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Understanding the allocation and use of street space in activity centres

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Abstract

The allocation of street space is strongly contested in many cities, particularly in activity centres where movement and place objectives are often in conflict with one another. Using a case study of Melbourne's activity centres, the aim of this research was to understand how much street space is allocated and used by each mode of transport, and to explore factors that are associated with the use of each mode of transport. Multi-modal observational person counts and street measurements were undertaken at 57 different locations within 36 activity centres across Melbourne during 2020. For each site, data related to street and activity centre characteristics were compiled. Key results showed that on average, based on the principle of egalitarianism, pedestrian space in the form of footpaths is significantly undersupplied, while bicycle lanes, car parking and shared general traffic/bus lanes were oversupplied. However, when viewed across individual sites, considerable variability was found in street space allocation vs. use. Results also showed a number of street/activity centre characteristics that were associated with use of the street space by mode. Among others, these included footpath width, clearways, movement and place classifications, distance to the Central Business District (CBD), presence of car sharing, car ownership, income and age. The research findings can be used to better inform decision-making on street space reallocation through identifying locations where street space could be allocated more equitably to users.

1. Introduction

The allocation of street space is strongly contested in many cities. This is particularly relevant in activity centres where high traffic flows conflict with popular places and key destinations in their own right. Various frameworks have been developed to acknowledge the diverse role of streets by classifying them based on the significance of their link/movement and place functions (Department of Transport 2019; Diemer et al. 2018; Jones, P et al. 2007).

Previous research on the topic of street space allocation has considered a range of governance and political issues (Jones, I 2014), ethical principles (Creutzig et al. 2020b) and methods for allocating street space (Currie et al. 2004; Jones, P 2016). However, very few studies have explicitly measured how much actual street space is allocated and used by each mode of transport in cities, with most focused on flow/movement measures. This is despite the importance of allocating street space in a fair and equitable manner (Creutzig et al. 2020b; Nello-Deakin 2019). Previous studies that have measured street space allocation have mostly been limited to European cities (Gössling et al. 2016), with little understanding of factors associated with use of the street space.

Using a case study of Melbourne's activity centres, the aim of the research underlying this paper[1] is to understand how much street space is allocated and used by each mode of transport and to explore factors that are associated with the use of each mode of transport. The research is informed by multi-modal observational space use person counts and street space measurements undertaken at 57 different locations within 36 activity centres across Melbourne during 2020. For the purpose of this research, an activity centre is defined as a community hub providing a broad range of goods and services, focusing on mixed-use development such as offices, retail, entertainment, higher density housing, education and medical services (DELWP 2019). Examples of activity centres range from local shopping strips to Central Business Districts (CBDs). A key feature of activity centres is their concentration of people-activity (Coath 2017).

An understanding of street space allocation and use by transport mode can help in identifying locations where street space could be allocated more equitably to users. This is particularly relevant in areas where movement and place objectives are in conflict with one another, such as activity centres, and where cities are looking to provide greater priority to more sustainable forms of transport, e.g. walking, cycling and public transport (NYC Department of Transport & Gehl Architects 2014). It is also relevant in the context of COVID-19, where greater space for pedestrians and cyclists is being sought to support physical distancing and increased uptake of these forms of transport (UCI 2020), alongside efforts to increase outdoor dining opportunities through converting on-street car parking to 'parklets' (City of Melbourne 2020).

The remainder of this paper is structured as follows. Section 2 provides a review of the literature on street space allocation studies, followed by Section 3 which describes the method used for selecting sites and undertaking the data collection and analysis. Section 4 presents the results of the analysis, including the use of correlations to explore factors associated with the use of each mode of transport. Section 5 concludes the paper with a discussion of the implications and policy and practice, along with areas for future research.

2. Literature review

Results from previous studies that have measured street space allocation and use are summarised in Table 1. In all studies, the percentage of space allocated to cars exceeded the percentage of people using cars, while the opposite was generally true for cyclists and public transport users. The amount of space for pedestrians was generally similar to – or exceeded – the amount of people walking, except in the case of Melbourne's Central Business District (CBD) where walking represented 89% of all trips but was allocated only 26% of the street space.

