Capturing high street dynamics on a finer scale: a case study in the context of COVID-19

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GISRUK 2024

Summary

This study delves into the evolution of high streets' vitality during different periods – pre, during, and post the COVID-19 pandemic – by analysing hourly footfall patterns on high streets. While prior research primarily focused on weekly or monthly footfall changes, this investigation employs time series clustering to categorise high streets based on granular temporal patterns. Through extensive analysis, the study reveals the diverse functionalities of high streets and illustrates the immediate and enduring impacts of lockdown measures on high street dynamics and human behaviours. The study highlights the importance of finer-scale dynamics and contributes insights crucial for future development planning.

KEYWORDS: High street, dynamics, footfall, finer scale, COVID-19.

1 Introduction

High streets are important urban areas that serve as centres for commerce, social interaction, and cultural activities. Taking London as an example, high streets are home to 41% of businesses and 28% of all jobs in the capital (pre-pandemic). London's high streets are also inclusive, participative, accessible places in the city, with 90% of all Londoners living within 10 minutes of their local high street (GLA, 2023). Before the COVID-19 pandemic, high streets around the world already struggled to attract sufficient visitors to remain economically sustainable and the pandemic exacerbated the downturn (Enoch et al., 2022). Although COVID-19 is no longer a public health emergency of international concern (WHO, 2023), its long-term effects linger and continue to shape urban landscapes. One important aspect in future recovery and development plan is to establish long-term and comprehensive assessment of high streets performance.

Footfall is considered as the "lifeblood" of a retail centre vitality and viability (Birkin et al., 2017)

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and has been used as a proxy measure for high street performance. Within the COVID-19 context, Enoch et al. (2022) used footfall data to analyse the impact of COVID-19 pandemic on six high streets in England. Ballantyne et al. (2022) used a mobile phone app location dataset to examine the recent recovery of retail centres from the pandemic. In a most recent study, Wang et al. (2023) examined the long-term performance change of London's high streets. Through clustering analysis, they revealed the spatial distribution of clusters and the underlying causes of varying recovery pattern. Existing literature primarily measures the impact of the pandemic through changes in weekly footfall values, which is an intuitive way of revealing long-term trends. However, the vitality of urban spaces also changes on a daily or even hourly basis, necessitating the exploration of their dynamic evolution on a finer temporal scale. In this study, we conduct a detailed examination of hourly footfall pattern during different periods, i.e., before, during and post pandemic. Specifically, we perform time series clustering to categorise high streets into groups with unique patterns. By presenting and analysing the changes of patterns throughout the specified periods and the geographical distribution of different clusters, we uncover the varying dynamics of high streets and illustrate both the immediate and lasting impact of lockdown measures.

In the following sections, we describe the dataset used in this study, followed by a brief introduction to the methods employed. We present the results and discuss their implications in Section 4. Finally, we conclude the paper by summarising the main findings and contributions.

2 Data

Mobile phone app location data: It is a large-scale mobility dataset containing millions of anonymous users' mobile phone GPS trajectory data (collected from tens of location-based service apps) provided by Location Sciences under GDPR compliance. Our study focuses on February in three consecutive years (2020-2022) to analyse high street performance before, during, and after the pandemic. This selection facilitates year-on-year analysis, ensures representation of distinct pandemic stages and minimises holiday-related influences. The dataset features a high sampling rate and a consistent collection method across the country, making it suitable and representative for our study.

High street boundary dataset: Provided by the Greater London Authority[1], this is a shapefile containing the boundaries of 616 London high streets located outside the Central Activity Zone.

3 Method

3.1 Footfall calculation

Stay detection: We identify stays where individuals remain stationary for more than a specified duration (in this study, we set the threshold at 5 minutes). Hourly footfall calculation: Stays are joined to high street boundaries, and footfall is calculated on an hourly basis. The one-month hourly footfall is then averaged and aggregated into 24 hours (of a day).

[1] https://data.london.gov.uk/dataset/gla-high-street-boundaries

3.2 K-means time series clustering

We utilise a K-means time-series clustering algorithm to group hourly footfall time series. Dynamic time warping is employed to calculate the distance metric, chosen for its robustness to temporal shifts or distortions. The optimal cluster number K is determined using the Elbow method and the Silhouette score.

