Exploring the Relationship Between Urban Spatial Characteristics and Subjective well-being (SWB) in London： A Multi-variable Analysis

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1. Research Aim

According to spatial dialectics (Soja 1980), there is an interactive relationship between urban space and human perception. The investigation aims to explore: What urban spatial characteristics can influence the subjective well-being (SWB) in London? Therefore, the hypothesis is that favorable urban spatial characteristics, such as green spaces and transportation accessibility, are significantly positively correlated with SWB. Conversely, negative features such as crime rates and obesity rates are significantly negatively correlated with SWB.

2. Literature Review

There are numerous studies that have demonstrated the relationship between urban spatial characteristics and SWB. One approach to conceptualizing the impact of the urban environment on SWB is to assume that overall life satisfaction is influenced by satisfaction in specific domains of life, such as family life or occupational life (Sirgy & Wu 2013). Researches by Leyden et al. (2011) as well as Ettema and Schekkerman (2016) indicate that the residential environment not only provides a platform for interpersonal interactions but also facilitates engagement in social activities, which are crucial for enhancing well-being. These interactions and activities contribute to the formation of social capital, which significantly impacts an individual's psychological well-being and happiness (Putnam 2000). Therefore, the urban environment may directly influence our daily functioning and our perception of it, allowing us to weigh the importance of environmental factors that affect SWB (Brereton et al. 2008).

Morris (2011) found that the influence of the residential environment on well-being is limited to factors such as railway transportation, population density, neighborhood safety, and the use of recreational facilities. Arifwidodo and Perera (2011) discovered that perceived neighborhood safety and accessibility to urban facilities both affect well-being. Cao (2015) utilized subjective features related to the community (e.g., the presence of parks and open spaces, safe play facilities, crime rates) as well as broader urban areas (e.g., distance to work or city center, distance to shopping centers) and found that both significantly impact life satisfaction through mediating structures of accessibility and disturbance. Pfeiffer and Cloutier's (2016) research indicated that open, natural, and green spaces are among the primary driving factors of well-being. Mouratidis (2021) proposed a conceptual model for SWB by synthesizing the literature in the field. The model suggests seven pathways through which the physical environment influences well-being, including travel, leisure, work, social relationships, residential well-being, emotional responses, and health. These pathways overall encompass the urban elements that impact subjective well-being.

Based on this framework, and in conjunction with the GLA's evaluation of the London Well-being Index subdivided into 12 measures (GLA 2011), we summarize 13 urban environmental variables (Table 1) that influence subjective well-being. These variables represent how the urban environment and individuals' SWB interact with each other through different pathways. The research of Ettema and Schekkerman (2016) suggests that multiple linear regression model is efficient to build the relation between spatial features and SWB, for it demonstrates flexibility and adaptability in dealing with empirical data, enabling the capture of more complex relationships between variables through the inclusion of interaction terms or polynomial terms (James et al. 2013).

Table 1: Pathways and variables of urban spatial characteristics influence SWB

Pathways	Sub-indicator
Travel	PTA (Public Transport Accessibility) scores
	Travel by bicycle
Leisure	Homes with good access to nature (%)
Work	Unemployment rate
Social Relationships	Population density
Residential Well-being	Crime rate
	Deliberate fires
	Unauthorised public absence
	GCSE point scores
	dependent children in out-of-work households (%)
Health	Life expectancy
	Childhood Obesity
	Incapacity benefits claimant rate

Although the theoretical framework comprehensively considers the urban factors influencing SWB, the qualitative framework fail to demonstrate the influence level. Therefore, the quantitative methods need to be employed for further considering the relationship and test existing theory. In this investigation, by modeling and analyzing urban data from London, findings that challenge existing theories have been uncovered: There is no statistically significant relationship between SWB and indicators such as green space, transport accessibility, crime rates, and education which are considered as significant factors by other researches.

3. Data

The data used in this investigation were collected and published by GLA (Greater London Authority) and made available on the LONDON DATASTORE (GLA 2013). The data are at the ward level, and the time span covers the years 2009 to 2013 (with several indicators only available for 2011 and 2012).Due to surveys size, the availability of data at smaller geographic areas is limited. This means that the indicators used to calculate SWB may not be perfect measures, although they are the best available at present.

Based on the modeling results, 4 independent variables with significant statistical influence (p-value < 0.05) and the denpendent variables will be presented.