Methods used by the studies to measure allocation of the street space by mode included manual physical measurements (Creutzig et al. 2020b) or automated means such as the use of digital satellite imagery and GIS (Gössling et al. 2016; Lefebvre-Ropars et al. 2021a, 2021b; Nello-Deakin 2019). Methods used to measure use of the street space by mode included direct observational counts (Creutzig et al. 2020b) or the analysis of secondary data such as household travel surveys (Gössling et al. 2016; Lefebvre-Ropars et al. 2021a, 2021b; Nello-Deakin 2019).

A methodological issue with measuring the use of street space is whether to account for inherent differences between modes, e.g. physical space requirements and average trip distances. In an analysis of street space allocation in Amsterdam, Nello-Deakin (2019) adjusts for physical space requirements and average trip distances by mode, but finds that these adjustments do not

[1] This paper builds upon a working paper titled 'Street space allocation and use in Melbourne's activity centres' (De Gruyter et al. 2021).

necessarily support a sustainable transport agenda as greater weight is inherently given to the car which takes up more space and is associated with longer trip distances. He finds that while cars account for 32% of all users, they would need 96% of the space if adjusted for their physical space requirement. Nello-Deakin (2019) therefore suggests focusing on speed instead, arguing that a city dominated by shared spaces at low speeds might be more equitable than a city with traffic segregation and high speeds. However, no such adjustment is undertaken in his analysis. Creutzig et al. (2020b), on the other hand, adjusts for average travel speeds by mode, but does so by giving greater weight to transport modes with higher speeds (i.e. cars), placing an emphasis on 'movement' and further discriminating against sustainable transport modes, particularly walking.

Table 1: Summary of key results from studies measuring street space allocation and use

Location	Cars	Pedestrians	Cyclists	Public transport
Berlin, Germany (Creutzig et al. 2020b)				
% Space	60% [a]	30%	6%	4%
% Use	37%	29%	16%	18%
Difference	+23%	+1%	-10%	-14%
Freiburg, Germany (Gössling et al. 2016)				
% Space	55% [a]	25%	2% [b]	7%
% Use	32%	23%	27%	18%
Difference	+23%	+2%	-25%	-11%
Amsterdam, The Netherlands (Nello-Deakin 2019)				
% Space	51% [a]	40%	7%	2%
% Use	32%	18%	27%	Not reported
Difference	+19%	+22%	-20%	-
Montreal, Canada (Lefebvre-Ropars et al. 2021a)				
% Space	82% [a]	16%	2%	<1% [c]
% Use	76%	7%	3%	14%
Difference	+6%	+9%	-1%	-14%
Melbourne CBD, Australia (Daly 2018)				
% Space	58% [a]	26%	Not reported	9%
% Use	2%	89%	Not reported	8%
Difference	+56%	-63%	-	1%

Source: authors' synthesis of the literature based on citations contained within the table.

[a] Includes space for on-street car parking.

[b] Represents bicycle only space; excludes shared space for cyclists and pedestrians.

[c] Represents space for transit priority lanes only; excludes shared space for transit and other modes.

In summary, while a small number of studies have measured street space allocation and use, these have focused mostly on European cities, with the only Australian study limited to Melbourne's CBD. In addition, very limited attempts have been made to account for differences in average travel speeds by mode, thereby focusing on flow/movement rather than people concentration, while no studies have explicitly explored factors associated with street space use as part of their analysis. The research underlying this paper therefore seeks to address these gaps using a case study of Melbourne's activity centres.

