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A data-driven approach to analysing the impact of COVID-19 on pedestrian traffic in Sydney

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Abstract

The COVID-19 pandemic has had a substantial impact on how people travel in cities. This study investigates the spatio-temporal patterns in walking in Sydney, Australia over a 10-year period from 2013 to 2021. Results suggest that mobility restrictions as a result of COVID-19 reduced average daily walking traffic by 40% on weekdays and by 50% on weekends. Results from a clustering analysis reveal the heterogeneity in the COVID-19 impacts over time and space across Sydney.

1. Introduction

The global spread of COVID-19 in early 2020 has forced governments to take measures to protect citizens and lessen the burden on healthcare systems. Different countries implemented various public health measures to slow down the spread of the virus. "Stay home" and "social distancing" by 1.5 meters have commonly been used as non-clinical strategies to tackle the pandemic in Australia since the outbreak of the disease. Active mobility patterns in cities with higher population densities have been significantly affected by COVID-19 (Pareek et al., 2020). People's travel behaviour has noticeably changed over the past few years. Extended and heavily enforced lockdowns forced a large fraction of the population to study and work from home when possible. The restrictions on mobility due to COVID-19 have put the significant role of walkability and walkable neighbourhoods in the spotlight (Kang et al., 2020). Studies revealed that physical activity has declined dramatically due to stay home policies, although it did not meet the recommended levels even before the pandemic (Tison et al., 2020, Guthold et al., 2018). Understanding the change in walking patterns in pre- and post-COVID-19 periods assists transport planners and engineers in making more informed decisions and policies.

There have been numerous studies on the impact of the COVID-19 epidemic on overall population mobility at different scales and with different modes (Borkowski et al., 2021, Gkiotsalitis and Cats, 2021). However, very few studies have explored the change in walking patterns. This paper aims to provide insights into the change in the spatial and temporal patterns of walking affected by COVID-19 in Sydney, Australia using empirical walking counts over a 10-year period from 2013 to 2021.

Walkability has been a subject of research for many years from different perspectives including sustainable development, public health, and urban planning. Despite having a few different definitions, walkability can be broadly described as the degree to which an environment, especially the built environment, is pedestrian-friendly and makes walking easy

(Hall and Ram, 2019). Research on walking patterns has made some very interesting progress lately, including the identification of functional urban zones and the detection of urban anomalies in human activity (Stier et al., 2020, Wu et al., 2020). Many experimental investigations using statistical analysis have been carried out to understand walking behaviour and estimate pedestrian safety under various walking conditions (Fujita et al., 2019). However, understanding walking behaviour requires more than descriptive analysis. A more quantitative methodology such as clustering has been used by Humagain and Singleton (Humagain et al., 2021) to examine the connections between walking patterns and spatial urban characteristics. Li and Xu (Li and Xu, 2021) applied clustering to pedestrian hourly count time series to reveal the changing patterns in walking before, during and after COVID-19 restrictions in Beijing, China.

There is very little documented and published empirical evidence on the impact of COVID-19 on pedestrian activities in Australia. Restricting unessential human mobility can lead to effective control of COVID-19 spread (Bassiri Abyaneh et al., 2021). In their study, (Beck and Hensher, 2020b, Beck and Hensher, 2020a) found that the use of active mobility decreased during the initial stages of Australian restrictions, with survey respondents indicating their intention to further reduce their usage in the future. Following the easing of restrictions, the researchers re-surveyed the participants about their use of active transport modes and found that they had indeed reduced their usage as confirmed by the respondents. A study by Wei et al. (Wei et al., 2021) reveals that the impact of the lockdown was more effective than the population movement in controlling COVID-19. A notable reduction of urban mobility is reported in both public and private transportation (Falchetta and Noussan, 2020) where mostly vehicle transportation is considered. While in this study pedestrian mobility is mainly focused.