4 Results and analysis

4.1 The hourly footfall clustering results

The clustering process yielded four groups during the pre-pandemic stage, three groups during the lockdown period, and five groups for the post-pandemic stage, as depicted in the heatmap shown in Figure 1. The color intensity within each cell signifies the relative footfall level during the respective hour of the day, with darker colors indicating higher footfall. "Pen portrait" labels have been assigned to each cluster based on the timing of peak footfall.

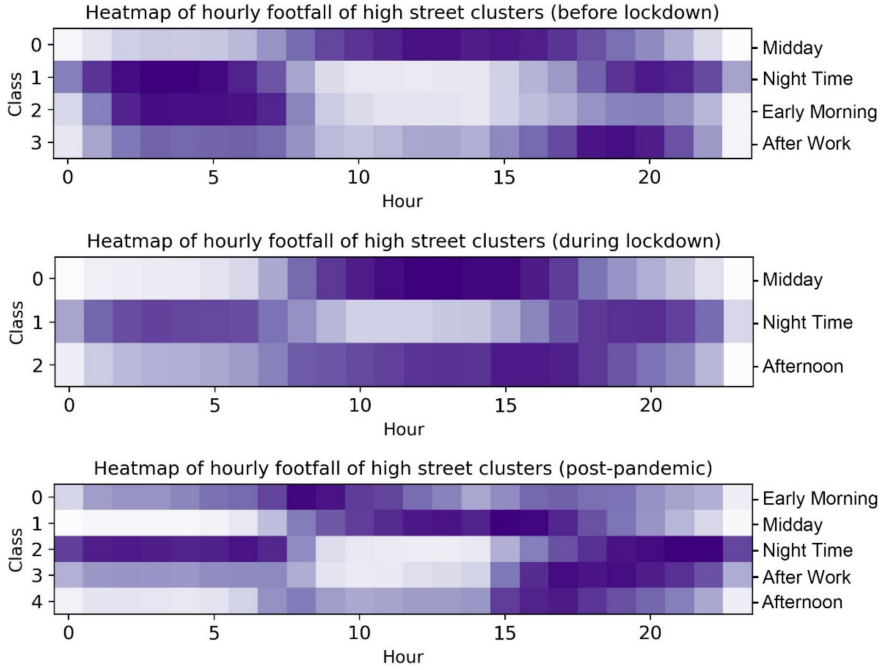

Figure 1: Heatmap of the hourly footfall of high street clusters

4.2 Proportional changes and pattern transforms

The Sankey diagram of high street clusters is shown in Figure 2, revealing several noteworthy observations. Firstly, the *Midday* cluster, characterised by a footfall peak around noon, is the dominant hourly pattern across London's high streets throughout the three specified periods. Moreover, two particular types, namely *After Work* and *Early Morning*, vanished during the lockdown and

re-emerged in the post-pandemic phase. This reflects the change of people's behaviour due to lockdown restrictions like work form home mandates. During the lockdown, with diminished office attendance, activities like early morning commutes and after work socialising no longer exists. Additionally, the *Afternoon* cluster emerged during lockdown and persisted even after most of the restrictions were lifted, indicating a lasting impact of the COVID-19 pandemic on the dynamics of high streets.