3. Research method

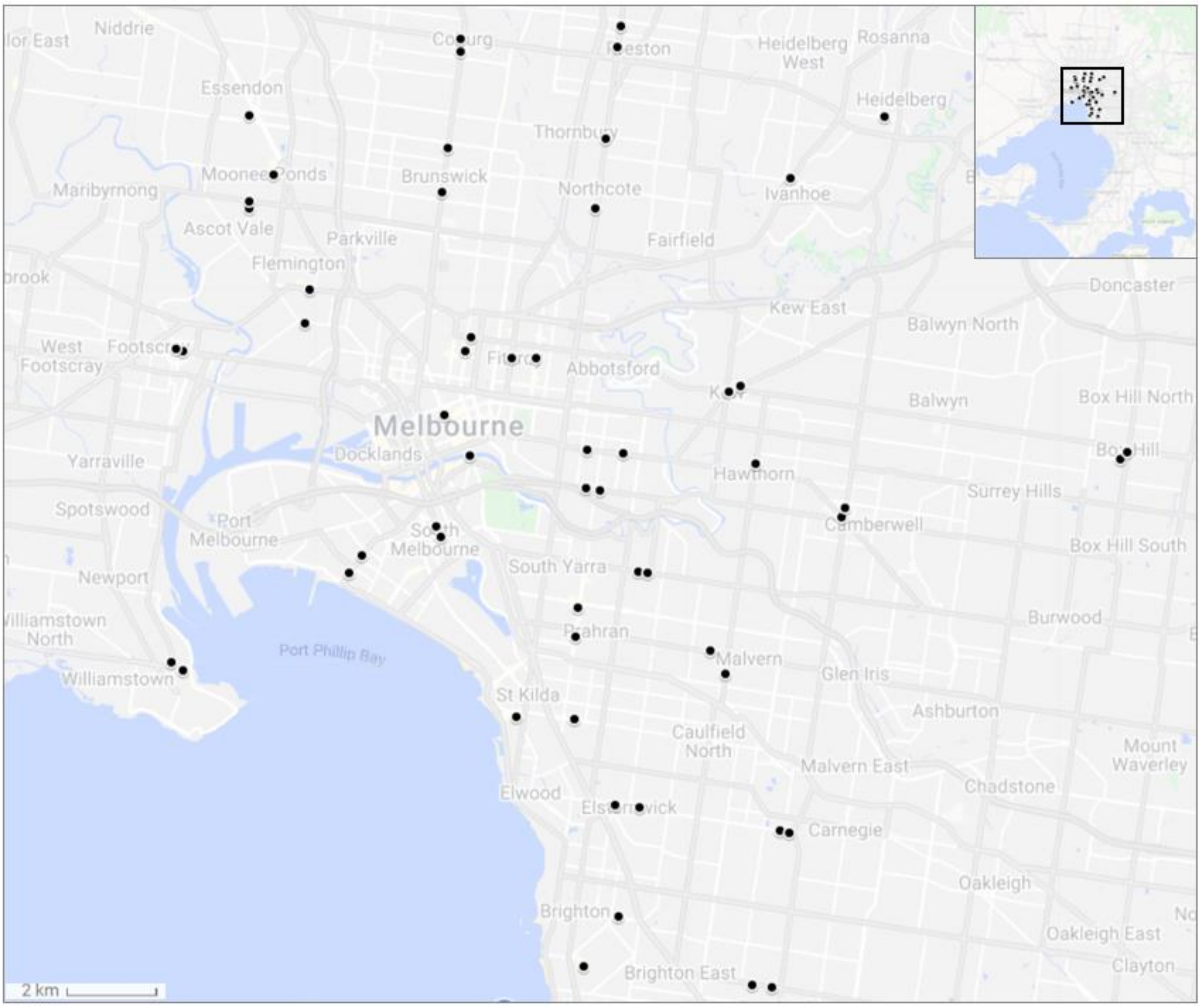
3.1. Site selection

Melbourne's activity centres were used as a sampling frame to select survey sites for the research as these locations tend to experience greater street space allocation challenges (Department of Transport 2019, p. 21). As noted in Melbourne's metropolitan planning strategy, *Plan Melbourne 2017-50*, activity centres are also critical to the creation of 20-minutes neighbourhoods. These are intended to give people the ability to meet most of their everyday needs within a 20-minute walk, cycle or local public transport trip of their home, thereby supporting the concept of ‘local living’ (DELWP 2017).

Melbourne has a total of 120 metropolitan and major activity centres (DELWP 2017). However, it was not possible to survey all of these activity centres with the resources available, so the selection of sites was mainly limited to major activity centres located within 10 km of Melbourne’s Central Business District (CBD), where access by all transport modes tends to be more evident. The site selection process resulted in a total of 36 activity centres.

Depending on the size and diversity of the activity centre, either one or two sites were chosen for surveying. Across all selected activity centres, consideration was given to ensuring a range of street space layouts were represented, including those with and without the following: car parking, clearways, landscaping, bicycle lanes, exclusive general traffic lanes, exclusive tram lanes, plus shared lanes for general traffic, trams and buses. In total, 57 sites were selected for surveying across the 36 activity centres. Figure 1 shows the location of these sites across Melbourne. A list of the sites is provided in Appendix A.