To study the impact of COVID-19 on walking patterns in Sydney, we use empirical hourly pedestrian counts collected across more than 100 locations in Sydney's central area. Results reveal that the average daily counts on weekdays and weekends increased from 2013 to 2017, and COVID-19 resulted in an overall reduction both in working and non-working days. The peak hour the walking count sites experience has changed during the pre- and post-COVID periods. Concerning days of the week, During the post-COVID period, the average walking counts on weekdays were significantly lower than the average counts on weekends.

The remainder of the paper is organized as follows. Next section, the material and methodology section introduce the data we used, the initial analysis and methodology utilized to get information from the data is established, then the rest of this section extends the analysis using k-means clustering to understand how COVID-19 affected the walking pattern. The result section provides the findings and effectiveness of the method. The last section concludes and discusses the research.

2. Materials and methodology

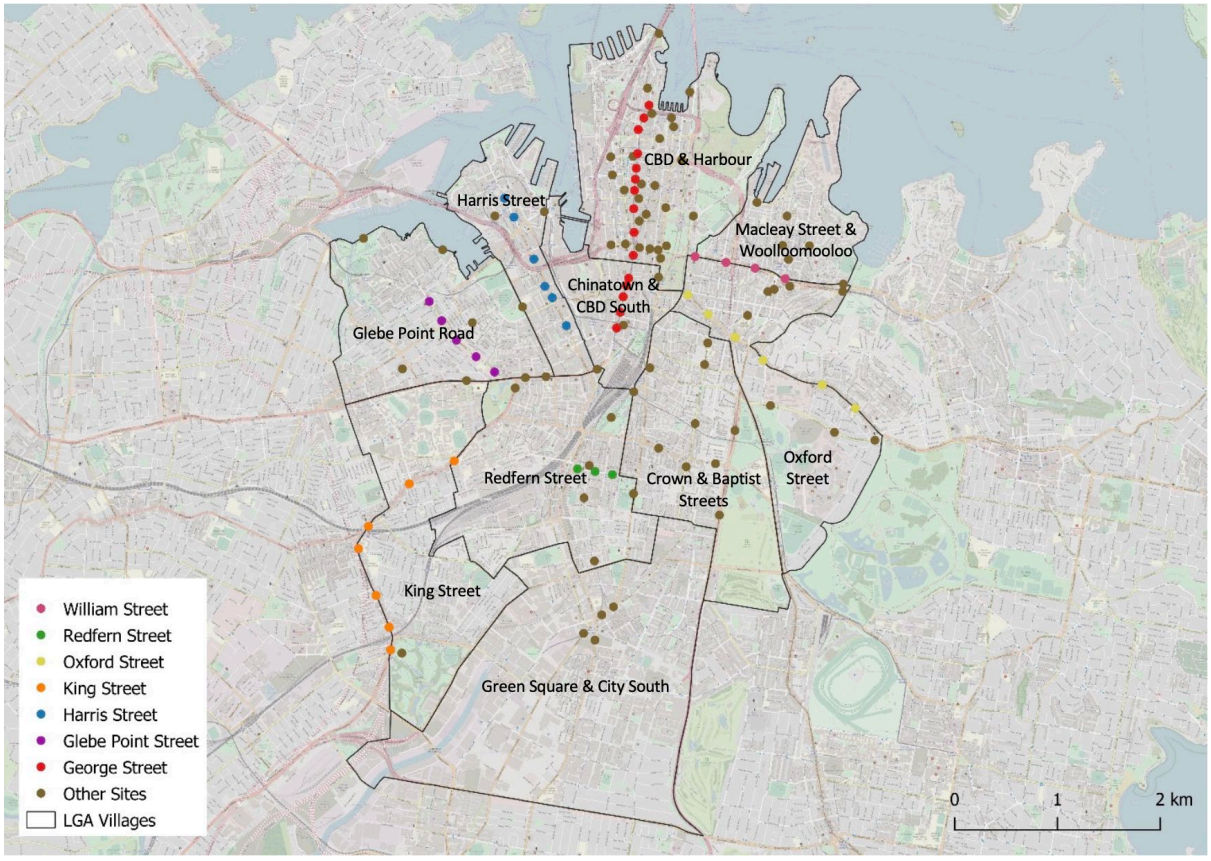
2.1. Data

This research uses the available hourly counted walking data from the City of Sydney [1] Local Government Areas (LGAs) from 2013 to 2021 except for 2018. The dataset contains the number of pedestrians across a total of 115 sites, 7 corridors, and 10 villages. The data covers

