SPATIAL INEQUALITIES IN PUBLIC TRANSPORT AVAILABILITY: INVESTIGATION WITH SMALL-AREA METRICS

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INTRODUCTION

- Public transport availability (PTA) is an important factor determining equitable access to basic amenities such as employment, healthcare, education, recreation, and shopping
- Reducing gaps in the provision of public transport services is vital for social equity, particularly for low-income families who cannot afford to own and use cars

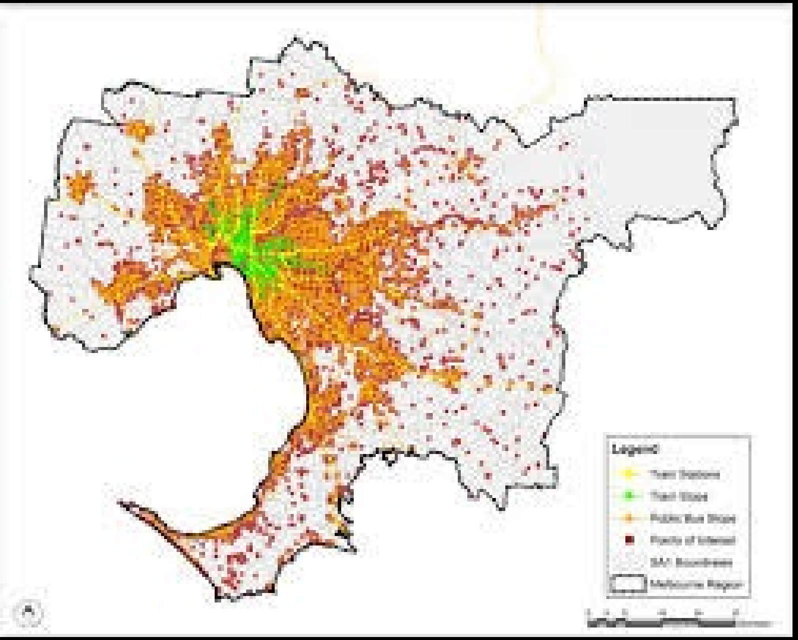
BACKGROUND TO RESEARCH

- Public transport support from central and local governments in the UK has been decreasing since 2008 (UK Department for Transport, 2016)
- In England nearly 1.5 million people are at high risk of suffering from 'transport poverty' (Sustrans, 2013)
- Hence, the need to identify areas at ‘high’ risk of transport poverty
- ‘Transport poverty’ could be proxied with
    - transport availability metrics
    - areas of low income
    - areas where a significant proportion of residents live more than a mile from their nearest bus stops or railway station
    - areas where it takes over an hour to access essential goods and services by walking, cycling or public transport (Sustrans, 2013)

PREVIOUS STUDIES AND TECHNIQUES

- Various methods and techniques have been deployed to study PTA and equity
- Earlier studies used proximity-based methods to assess PTA:
    - Number of stops, or
    - Proximity to stops (Fan et al., 2010)
- In the last two decades some studies (Rood, 1998; Ryus et al., 2000; Mamun and Lownes, 2011; Mavoa et al., 2012; Xu et al, 2015) attempted to measure it through the combination of spatial proximity and service frequency
    - Stops, number of routes and frequency of service
    - Providing a more complete and realistic picture of public transport availability

MOTIVATION



- However:
- Most of the earlier studies were conducted at city- or regional-level
- Focusing on public transport equity in specific areas with only few conducted on country-wide basis
- Those that have undertaken country-wide analysis used mainly decennial census (e.g. Rae,2016), or in combination with National household travel surveys (e.g. Goodman, 2013)
- However, Big Data opens up the ability to frequently assess country-wide transport quality at more localised levels , compared to the census or survey data

MOTIVATION – CONTD.

