans are increasingly targeted at making urban areas more sustainable (Mohammed *et al.*, 2016). Hence, urban smart growth policies, fostering compact and mixed land use development, walkable neighbourhoods and ensuring the availability of public transport and open spaces, have emerged as key strategies to create sustainable urban environments and improve neighbourhood social cohesion (Artmann *et al.*, 2019).

In this paper, we propose a set of simple yet robust summary indicators to capture change in the urban structure of the 12 largest British urban areas over the last 15 years, 2001-2016. Drawing on a series of unique historical datasets obtained from Ordnance Survey, the national mapping agency of Great

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Britain, and we specifically aim to:

1. Develop a set of twelve indicators at 1 km^2 grid level to measure three dimensions of urban structure: Compactness, Green space availability, and Walkability;
2. Build composite indices to combine individual indicators by domain – Compactness, Green space availability, and Walkability – and create an overall Sustainable Urban Development Index of British neighbourhoods;
3. Establish the spatial and temporal structure of changes in urban structure to identify patterns of redevelopment and decline.

2. Materials and methods

We used four temporal samples (2001, 2006, 2011 and 2016) to cover 15 years of urban transformation extracting data from the Ordnance Survey (OS) database for the 12 largest urban areas in Great Britain: Bristol, Edinburgh, Glasgow, Leeds, Liverpool, London, Manchester, Newcastle upon Tyne, Nottingham, Sheffield, Southampton and Birmingham. According to 2011 Census, these areas cover 80% of the Great Britain population. We employed the Functional Urban Areas (FUAs) layer produced by OECD (OECD, 2013) to define urban area extents. FUAs provide a common definition of metropolitan areas as 'functional economic units' across 29 OECD countries. These areas are dependent on population density and travel-to-work flows and offer a more accurate representation of functional labour market activity than administrative boundaries (Casado-Díaz *et al.*, 2017; Rowe *et al.*, 2017).

We used data from three OS product sources:

1. OS AddressPoint database - that provides information on residential and commercial addresses for 2001, 2006 and 2011;
2. OS AddressBase - that provides information on residential and commercial addresses for 2016; and
3. OS MasterMap Topography Layer - that provides information on polygons capturing building footprints, green space, roads and paths.

The methodological framework developed in this study includes four stages as presented in **Figure 1**. Stage 1 involved the calculation of 12 individual indicators of urban structure at 1 km^2 grid level using OS data. These indicators were used to capture three distinctive domains in Stage 2 and they were standardised and weighted within each domain in Stage 3. In the final Stage 4, we used the three domain-specific ranks to calculate an overall Sustainable Urban Development Index (SUDI).