[1] https://www.cityofsydney.nsw.gov.au/

the period October 2013 to March 2021 in autumn and spring from 6 am to 11 pm. To distinguish and better understand the impact of each criterion on the walking patterns, the data is divided into several parts based on spatial and temporal criteria. The temporal criteria differentiate between the day of the week whether it is weekdays or weekends, time of day including morning, afternoon, and night, Pre- and Post-Covid years, and for the spatial criterion sites, corridors and villages are used in different analyses. Figure 1 depict the outline of corridors, walking count sites, and villages.

Figure 1: Spatial distribution of the corridors, walking count sites, and villages in the City of Sydney



2.2. Walking pattern analysis in the City of Sydney

The first confirmed COVID-19 case in New South Wales (NSW) was identified on 19 January 2020 in Sydney. Following the outbreak of COVID-19, the first lockdown for NSW began on 31 March 2020. To detect the change in the walking pattern, we compared walking count data from 2013 to 2021, implementing a descriptive analysis by time of day, day of the week, sites, corridors, and villages. We use mean daily pedestrian count across years considering both weekdays and weekends, plus the percentage change in average daily count in each site to understand the difference between weekdays and weekends changes over the years. Changes in the peak period of walking patterns on weekdays and weekends across villages and corridors are observed using heatmaps as well as time series clustering. The mapping of pedestrian patterns is also supported by an analysis of the proportion of changes at each site.

2.3. Time series clustering

Peak hours have direct or indirect effects on the spread of Covid-19. Requests to work from home lead to the reduction of the need to travel to work and prevent contact in the workplace or transportation, especially during peak times (OECD). In this study, by clustering all walking count series at each site according to hourly pedestrian count, we can group sites after determining the clusters and further derive the corresponding patterns and characteristics of walking counts. Instead of focusing on the shape of specific outflows, we calculated the normalized flow to describe the structure of the outflow. The min-max scalar scales all the data series between 0 and 1 (Tian and Chen, 2021). In addition to this normalization, a fast Fourier transform (Cochran et al., 1967) is applied to smooth all the time series. This process helps to retrieve the structure of the series according to peak hour rather than capturing all the fluctuation in the time series.

We split the series based on pre- and post-covid, and weekday or weekend into four categories. Then k-means clustering (Bishop and Nasrabadi, 2006) was applied to classify the time series of each category with 5, 6, 4, and 4 clusters for pre-covid weekday, pre-covid weekend, post-covid weekday, and post-covid weekend respectively. The number of clusters K is a hyperparameter that needs to be determined empirically, and a reasonable K value can cluster the data set into distinct subsets accurately, therefore the clustering algorithm we utilized is this semi-supervised machine learning method (Petitjean et al., 2011). We chose the number of clusters using a plot of average silhouette width against the number of clusters, for between 2 and 10 clusters. The silhouette width decreased significantly at the number chosen for each cluster.