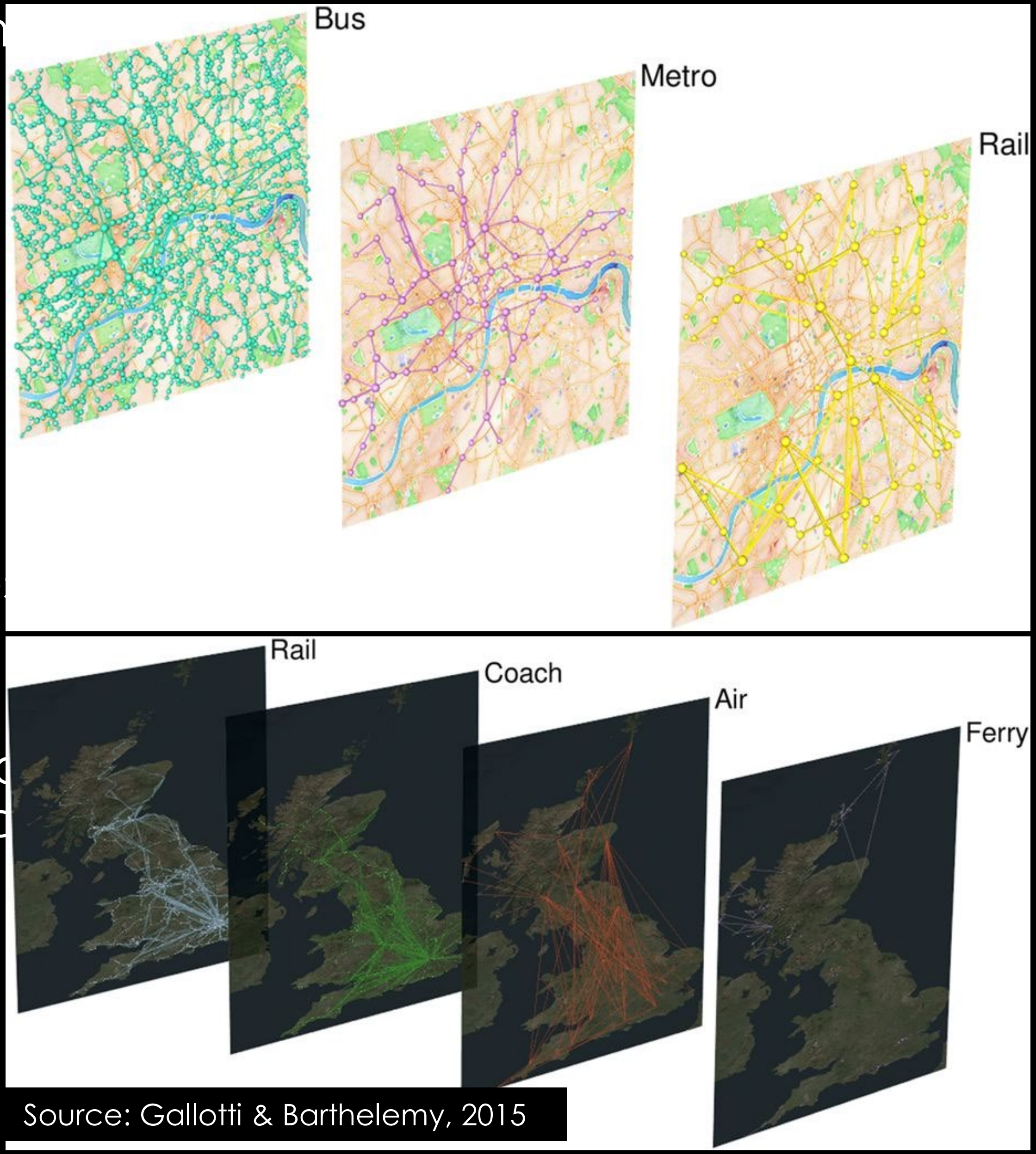
- Futhermore:
- Majority used only global comparisons at the national scale (e.g., ranking all the areas in a nation)
  - Global comparisons enable policymakers to understand spatial inequalities between regions or cities
    - Likely to neglect the effects of regional difference in economic development and infrastructure policies
    - Could lead to inference fallacy
  - Local comparisons enable policymakers to understand spatial inequalities within regions or cities

OBJECTIVES

- Hence:
- This research aims to bridge three research gaps
  - Accurately measure and map PTA at a highly disaggregated level (small-area)
    - Combining spatial proximity and service frequency using emerging forms of data
  - Identify areas with low PTA using global and local comparisons
  - Examine risk of ‘transport poverty’ based on intersection of PTA, income and car availability

DATA

- Schedule data (TransXchange format) of bus, ligh rail, tram and ferry services in England, Wales and Scotland from UK Traveline Information Limited
- Schedule data of train services in England, Wales and Scotland (GB Rail Network) CIF format (already converted to GTFS by GB Rail GTFS)
- Hourly number of trips in progress on workdays in England for 2015 from UK National Travel Survey (Monday to Friday) (GOV.UK, 2013)
- Transport accessibility data (average journey time in minutes to nearest key services by public transport / walking, bicycle, or car) from GOV.UK
- Income (MSOA level) - average weekly househol income in 2013/14 from Office for National Statistic
- Car and van ownership (MSOA level) from ONS
- Road network dataset covering the entire UK (Ordnance Survey, 2017).