Figure 1: Location of survey sites across Melbourne



Source: map created by authors using Google ‘My Maps’

3.2. Data collection

At each site, multi-modal observational person counts were undertaken by the researchers positioned on the footpath at each site, facing perpendicular to the street. A form was used to separately record the number of people passing an imaginary line (perpendicular to the street) in both directions using the following categories: people in cars, people walking/standing, cars parked, people on bicycles, people on trams, people on buses, people in trucks, people on motorbikes, and other.

At each site, the multi-modal observational person counts were undertaken on weekdays (excluding public holidays) for two separate periods of 45 minutes each, covering peak and off-peak conditions and totalling 1.5 hours per site. This amount of survey time is generally consistent with previous street space allocation studies that have used observational counts (Creutzig et al. 2020a). As some activity centres are not particularly active until late morning (some shops do not open until 10am), the surveys were restricted to afternoon periods only. Survey periods for each site are listed in Appendix A.

While each site could have been surveyed for a longer time period, a trade-off was made between the number of sites covered and the duration of each survey, particularly given the large number of activity centres located across Melbourne. However, to understand how the use of street space changes over the day, the first site (Glenferrie Road, Hawthorn) was surveyed over a continuous 10-hour period (8am-6pm) on a weekday. This showed that average conditions were generally observed in the afternoon period, corresponding to when the surveys for all other sites were undertaken. While these sites were surveyed for only 1.5 hours each in total, over 2,000 people were counted on average at each site over this limited time period, providing a relatively large sample for analysis purposes.

In addition to undertaking counts, the amount of street width (in centimetres) given to each of the following street elements on each side of the road (where present) was recorded using a measuring wheel at each site: footpath, landscaping, car parking, bicycle lane, exclusive general traffic lane, exclusive tram lane, shared general traffic/tram lane, shared general traffic/bus lane, and shared general traffic/tram/bus lane. At some sites, clearways were in place where greater space is given to general traffic and/or cyclists at certain times of the day through prohibiting on-street parking. At these sites, the street measurements were recorded separately for clearway and non-clearway conditions.

The data collection was undertaken from October to mid-December 2020. During this time, Melbourne was subject to various forms of restrictions associated with COVID-19. While a relatively large number of people were counted during the surveys (>2,000 people per site on average), it is not clear how the restrictions may have affected mode shares at each site, in the absence of any equivalent survey data for other (non-restricted) times of the year.

For each site, data related to street and activity centre characteristics were also compiled. Summary statistics are provided in Table 2, including units and sources. Street characteristics were largely determined through site visits, while activity centre characteristics were compiled using GIS and secondary data sources. The activity centre characteristics, while not exhaustive, represent various built environment and socio-demographic factors that have been found in previous research to be associated with travel behaviour (Boulange et al. 2017; De Gruyter et al. 2020; Ewing & Cervero 2010), plus variables that are relevant to planning complete streets (Dehghanmongabadi & Hoskara 2020). It was therefore hypothesised that these factors could also be associated with the use of each transport mode in the activity centres. As can be seen from Table 2, there is much variability in the magnitude of both street and activity centre characteristics across the sites.

