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How does the built environment shape leisure active travel during COVID-19 travel restrictions? Evidence from Melbourne

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Abstract

COVID-19 restrictions impose significant changes on human mobility patterns, with some studies finding significant shifts in walking and cycling in some cities. However, to date there is little understanding on how the neighbourhood-level built environment influenced active travel behaviour during the COVID-19 restrictions. We aimed to answer this question by examining recreational walking and cycling during different stages of lockdown in Melbourne, Australia. We compared self-reported changes in active travel data from 1344 respondents between pre- and two different stages in lockdown by various built environment factors of their residential neighbourhoods. We found that walking and cycling declined significantly during the two stages of lockdown in general. However, the mobility decline was slower in neighbourhoods with a high level of green spaces, residential area, and residential density. This is particularly true for the regular cyclist and walkers. The findings suggest the need for an equity in the design of the built environment to maintain/promote active transport.

1. Introduction

The link between physical activity and health, physical and mental, has long been known (Warburton and Bredin, 2016, Biddle et al., 2019). Active travel is potential means of physical activity which can contribute to people's health. It can be considered to be a potential low-cost strategy to improve communities' health and wellbeing. There is a close relationship between built environment and active transport (Sallis et al., 2018). Exposure to supportive built environment such as bike path and green space, can affect people's attitudes toward active travel and consequently travel behaviour.

On January 2020 the World Health Organization (WHO) declared an emergency in regards to COVID-19. Consequent responses such as social distancing, movement restrictions, work from home and travel bans were introduced in different countries and communities. People's movement and public activities were greatly restricted, causing mobility disruption and modal shift (Barbieri et al., 2020). As a consequence of these restrictions, the amount and pattern of travel changed. This change in mobility pattern is not identical for all transport modes (Bucsky, 2020) and for all neighbourhoods. Road networks, which are dominated by cars and play a major role in urban mobility, were empty due to travel restrictions, working from home, e-learning and reduced number of public activities (De Vos, 2020).

In addition, the pandemic reduced opportunities for out-of-home activity and physical exercise, which can cause social isolation. Recreational walking and cycling became one of the few options for exercise and outdoor socializing, helping people maintain their wellbeing. As a result, people expressed their wishes to have active transport infrastructures, sidewalks and cycling lanes during the pandemic (Nurse and Dunning, 2020). The local built environment is likely to have a significant impact on how easily people can walk and cycle during the travel restrictions of COVID-19. For this reason, we focus on leisure walking and cycling in this research to evaluate the effect of the built environment on them.

Early studies, using data sourced from CityMapper, Google mobility reports and household surveys, reported that there was a shift in modes and trip purposes during the pandemic (Beck and Hensher, 2020, Boroujeni et al., 2021). Many of these studies focused on reductions in work trips and changes to work travel mode (Pullano et al., 2020, Fatmi, 2020). A few studies looked at changes to recreational and social trips (Venter et al., 2020, Landry et al., 2021). However, there is a disagreement over whether walking and cycling increased or decreased during the pandemic. Some studies found a strong increase in the use of parks and large increases in cycling rates (Buehler and Pucher, 2021, Venter et al., 2020) while others found a decrease in outdoor recreation trips (Landry et al., 2021).

Although these studies examined a range of explanatory factors, they did not consider the potential role that the built environment might play in influencing such behaviour changes during the pandemic. The built environment is the human-made surroundings that support human needs. A long history of research explores how built environment characteristics affect travel behaviour (Ewing and Cervero, 2010). As there are different built environment characteristics in each neighbourhood, the response to COVID-19 restrictions may be varied across different neighbourhoods. However, how people in different neighbourhoods with different built environment characteristics respond to COVID-19 pandemic is not yet known. This leads us to explore the effects of the built environment on active travel behaviour during the pandemic.

The guiding research question of this paper is: How do neighbourhood built environment characteristics influence the dynamics of recreational walking and cycling during the pandemic?

This paper provides an exploration of whether built environment characteristics impact people’s local mobility in different stages of lockdown. We use Melbourne as a case study because of its experience of extremely restrictive lockdowns in two different stages.

In the remaining part of this paper, first we discuss the methodology applied in this study to answer the research question in Section 2. We then present our findings in Section 3. Finally, we discuss our findings in policy term and provide future research directions.