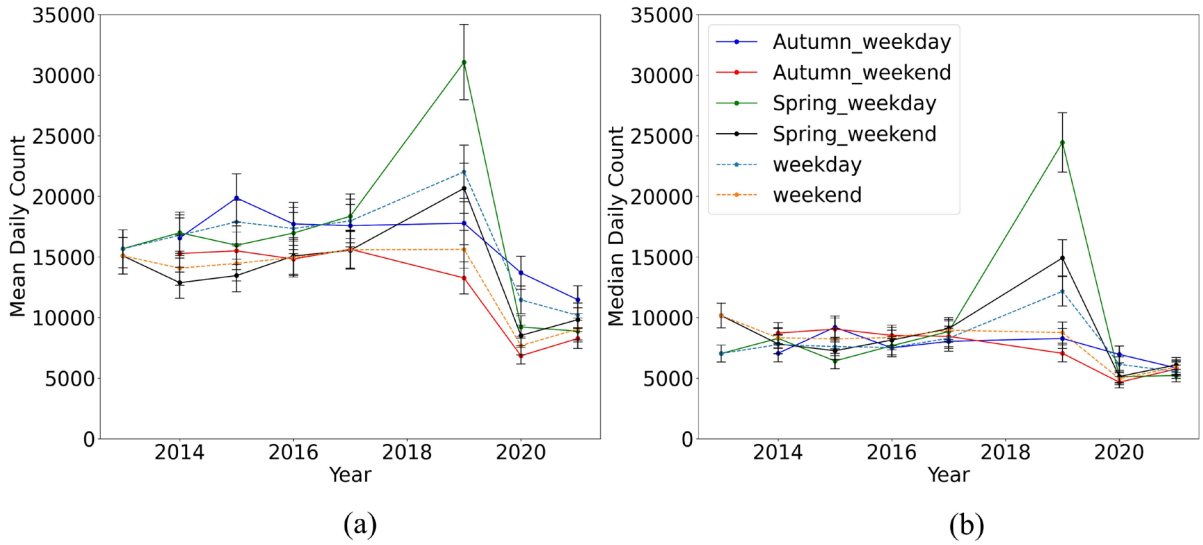
3. Results

Although COVID-19 response measures differed between metropolitan areas, in most Australian cities, lockdown and social distancing started after the declaration of NSW emergency. The scope of this lockdown order prohibited the people in the City of Sydney LGA from leaving their homes except for necessities like grocery shopping, work, or school for those who are unable to work or learn from home, compassionate reasons, or any other vital services.

COVID-19 restrictions reduced the number of walking trips on both weekdays and weekends. However, in general the number of walking trips were higher on weekdays than weekends (see Figure 2). More precisely, the average daily count during post-COVID (2020-2021) on weekdays is 41% smaller than pre-COVID (2013-2019), and the average daily count during post-COVID on weekends is 47% smaller than pre-COVID.

The average daily pedestrian counts in Spring versus Autumn on weekdays vary very little (less than 5%). Due to a significantly smaller number of sites being included in the survey, which can skew the results in favor of locations with generally higher pedestrian activity, data from 2018 and 2019 were not included in the analysis, and those that are available are deemed to be outliers. Analyzing the data considering seasonality, the weekly average post-COVID pedestrian count was 30% lower than the pre-COVID level, weekend counts during post-COVID in the autumn were 50% lower than weekends during pre-COVID. Furthermore, the post-COVID weekday average daily count was 52% lower than the pre-COVID average daily count. Weekend post-COVID counts in the spring were 45% lower than pre-COVID counts on average (Figure 2).

Figure 2: Daily counts across all sites over years and seasons: (a) Mean daily count and (b) Median daily count.



