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Pedestrian activity in Melbourne, Australia in response to COVID-19

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Abstract

The COVID-19 pandemic has considerably influenced the travel behaviours of the entire global population. One of the most significantly impacted areas of Australia in terms of mobility is the Melbourne CBD. Melbourne has been subject to several government-imposed lockdowns and is critical to Australia's economy, yet there is no existing research which focuses on how pedestrian activity within the city has changed in response to COVID-19. The aim of this paper is to quantify the magnitude of the change in pedestrian activity across the Melbourne CBD, and to determine whether these volumes are on course to return to pre-COVID-19 levels. The paper draws on data from the City of Melbourne's Pedestrian Counting System from January 2019 to April 2021. We found that during the worst parts of lockdown, Melbourne recorded pedestrian volumes that were approximately 90% lower than the corresponding month in 2019. During a typical weekday in 2020, pedestrian volumes during morning, lunchtime and evening peaks were particularly impacted. As of April 2021, the City of Melbourne was still recording pedestrian volumes that were well below 2019 levels. Weekday pedestrian volumes continue to lag behind weekend ones, confirming that weekday activity should be of primary concern for key policy makers. These insights are likely to be valuable to the City of Melbourne, as well as other major global CBDs, which are all likely to be facing similar decreases in activity due to the pandemic. It is hoped that these findings will enable key policy makers in Australia and around the world to make informed decisions about how best to position their cities for a swift recovery.

1. Introduction

1.1. Background

The COVID-19 pandemic has had a profound impact on the mobility of all global citizens. After recording its first case in Hubei, China in late 2019, the novel coronavirus quickly spread across the globe, and was officially declared a pandemic by the World Health Organisation on 11 March 2020.

The first Australian case of COVID-19 was detected on 25 January 2020. As other countries began to experience the exponential growth and severe impacts of the virus, Australia's case numbers lagged. On 16 March 2020, the Victorian Government announced a state of emergency, enabling the introduction and enforcement of a host of restrictions, designed to protect public health. These measures, their scope and their timing have had a tremendous impact on the travel behaviour of the population, unlike anything seen in the last century.

Each country, city and neighbourhood has observed significant changes in travel behaviour due to a combination of government-imposed restrictions and a risk-averse human response to the pandemic (and these situations continue to evolve as the pandemic gains and loses ground in

different countries and cities). Australia's most significantly impacted region is Victoria, which as of April 2021 recorded 68% of Australia's total COVID-19 cases (Australian Government Department of Health 2021). Unlike other states and territories in Australia, Victoria has experienced two significant waves of COVID-19 cases, and has consequently been subject to longer and more-restrictive lockdowns than other parts of the country (Table 1). Within Victoria, federal and state lockdowns have restricted travel distance, the time permitted for outdoor activities and the eligible reasons to leave home. Greater Melbourne's 5km trael radius is an especially unique restriction, unseen elsewhere in Australia. But as lockdowns have eased, lingering restrictions and attitudes towards the pandemic have seen lower overall mobility (Google 2021), despite Victoria recording little to no COVID-19 cases (Victorian DHHS 2021).

Table 1: Key dates in Victoria's COVID-19 timeline

Date	Description
16-Mar-20	Victoria enters state of emergency – large events cancelled and social distancing introduced
23-Mar-20	Stage 1 restrictions – closure of hospitality venues, gyms and places of worship
30-Mar-20	Stage 3 restrictions – maximum gathering of two people
13-May-20	First relaxation of restrictions – reverting to five visitors in homes
1-Jun-20	Significant relaxation of restrictions – hospitality venues reopen and 20 visitors per home
20-Jun-20	Minor restrictions reinstated as case numbers rise and second wave begins
30-Jun-20	Localised lockdowns imposed on 10 Melbourne suburbs
7-Jul-20	Victoria's second lockdown begins – Stage 3 restrictions implemented
19-Oct-20	Restrictions significantly eased, with further easing on 27-Oct-20
30-Nov-20	Workplaces return to 25% capacity
12-Feb-21	Victoria enters a snap 5-day lockdown
26-Mar-21	Workplaces return to 100% capacity

One of the most significantly impacted areas of Victoria in terms of mobility is the Melbourne CBD. Key drivers including work from home arrangements, venue closures and a tourism halt have seen cities such as Melbourne grind to a stand-still. The Melbourne CBD is critical to Australia's economy, representing 7% of Australia's GDP in 2019 (Capp 2021). Therefore, as Melbourne's CBD continues to operate well below capacity, Australia will continue to struggle both economically and socially.