Source: Gallotti & Barthelemy, 2015

DATA PROCESSING

- Converted to GTFS
  - For TransXchange format - using modified version of a Python conversion tool (Mooney, A., 2016).
  - GTFS schedule data of train services that is converted from CIF format schedule data by GB Rail GTFS (Rail Delivery Group, 2016)
- Merged GTFS datasets of bus, tram and ferry services and train services to get a dataset containing:
  - 329,314 bus stops, 2,514 rail stations, 1,325 tram stations and 306 ferry stations in operation in GB
  - 17,880 bus routes, 5,770 rail routes, 93 tram routes and 139 ferry routes

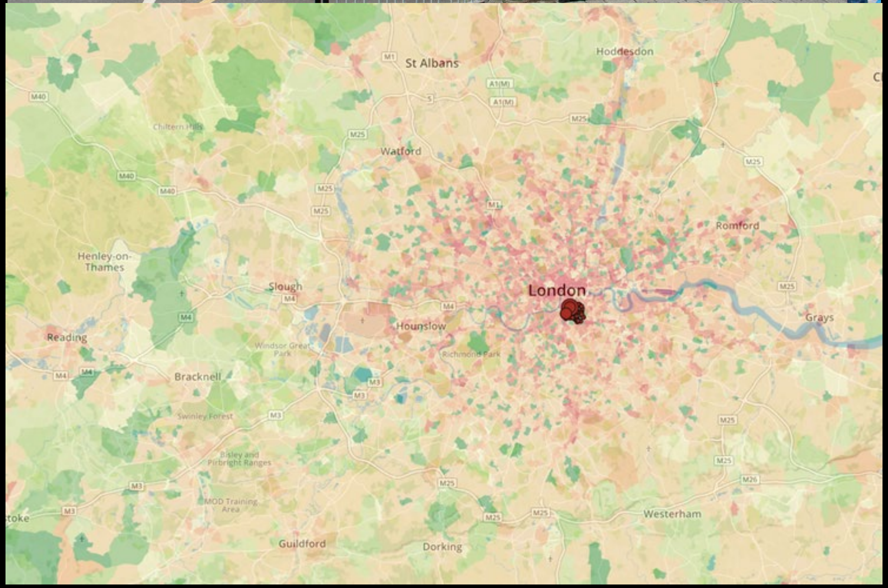
METHODS

- GTFS data used to measure and map PTA combining spatial proximity and service frequency
- Investigate spatial inequalities of PTA across England and Wales
  - Identify areas of low PTA with global comparison low levels – comparing areas with all other areas
  - Identify areas of low PTA with local comparison – comparing areas with only neighbouring areas
- Examine population (households) at high risk of transport poverty according to a combined spatial analysis of PTA, income and car availability
  - Using spatial clustering

CALCULATION OF STOP-LEVEL TAI

- Weighted Transport Availability Index (TAI) used to represent PTA at the stop/station level
- Weights apportioned to service hours based on trip demand (high demand of trips within an hour means high importance of the hour)
    - Hourly number of trips in progress on workdays in England for 2015 used
- Hence weighted TAI is the weighted hourly number of trips passing a station (stop) from Monday to Friday

$$Weighted\_TAI(i) = \frac{1}{5}\sum_{t \in T} cnt\_trip(i,t) \ * w(t)$$



AGGREGATION OF STOP-LEVEL TAI TO LSOA-LEVEL

- Middle Layer Super Output Areas (MSOAs) and Lower Layer Super Output Areas (LSOAs) are spatial units for small-area analysis
- Income and car availability data available at the MSOA level
- Hence, aggregate stop-level TAIs to MSOAs to ensure TAI geographic linkability to income and car availability
- Using:
    - Service levels (hourly service frequency), and
    - Service areas (area within which people are willing to walk to the station/stop)
        - Represented with a circular buffer centered on a station/stop
        - Using pre-determined acceptable maximum walking distances for public transport modes (400m for bus and tram, and 800m for rail and ferry)