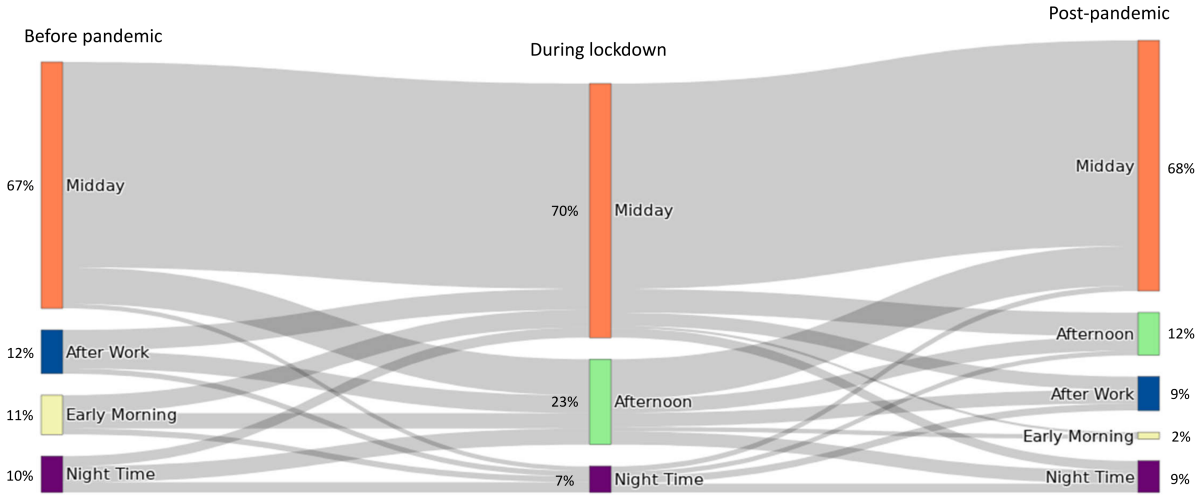

Figure 2: The Sankey diagram for high street clusters over three periods.

4.3 Spatial distribution

The spatial distributions of various high street groups and their changes throughout three phases are illustrated in Figure 3. Notably, the map highlights the distinct emergence and retention of the *Afternoon* type as well as a significant reduction in the *Early Morning* type. Furthermore, it is noteworthy that the majority of connected high streets, indicated by prominent and continuous lines extending from Central London along specified routes to the London boundary, as well as high streets with relatively large areas, fall into the *Midday* category.

5 Conclusions

This study investigated high street dynamics through a more detailed examination of footfall changes on a finer scale. A time series clustering revealed distinct hourly patterns among different high streets. By comparing the clustering results in different phases, we uncovered the immediate and enduring effects of lockdown measures on high street dynamics as well as human behaviours. Our work provides a different perspective for analysing high street performance, and the proposed method is applicable to other urban areas. The findings presented in this paper could assist policymakers to make more informed decisions for regenerating and revitalising high streets.