Aside from being Australia's second largest business hub, the city and its neighbouring suburbs are home to schools, universities, large sporting stadiums, retail precincts, hospitality venues and cultural centres. As a result, a diverse range of users visit and interact with the city each day. The travel habits of these different user groups are likely to have been significantly altered since the first government restrictions came into effect in Melbourne in March 2020.

Yet based on peer-reviewed research to date, it is difficult to predict the degree to which pedestrian activity within the Melbourne CBD might be impacted during the COVID-19 pandemic (Table 2). Each of the peer-reviewed papers in this table focuses on travel impacts due to COVID-19. Though there are three articles that focus on changes in pedestrian activity, they do not focus on Victoria, Melbourne, or on CBDs specifically, which results in vastly different considerations and findings. Similarly, the four articles which focus on Melbourne/Victoria fail to consider pedestrians volumes specifically. Further, none of the

existing research uses data from late 2020 or early 2021. This gap in time is particularly important as many new impacts and trends are likely to have emerged during this period.

Table 2: Literature review and identification of knowledge gap

Article reference	Proposed scope				
	Quantifies a change in travel volumes?	Focuses on pedestrian volumes/ activity?	Focuses on Victoria and/or Melbourne?	Includes data from 2021?	Focuses on post-COVID-19 recovery?
(Szczepanek 2020)	✓	✓	×	×	×
(Boroujeni, Saberian & Li 2021)	✓	×	✓	×	×
(Wang, Liu & Hu 2020)	✓	×	✓	×	✓
(Shamshiripour et al. 2020)	✓	×	×	×	✓
(Munawar et al. 2021)	✓	×	✓	×	✓
(Beck & Hensher 2020)	✓	×	✓	×	✓
(Borkowski, Jażdżewska-Gutta & Szmelter-Jarosz 2020)	✓	×	×	×	×
(Zecca et al. 2021)	✓	✓	×	×	×
(Zhang & Fricker 2021)	✓	✓	×	×	✓
(Engle, Stromme & Zhou 2020)	✓	×	×	×	×

In addition to the above literature, several non peer-reviewed sources were also considered. Loader (2020), Bandara (2020), Mitchell-Wong (2020) and the Australian Road Research Board (2020) have all addressed the changes in pedestrian volumes in the Melbourne CBD since the onset of COVID-19. They have all utilised data from the City of Melbourne's Pedestrian Counting System. However, their analyses do not include pedestrian volume data from late 2020 and early 2021, and consequently do not address Melbourne's post lockdown recovery.

1.2. Research objectives

Based on this literature review, the proposed research has two primary objectives. The first is to quantify the magnitude of the change in pedestrian activity within the Melbourne CBD and its neighbouring suburbs, and to analyse how these effects have varied across different stages of the pandemic and across different parts of the city. The second objective is to measure the degree to which these volumes are recovering in early 2021.

2. Methods

2.1. Research scope

The City of Melbourne municipality has been chosen as the focus of the proposed research due to the large quantity of available pedestrian data, its importance to Australia's economy, and its unique exposure to two major lockdowns. Using open data from the City of Melbourne's Pedestrian Counting System (City of Melbourne 2021), the effects of COVID-19 restrictions on the City of Melbourne's pedestrian activity will be analysed temporally and spatially.

The majority of the pedestrian counting sensors are located within the Melbourne CBD and as a result, this research will predominantly focus on the CBD. However, sensors outside of but in close proximity to the CBD will be included. Therefore, the scope of this research will extend to the Docklands, Southbank, South Wharf, Carlton, and North Melbourne.

2.2. Data description

The data used in this analysis is from the City of Melbourne's Pedestrian Counting System. This automated system comprises 76 pedestrian counting sensors, spread across various locations within the City of Melbourne. The sensors are installed under awnings or on light poles, creating a counting zone on the footpath area below. As pedestrians pass through each counting zone, bi-directional pedestrian movements are recorded by the sensors. The sensor data is processed and stored on-site, before being transferred to the server in 15-minute intervals (City of Melbourne 2021).

The final dataset includes an hourly total of bi-directional pedestrian movements across each day and each sensor location. This particular analysis will use pedestrian sensor data from January 2019 until April 2021 (the most recently available period when this analysis was conducted). However, it should be noted that the City of Melbourne has been recording and uploading this data since May 2009 (City of Melbourne 2021).

This dataset offers the potential to analyse pedestrian volumes spatially and temporally. The positioning of the sensors ensure that pedestrian activity can be tracked across various different areas within the City of Melbourne municipality. Further, the dataset contains the required granularity to allow for analysis on an hour-by-hour basis.