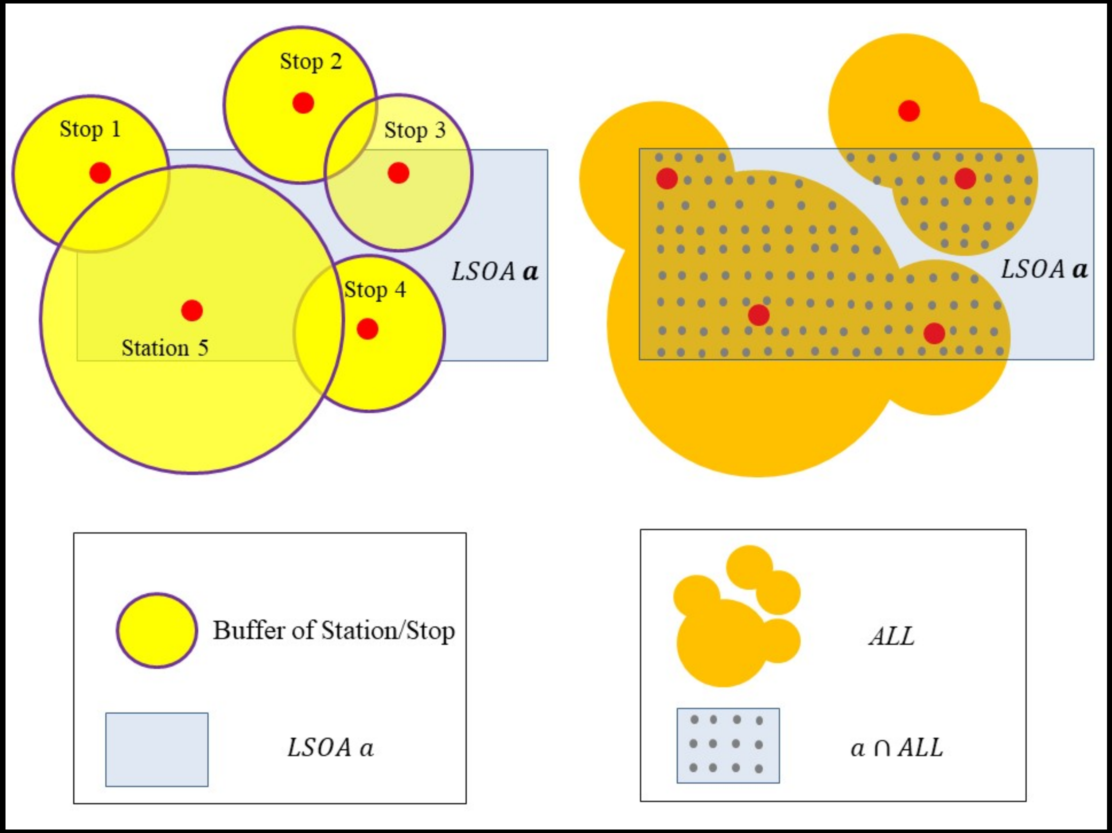
AGGREGATION OF STOP-LEVEL (CONTD.)

- Overlap each station/stop's buffer with LSOAs to know which LSOA is served by which stations/stops
- Then Stop-level TAI aggregated to LSOA-level TAI

$$TAI(a) = \sum_{i \in S(a)} Weighted\_TAI(i) * \frac{Area\,(i \cap a)}{Area\,(a)}$$