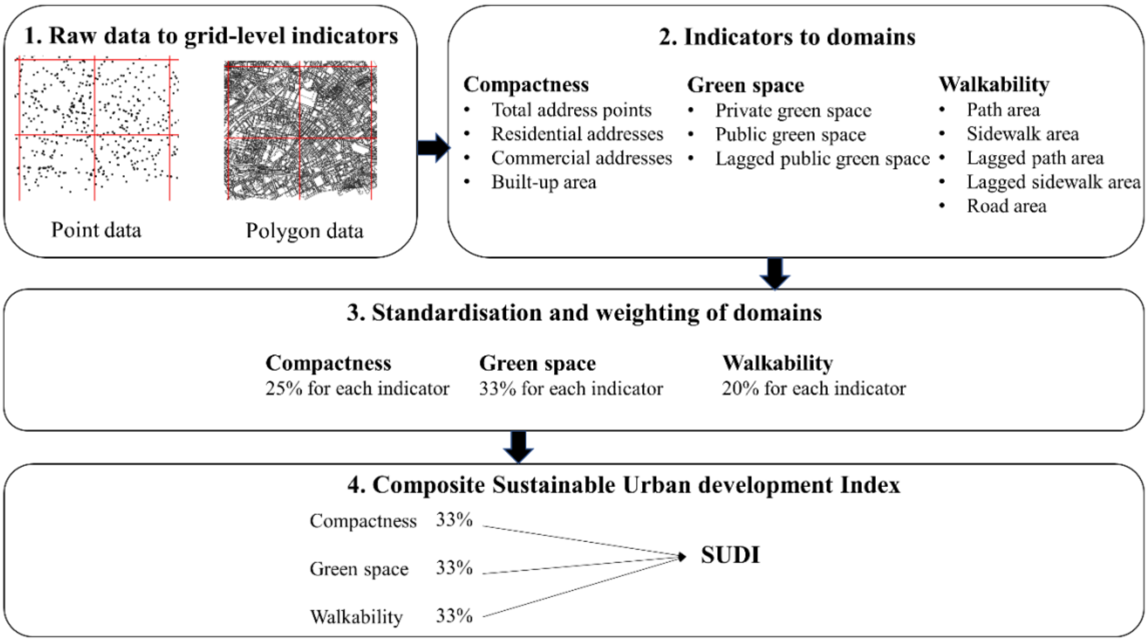

Figure 1 The diagram shows the overall methodology which consists of four stages, from raw data to the final output.

3. Results and discussion

Figure 2 shows the distribution of neighbourhoods (grids) across SUDI deciles by FUA over 2001-2016. FUAs have been ranked from top left to bottom right based on the number of best performing neighbourhoods (i.e. 1st decile) in 2016. The horizontal line indicates the average distribution for each decile (i.e. 10% as we have used deciles) and how each FUA deviates from this line. Our results reveal marked differences across the 12 FUAs in our sample. Out of all, 12-18% of neighbourhoods in Edinburgh, London and Newcastle scored in the best performing decile in 2016, while only 3-7% of neighbourhoods ranked in the best performing decile in Leeds, Southampton and Birmingham. When looking at the worst performing decile, British cities tended to be more similar than when analysing the best performing decile, yet variations exist. Around 13% of neighbourhoods are consistently at the worst performing decile in Manchester, but it accounts only for 3% in Newcastle.

