Quantitative Methods - Written Report

Why Birmingham is the city with the best health accessibility among UK's top five metropolitan cities

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1 Introduction

Healthcare accessibility refers to an individual's "distance" from health services, which reveals the degree of health within a given area. However, some studies (Fraser and Edwards, 2010; Shortt *et al.*, 2016) have found that some unconventional access factors also affect this accessibility. For example, neighborhoods with more fast-food restaurants in the vicinity have higher rates of obesity among residents on average. Therefore, accurately defining health accessibility is considered problematic.

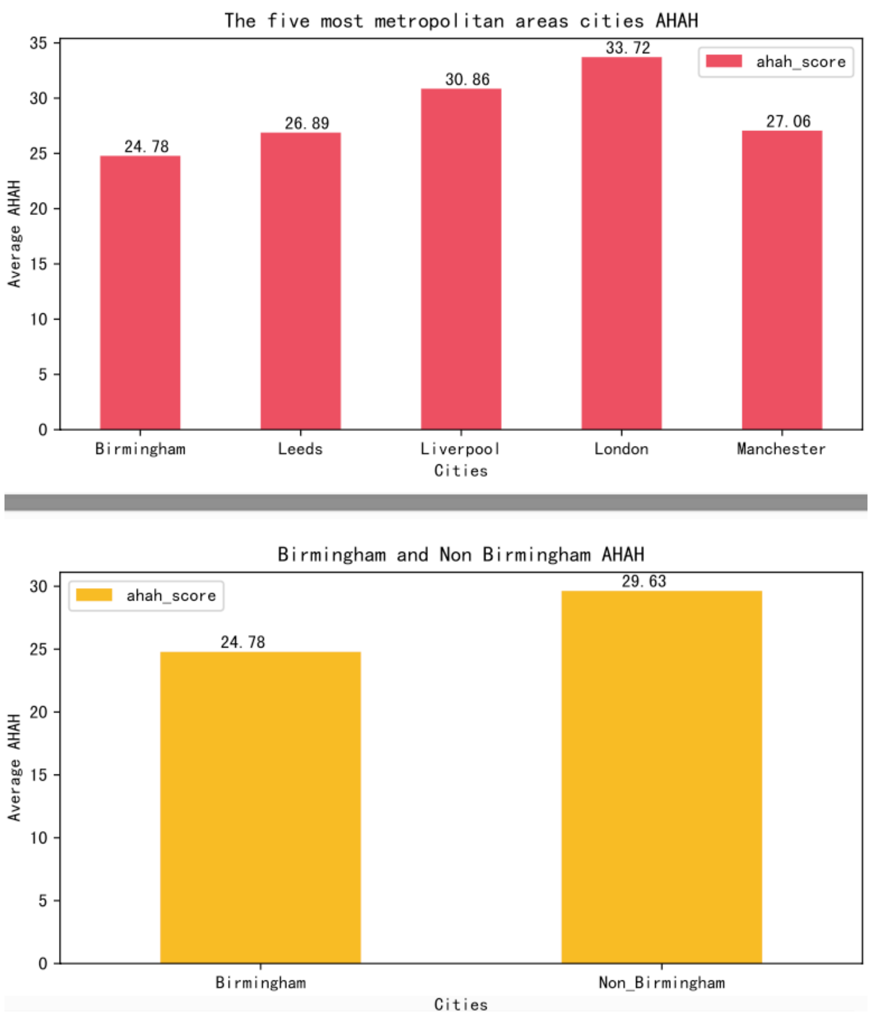
Previous scholars considered influencing factors from different aspects. For example, Richardson *et al.* (2010) provide an example of an environmental index. Launay *et al.* (2019) proposed an index of accessibility in health care calculated for factors including education and culture. With prior research, Green *et al.* (2018) offered a new composite index - AHAH(Access to Healthy Assets and Hazards) constructed from four individual dimensional scores: health services, retail environment, the physical environment, and air quality. The AHAH revealed significant urban-rural differences, with urban areas generally outperforming rural areas.

A metropolitan area comprises a significant city, its suburbs, and the nearby cities, towns, and surrounding, where the central city has significant economic and social influence over these areas. The UK's first five most significant metropolitan areas are London, Birmingham, Manchester, Leeds, and Liverpool, respectively (Elledge, 2015). However, among the five cities, Birmingham performs best on the AHAH index.

This study aims to investigate the reasons why Birmingham performs best among the five cities. Moreover, this study will discuss other correlated indexes to explore the reasons behind the performance.

Section one presents the research data. Section two demonstrates the employing methods, and section three presents the results and corresponding discussion. Section four for the conclusion.