2. Research context

Melbourne is the capital and most-populous city of the Australian state of Victoria. We chose Melbourne as a case study location because Melbourne experienced the two longest and most restrictive lockdown periods in the world in 2020. The first lockdown restrictions were progressively implemented by Australian government in mid-late March 2020 to restrict citizens’ movements and reduce their opportunities to gather with other people outside their household. It lasted till mid May 2020. The second wave of infections emerged in Victoria during May and June, which led to a second lockdown in late June which eventually lasted almost four months in Victoria. The second wave ended when the city recorded no new cases on 26 October 2020. In these lockdown periods, a 5-kilometre travel restriction forced people to stay in their neighbourhood and use their local infrastructure for all purposes (with few exceptions for essential work trips). Schools were closed for much of these periods and any non-essential workers were forced to work from home. These two lockdowns in Melbourne made a disruption in urban life. However, it has also provided an opportunity to conduct a case study to evaluate changes in active travel behaviour between three stages (pre-covid, first-, and second-lockdowns) and how these changes relate to the built environment in which the respondent lived.

2.1. Data

We used two different datasets to compare walking and cycling between different built environment characteristics. We used a self-reported questionnaire survey data to measure travel behaviour in different stages of lockdown. The survey was conducted as part of the 'C-19 Long Term Transport Impact Study' in Melbourne (Currie et al., 2021). We linked the travel data to different built environment indicators data derived for this study based on the residential suburbs reported by respondents.

2.1.1. Mobility data

The questionnaire survey was conducted through an online panel survey company. Both geographical and socio-demographic (Table 1) representations of the sample were maintained for generalisation of the findings. Based on Table 1, the sample was over-representative of females but the income and age characteristics were broadly similar to the Melbourne average. The survey was run in two different legs; the first covered the first lockdown in Melbourne and the second was after the second lockdown and latest travel restrictions were announced. As in this paper we are interested in whether behaviour changed during the two different lockdown periods, we analysed data from the second wave of this dataset (sample size 1,344 responses), which ran from 16 July to 8 August 2020. Although the survey gathered a range of information from the respondents, we only used their recreational walking and cycling data in this paper.

Table 1: Sociodemographic characteristics of sample

Socio demographic characteristic		Sample Percentage
Gender	Male	37.9%
	Female	62.0%
Income	Low (0-$530 per week)	34.0%
	Medium ($530-$1870 per week)	48.70%
	High (> $1870 per week)	17.3%
Age	Youth (15-24)	11.8%
	Adult (25-64)	72.0%
	Older adult (>65)	16.1%

Respondents were asked to indicate how often they walked and cycled for recreational purposes in three stages: Stage 1 pre-COVID, Stage 2 during first lockdown and Stage 3 during second lockdown. Their responses were recorded on a seven-point scale:

0. Didn't do this
1. 1 time a week
2. 2 times a week
3. 3 times a week
4. 4 times a week
5. 5 times a week

6. More than 5 times a week

In order to analyse the level of walking and cycling, we also defined new dichotomous variable: *who didn't do walking/cycling and who walked/cycled no matter how many times.*

Moreover, we grouped participants based on their responses in different stages of lockdown, and define walker/cyclist type based on their behaviour adaptation. Further details are provided in section 3.1.

2.1.2. Built environment data

The built environment indicators that affect recreational walking and cycling, including residential area, residential density (Forsyth et al., 2007), green space area (Watts et al., 2013), and land-use mix (Cervero and Kockelman, 1997), were identified from the literature (Loh et al., 2019, Kärmeniemi et al., 2018, Duncan et al., 2005),.

To quantify the built environment characteristics, baseline data were downloaded from Victorian Government open data and GIS methods are utilised to form indicators. For dwelling numbers in each neighbourhood, the 2016 census data which are readily available on the website of Australian Bureau of Statistics (https://www.abs.gov.au/) were used. Green space percentage was calculated based on the total area of parklands within each neighbourhood. Residential area percentage was determined based on the total area of residential blocks in each neighbourhood, and residential density was based on the number of dwellings in each neighbourhood.

Land-use diversity index was measured by simpson's diversity index, based on the formula 1 in which a is the total area of specific land-use in neighbourhood and A is the total area of all land-use categories. This indicator value ranges from 0 to 1 and the higher value, the more diverse land-use pattern (Kamruzzaman and Hine, 2013).

$$\text{Land-use diversity} = 1 - \sum \left(\frac{a}{A}\right)^2 \qquad (1)$$

In order to conclude comparative analysis between each built environment characteristics, we considered quartiles of each built environment characteristics. The distribution of built environment variables is provided in Table 2 and the spatial distribution of them is provided in Figure 1.