Table 2: Summary statistics for street and activity centre characteristics

Characteristic	Units	Source	Range	Mean	Median
Street characteristics					
Footpath	0 = no, 1 = yes	Site visit	1 - 1	1.00	1
Landscaping	0 = no, 1 = yes	Site visit	0 - 1	0.16	0
Car parking	0 = no, 1 = yes	Site visit	0 - 1	0.92	1
Bicycle lane	0 = no, 1 = yes	Site visit	0 - 1	0.30	0
Exclusive general traffic lane	0 = no, 1 = yes	Site visit	0 - 1	0.22	0
Exclusive tram lane	0 = no, 1 = yes	Site visit	0 - 1	0.06	0
Shared general traffic/tram lane	0 = no, 1 = yes	Site visit	0 - 1	0.48	0
Shared general traffic/bus lane	0 = no, 1 = yes	Site visit	0 - 1	0.34	0
Shared general traffic/tram/bus lane	0 = no, 1 = yes	Site visit	0 - 1	0.08	0
Clearway at anytime	0 = no, 1 = yes	Site visit	0 - 1	0.45	0
Clearway during survey period	0 = no, 1 = yes	Site visit	0 - 1	0.16	0
Car parking charges	0 = no, 1 = yes	Site visit	0 - 1	0.22	0
Parking time restriction	mins	Site visit	30 - 120	72.7	60
Posted speed limit	km / hr	Site visit	30 - 60	40.8	40
Tram services	0 = no, 1 = yes	PTV	0 - 1	0.63	1
Bus services	0 = no, 1 = yes	PTV	0 - 1	0.39	0
PT frequency during survey period	Total services / hour	PTV	0 - 84	17.65	14
Movement classification[a]	n/a	DOT	1 - 4	2.53	3
Place classification[b]	n/a	DOT	1 - 4	2.94	3
Activity centre characteristics					
Size of activity centre	ha	GIS	1.7 - 194.0	18.80	10.7
Network distance to nearest train station	m	GIS	52 - 3,510	751.30	510
Network distance to nearest supermarket	m	GIS	15 - 776	189.30	151.5
Network distance to nearest pharmacy	m	GIS	6 - 613	141.60	107.5
Distance to CBD	km	GIS	0.31 - 14.04	6.47	6.11
Car sharing vehicle within 400 metres	0 = no, 1 = yes	Car share websites	0 - 1	0.55	1
Total intersection density	Intersections / sq. km	GIS	59.7 - 224.8	119.30	110.4
4+ way intersection density	Intersections / sq. km	GIS	6.0 - 73.6	26.20	20.9
Employment density in local area[c]	Jobs / sq. km	ABS census	726.3 - 105,024.8	6,438.0	3,856.9
Residential population density in local area[d]	Persons / sq. km	ABS census	320.4 - 16,915.4	4,567.60	4,154.1
Employment + residential population density in local area	Jobs + people / sq. km	ABS census	4,133.4 - 116,023.8	11,005.70	7,388.7
Average car ownership in sub-region[e]	Cars / household	ABS census	0.30 - 1.81	1.32	1.35
Median household income in sub-region[e]	$ / week	ABS census	840.1 - 1,972.3	1,564.0	1,627.2
Average resident age in sub-region[e]	Years	ABS census	28.9 - 44.7	37.9	37.7

Note: PT = public transport; PTV = Public Transport Victoria; DOT = Department of Transport; GIS = Geographic Information System; ABS = Australian Bureau of Statistics.

[a] Movement classifications range from 1 (mass movement of state/national significance) to 5 (local movement only).

[b] Place classifications range from 1 (state/national significance) to 5 (local significance only).

[c] For employment density, local area refers to any Destination Zones (DZNs) from the census that intersect or are within the activity centre. There are 2,352 DZNs across metropolitan Melbourne with a median size of 0.77 km^2.

[d] For residential population density, local area refers to any Statistical Areas Level 1 (SA1s) from the census that intersect or are within the activity centre. There are 10,289 SA1s across metropolitan Melbourne with a median size of 0.15 km^2.

[e] For car ownership, household income and resident age, sub-region refers to any Statistical Areas Level 2 (SA2s) from the census that intersect or are within the activity centre. There are 309 SA2s across metropolitan Melbourne with a median size of 7.7 km^2.

3.3. Data analysis

For each site, the percentage of street space allocated to each mode of transport was estimated from the street measurement data. This was then compared to the percentage of people observed using each mode of transport along the street at each site. Where space was shared among different transport users, such as in shared general traffic/tram lanes, the percentage of street space allocated to that shared space was compared against the percentage of people using each mode of transport available within that shared space. Where clearways were present at a site, the results were analysed separately for clearway and non-clearway conditions. The comparisons of street space allocation vs. use by mode at each site were then used to indicate the extent to which each site was over or under supplied (for lack of a better term) in terms of street space by transport mode. While the term over/under supply is imperfect, the comparison adopted the principle of 'egalitarianism', in which the distribution of street space is considered fair where space is distributed to each mode according to its demand (Lefebvre-Ropars et al. 2021b).

As the counts at each site were based on people flow, this typically resulted in more people being counted in cars than slower modes such as walking, even if more pedestrians could be observed along a street segment than people in cars. To account for differences in travel speeds by mode, a measure of 'concentration' for each mode was estimated based on:

$$k_m = \frac{q_m}{v_{sm}}$$

where k_m = concentration of mode m (people/km), q_m = people flow of mode m (people/hour), and v_{sm} = mean space speed of mode m (km/hr). This is the fundamental transport speed/flow relationship which relates time and space measurements. It is a conversion of the continuity of flow equation ($q = k \times v_s$) (Taylor et al. 2000) and provides a more suitable measure of street space use by mode through estimating the number of people per km at each site. However, as travel speeds were not measured at the sites, a set of average travel speeds by mode were assumed, as detailed in Table 3.