A key limitation of this dataset is the positioning of the sensors. The sensors offer inconsistent and ununiform coverage across the City of Melbourne. The majority of the sensors are positioned in the centre of the CBD, with limited coverage across the rest of the municipality. Another limitation of this dataset is that sensors are often inoperable, undergoing maintenance or not in operation. This results in a final dataset with many empty datapoints, which can have a significant impact on each hour's or each location's total count. It necessary to recognise which sensors are in operation at each point in time, to ensure accurate comparisons between different locations and times of the year.

2.3. Methodology

After initial investigation, it was determined that the analysis would need to differentiate between weekends and weekdays, as these two parts of the week demonstrated distinctly different patterns. As a result, Wednesday was selected as a typical weekday and Saturday as a typical weekend day. Wednesday was chosen due to it being situated in the middle of the working week and because of the small number of public holidays that it coincides with. Saturday was chosen as it experiences higher pedestrian volumes and a more vibrant night life than Sunday.

To capture the effects of COVID-19, pedestrian counts were constructed for each month of 2019, 2020 and the first part of 2021. A data file for the first Wednesday and Saturday of each month was downloaded from the City of Melbourne's Pedestrian Counting System. The average daily pedestrian count at each sensor for the previous four weeks was used. For example, the average daily counts for a Wednesday in January 2021 were found using the data file for the first Wednesday of February 2021. Due to the granular nature of the datasets, with each including pedestrian counts for over 70 sensors, average monthly pedestrian counts were deemed sufficient.

The next step involved cleaning and processing the monthly datasets. To allow for accurate and unbiased comparisons across different months, it was necessary to exclude certain sensors from the dataset. Sensors that were unavailable, undergoing maintenance or inoperable during any of the relevant months were removed (Rodríguez, Brisson & Estupiñán 2009). This resulted in the exclusion of 40 sensors (Figure 1).

In line with the research scope, this data cleaning process was undertaken for all of the months between and including January 2019 and April 2021. The period of January 2020 to April 2021 was the focal point of the analysis, whereas the period January 2019 to December 2019 was used as a 'normal' non-COVID-19 comparative period. The resultant monthly datasets each contained an identical set of sensors, and consequently, comparable pedestrian counts.

As depicted in Table 3 and Figure 1, a portion of the available pedestrian sensors were classified based on their location. This classification was used to create outputs that showed fluctuations in pedestrian volumes across different parts of the City of Melbourne. It should be noted that train stations have been used as a proxy for commuter/business activity.

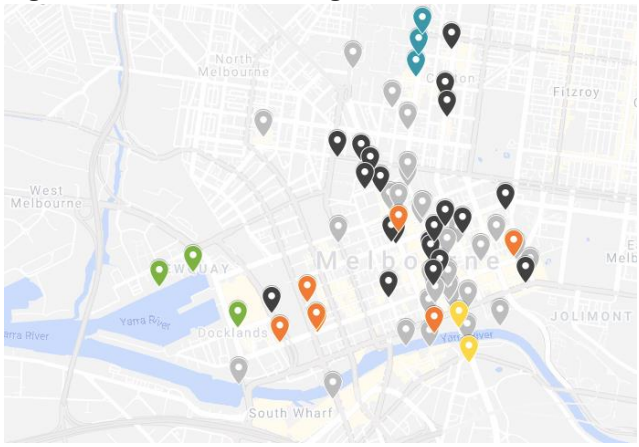
Other key outputs were generated by summing the total pedestrian counts for each month, or across each hour of a typical day. In all instances, the pedestrian volume figures represent an average day or average hour for the given month. For outputs that present a change in pedestrian volumes, the corresponding month in 2019 was used as the comparative period. For example, pedestrian volumes in January 2020 and January 2021 were compared with those from January 2019.

This methodology will ensure that pedestrian volumes and changes in pedestrian volumes can be accurately measured and compared. The resulting outputs will enable the efficient analysis of pedestrian activity spatially and temporally, and will allow for conclusions to be drawn as to whether the City of Melbourne is well-positioned to return to pre-COVID-19 levels of foot traffic.

Table 3: Pedestrian counting sensor classification

Category	Label	Sensor names / number of sensors
Train stations		Flinders St Station Underpass Southern Cross Station Collins Place (North) Spencer St - Collins St (North and South) Melb Central - Elizabeth St (East) Bourke St - Spencer St (North)
Docklands		Victoria Point Waterfront City New Quay
Southbank		The Arts Centre Princes Bridge
University campus		Grattan St - Swanston St (West) Monash Rd - Swanston St (West) Tin Alley - Swanston St (West)
Other - included		21 sensors
Other - excluded		40 sensors