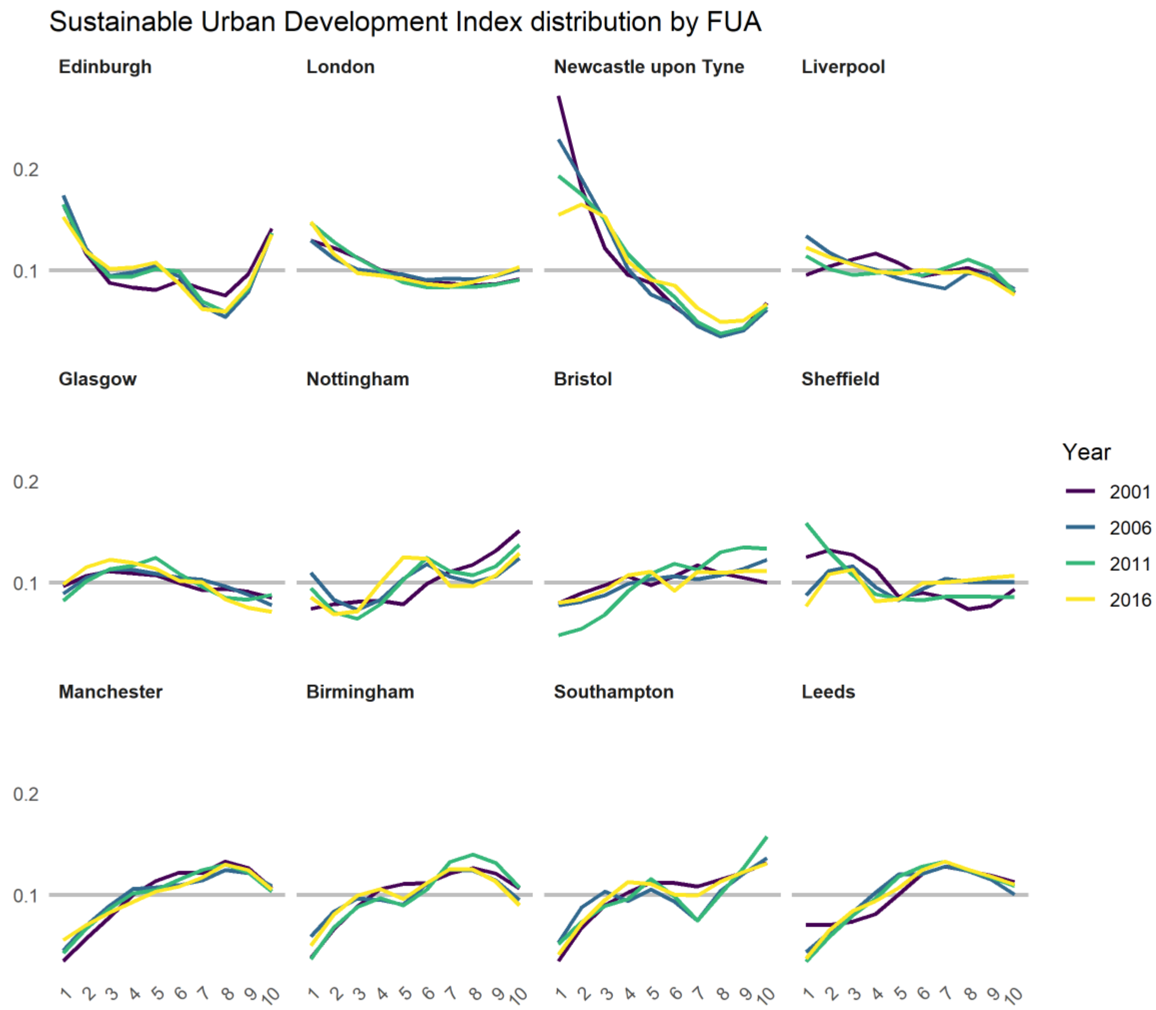

Figure 2 Line plots of the distribution of grids that belong to each decile of the Sustainable Urban Development Index by FUA and year.

While differences across British urban areas exist, there seems to be a consistent local spatial pattern. **Figure** 3 shows the spatial distribution of SUDI deciles across FUAs in the sample in 2016. It reveals that neighbourhoods in the best performing deciles tend to be in the urban cores of cities, while worst performing deciles in the periphery. Looking at the previous years, we see a gradual increase in the ranking of neighbourhoods in or around city centres (see S6 in the Supplemental Material). Arguably these patterns reflect the geography of implementation of city urban regeneration strategies in British metropolitan areas which have largely focused on revitalising city centres (Hamnett, 2003).