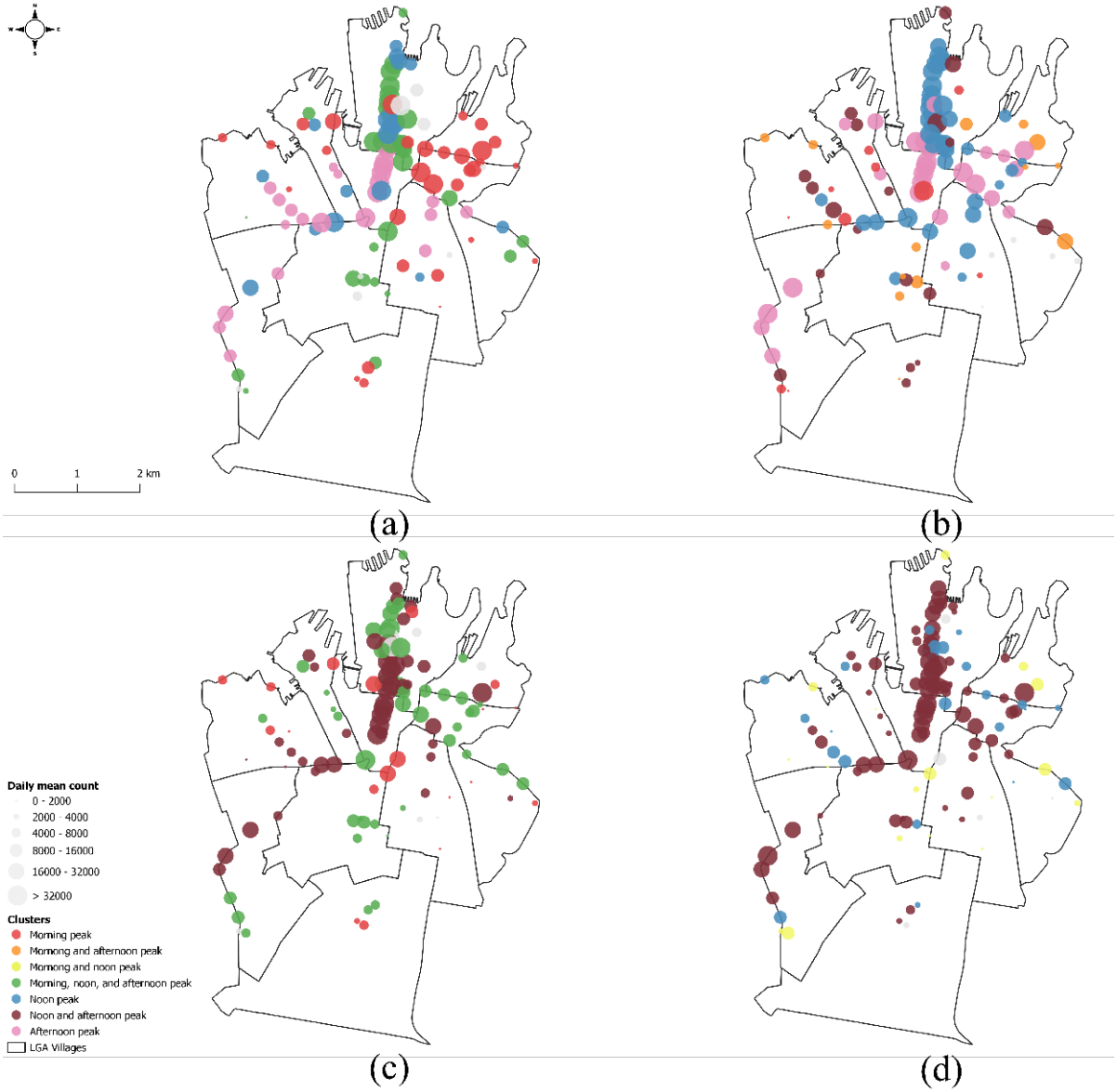
To understand the substantial impact of the COVID-19 response measures on walking across different sites, we investigated the spatial changes on both weekdays and weekends. Although the spatial distribution of pedestrian flow in most of the sites across LGA experiences a significant deduction, there are still some locations where the walking count increases between 2020 and 2021 (Figure 2). In contrast, the pedestrian daily average volume increased from 2013 to 2019 in most of the sites.

The main idea is to find similarities between different time series and to pair them under the same group, known as a cluster, such that the time series in the same cluster follows a similar pattern to those in other clusters. The clusters obtained from the algorithm are belonging to either of the following eight categories: morning peak, morning and afternoon peak, morning and noon peak, morning and noon and afternoon peak, noon peak, noon and afternoon peak, afternoon peak, and an outlier cluster for those time series belong to none of the other 7 clusters. While there may be instances of repetition within clusters, such as the presence of both "noon and afternoon peak" and "noon peak," it's important to recognize that these clusters do indeed exhibit distinct characteristics. To elaborate, "noon peaks" are representative of specific patterns related to foot traffic and movement during the midday hours, characterized by increased pedestrian activity, often associated with lunchtime and midday work breaks, whereas the "noon and afternoon peak" cluster signifies a separate trend involving a continuation of elevated pedestrian walk, indicating the extended period of high activity that persists beyond the typical noon peak, potentially linked with post-lunch activities or other factors contributing to sustained pedestrian flow. The results of clustering are shown in Figure 3.