Table 3: Average travel speeds (by transport mode) assumed for analysis purposes

Mode	Average travel speed (km/hr)	Comments	Supporting references
Walk	4.3 km/hr	Generally accepted speed for determining pedestrian walk times in Australia.	Truong et al. (2018)
Bicycle	22.7 km/hr	Average cycling speed measured in Melbourne's activity centres.	Lawrence et al. (2018)
Tram	11 km/hr in central city; 16 km/hr elsewhere	Accounts for on-street (shared space) running, plus delay due to boarding/alighting, congestion and traffic signals.	City of Melbourne (2019b)
Bus	22 km/hr	Accounts for delay due to boarding/alighting, congestion and traffic signals.	Stanley (2011)
Car	75% of posted speed limit	Accounts for delay due to congestion and traffic signals. Average speed ranged from 22.5 – 45 km/hr but was usually 30 km/hr as posted speed limit was 40 km/hr at most sites.	AAA (2018); DOT (2020); Infrastructure Victoria (2020)
Truck	75% of posted speed limit	Assumed to be same as car.	-
Motorbike	75% of posted speed limit	Assumed to be same as car.	-
Parked car	Weighted average of 75% of posted speed limit for time spent travelling 1km and 0 km/hr for time spent parked (assumed to equal 75% of parking time restriction)	Assumed to be same as car when moving and 0 km/hr when stationary (parked). Average speed ranged from 0.7-2.5 km/hr depending on posted speed limit and parking time restriction.	City of Melbourne (2019a)

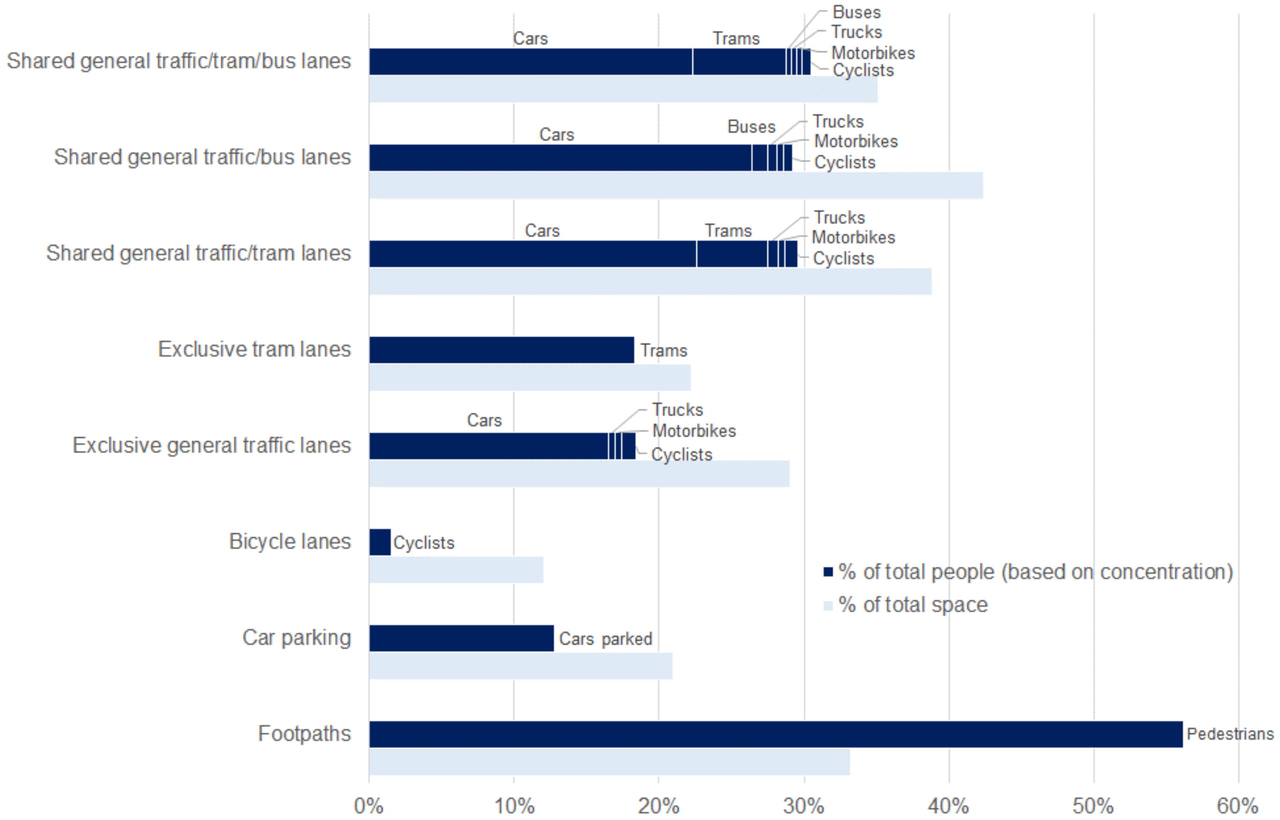
A correlation analysis was then undertaken to explore the association between selected street/activity centre characteristics in Table 2 and the percentage of people using each mode of transport (based on concentration) at each site. As the percentage of people using each mode of transport is a continuous variable, Pearson correlation coefficients were used to indicate the strength of the association with street/activity centre variables that were also continuous. For street/activity centre variables that were categorical, eta coefficients were calculated using SPSS (version 26) to indicate the strength of the association.