- Incorporate population in aggregating LSOA-level TAI to MSOA-level TAI

$$TAI(A) = \sum_{j \in S(A)} TAI(j) * \frac{POP(j)}{POP(A)}$$



OTHER AVAILABILITY MEASURES - SERVICE DENSITY

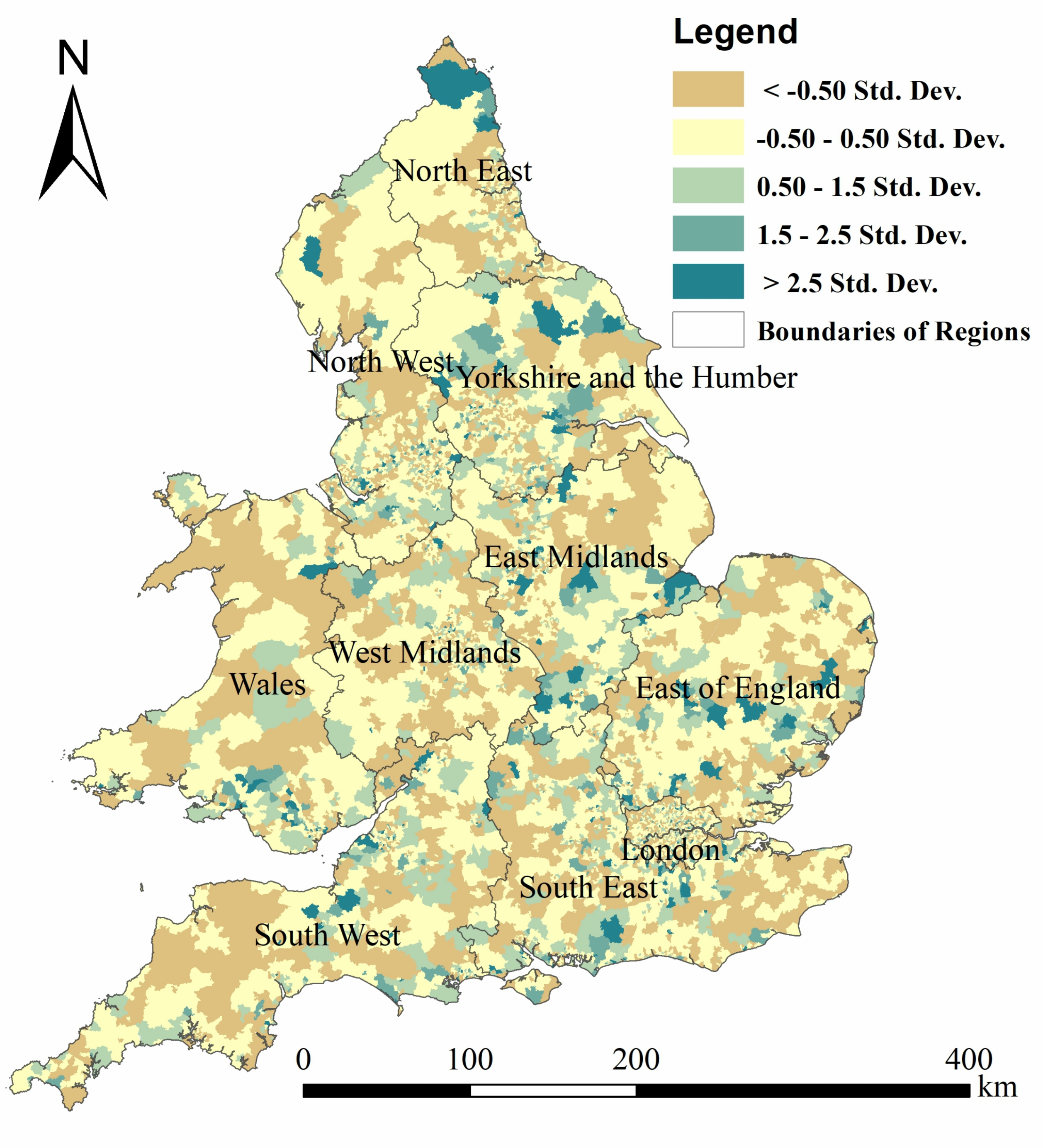
- In addition to TAI other metrics calculated include:
  - Density of Stops/stations (DOS)
  - Density of Routes (DOR)
  - Density of Night Stops/stations (DONS – 12am – 5am)

GLOBAL SPATIAL INEQUALITIES OF PTA

- Gini coefficient is commonly used to measure levels of inequality,
  - Limitation – not easily decomposable or additive
- Hence:
- Theil indices (family of generalized entropy (GE)used to measure the spatial inequalities of MSOA-level TAI across England and Wales
  - GE calculated with different values of '**a**' (GE(0), GE(1) and GE(2)) to analyse the sensitivity of GE to coefficients
  - Specifically, GE(0), GE(1) and GE(2) calculated for each region and each of the main cities to measure the levels of spatial inequalities in MSOA-level TAI to avoid parameter influence
- Areas of low PTA identified

LOCAL SPATIAL INEQUALITIES OF PTA

- Improved A Multidirectional Optimal Ecotope-Based Algorithm (AMOEBA) developed by Duque et al. (2011) was used to identify spatial clusters at local levels
- AMOEBA is implemented using ClusterPy (RiSE group)
- Areas of low PTA identified