Table 2: Statistical summary of variables which have significant influence

	Life Expectency	Unemployment Rate	Population Density	Travel by Bicycle	Subjective Well-being
count	625.000000	625.000000	625.000000	625.000000	625.000000
mean	82.005600	5.982528	80.347469	3.910400	7.641664
std	2.263928	3.154023	47.274419	3.377599	0.277357
min	76.000000	0.460000	1.769933	0.200000	6.880000
25%	80.400000	3.360000	45.442021	1.300000	7.440000
50%	81.900000	5.480000	68.584299	2.800000	7.640000
75%	83.400000	8.060000	108.045662	5.800000	7.860000
max	90.300000	19.660000	264.977478	19.100000	8.460000

Figure 1: Box plots of variables which have significant influence

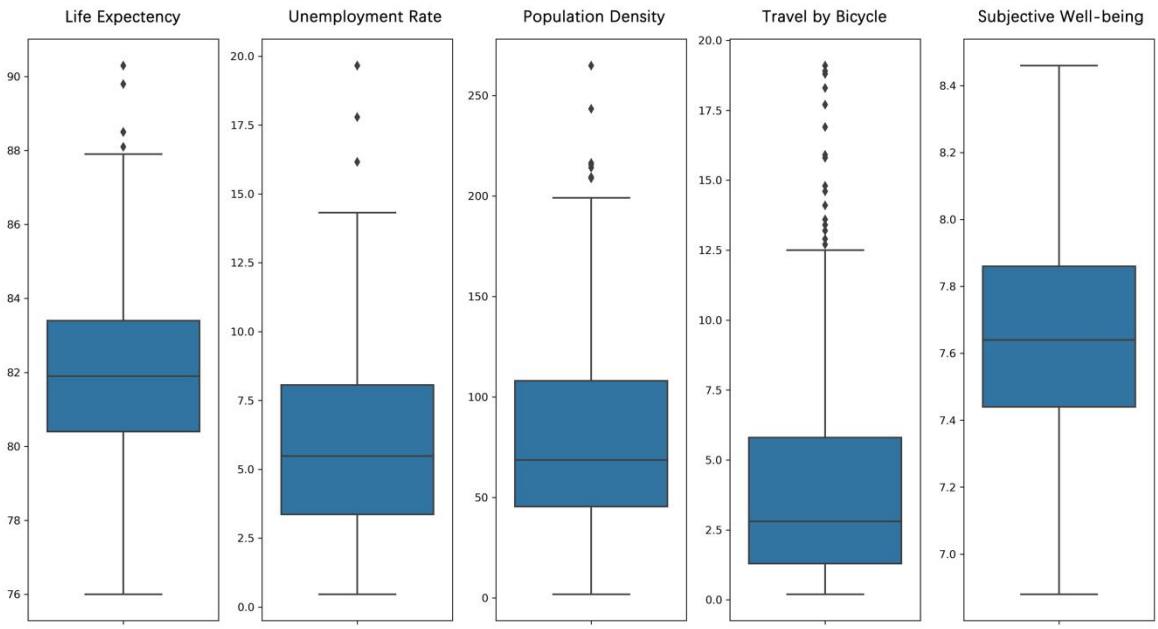
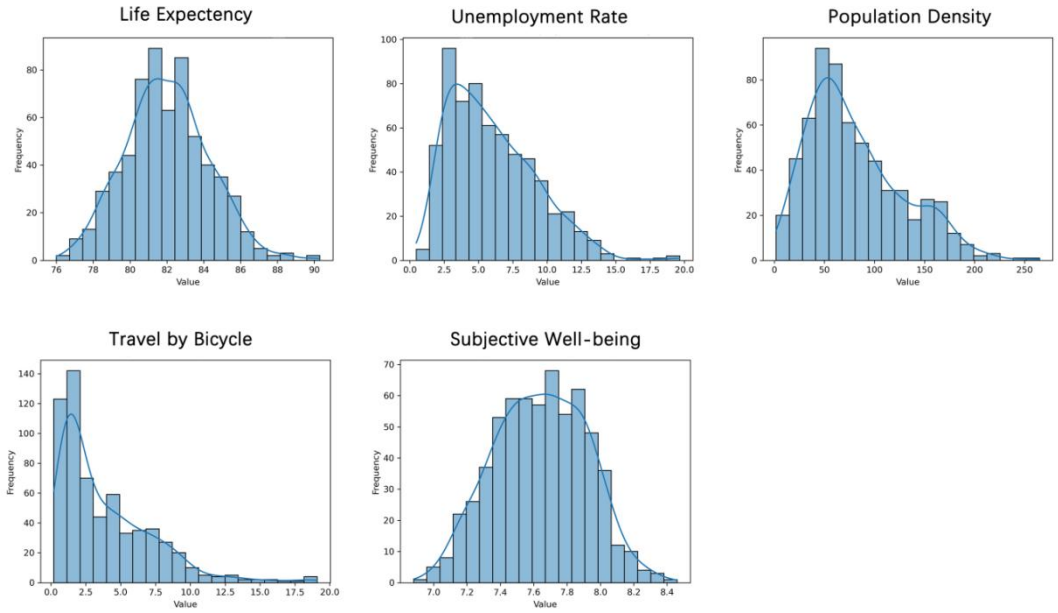