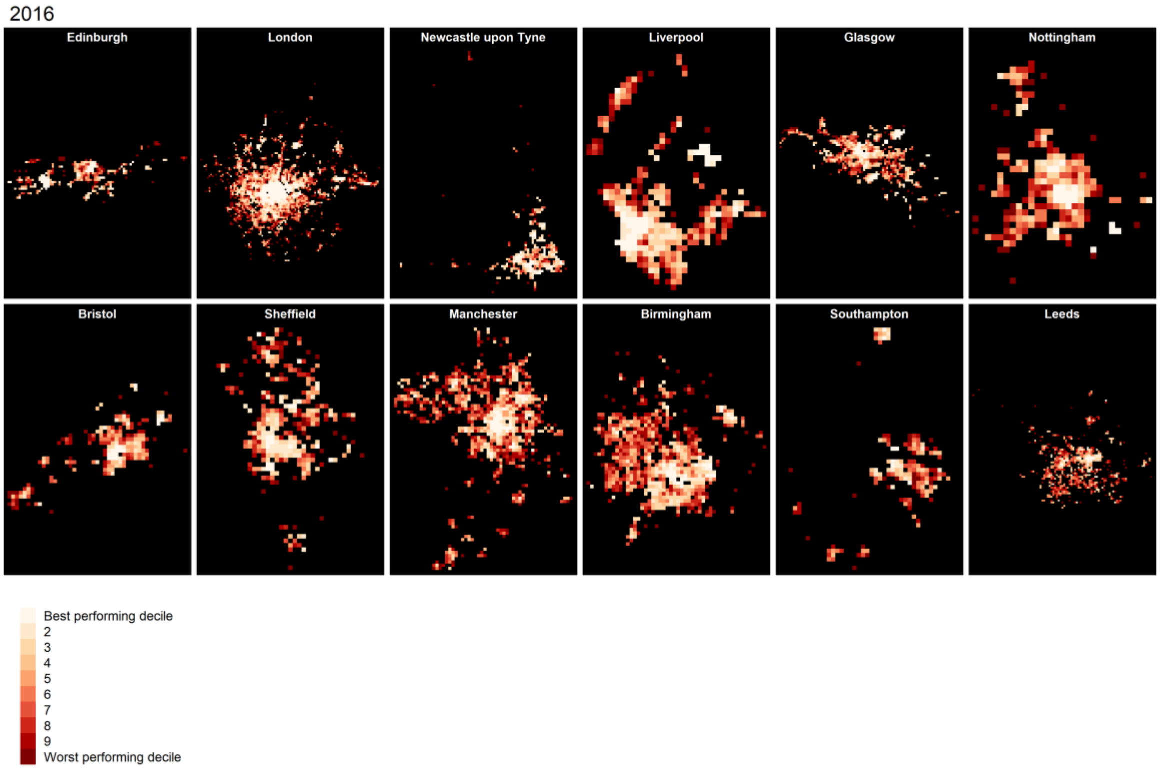

Figure 3 Maps showing the spatial distribution of SUDI index ranking in 2016. Interactive maps showing the distribution of SUDI deciles can be found in https://patnik.github.io/sustainable-urban-development-index/.

To examine the timing and extent of changes in local urban structure across FUAs, we created a typology to capture the long-term trajectory of neighbourhood change (i.e. from 2001 to 2016). We performed k-means cluster analysis and identified eight distinct classes of neighbourhood change as discussed in Subsection 2.7. The input data was the absolute difference in the deciles for each neighbourhood (for both SUDI and the three domains) in the overall period 2001-2016 and each sub-period (i.e. 2001-2006, 2006-2011 and 2011-2016. Separate analyses were run for neighbourhoods displaying a decreasing SUDI decile rank change and for neighbourhoods reporting an increasing SUDI decile ranking change.

Figure 4 shows the resulting clusters (columns) of neighbourhoods moving up and down in the SUDI ranking in separate panels for the overall index and each domain (rows). The top panel shows the changes over the entirety of the period in analysis (2001-16) and the three sub-panels for each of the three sub-periods, 2001-06, 2006-11 and 2011-16 (note that the total change is not the sum of the individual domains for a given year). Cell numbers represent the median decline change in the relevant ranking indicator (rows). Positive values indicate a decline in ranking, while negative values indicate an increase in ranking (i.e. higher ranking in 2016 compared to 2001 results in a negative number). The first row in each period panel shows the change in the overall SUDI ranking, and second to fourth rows display the change in each constituent domain index. For example, a change in the SUDI of -4 would indicate increase from decile 6 in 2001 to decile 2 in 2016.