4. Results

4.1. Street space allocation vs. use

Figure 2 provides a comparison of street space allocation and use, averaged across all sites. The percentage of total space given to footpaths on average (33%) was far less than the percentage of total people observed using footpaths on average (56%), indicating an undersupply of space for pedestrians (based on the principle of egalitarianism). Exclusive tram lanes were only slightly oversupplied (22% of total space vs. 18% of total people), as were shared general traffic/tram/bus lanes (30% of total space vs. 35% of total people). However, other street elements were greatly oversupplied, particularly bicycle lanes (12% of total space vs. 2% of total people), car parking (21% of total space vs. 13% of total people) and shared general traffic/bus lanes (42% of total space vs. 29% of total people).

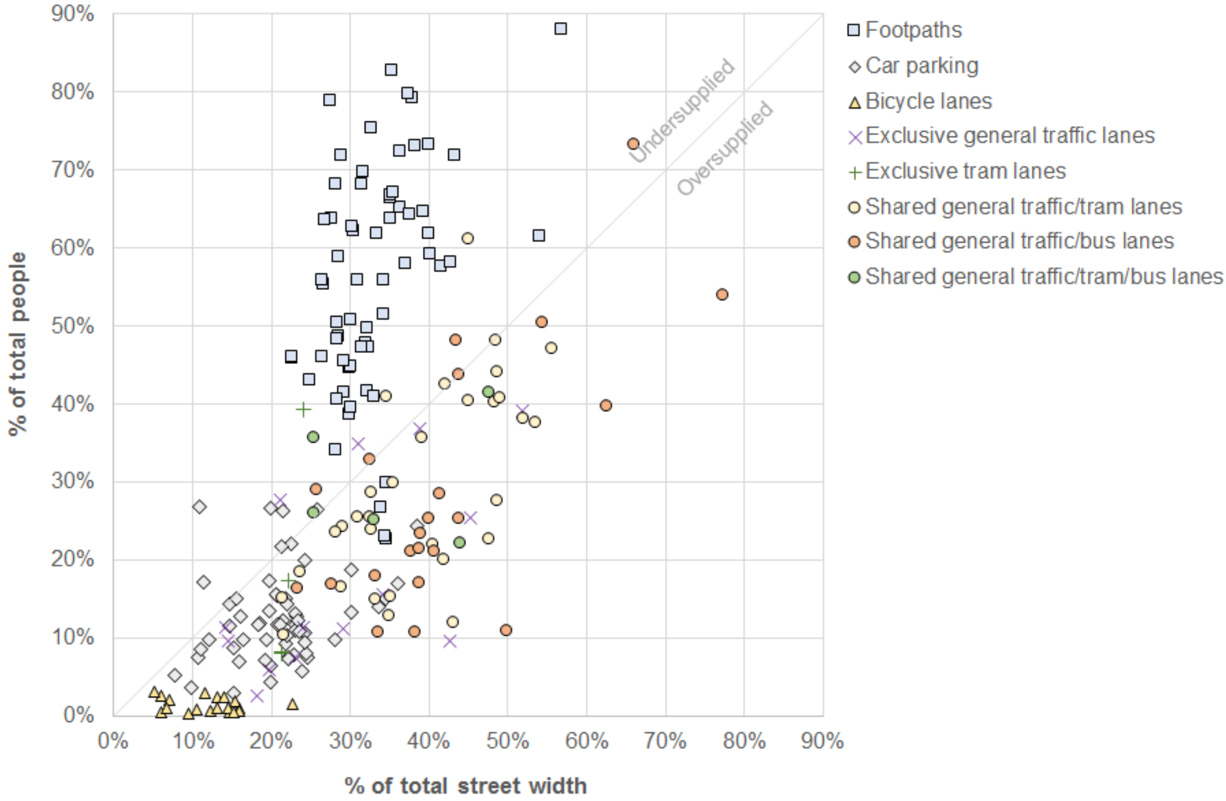
Figure 2: Average street space allocation vs. use across all sites