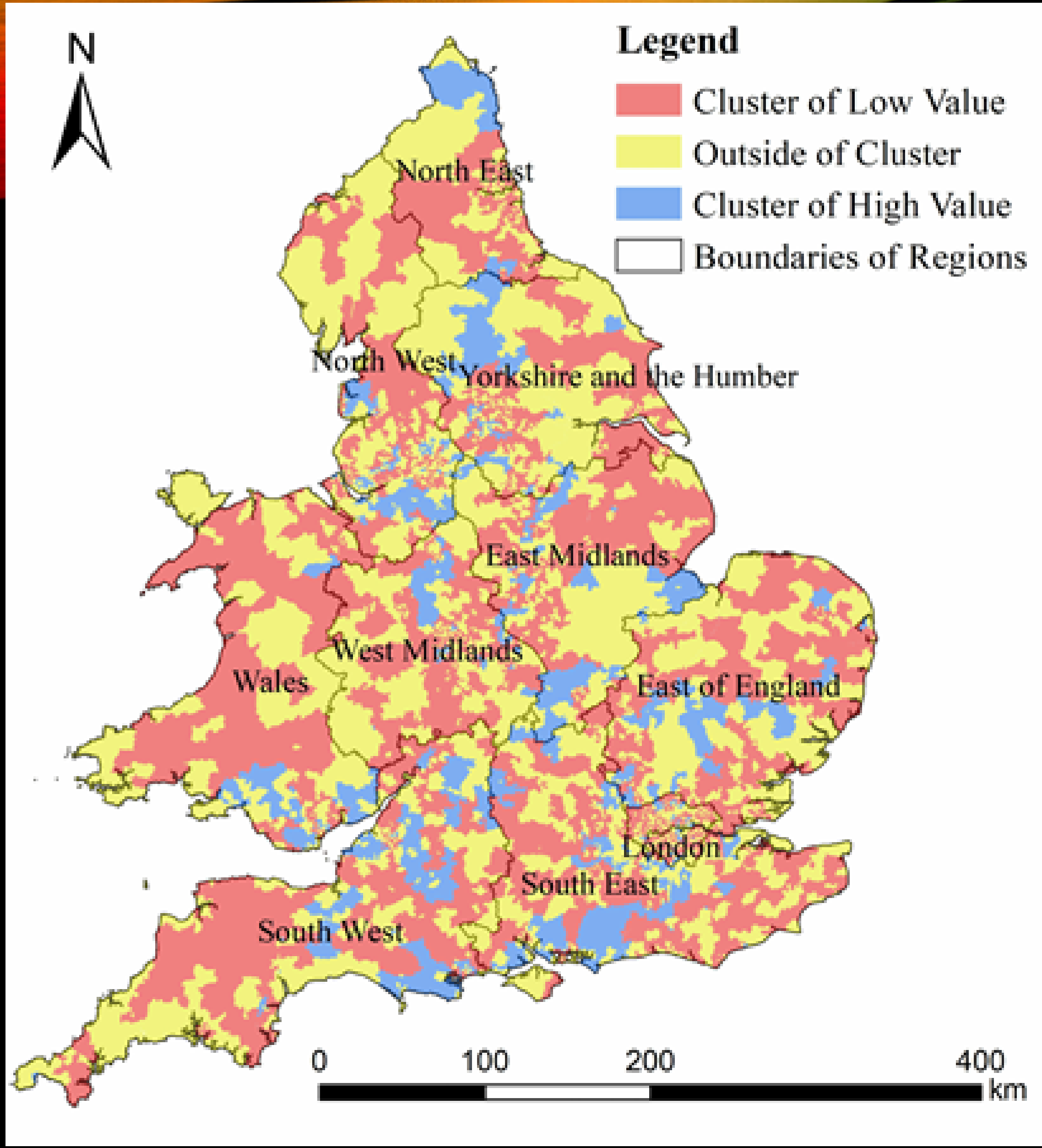


RESULTS

- MSOA-level TAI classified into 5 levels according to the mean and standard deviation of MSOAs' TAIs
- GE indices reveal that North West, Yorkshire and the Humber, East Midlands, South West, and Wales are facing relatively high levels of spatial inequalities in public transport availability
- North East, West Midlands, East of England, London, and the South East regions are facing relatively low levels of spatial inequalities