2.2. Analysis method

In this study we used three different analyses to understand the travel behaviour adaptation during stages of lockdown. First, we used repeated measures ANOVA, based on the formula 2 in which MST is mean sum of squares of treatment and MSE is mean square of error, to compare mean difference in level of walking and cycling between the three stages. Second, to determine if there are differences between walked/cycled and did not walk/ did not cycle in three before mentioned study time as it is a dichotomous dependent variable, we used Cochran's Q test, which is an extension of McNemar test based on Chi square distribution for testing differences between repeated data, to find out differences in the different stages of this study. Third, for examining any relationship between walker/cyclist type and built environment characteristics we used the Chi-square test, based on the formula 3 in which O represent observed value and E represent expected value. For all the statistical test confidence interval 95% was chosen and the null hypothesis for all of them is there is no difference between different stages of study.

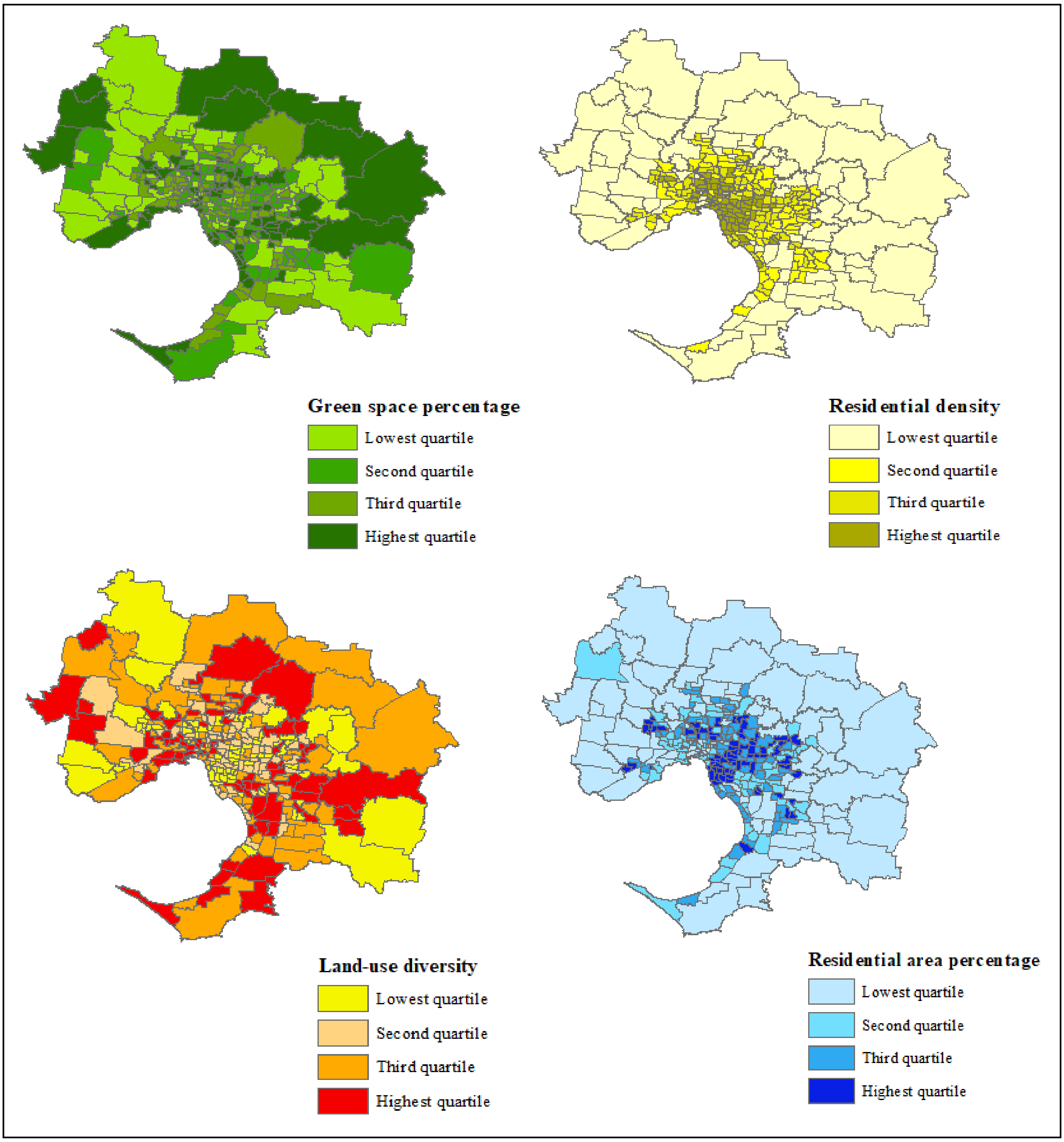
$$F = \frac{\text{MST}}{MSE} \qquad (2)$$