Figure 1: The average AHAH distribution



2 Data

For research purposes, this study collected four datasets. This section discusses the sources of the collected datasets and their usefulness.

The AHAH dataset was acquired from the Consumer Data Research Center(CDRC), a division of the Big Data Network of the UK Economic and Social Research Council. This dataset contains 15 attributes for England, Wales, and Scotland. For this work, only data within five metropolitan cities are extracted based on the LSOAs. This work collected three other datasets which contain indicators proved correlated to health accessibility (AHAH)(Green *et al.*, 2018): Population density estimates (Census, 2021), index of multiple deprivations (National statistics), and General Health in England and Wales (Office for National Statistics, 2021).

Final dataset was merged by four datasets with LSOAs. The following variables are selected for analysis: population density, number of people with long-term illness, IMD rank, AHAH scores in four different domains, and composite AHAH score. The combined dataset contains 6410 data, 4813 for London, 641 for Birmingham, 292 for Manchester, 301 for Leeds, and 357 for Liverpool.

Figure 2: Mergered dataset format

lsoa	population	long_term_val	imd_rank	ah3h	ah3g	ah3e	ah3r	ahah_score	city
E01032126	2001	2078	22523.0	-0.482468	-0.099151	0.226781	-0.143153	13.163740	Birmingham
E01032133	1654	1647	14549.0	0.019270	0.349157	0.074200	-0.087675	18.394021	Birmingham
E01032135	1726	1648	32627.0	0.471966	0.273648	0.065601	-0.506255	19.286680	Birmingham
E01032142	2393	1531	28940.0	0.731854	-0.852340	-0.033632	-0.348561	16.016457	Birmingham
E01032145	1654	1451	30512.0	0.312479	0.259284	0.104122	-0.436432	18.307733	Birmingham
...	...	...	...	...	...	...	...	...	...
E01033604	1521	1236	6478.0	-2.667117	0.251919	2.265565	2.034311	50.443782	London
E01033605	2142	2046	4098.0	-1.948792	0.299573	2.265565	1.685901	47.551005	London
E01033606	1243	1068	19938.0	-1.113304	0.347528	1.786133	1.789196	46.094220	London
E01033607	1322	1199	12626.0	-1.221570	0.266445	1.786133	1.563255	42.981557	London
E01033608	1646	1416	18794.0	-0.536245	0.297618	2.061620	1.174910	42.828701	London

3 Methodology

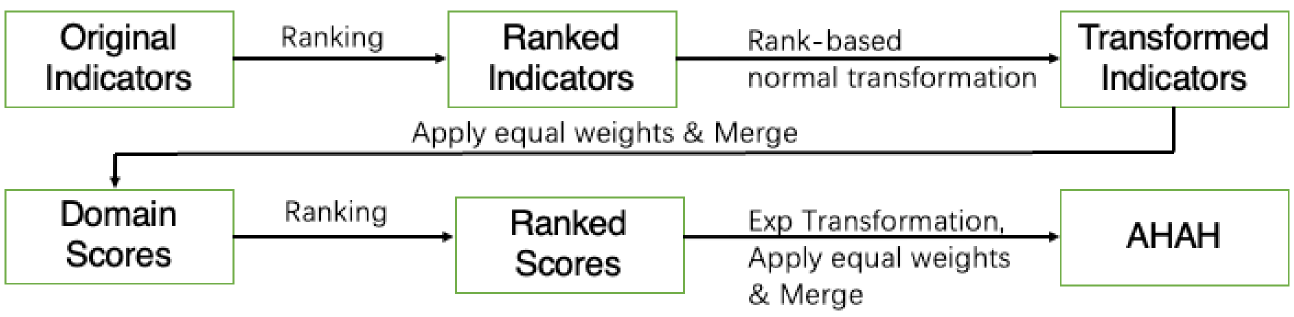
AHAH datasets contain a total of 14 indicators and their corresponding rank. The developer applied the Rankit transformation method to each ranked variable to reach a standard normal distribution.

The transformation calculation formula for score 'X':

$$X = -23In(1 - R(1 - exp^{\frac{-100}{23}})) \tag{1}$$

'23' is the scaling constant to minimize cancellation effects; 'ln' refers to the natural logarithm; 'R' refers to the rank value; 'exp' is the exponential transformation. Then, based on the domain classification, sum each domain's sub-indicators at an equal weight as the domain score and corresponding ranked scores. Among the four domains, The green space score was considered health-promoting, and retail and air quality scores were evaluated as health-negativing. Further, the overall index of "Access to Healthy Assets and Hazards" (AHAH) was created by transforming and combining four domain scores.