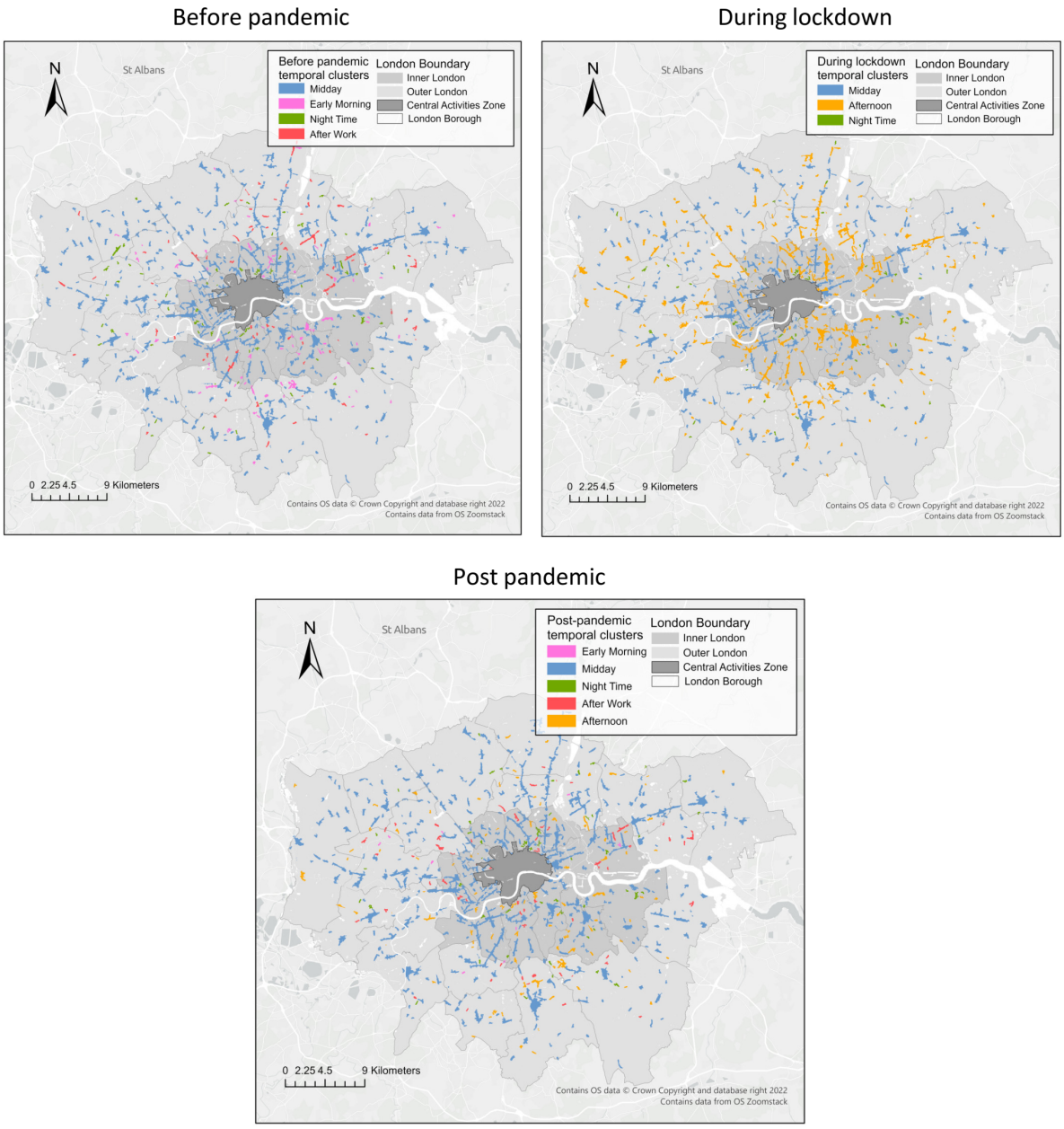

Figure 3: Spatial variation of high street hourly profiles during three periods.

6 Acknowledgements

The first author's PhD research is jointly funded by China Scholarship Council and the Dean's Prize from the University College London.

7 Biography

Xinglei Wang is a PhD student at SpaceTimeLab, Civil, Environmental and Geomatic Engineering, University College London. His research interests include spatial-temporal data mining, deep learning, and GeoAI, with a focus on applications in human mobility and behaviour.

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References

Ballantyne, P., Singleton, A., & Dolega, L. (2022). Using unstable data from mobile phone applications to examine recent trajectories of retail centre recovery. *Urban informatics*, *1*(1), 21.

Birkin, M., Clarke, G., & Clarke, M. (2017). *Retail location planning in an era of multi-channel growth*. Routledge.

Enoch, M., Monsuur, F., Palaiologou, G., Quddus, M. A., Ellis-Chadwick, F., Morton, C., & Rayner, R. (2022). When covid-19 came to town: Measuring the impact of the coronavirus pandemic on footfall on six high streets in england. *Environment and Planning B: Urban Analytics and City Science*, *49*(3), 1091–1111.

GLA (2023). High streets for all — london city hall. `https://www.london.gov.uk/who-we-are/what-mayor-does/priorities-london/londons-recovery-coronavirus-crisis/london-partnership-board/recovery-context/high-streets-all`. Accessed: 2024-01-22.

Wang, X., Zhang, X., & Cheng, T. (2023). The ups and downs of london high streets throughout covid-19 pandemic: Insights from footfall-based clustering analysis (short paper). In *Proceedings of the 12th International Conference on Geographic Information Science (GIScience 2023)*, volume 277 (pp.80).: LIPIcs: Schloss Dagstuhl-Leibniz-Zentrum fur Informatik.

WHO (2023). Who chief declares end to covid-19 as a global health emergency. `https://news.un.org/en/story/2023/05/1136367`. Accessed: 2024-01-22.