Figure 2: Histograms of variables which have significant influence



The dataset indicates variability across different metrics, with some like life expectancy and subjective well-being showing a tendency towards normal distributions, while others like unemployment rate, population density, and travel by bicycle are right-skewed with several outliers indicating extreme values. The data points for these skewed distributions are mostly clustered at the lower end, with a tail stretching towards the higher end, showing that most areas have low rates with a few exceptions having very high rates. The presence of outliers in the box plots for these variables further emphasizes the existence of extreme values that significantly differ from the rest of the data.

Figure 3: Scatter plots of variables which have significant influence

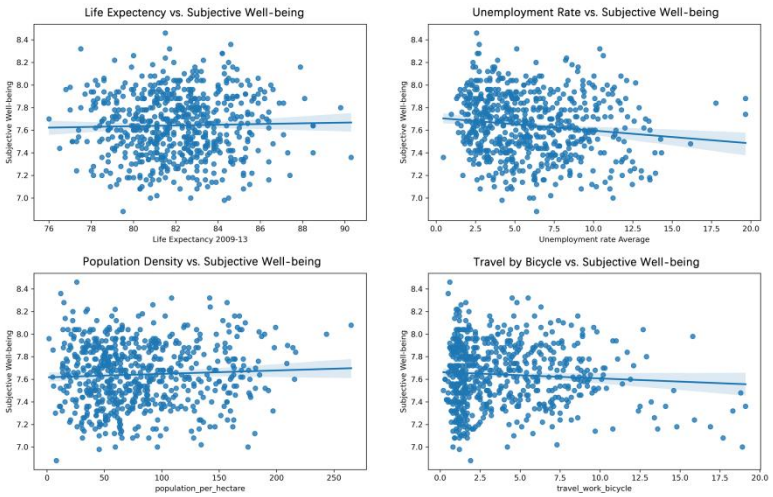
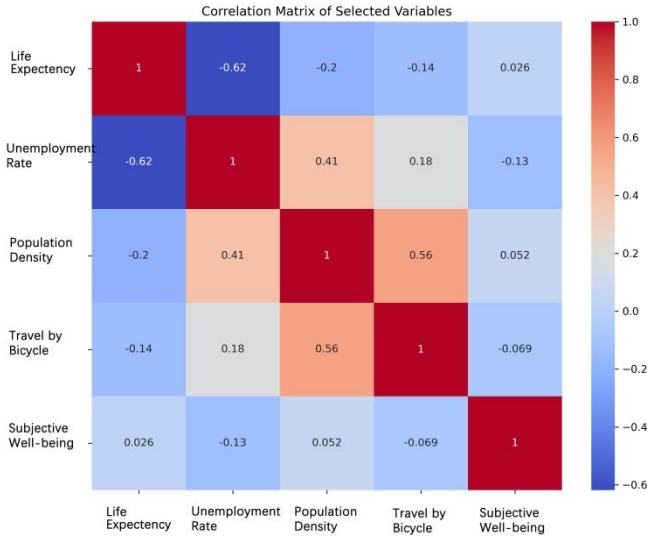


Figure 4:Correlation matrix of variables which have significant influence



In the scatter plots and correlation matrix, 2 intriguing features were summarised : 1) The dataset reveals a significant inverse relationship between life expectancy and unemployment, which might be of interest to policymakers; 2) subjective well-being does not show strong linear correlations with any of the variables considered, indicating its complex nature and the possibility that it is influenced by a combination of factors not captured by this dataset.