Figure 1: Pedestrian counting sensor location and classification



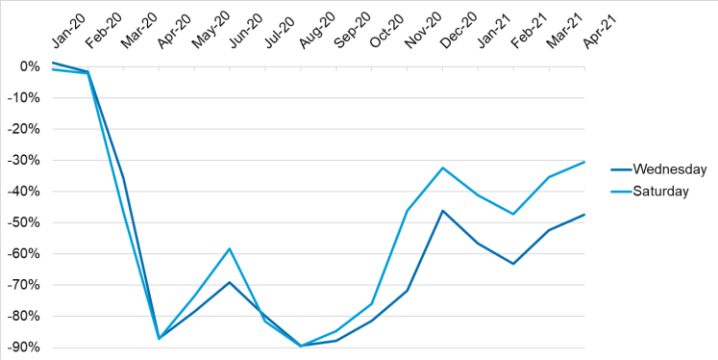
3. Results

3.1. Weekends and weekdays versus 2019

Before looking deeper into daily and hourly trends, it was first necessary to observe how pedestrian activity changed across 2020 and the first part of 2021. On a monthly basis, pedestrian volumes on a typical weekday (Wednesday) and a typical weekend day (Saturday) have followed a similar trend (Figure 2). Volumes reached a low point in April 2020, coinciding with the first Victorian lockdown, before increasing through May and June 2020.

The most significant drop in pedestrian volumes was recorded during the second Victorian lockdown, in August 2020. The initial recovery in pedestrian volumes following the second lockdown appeared to be slower than the first lockdown. However, a more rapid improvement was seen in November and December 2020. The third Victorian lockdown in February 2021 halted the momentum of the recovery, before further improvements were recorded in March and April 2021.

Figure 2: Change in monthly pedestrian volumes versus same month in 2019



With regard to the magnitude of these trends, the most significant declines were experienced in April 2020 and August 2020 (when compared to the corresponding months in 2019). On a typical Wednesday, average daily pedestrian volumes in April 2020 were down 87% versus April 2019, and down 89% in August 2020 versus August 2019. Similarly, on a typical weekend day (Saturday), average daily pedestrian volumes in April 2020 and August 2020 were down 87% and 90% respectively.

While a similar overall trend was experienced across Wednesdays and Saturdays, Saturday volumes consistently experienced less-significant declines, especially during the recovery from the first lockdown and from September 2020 onwards. In the most recently available month of data, April 2021, pedestrian volumes on a Wednesday were 47% lower than April 2019, whereas Saturday volumes were 31% lower. These figures highlight a significant improvement from the lows of April and August 2020, but they also demonstrate the disparity in the rate of recovery of pedestrian volumes on weekdays versus weekends.

3.2. Weekend volumes by hour

On an hourly basis, a typical weekend day (Saturday) followed a consistent trend during 2019 (Figure 3). Pedestrian volumes would rise sharply through the morning and peak at approximately 1pm, before gradually decreasing over the remainder of the day. Beginning in March 2020 not only did volumes drop overall, the curve flattened significantly, in particular losing the ‘bump’ in the evenings (Figure 4). From November 2020 onwards, strong signs of recovery were observed, with April 2021 recording the highest average daily weekend volume since February 2020 (Figure 5). Perhaps even more promising is that the evening ‘bump’ has returned, signifying a gradual return of Melbourne’s nightlife.