$$\chi^2 = \sum \frac{(Oi - Ei)2}{Ei} \quad (3)$$

Table 2: Built environment measurement method and their quartile measurement

Measure	Measurement method	Lowest quartile	Second quartile	Third quartile	Highest quartile
Residential Area percentage	Area of residential blocks divided by neighbourhood area (Km^2)	0-34.47	34.47-58.89	58.89-75.68	75.68-97.66
Residential density	Number of dwellings divided by neighbourhood area (Km^2)	0-581.79	581.79-918.825	918.825-2075.586	2075.586-6874.92
Green space percentage	Area of parklands divided by neighbourhood area (Km^2)	0-6.09	6.09-11.38	11.38-18.38	18.38-66.31
Land use diversity	Simpson diversity index	0-0.38	0.38-0.52	0.52-0.68	0.68-2.29

Figure 1: Spatial distribution of built environment characteristics in Greater Melbourne area



3. Results

In this section, we first analysed changes in leisure walking and cycling during the stages of the study. Then we compared these changes based on built environment characteristics.

3.1. Summary of COVID-19 mobility response

Table 3 shows that on average leisure walking reduced over time, especially during the second lockdown. The change in mean walking level during different stages of the study was statistically significant ($F(2,2686) = 29.233$, $p < 0.001$) based on repeated measures ANOVA. The percentage of people who say they 'never walked' increased from 19% before COVID-19 to 30% during the second lockdown. The results of the Cochran's Q test for walked/did not walk showed that the change in walking level during different stages of lockdown was statistically significant ($\chi 2(2) = 104.478$, $p < 0.01$).

Table 3: Leisure walking distribution during the pandemic

	Before COVID-19	First lockdown	Second lockdown
Didn't do this	19.2%	22.9%	30.4%
1 per week	13.3%	13.9%	13.0%
2 per week	17.4%	13.5%	14.4%
3 per week	16.6%	14.8%	10.1%
4 per week	10.3%	10.3%	9.3%
5 per week	10.3%	11.3%	10.7%
5+ per week	12.9%	13.2%	12.1%
Total walked	80.8%	77.1%	69.6%
Mean	2.68	2.63	2.36
Std. Deviation	2.00	2.09	2.14

Note: Change in mean and percentage who walked were both statistically significant

Table 4 shows that overall, the leisure cycling rates were much lower than leisure walking rates. Similar to leisure walking, average cycling had a declining trend during the first and second lockdown stages. The changes in mean cycling level between different stages were statistically significant ($F(2,2686) = 27.773,0$ $p < 0.01$) based on the analyses of a repeated measures ANOVA. Similarly, the percentage of people who choose to ride a bike as their leisure physical activity dropped from 24.5% before COVID-19 to 21.0% in the first lockdown and 16.8% in the second lockdown. Based on the Cochran's Q test results for cycled / did not cycle, the changes in cycling level during different stages of lockdown is statistically significant ($\chi 2(2) = 72.518$, $p < 0.01$).

Table 4: Leisure cycling distribution during the pandemic

	Before COVID-19	First lockdown	Second lockdown
Didn't do this	75.5%	79.0%	83.2%
1 per week	9.3%	8.4%	6.8%
2 per week	5.5%	4.7%	3.2%
3 per week	4.5%	3.8%	2.8%
4 per week	2.3%	1.9%	1.9%
5 per week	1.4%	1.1%	1.1%
5+ per week	1.4%	1.1%	1.1%
Total cycled	24.5%	21.0%	16.8%
Mean	0.59	0.49	0.41
Std. Deviation	1.27	1.16	1.11

Note: Change in mean and percentage who cycled were both statistically significant

In order to further explore travel behaviour adaptation during different stages of lockdown, we considered four different groups of participants based on their pre- and during-covid walking/cycling status as shown in Table 5. Table 5 indicates that walking is more popular than cycling, the percentage of people who never walked during this study (12.5 %) is far less than the percentage of people who never cycled (70.6 %). The proportion of 'new' walkers / cyclists is quite modest (6.7% and 4.9% respectively) and is smaller than the proportion of people who stop walking/cycling during the pandemic (18.2% and 11.5% respectively).