RESULTS - MAIN CITIES

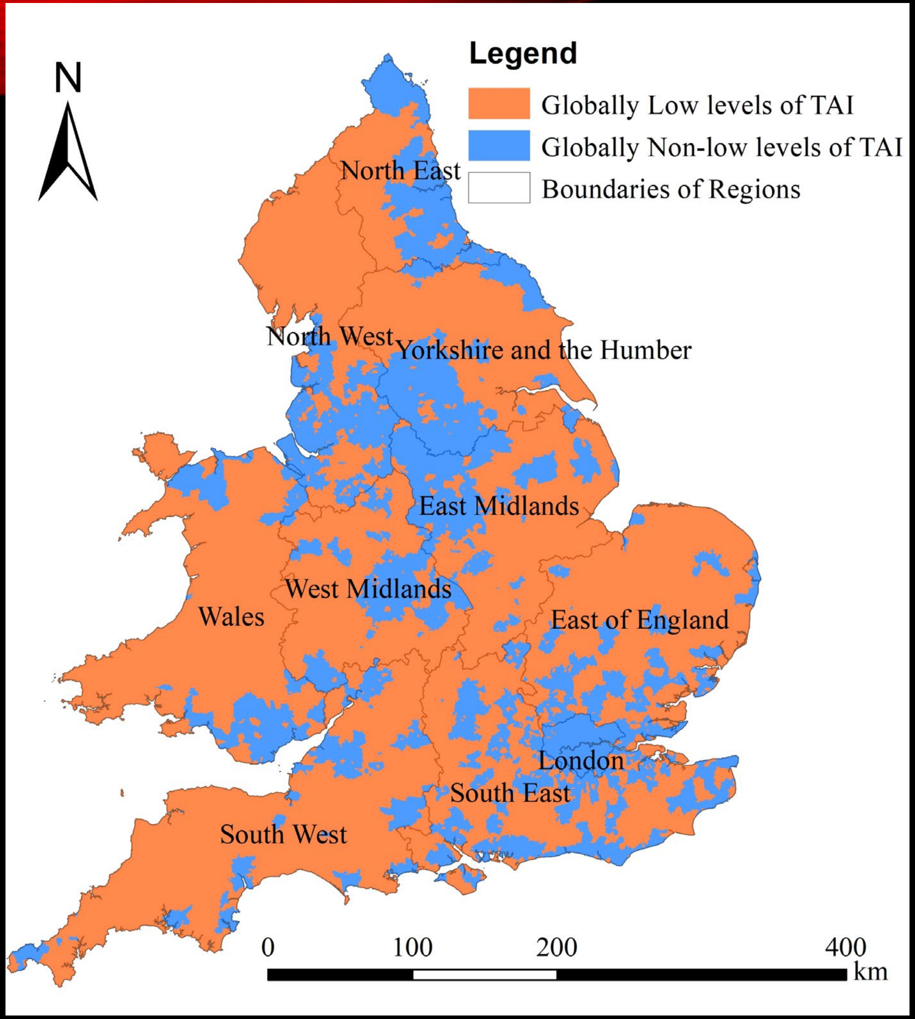
- Levels of spatial inequalities in MSOA-level TAI within the main cities (London and 20 cities - 30% of the total population) of England and Wales using GE indices
  - Leeds, Bradford, Bristol, Cardiff, Wakefield, Nottingham, Leicester, and Swansea are facing relatively high spatial inequalities of public transport availability
  - Birmingham, Sheffield, Manchester, Coventry, Sunderland, Hull, Plymouth, and Derby are facing relatively low spatial inequalities



RESULTS – LOCAL SPATIAL COMPARISONS

- Inequalities of TAI - local spatial comparisons
- High values represent clusters of high TAI and vis versa
- Estimated 9,690,365 (41%) households living in areas with locally low levels of availability
- 2,088,700 households in income poverty and 2,514,450 no-car households are living in the locally low availability areas