Figure 3: Average hourly pedestrian counts on Saturdays in 2019

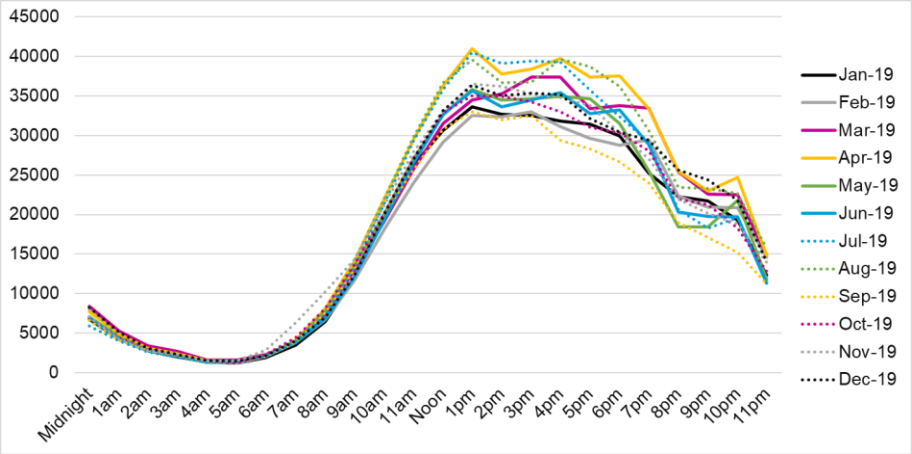
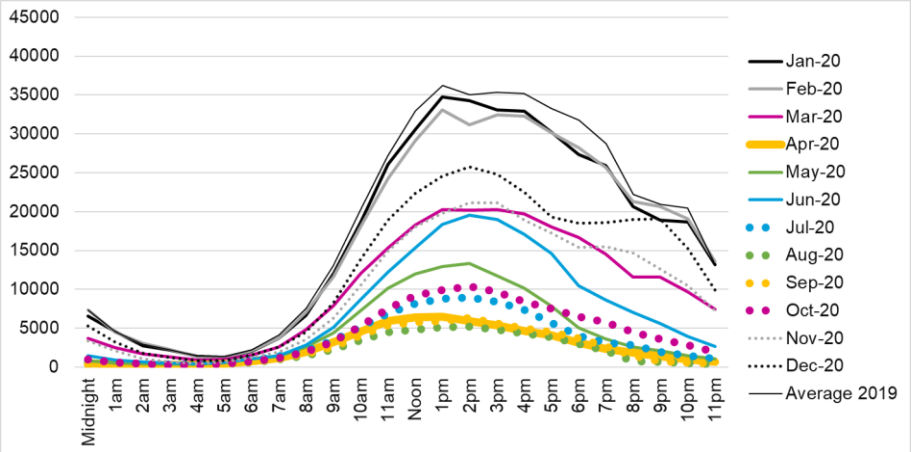
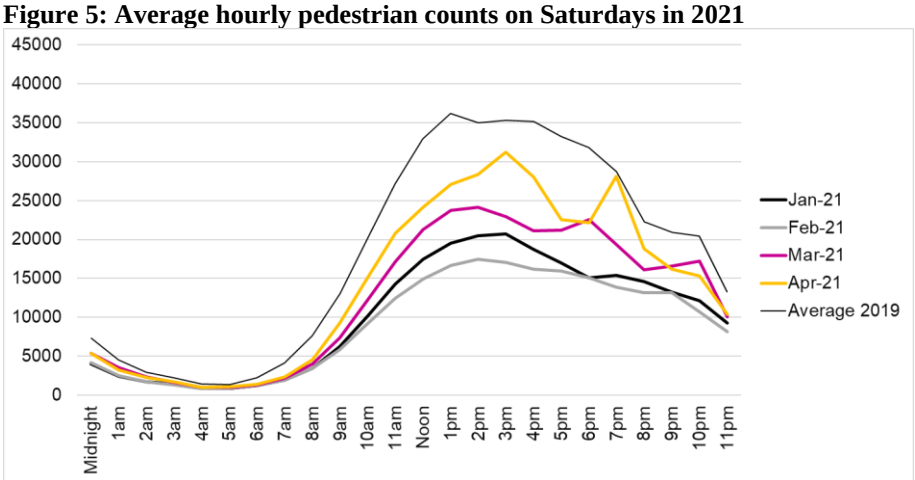


Figure 4: Average hourly pedestrian counts on Saturdays in 2020



Note: Melbourne was largely in 'lockdown' in April, July, August, September and October, shown in bold

Figure 5: Average hourly pedestrian counts on Saturdays in 2021



3.3. Weekday volumes by hour

Pedestrian volumes on a typical weekday in 2019 followed a distinct pattern, with apexes at 8am for the morning peak, at 12pm and 1pm over lunchtime, and at 5pm for the evening peak (Figure 6). This pattern continues through until March 2020, but from April 2020 onwards there is a pronounced change in the shape of the weekday pedestrian volume curve – there are no longer any morning, lunchtime, or evening peaks (Figure 7). Afternoon and evening

volumes start to recover from December 2020, but the three distinct peaks only begin to return in March 2021 (Figure 8). This represents a much slower recovery versus weekend activity.