Table 5: participants categories based on their travel behaviour adaptation and their distribution

Participant category	Definition	Percent walkers	Percent cyclists
Always walker/cyclist	Walk/ cycle in all stages	62.6%	13.0%
New walker/cyclist	Did not walk/ cycle before COVID-19 but walk/cycle in at least one stage of lockdown	6.7%	4.9%
Former walker /cyclist	Walk/ cycle before COVID-19 but stop walking/cycling in at least one stage of lockdown	18.2%	11.5%
Never walker/cyclist	Did not walk/ cycle in all stages	12.5%	70.6%

3.2. Built environment and COVID-19 mobility response

Figure 2 shows changes to self-reported leisure walking during different lockdown stages by different built environment characteristics. We consider the mean value of responses as a mobility index in these charts.

Figure 2 (a) shows that there are little changes in walking level in the highest green space quartile. Figure 2 (b) indicates that we have the lowest level of walking and highest changes in walking level specially in the second lockdown in the lowest residential density quartile. Figure 2 (c) represents that the most diverse neighbourhoods recorded the least walking level. It is possible that these changes happened because land-use diversity functionality changed during the pandemic. In other words, many activity centres that previously act as enablers for walking were closed during the lockdown. Figure 2 (d) represents that we have the least walking level in the lowest quartile of residential area percentages. Besides we have highest changes in walking level in those neighborhoods. To determine which of these changes is statistically significant, we used repeated measures ANOVA tests; only the residential percentage had a significant effect on changes to walking ($F(6,2680) = 2.431$, $p < 0.05$).

Figure 3 shows the changes in leisure cycling during lockdown stages. Figure 3 (a) shows that people who live in the lowest quartile of green space had the highest cycling level before COVID-19 but their cycling level dropped significantly in lockdown. On the other side, people who live in the highest quartile of green space had less change in cycling level. Figure 3 (b) indicates that in higher residential density we had higher cycling level and fewer changes during different stages of lockdown. Figure 3 (c) represents that people in all land-use diversity quartiles experience decrease in cycling level. Figure 3 (d) demonstrates that in the lowest residential areas we had the highest level of cycling and the highest changes during different stages of study. While there is less cycling level in high residential percentage areas, it is steadier. As shown by the results of repeated measures ANOVA, that both residential ($F(6,2680) = 2.218$, $p < 0.05$) and green space percentage ($F(2,2680) = 3.196$, $p < 0.05$) have a significant effect on cycling changes.

Finally, we consider the four groups of participants based on their record of leisure waking/cycling (Table 5) and compare their distributions in different built environment characteristics (Tables 6 and 7).

Table 6: Distribution of walker type based on the built environment characteristics

Built environment index	Quartile	Always walker	Former walker	New walker	Never walker
Residential area *	Lowest quartile	21.05%**	32.24%**	25.56%	26.79%
	Second quartile	26.52%	25.71%	28.89%	26.19%
	Third quartile	25.21%	24.49%	23.33%	23.21%
	Highest quartile	27.23%	17.55%	22.22%	23.81%
Residential density *	Lowest quartile	21.20%**	30.20%	18.90%	39.30%
	Second quartile	25.30%	22.40%	32.20%	22.60%
	Third quartile	28.30%	20.80%	23.81%	23.33%
	Highest quartile	25.20%	26.50%	18.90%	20.80%
Green space area	Lowest quartile	21.52%	26.94%	17.30%	30.00%
	Second quartile	24.73%	22.86%	26.67%	26.79%
	Third quartile	25.80%	20.41%	27.78%	24.40%
	Highest quartile	27.94%	29.80%	23.33%	23.81%
Land-use diversity	Lowest quartile	28.42%	22.86%	25.56%	23.21%
	Second quartile	25.68%	24.08%	14.44%	24.40%
	Third quartile	22.59%	27.35%	26.67%	23.21%
	Highest quartile	23.31%	25.71%	33.33%	29.17%

** Chi-square significance test show statistically significance difference between groups, $p < 0.05$*

*** Bonferroni adjustment (Chi-square post hoc test) test show statistically significance, $p < 0.003$*

Table 6 shows that in general, green space and land-use diversity do not significantly impact whether people start or stop walking during the pandemic. However, residential area and residential density were both significantly related to walker type. ‘Always walkers’ were significantly less likely to live in low-density neighbourhoods or neighbourhoods with a low residential percentage; similarly, ‘Former walkers’ were more likely to live in neighbourhoods with a low residential percentage.