4. Methodology

The selection of a multiple linear regression model in this study offers distinct advantages. It allows for the simultaneous consideration of multiple independent variables on the dependent variable, and facilitating the quantification of each independent variable's individual contribution which enhances interpretability and applicability for policy decisions (Montgomery et al. 2012).

VIF method is employed to identify and remove one highly collinear independent variable (% dependent children in out-of-work households Average, VIF=9.7) to ensure model accuracy, so 12 independent variables are involved finally. Subsequently, we standardized the data to eliminate scaling issues and mitigate potential multicollinearity among variables. Finally, we fitted a linear regression

model using stat model. Based on the fitting results, we identified the independent variables that demonstrated statistical significance (p-value < 0.05). 4 assumptions are tested after fitting the model and the results indicate that the model basically met all assumptions which perform good dependability.

5. **Results**

5.1 The regression model

The model reveals only 4 urban environmental factors exhibit a statistically significant relationship (p-value < 0.05) with SWB, include unemployment rate, life expectancy, population density, and bicycle travel rate. However, the model's explanatory power is relatively low (R-squared = 0.065), indicating that additional significant factors are not considered in this model. It is worth noting in the case of London, most variables, including commonly supported factors like crime, transportation, and accessibility to green spaces, did not demonstrate reliable statistical associations with subjective well-being. This finding challenges existing theories, suggesting the need for further exploration of potential underlying connections. Moreover, the negative relationships observed between life expectancy and well-being, as well as between bicycle travel and well-being, are intriguing and warrant further investigation to comprehend the underlying dynamics.

Above all, two primary issues need to be discussed: 1) the possible reasons for the disparities between the modeling results and existing theories, and 2) the potential causal links between the dependent and independent variables, elucidating how they influence well-being.

Table 3: Result of multi-linear regression model

Pathways	Sub-indicator/Variable	Coef	P-value
	Constant	1.45E-15	1.000
Travel	PTA scores	-0.0171	0.776
	Travel by bicycle	-0.1406	0.007
Leisure	Homes with good access to nature (%)	0.0403	0.335
Work	Unemployment rate	-0.259	0.001
Social Relationships	Population density	0.2662	0
Residential Well-being	Crime rate	-0.0397	0.437
	Deliberate fires	0.0624	0.228
	Unauthorised public absence	0.0706	0.282
	GCSE point scores	0.1231	0.072
Health	Life expectancy	-0.1170	0.033
	Childhood Obesity	0.0215	0.724
	Incapacity benefits claimant rate	-0.0047	0.945

5.1 Assumption Tests

Four hypothesis tests were conducted. Specifically, the test for multicollinearity was performed during the data cleaning stage, and the variable (% dependent children in out-of-work households Average, VIF=9.7) was removed due to high collinearity.

Figure 5: Quantile-Quantile plot of residuals

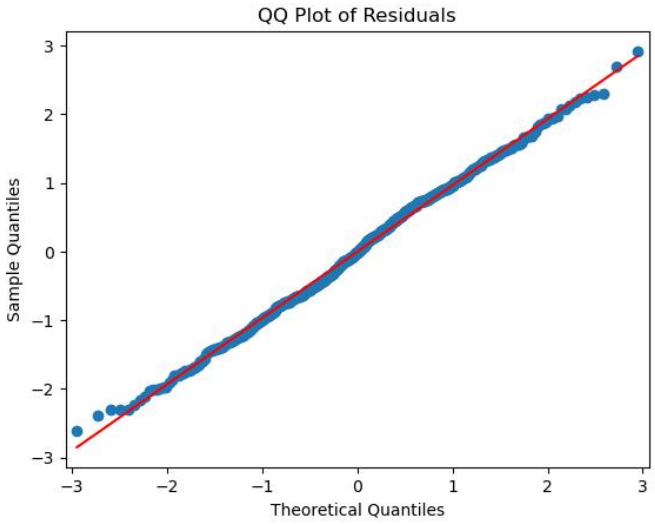
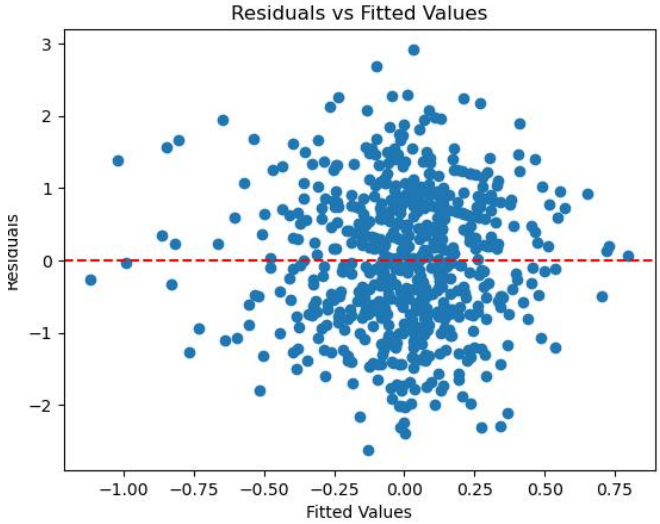