Figure 6: Average daily pedestrian counts on Wednesdays in 2019

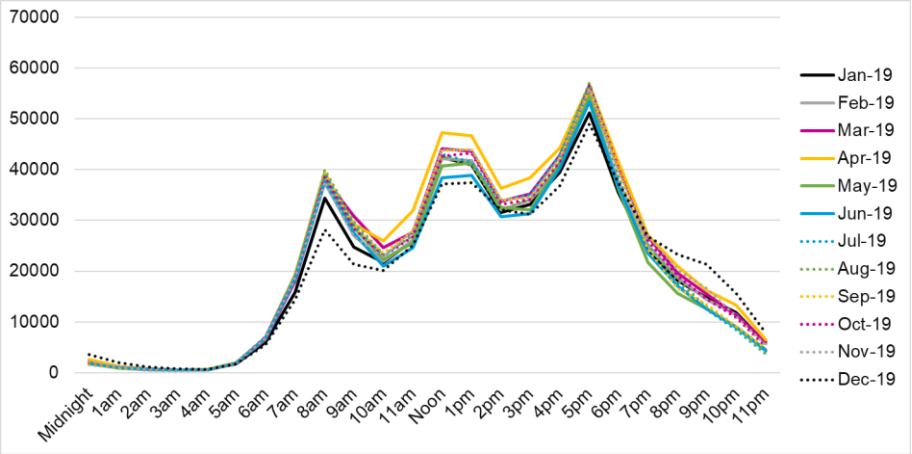
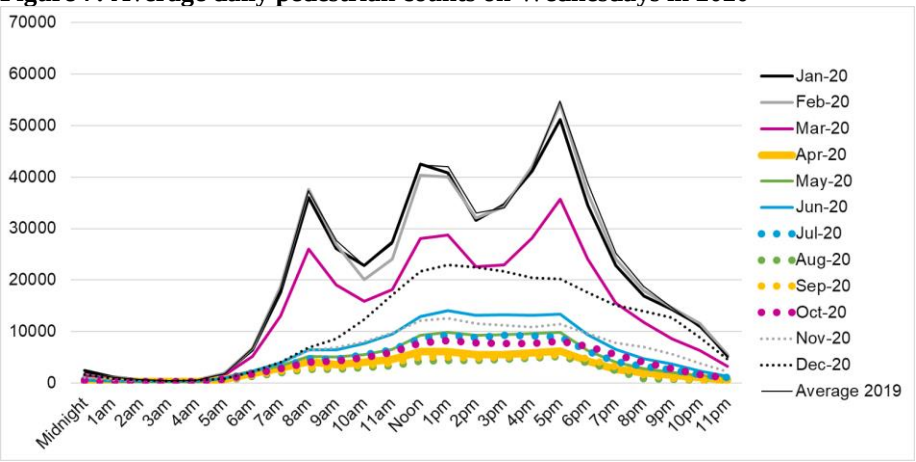
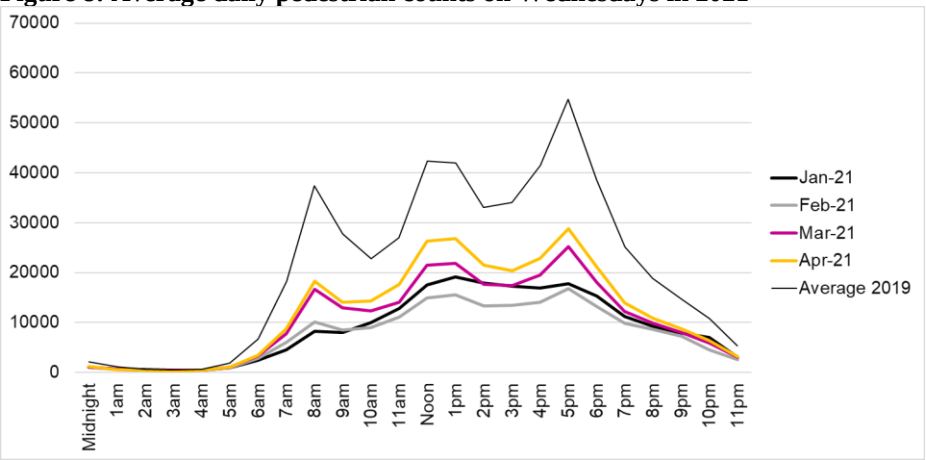


Figure 7: Average daily pedestrian counts on Wednesdays in 2020



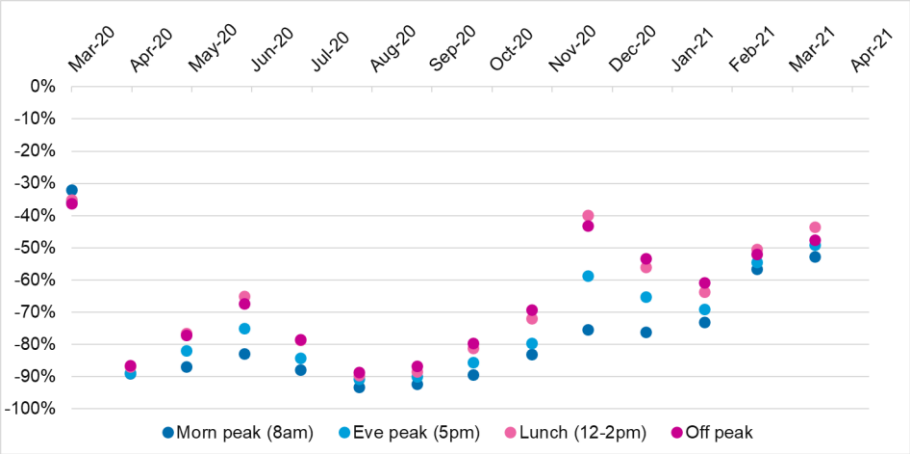
Note: Melbourne was largely in 'lockdown' in April, July, August, September and October, shown in bold