Table 7 shows the distribution of different cyclist by considering different built environment characteristics. No association between cyclist type and green space area, residential area or land-use diversity was observed. Most cyclists (always cyclist, former cyclist, and new cyclist) are in higher residential density neighbourhoods; in contrast, ‘Never cyclists’ are more likely to be in the lowest density neighbourhoods.

Table 7: distribution of cyclist type based on the built environment characteristics

Built environment index	Quartile	Always cyclist	Former cyclist	New cyclist	Never cyclist
Residential area	Lowest quartile	20.57%	27.92%	24.24%	24.13%
	Second quartile	30.29%	26.62%	36.36%	25.08%
	Third quartile	28.57%	25.32%	12.12%	24.76%
	Highest quartile	20.57%	20.13%	27.27%	26.03%
Residential density *	Lowest quartile	20.60%**	18.80%	25.8%	26.70%**
	Second quartile	19.40%	24.70%	18.20%	26.40%
	Third quartile	29.70%**	25.30%	28.80%	24.30%
	Highest quartile	30.30%	31.20%	27.30%	22.60%
Green space area	Lowest quartile	26.29%	25.97%	21.21%	22.02%
	Second quartile	19.43%	18.18%	33.33%	26.24%
	Third quartile	25.71%	25.32%	21.21%	24.76%
	Highest quartile	28.57%	30.52%	24.24%	26.98%
Land-use diversity	Lowest quartile	25.14%	27.27%	30.30%	26.45%
	Second quartile	25.14%	22.08%	19.70%	25.08%
	Third quartile	23.43%	22.08%	27.27%	23.92%
	Highest quartile	26.29%	28.57%	22.73%	24.55%

** Chi-square significance test show statistically significance difference between groups, $p < 0.05$*

*** Bonferroni adjustment (Chi-square post hoc test) show statistically significance, $p < 0.003$*

Figure 2: dynamics of leisure walk by considering built environment characteristics