Figure 3: Summary of the Statistical Methods used to create the AHAH index



For the AHAH index, a more significant score means a neighborhood with a poorer health environment (and vice versa). This explanation is also applicable to the four specializations. In addition, ecological and individual-level health patterns are also considered relevant to health accessibility ins the previous study (Macintyre, Macdonald and Ellaway, 2008). These indices generally refer to overall IMD rank, limiting long-term illness, population density, poor health, and income sector rank. However, Green *et al.* (2018)'s findings indicate that AHAH is only associated with individual-level health patterns, not ecological measures.

Therefore, we propose two hypotheses from two perspectives:

Hypothesis One: Scores of retail and/or health and/or physical environment and/or air are lower in Birmingham

Hypothesis Two: The individual-level health factors have more health-promoting impact on Birmingham

3.1 Hypothesis One

Two one-tailed mean comparison tests can be used to test the first hypothesis. By using pooled variance two-sample t-test method, we identify the direction and the relationship between the statistical variables.

Figure 4: Descriptive summary of each domain

	Birmingham	Not Birmingham
Mean of AHAH (Health)	**-0.475**	**-0.7916**
Variance of AHAH (Health)	0.2597	0..3555
Std. Dev. of AHAH (Health)	0.5096	0.5962
Mean of AHAH (Physical Environment)	**0.0009**	**0.3139**
Variance of AHAH (Physical Environment)	0.3281	0.3216
Std. Dev. of AHAH (Physical Environment)	0.5728	0.5671
Mean of AHAH (Air Quality)	**0.9528**	**1.2359**
Variance of AHAH (Air Quality)	0.1839	0.2862
Std. Dev. of AHAH (Air Quality)	0.4289	0.535
Mean of AHAH (Retail)	**0.2939**	**0.7418**
Variance of AHAH (Retail)	0.248	0.3742
Std. Dev. of AHAH (Retail)	0.498	0.6117

3.1.1 Test of difference in means of health score

H_0: Health domain $score_{Birmingham}$ = Health domain $score_{noBirmingham}$

H_1: Health domain $score_{Birmingham}$ > Health domain $score_{noBirmingham}$, $\alpha = 0.05$

3.1.2 Test of difference in means of physical score

H_0: Physical domain $score_{Birmingham}$ = Physical domain $score_{noBirmingham}$

H_1: Physical domain $score_{Birmingham}$ > Physical domain $score_{noBirmingham}$, $\alpha = 0.05$

3.1.3 Test of difference in means of air score

H_0: Air domain $score_{Birmingham}$ = Air domain $score_{noBirmingham}$

H_1: Air domain $score_{Birmingham}$ > Air domain $score_{noBirmingham}$, $\alpha = 0.05$

3.1.4 Test of difference in means of retail score

H_0: Retail domain $score_{Birmingham}$ = Retail domain $score_{noBirmingham}$

H_1: Retail domain $score_{Birmingham}$ > Retail domain $score_{noBirmingham}$, $\alpha = 0.05$

3.2 Hypothessis Two

As Green *et al.* (2018) suggested, an individual domain like health and wellbeing are stronger predictors than the overall index. In this case, this work considers more than one individual factor but all domains. Furthermore, this approach can aggregate the inherent complexity of health accessibility(Gatrell, 2005).

Test of hypothesis two based on five regression models. All five models correspond to the same independent variables: population density, limiting long-term illness, and IMD rank. Indicators of poor health and income domain rank were dropped to minimize the potential multicollinearity since the two variables describe the duplicated objects. The dependent variables of the models are different(five individual scores). The β coefficients of the models will demonstrate the individual health difference in Birmingham compared to the non-Birmingham cities.

The regression formula :

$$AHAH_i(total/retail/health/physical/air) = \alpha + \beta_1 * Population_i + \beta_2 * Illness_i + \beta_3 * IMDRank_i + \varepsilon \quad (2)$$

4 Results

4.1 On Hypothesis One

4.1.1 H_1: Health domain $score_{Birmingham}$ > Health domain $score_{noBirmingham}$

Figure 5: Health domain t-test result

Mean diff	0.316569
t	14.7021
Std Error	0.0215323
df	857.246
p value (one-tail)	4.19968e-44
p value (two-tail)	8.39936e-44
Lower 95.0%	0.274307
Upper 95.0%	0.358832

This first test result shows a p-value < 0.05, which means we can reject the null hypothesis that the distance on average to the nearest health service is further in Birmingham.