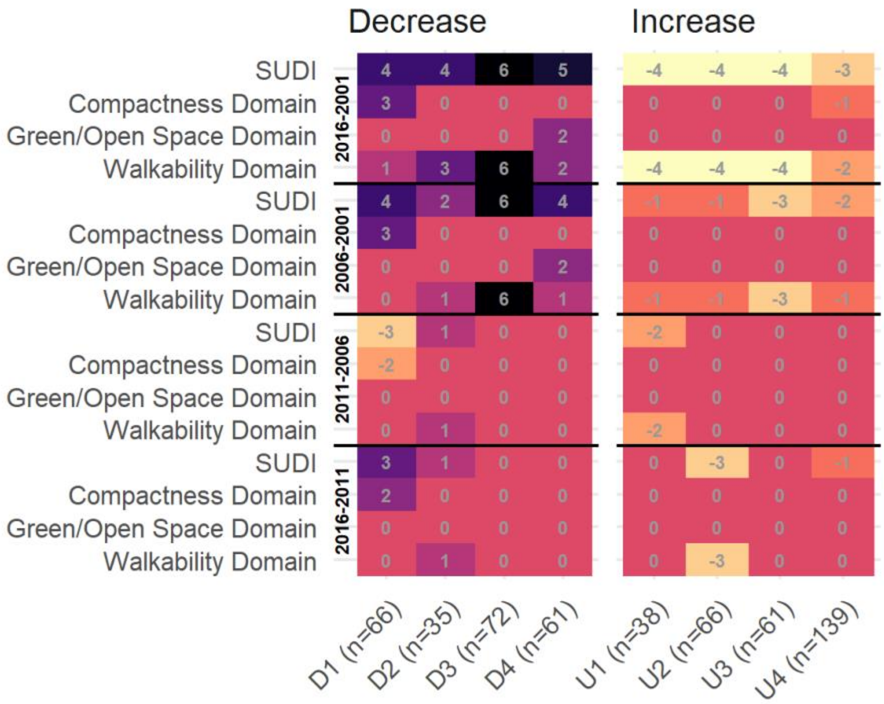

Figure 4 Median value of decile change in ranking domain by cluster and trend (increase or decrease).

The identified cluster classification captures distinctive trajectories of change. Clusters containing neighbourhoods experiencing a decrease in SUDI decile ranking reveal changes driven by distinctive set of urban features.

- *Cluster D1* encompasses neighbourhoods with a decline of a median equals to 4 in the overall SUDI ranking between 2001 and 2016 driven by a decline in the Compactness index. Urban Compactness seems to have declined during 2001-2006 and 2011-2016 but counterbalanced by rises in the intervening period 2006-2011. Neighbourhoods in this cluster are mainly found in London. Thus, an increase in Compactness domain in the intervening period 2006-2011 coincides with an intense period of urban development in London, resulting from a range of large-scale infrastructure projects undertaken in preparation for the Olympic Games of 2012.
- *Cluster D2* contains neighbourhoods experiencing a decline in the overall SUDI ranking mainly triggered by small drops in the Walkability domain. Drops of 1 decile change occurred in the three sub-periods in analysis but translated in a greater compounded decline of 4 declines in the overall SUDI ranking over the entire 2001-16 period.
- *Cluster D3* comprises neighbourhoods registering the largest declines in the SUDI ranking with a median of 6 deciles driven by reductions in the Walkability domain in 2001-2006.
- *Cluster D4* includes neighbourhoods recording declines in SUDI ranking triggered by reductions in the Green space and Walkability domains particularly in 2001-2006. Cluster D1, D3 and D4 consists of similar number of neighbourhoods. Cluster D2 is of smaller size.

4. Conclusion

This study is a first attempt to provide an analytical framework that captures the spatiotemporal patterns of urban structure change in Great Britain. By employing Ordnance Survey's data for the 12 most populous FUAs from 2001 to 2016, we developed a set of indicators capturing three domains (Compactness, Green Space and Walkability) and a composite index at 1 km^2 grid level. Our analytical framework provides a robust tool that can efficiently reveal changes in urban structure. Using the Sustainable Urban Development Index and its domain rankings, we can understand differences in the characteristics of urban structure between and within urban areas over time. By establishing the spatial and temporal structure of changes in urban fabric, past urban planning interventions can be assessed to inform future planning strategies.

5. Acknowledgements

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Biographies

Nikos Patias is a PhD student at the Department of Geography and Planning in the University of Liverpool and member of Geographic Data Science Lab. His research focuses on assessing the extent, sequence, pace and spatial pattern of neighbourhood change in Britain. He holds a master's degree in 'Real estate and planning' from Heriot Watt University. Prior to this, he completed his undergraduate degree on 'Spatial planning and development' at the Aristotle University of Thessaloniki.

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Dr Stefano Cavazzi is a Principal Innovation and Research Scientist at Ordnance Survey where he leads the development of GIS and geomatics research programmes. Ordnance Survey (OS) is the national mapping agency for Great Britain, and a world-leading geospatial data and technology organisation. Stefano has fifteen years of experience in the geospatial sector in both academia and industry specialising in geospatial data science. He holds a PhD from the University of Cranfield where he investigated spatial scale analysis to model earth's terrain attributes used as primary inputs in machine learning methods.

Dani Arribas-Bel is interested in computers, cities, and data. He is a senior lecturer in Geographic Data Science at the Department of Geography and Planning of the University of Liverpool and ESRC Fellow at the Alan Turing Institute. Dani is currently working on methods and approaches to leverage new forms of data such as remotely sensed imagery to better characterise and understand cities.