Figure 6: Scatter plot of residuals against fitted values



1) Linear relationship: The linear relationship can be visually checked (Figure 3) between the independent variables and the dependent variable, although the distribution of data points appears to be scattered.

2) Normally distributed error: The Quantile-Quantile plot (Figure 4) demonstrates the distribution of model residuals. It can be observed that the residuals generally follow the pattern of a normal distribution.

3) Homoscedasticity: Based on the scatter plot of residuals against fitted values, there does not appear to be any clear non-random patterns in the residuals, suggesting that the assumption of homoscedasticity is generally met.

4) Independence: The value of the Durbin-Watson statistic is 1.583, which is close to 2 indicating a low degree of autocorrelation. Therefore, the assumption holds.

6. **Discussion**

6.1 The theory gap

The model indicates only 4 variables have significant relationship with SWB, leading to disparities with existing theoretical frameworks. This could be attributed to several factors. 1) the cultural dependency could be a potential reason. Diener and Suh (2000) noted in their research that cultural factors such as values, social norms, and expectations influence individuals' perception of happiness, indicating that the criteria for evaluating well-being may vary significantly across different cultural regions. 2) some variables may have indirect rather than direct effects on SWB, necessitating more complex models for analysis, such as SEM or Multilevel model. 3) the scale of measurement in this study was at the ward level, and the data scale and sample size may not have been sufficient to reveal their underlying relationships.

6.2 Interpretation of significant variables

Unemployment rate, life expectancy, and bicycle travel rate are negatively associated with SWB. The negative correlation of the unemployment rate (coef.: -0.2539) supports the theory that stable employment enhances happiness. However, the negative relationships between life expectancy and bicycle travel rate challenge conventional expectations.

Regarding negative relation of life expectancy (coef.: -0.117), one explanation is a longer life expectancy may indicate a higher proportion of elderly individuals, leading to increased chronic disease burden and healthcare needs, which can negatively impact subjective well-being (Stacherl & Sauzet 2023). Moreover, higher life expectancy may be linked to social isolation, insufficient community support systems, or the loss of younger populations, all of which can decrease SWB (Xu et al. 2022).

For the bicycle travel rate (coef.: -0.1406), inadequate bicycle infrastructure, which makes cycling inconvenient or unsafe, can result in a negative travel experience and lower subjective well-being (Singleton 2019). Additionally, if the increased bicycle travel is driven by economic pressures or limited availability of other transportation options, rather than being a choice motivated by health or environmental concerns, it may reflect unfavorable factors in overall quality of life.

The positive coefficient (0.2662) of population density aligns with conventional expectations. Areas with higher population density typically offer more employment opportunities, social activities, and better infrastructure, contributing to the formation of social support networks and subsequently enhancing subjective well-being.

7. Conclusions

In summary, we found significant relationships between 4 urban spatial characteristics and SWB: unemployment rate, life expectancy, bicycle travel rate, and population density. Firstly, the results suggest that the current researches on SWB assessment framework may be insufficient to support the case study of London, indicating that there may be additional relevant variables that need to be considered. This investigation is limited by accessible data of London, it requires more types of official data to improve the model in the future. Lastly, the negative correlations of life expectancy and bicycle travel rate contradict conventional theoretical expectations, suggesting the need to consider the unique urban context when studying SWB in London. Future research can explore the potential social or economic factors at play that contribute to this negative correlation.

8. Data and Code Availability

Datasets used in this paper are publicly available and sources are provided in the Github repository:
https://github.com/songzimen/London_subjective-well-being_model.git

Total Word Count: 1743

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