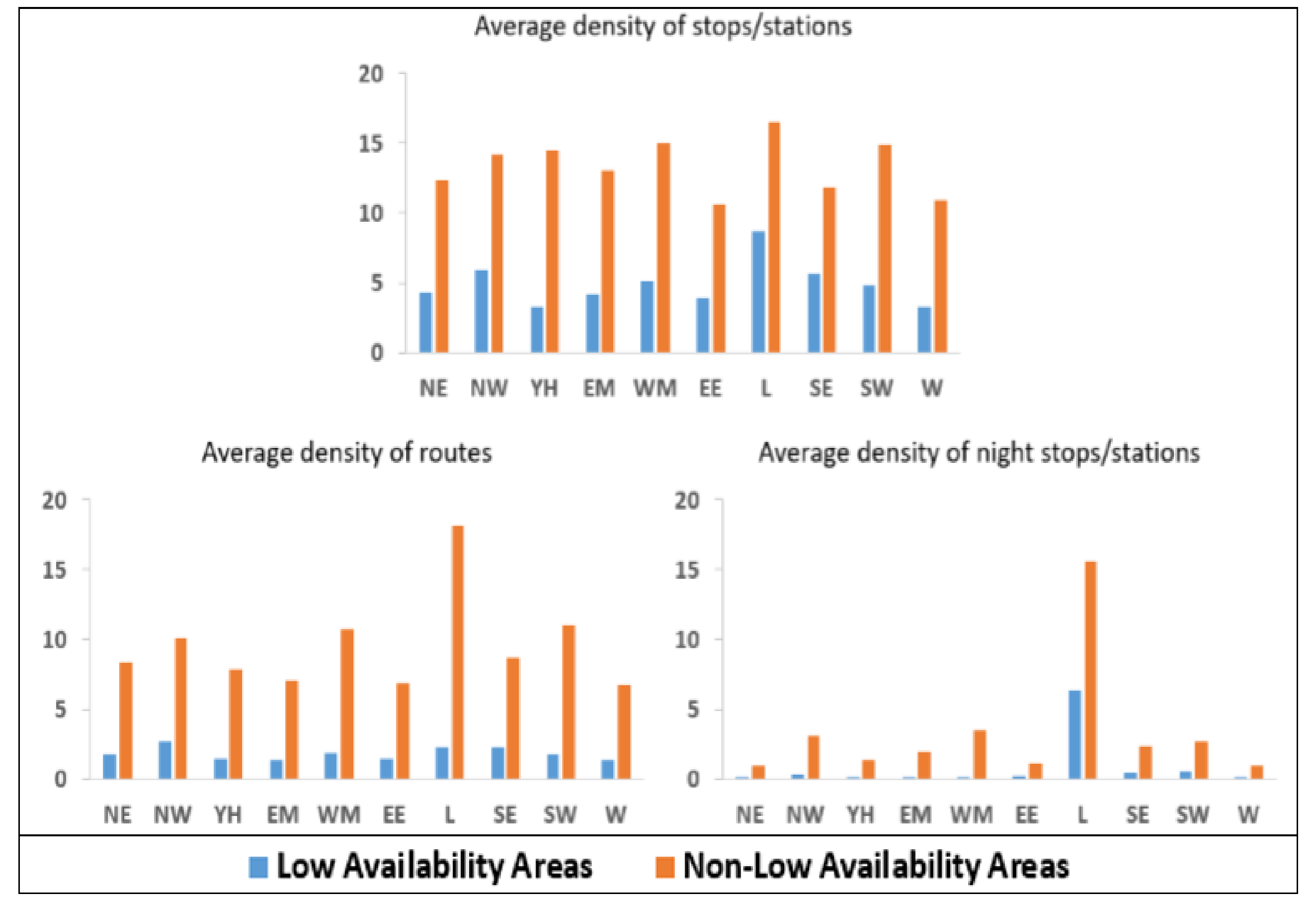
RISK OF TRANSPORT POVERTY



Levels of TAI – Global spatial comparisons

- Globally - higher proportion of households living in East Midlands, East of England, South East, and South West are likely to have less sufficient transport services than households living in the other regions
- Locally - higher proportion of households living in North West, West Midlands, and London are likely to have less sufficient transport services than households living in their neighbouring areas
- At the city scale (local comparison) - Birmingham, Liverpool, Manchester, Bristol, Wakefield, and Nottingham rank high (more than 50% of households in income poverty and no-car households are living in low availability areas)

AVAILABILITY MEASURES, SERVICE DENSITY AND JOURNEY TIMES TO KEY SERVICES



Key: North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East of England, London, South East, South West, and Wales

- Night service is very limited in all low availability areas - except in London

FINDINGS

- Spatial inequalities of TAI exhibit different regional patterns between global and local comparisons
- The percent of population in low availability areas (locally) differ slightly from one region to another; whilst the percent of population in low availability areas (globally) differ largely from one region to another
  - For instance, North East, North West, West Midlands and London face a higher proportion of population living in the locally low availability areas, although they have a lower proportion of population living in the globally low availability areas
  - Birmingham, Liverpool, and Manchester face a higher proportion of population living in the locally low availability areas although they have zero population living in the globally low availability areas
  - Swansea has the highest proportion of population living in the globally low availability areas, but zero population living in the locally low availability areas

FURTHER WORK

- Exploring labour market, employment and health and social outcomes of public transport-dependent populations across the UK
- Relationship between PTA and transport accessibility at small area levels
- Examine seasonal or annual variations in public transport availability using data from several years, in relation to seasonality in employment levels
- Linking to real-time public transport arrival, departure and delay feeds and social media sentiments to gauge actual public transport service quality
- Estimate travel times to key destinations (e.g., workplace, school, hospital, etc.) at the small area levels

CONCLUSION

- The significance of the approach is the use of a novel dataset to generate metrics that allow continuous monitoring of PTA at small-area scale on a country-wide basis
- Identification of sub-city areas at greatest risk of transport poverty
- Approach provides ability to track PTA given changes to work patterns, other employment and labour market changes, as well as changes in the socio-demographics, land-use patterns and built environment in the surrounding areas
- Automation of data capturing on an ongoing basis so as to create a longitudinal dataset that would be invaluable to monitoring public transport quality including seasonality and other temporal dynamics, in addition to spatial and network coverage, over time
- Data will be available in a paper
- Contact Dr Yeran Sun yeran.sun@glasgow.ac.uk for further details