4.1.2 H_1: Physical domain $score_{Birmingham}$ > Physical domain $score_{noBirmingham}$

Figure 6: Physical environment domain t-test result

Mean diff	-0.313046
t	-13.1844
Std Error	0.0237436
df	794.7
p value (one-tail)	2.42665e-36
p value (two-tail)	4.85329e-36
Lower 95.0%	-0.359654
Upper 95.0%	-0.266439

The second test result presents that we cannot accept our alternative hypothesis since the mean difference=-0.31. Instead, neighborhoods in Birmingham are more accessible to green space on average.

4.1.3 H_1: Air domain $score_{Birmingham}$ > Air domain $score_{noBirmingham}$

Figure 7: Air domain t-test result

Mean diff	-0.283052
t	-15.478
Std Error	0.0182874
df	888.039
p value (one-tail)	2.54049e-48
p value (two-tail)	5.08099e-48
Lower 95.0%	-0.318944
Upper 95.0%	-0.247161

Similar to the second test, the third test result shows Birmingham has better air quality on average.

4.1.4 H_1: Retail domain $score_{Birmingham}$ > Retail domain $score_{noBirmingham}$

Figure 8: Retail domain t-test result

Mean diff	-0.447882
t	-21.1416
Std Error	0.0211849
df	880.262
p value (one-tail)	7.47257e-81
p value (two-tail)	1.49451e-80
Lower 95.0%	-0.489461
Upper 95.0%	-0.406304

This test result indicates areas in Birmingham farther away from retail facilities. Pinto *et al.* (2017) suggest these outlets are highly correlated with health issues.

4.1.5 Overall result hypothesis one

Birmingham has more green space, better air quality, and less unhealthy retail presence at the average neighborhood level. However, Birmingham's health service accessibility is relatively worse than in non-Birmingham areas.

4.2 On Hypothesis Two

Figure 9: Regression Models Coefficients

	Outcome Variables		
	AHAH Score(OLS)	Health Score(OLS)	Physical Environment Score(OLS)
Population Density	0.0104	-0.0003	0.0004
Long Term Illness	-0.0098	-	-0.0003
IMD Rank	-0.0001	1.243e - 05	-9.177e - 06
Note: All models are OLS regression models. We report beta coefficients and 95% Confidence Limits for these estimates. And '-' means the beta coefficient is not significant			
	Retail Score(OLS)	Air Score(OLS)	
Population Density	0.0005	0.0002	
Long Term Illness	-0.0005	-	
IMD Rank	-	-1.641e - 0.5	

We detect some association through the disaggregation analysis of Birmingham's AHAH regression interpretation.

For the total AHAH score, Birmingham health accessibility obtains, on average, 1.04% less healthy than non-Birmingham residents for an additional unit of density. On the contrary, an additional unit of long-term illness and IMD rank yields an increase of 0.98% and 0.01% health degree for Birmingham.

For the health domain score, the results demonstrate that neighbors are healthier when Birmingham's population density increases. Meanwhile, the greater the deprivation index, the worse the health index in Birmingham.

For the physical environment health degree, which refers to blue and green space, the area of green space reduces when the population density increases. However, when the number of diseases or IMD increases, the number of green spaces increases in Birmingham.

For the retail domain score, the results show that when Birmingham has a larger population, there are more retail outlets. Moreover, when the number of long-term illnesses increases, retail score diminishes.

For the air score, when Birmingham's population increases, the air quality deteriorates. When the degree of deprivation increases, the air quality improves.

From the result of hypothesis one, the neighbors in Birmingham are generally healthier than non-Birmingham. More specifically, the physical, retail, and air domain. Therefore, we can infer that more cases of illness or deprivation occur in Birmingham, which is why Birmingham has healthier neighbors than non-Birmingham cities. Moreover, this interpretation also explains that minor health domain performance in Birmingham compared to non-Birmingham cities is due to more people being deprived.

4.3 Limitations to the model

While we demonstrate associations between health accessibility and individual health patterns, the internal relationship still can not be explained, which limits the explanatory power of this work. Future research will be required to understand the underlying drivers of these associations, contributing to the description of neighborhood health accessibility.

5 Conclusion

Our analysis demonstrates why Birmingham's neighborhood health accessibility is the highest of the top five metropolitan cities from two aspects. On the one hand, Birmingham has more green space, better air, and less retail presence at an average neighborhood size. However, on the other hand, we observed that Birmingham enlarges more accessibility when long-term illness or IMD rank increase than non-Birmingham cities, which implies more illness and deprivation in Birmingham. We confirm this assumption by disaggregating AHAH scores with three individual-level factors. Regardless, this fact can not prove that Birmingham's IMD and illness indicators must be greater than London's. Because of the metropolitan scale difference. Future research on the internal relationship between individual-level health patterns and health accessibility will contribute to this issue.

Word count: 1745

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