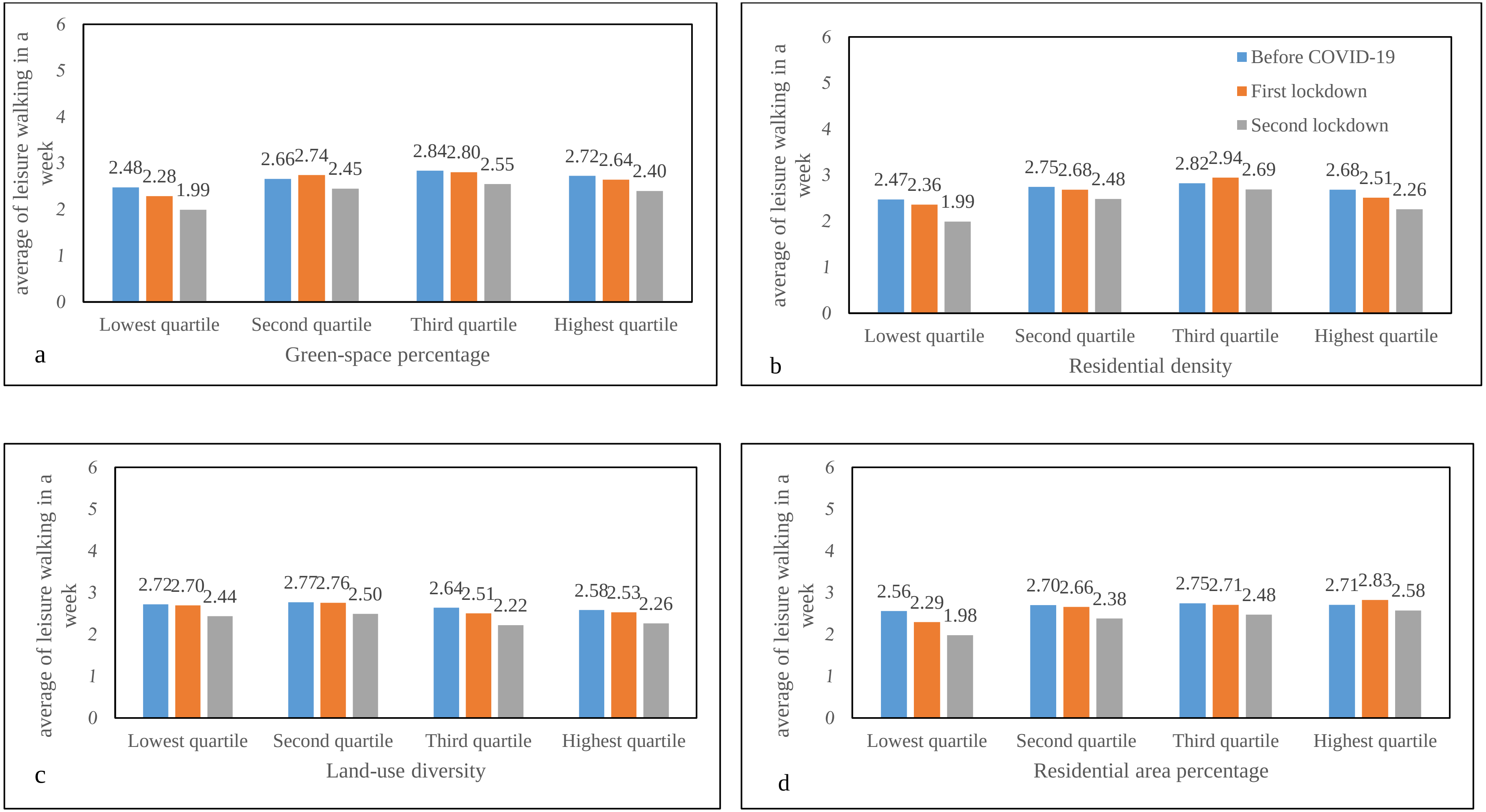
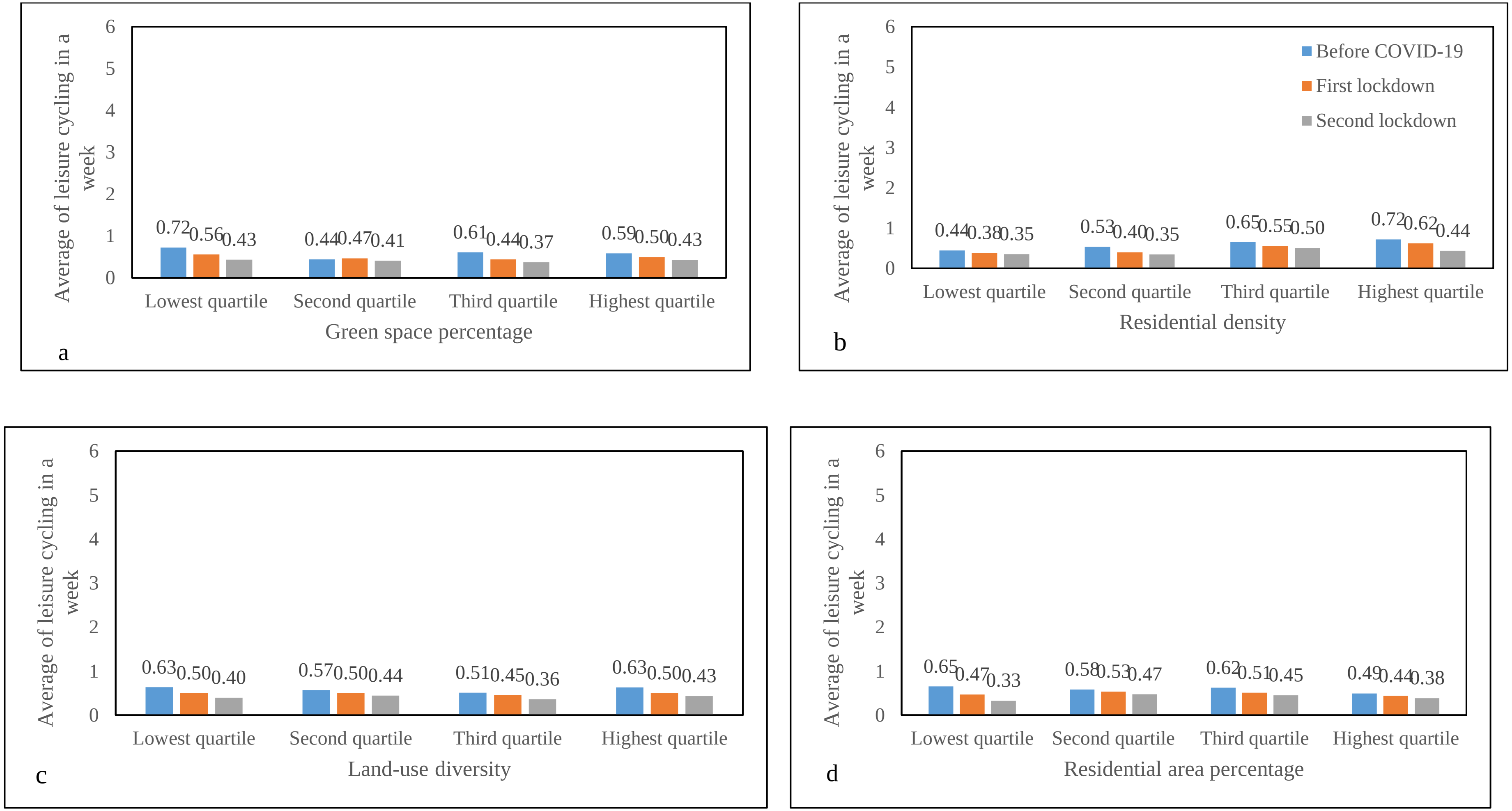