Figure 8: Average daily pedestrian counts on Wednesdays in 2021



By comparing the change in on- and off-peak volumes versus the same month in 2019, it is clear that morning peak volumes have consistently been the most adversely impacted (Figure 9). Evening peak volumes have also been impacted significantly, but to a lesser degree. Lunchtime peak and off-peak volumes experienced less of a drop overall.

Figure 9: Change in pedestrian volumes at peak times versus the same month in 2019



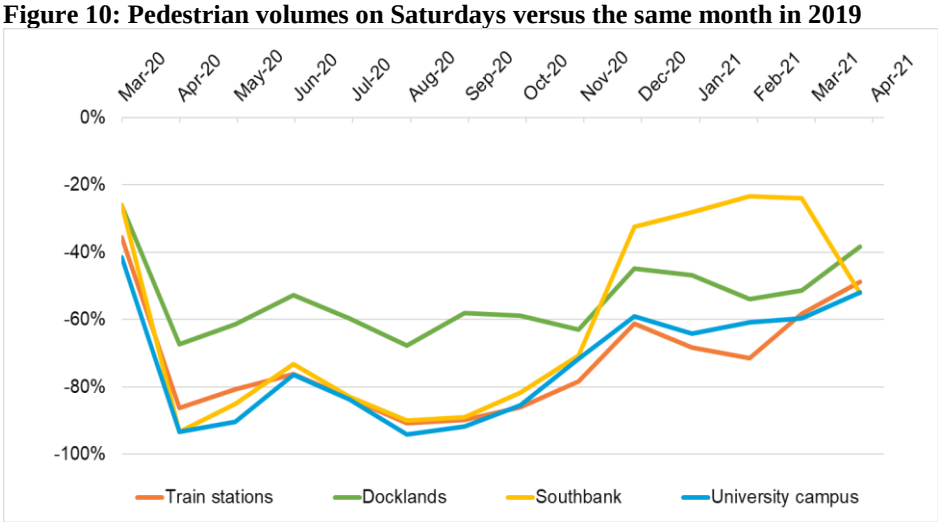
3.4. Pedestrian activity across different parts of the city

Using the classification outlined in Table 3 and Figure 1 above, we plotted pedestrian volumes across different parts of the city (Figures 10 and 11). Train stations, university campuses and Southbank volumes all followed a similar pattern on both weekends and weekdays from March 2020 to November 2020.

On weekends, the most significant decrease in pedestrian volumes was recorded in Southbank (down 95% in April 2020). Whereas, on weekdays, university campuses experienced the largest decrease in volumes (down 94% in August 2020).

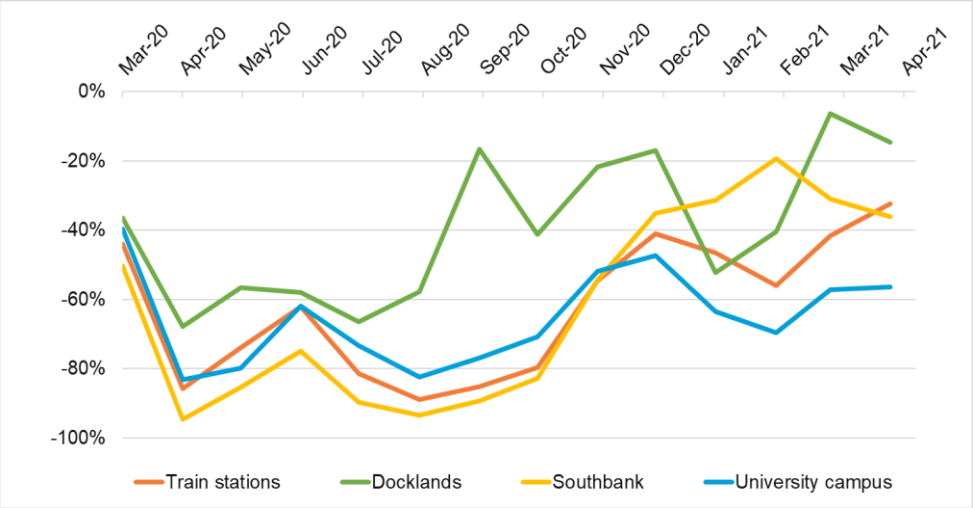
Across the period, the Docklands experienced the smallest decline in pedestrian volumes on both weekends and weekdays. The Docklands recorded particularly high volumes on weekends from September 2020 onwards. In April 2021, weekend volumes in the Docklands had almost completely recovered – only 6% below April 2019 levels.