A straightforward model of the walking counts time series profile across various sites is provided by the clustering results. The model can be used to spot anomalies and gain a better understanding of how different sites' patterns of land use and pedestrian activity compare in terms of trips taken for business and leisure. Most locations in the CBD & Harbour village display three peaks during the pre-COVID (2013-2017) period in the morning, noon, and afternoon on weekdays, indicating a significant presence of both work (commuting) trips and non-work journeys in the village. Over the same period, the majority of the sites along Glebe

Point Road, King Street, Chinatown, and CBD South villages show an afternoon peak that suggests considerable pedestrian activity, including both leisure and work-related journeys to and from home trips. In contrast, most locations throughout the whole LGA during weekends, both before and after COVID periods only show peaks at noon and in the afternoon, indicating predictable patterns associated with weekends spent on recreation.

Figure 3. The spatial distribution of sites and identified clusters across the LGA: (a) pre-COVID (2013-2017) on weekdays and (b) pre-COVID (2013-2017) on weekends (c) post-COVID (2020-2021) on weekdays and (d) post-COVID (2020-2021) on weekends. Colours represent different clusters. The size of the circles represents the average daily count per site over years.



4. Conclusion and discussion

Urban travel behaviour is known to have significantly been disrupted by COVID-19. In this study, we analysed the pedestrian walking patterns in the City of Sydney LGA over a 9-year time period before and during COVID-19. We assessed the patterns of walking count using various techniques throughout different villages introduced by the City of Sydney urban planners considering changes in pedestrian walking patterns in response to COVID-19.

We first quantify the daily and hourly pedestrian count changes at the site and village level in LGAs. Then a clustering algorithm specifies the changes in each walking count site based on the peak hour it experiences before and after the pandemic outbreak. The results confirm that the total number of pedestrians after the pandemic dropped in most of the sites. This drop owes to the deduction in the necessity of walking to work or school, to shop, and to other amenities, and the surpass of walking count is in leisure sites. The spatial and temporal pattern of hourly count barely changes across the villages, compared to the dramatic changes in peak hours across the sites resulting from the clustering method.

The pedestrian data from the city of Sydney has some limitations. For instance, the travel purpose of each pedestrian is not provided where we can readily define the reasons for the changes in peak hours across the years (Anwari et al., 2021). Pedestrian count in some sites is not available for a specific date which limits our clustering results for pre-covid to 2013 to 2017 only.

To accurately determine the level of consistency or inconsistency in changes brought about by the COVID-19 era, it is essential to have access to additional data that has been collected using the same methodology. Without this crucial information, any conclusions drawn may be incomplete or even inaccurate. By employing a consistent approach to data collection, we can gain a clearer understanding of the extent to which the pandemic has affected various aspects of society and the economy. This data can then be used to inform decision-making processes and identify areas that require further attention or intervention. This part of the research is handed to future studies.

The results help planners to understand the implication of walking patterns before and after the pandemic to make better decisions for operational approaches and making more pedestrian-friendly policies.

References

ANWARI, N., AHMED, M. T., ISLAM, M. R., HADIUZZAMAN, M. & AMIN, S. J. T. R. I. P. 2021. Exploring the travel behaviour changes caused by the COVID-19 crisis: A case study for a developing country. 9**,** 100334.

BASSIRI ABYANEH, A., ALLAN, A., PIETERS, J., DAVISON, G. J. U. I. & CITIES, F. 2021. Developing a GIS-based tourist walkability index based on the AURIN walkability toolkit—case study: Sydney CBD. 233-256.

BECK, M. J. & HENSHER, D. A. J. T. P. 2020a. Insights into the impact of COVID-19 on household travel and activities in Australia–The early days of easing restrictions. 99**,** 95-119.

BECK, M. J. & HENSHER, D. A. J. T. P. 2020b. Insights into the impact of COVID-19 on household travel and activities in Australia–The early days under restrictions. 96**,** 76-93.