Figure 3: dynamics of leisure cycling by considering built environment characteristics



4. Discussion

The way people live in cities and their interaction with the built environment and transportation infrastructure reshapes every day. Unpredictable events such as pandemics affect the relationship between people and how they use the built environment. COVID-19 related restrictions, such as travel distance restriction and closing entertainment facilities, highlight the importance of local access to urban infrastructures such as open spaces and bike paths.

In some studies undertaken during the pandemic, the usage rates of open spaces (O'Sullivan, 2020) as well as the cycling rates (Buehler and Pucher, 2021) increased. However, in this study, we found that leisure walking and cycling rates both decreased during COVID-19 restrictions, especially during Melbourne's longer 'second wave' restrictions. Only a very small percentage of respondents were 'new' walkers or cyclists. This could be for a number of reasons. First, the survey data used in this study is 'self-reported,' so there could be recall bias among participants. Second, this study only surveyed adults, who may be walking or cycling with children (this was not asked in the survey). Third, reported increases in cycling may be focussed around specific bicycle infrastructure, whereas this study was conducted across Melbourne where cycling infrastructure is generally poor or non-existent. At the time of writing, we did not have an accurate measure of cycling infrastructure, but this should be examined in future research.

This study also explored whether different urban forms and design factors can affect the dynamics of recreational active travel during the pandemic. Some characteristics of the built environment lead to different mobility patterns. Although in general we saw a decrease in the level of leisure physical activity, there was less reduction in walking/cycling in neighbourhoods with more green space area, residential density and residential area. Land-use diversity was not a significant factor in any of the analyses, suggesting that its functionality as a mobility enabler reduces during the pandemic when the restrictive measures were in place. It seems that lockdown and restriction, and closing all non-essential businesses such as restaurants, cafes, sports centres, libraries, decreased the effect of land-use diversity in generating leisure walking travel. Therefore, the impacts of COVID-19 on mobility and travel behaviour are varied in different neighbourhoods and highlight the importance of access to local facilities. The residential location of people and households is an important factor in assessing access to transport and mobility enablers and participation in out-of-home activities.

Residential density is the leading built environment factor. Results are aggregated in this stage, we need to have more investigation on high density areas. It is pssible that they have better access to mobility enablers such as footpath or cycling infrastructure. Although dense areas may have better access to facilities, they can create more face to face interaction and increase risk of infection among society. Moreover, working from home was a measure to reduce spread of COVID-19 and change people's lifestyle and create more flexibility for them about where they want to locate (Whitaker, 2021) which may encourage them to moving out of central areas and into the suburbs. This can highlight spatial inequity in access to urban infrastructure in the future.

Analysis across the neighbourhoods based on the built environment characteristics provides an aggregate understanding for all residents of a neighbourhood and their access to the built environment infrastructure. However, people's individual characteristics also pay a role in their interaction with the built environment and travel behaviour. As the next step of this research, we will consider the role of sociodemographic characteristics to have a more accurate understanding of travel behaviour adaptation in Melbourne lockdown. Besides, by considering other built environment factors such as cycling infrastructure and connectivity story become clearer. Moreover, we have to consider this fact that people in two different points of a neighbourhood have various exposure to the built environment infrastructure and for future studies researchers can consider detailed location-based questions like the nearest intersection to participants' home for more accurate analysis.

In conclusion, the urban and transport infrastructure are travel choice enablers (Silva et al., 2014). It can promote or limit residents' physical activity participation (McCormack et al., 2010) or specific modes of transport. The COVID-19 pandemic and consequent travel restrictions stresses the importance of a local built environment in influencing people's active travel behaviours.

5. Acknowledgements

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