Figure 10: Pedestrian volumes on Saturdays versus the same month in 2019



University campus volumes were initially more significantly impacted on weekdays versus weekends, likely due to university closures. However, on both weekends and weekdays, university volumes have been particularly slow to recover, down 56% on weekends and 52% on weekdays in April 2021. This lag is likely due to the absence of international students and dwindling on-campus student activity.

Figure 11: Pedestrian volumes on Wednesdays versus the same month in 2019



Weekday volumes around train stations have also been particularly slow to recover, consistently recording the largest declines through October 2020 (-85%) to February 2021 (-72%). But March and April 2021 have seen train station volumes recover at a much faster rate, reaching -52% in April 2021. Using train station volumes as a proxy for business activity, these figures suggest that business activity is rebounding strongly. The recovery in weekday volumes was eclipsed by weekend train station volumes, which climbed to -32% in April 2021, closing in on pre-COVID-19 levels.

4. Discussion

4.1. Weekend nightlife vs weekday business activity

The change in weekend pedestrian volumes during the worst parts of COVID-19 was characterised by a significant decrease in the late-afternoons and evenings (Figures 4 & 5). March and April 2021 have shown signs of a recovery in this aspect, with considerably higher volumes after 6pm. This demonstrates the return to nightlife across the City of Melbourne, likely due to the return of crowds at live sporting events at the MCG and Docklands Stadium. This is also the likely cause of strong weekend volumes across the Docklands in March and April 2021, which saw an almost full recovery in foot traffic when compared with April 2019 (Figure 10).

From December 2020 until February 2021, government-imposed workplace capacities varied between 25%-75%, resulting in significant drops in pedestrian activity during the morning and evening peaks. This trend was also captured in weekday volumes around train stations, with particularly low volumes recorded in January and February 2021. However, a return to 100% workplace capacity in March 2021 did see a strong rebound in morning and evening peak volumes, and in weekday train station volumes – both are encouraging signs.

Overall however, weekend pedestrian volumes are far closer to a full recovery than weekday ones. The discrepancy between the overall recovery in weekend and weekday volumes is significant, and is showing no signs of converging. This confirms that weekday activity should be of primary focus for key policy makers who wish to restore the City of Melbourne in a post-COVID-19 environment.

4.2. Residential areas have rebounded strongly

Throughout March to November 2020, the Docklands consistently recorded the lowest drop in pedestrian volumes on both weekends and weekdays when compared to other parts of the city

(Figures 10 and 11). From each month following November 2020, either Southbank or the Docklands recorded the lowest drop in pedestrian volumes. This is likely due to the high residential populations in these two areas. Beck and Hensher's analysis of Google mobility data supports this (Beck & Hensher 2020). They found that since the onset of COVID-19, the 'residential' category has been the strongest performing category in terms of mobility in Australia. This is further supported by a Google mobility report from May 2021, which shows that within the City of Melbourne, trips to residential areas have experienced a higher growth rate than all other categories (Google 2021).

This demonstrates the importance of planning cities which are not just business centres, but also include a healthy residential population. The example of Melbourne teaches us that cities with a strong reliance on business activity are prone to large drops in overall pedestrian activity, under circumstances where workplaces are closed or partially closed. This is particularly relevant as the global community continues its uptake of work from home habits. As people continue to work from home, business-reliant cities such as Melbourne will struggle to recover.

4.3. Future scope for research

The City of Melbourne's recovery from COVID-19 is still very much in-progress. As such, there is scope to continue monitoring pedestrian volumes temporally and spatially, until volumes return to pre-2019 levels. There is also the potential to look deeper into Melbourne's Pedestrian Counting System dataset, as the above research has excluded certain sensors and has only considered pedestrian counts on a monthly basis. One key limitation of this research was that it only focused on pedestrian volumes and neglected other modes of transport. Therefore, future research analysing how other modes of transport have been impacted by COVID-19 could also be undertaken.

These insights are likely to be valuable to the City of Melbourne, as well as other major global CBDs, which are all likely to be facing similar decreases in activity due to the pandemic. By understanding the magnitude of the change in mobility and the likelihood of returning to pre-COVID-19 activity levels, key policy makers in Australia and around the world will be able to make informed decisions about how best to position their cities for a swift recovery.

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