BISHOP, C. M. & NASRABADI, N. M. 2006. *Pattern recognition and machine learning*, Springer.

BORKOWSKI, P., JAŻDŻEWSKA-GUTTA, M. & SZMELTER-JAROSZ, A. J. J. O. T. G. 2021. Lockdowned: Everyday mobility changes in response to COVID-19. 90**,** 102906.

COCHRAN, W. T., COOLEY, J. W., FAVIN, D. L., HELMS, H. D., KAENEL, R. A., LANG, W. W., MALING, G. C., NELSON, D. E., RADER, C. M. & WELCH, P. D. J. P. O. T. I. 1967. What is the fast Fourier transform? 55**,** 1664-1674.

FALCHETTA, G. & NOUSSAN, M. The Impact of COVID-19 on transport demand, modal choices, and sectoral energy consumption in Europe. IAEE Energy Forum, 2020. 48-50.

FUJITA, A., FELICIANI, C., YANAGISAWA, D. & NISHINARI, K. J. P. R. E. 2019. Traffic flow in a crowd of pedestrians walking at different speeds. 99**,** 062307.

GKIOTSALITIS, K. & CATS, O. J. T. R. 2021. Public transport planning adaption under the COVID-19 pandemic crisis: literature review of research needs and directions. 41**,** 374-392.

GUTHOLD, R., STEVENS, G. A., RILEY, L. M. & BULL, F. C. J. T. L. G. H. 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1· 9 million participants. 6**,** e1077-e1086.

HALL, C. M. & RAM, Y. J. J. O. S. T. 2019. Measuring the relationship between tourism and walkability? Walk Score and English tourist attractions. 27**,** 223-240.

HUMAGAIN, P., SINGLETON, P. A. J. T. B. & SOCIETY 2021. Exploring satisfaction with travel time profiles towards understanding intrinsic utilities of travel time. 24**,** 22-33.

KANG, M., CHOI, Y., KIM, J., LEE, K. O., LEE, S., PARK, I. K., PARK, J. & SEO, I. J. I. J. O. U. S. 2020. COVID-19 impact on city and region: what's next after lockdown? 24**,** 297-315.

LI, Y. & XU, L. J. I. I. J. O. G.-I. 2021. The Impact of COVID-19 on Pedestrian Flow Patterns in Urban POIs—An Example from Beijing. 10**,** 479.

OECD. *Cities policy responses* [Online]. Available: https://www.oecd.org/coronavirus/policy-responses/cities-policy-responses-fd1053ff/ [Accessed 20 september 2022 2022].

PAREEK, M., BANGASH, M. N., PAREEK, N., PAN, D., SZE, S., MINHAS, J. S., HANIF, W. & KHUNTI, K. J. T. L. 2020. Ethnicity and COVID-19: an urgent public health research priority. 395**,** 1421-1422.

PETITJEAN, F., KETTERLIN, A. & GANÇARSKI, P. J. P. R. 2011. A global averaging method for dynamic time warping, with applications to clustering. 44**,** 678-693.

STIER, A. J., BERMAN, M. G. & BETTENCOURT, L. J. A. P. A. 2020. COVID-19 attack rate increases with city size.

TIAN, X. & CHEN, M. J. S. R. 2021. Descriptor selection for predicting interfacial thermal resistance by machine learning methods. 11**,** 739.

TISON, G. H., AVRAM, R., KUHAR, P., ABREAU, S., MARCUS, G. M., PLETCHER, M. J. & OLGIN, J. E. J. A. O. I. M. 2020. Worldwide effect of COVID-19 on physical activity: a descriptive study. 173**,** 767-770.

WEI, Y., WANG, J., SONG, W., XIU, C., MA, L. & PEI, T. J. C. 2021. Spread of COVID-19 in China: analysis from a city-based epidemic and mobility model. 110**,** 103010.

WU, L., CHENG, X., KANG, C., ZHU, D., HUANG, Z. & LIU, Y. J. I. J. O. D. E. 2020. A framework for mixed-use decomposition based on temporal activity signatures extracted from big geo-data. 13**,** 708-726.