Note: calculation of averages excludes zero values, e.g. sites where street elements were not present. Percentages therefore sum to greater than 100%.

While Figure 2 provides an indication of the amount of under/oversupply of street elements in the activity centres that were surveyed, based on the principle of egalitarianism, these results represent averages only. Figure 3 presents a comparison of street space allocation and use across individual sites. This highlights considerable variability in street space allocation vs. use for different modes, showing that at some sites, contrary to the average results in Figure 2, space for footpaths is oversupplied while space for car parking and shared general traffic/bus lanes is undersupplied. However, space for bicycle lanes is found to be consistently oversupplied at all sites. Again, it is noted that these results are based on the principle of egalitarianism, in which the distribution of street space is considered fair where space is distributed to each mode according to its demand.

Figure 3: Street space allocation vs. use by street element across individual sites



4.2. Factors associated with use of the street space

Table 4 presents the results of the correlation analysis, highlighting associations between selected street/activity centre characteristics and use of the street space at each site. The results are largely intuitive for each mode of transport. For example, footpath width is positively associated with the percentage of people walking but negatively associated with car and truck use, while bicycle lanes are positively associated with cycling and motorcycling.

Other key results include:

- Clearways are negatively associated with walking and car parking, but positively associated with cycling, car use, motorcycling and tram use
- A higher movement classification, denoting more local movement, is positively associated with walking and car parking, but negatively associated with travel by car, truck, motorcycle, bus and tram
- A higher place classification, denoting a place of less significance, is negatively associated with both bus and tram use
- Activity centres located further from the CBD are negatively associated with cycling, motorcycling and tram use, but positively associated with car parking and bus use
- Activity centres within 400 metres of a car sharing service are positively associated with cycling, motorcycling and tram use, but negatively associated with car parking and bus use
- Local population/employment densities have little association with street space use, yet there is a positive association with tram use and a negative association with car and bus use
- Car ownership in the sub-region is negatively associated with cycling, motorcycling and tram use, but positively associated with car use and car parking
- Income in the sub-region is negatively associated with bus use, while average resident age in the sub-region is negatively associated with cycling and tram use.

Table 4: Correlation analysis between street/activity centre characteristics and percentage of people using each mode of transport

Correlation coefficient[a]	Walk	Bicycle	Car	Car parking	Truck	Motorbike	Bus	Tram
Street characteristics								
Footpath width (m)	0.33 ***	-0.03	-0.33 ***	-0.19	-0.21 *	-0.06	-0.14	0.16
Bicycle lane (0=no, 1=yes)	0.07	0.45 ***	-0.13	-0.13	-0.12	0.21 *	-0.15	0.20
Exclusive general traffic lane (0=no, 1=yes)	-0.03	0.18	0.01	-0.22 *	0.01	0.09	-0.27 **	0.29 **
Clearway during survey period (0=no, 1=yes)	-0.32 **	0.34 ***	0.41 ***	-0.43 ***	0.13	0.22 *	0.19	0.29 **
Car parking charges (0=no, 1=yes)	-0.18	0.14	0.13	0.09	-0.01	0.29 **	0.20	-0.01
Tram services (0=no, 1=yes)	-0.07	0.26 **	-0.06	-0.18	0.05	0.20	-0.60 ***	0.52 ***
Bus services (0=no, 1=yes)	-0.07	-0.09	0.18	0.05	-0.02	-0.16	0.54 ***	-0.32 **
PT frequency during survey period (services/hour)	-0.24 *	0.19	0.15	-0.41 ***	0.12	0.22 *	0.31 **	0.64 ***
Movement classification[b]	0.39 **	-0.25	-0.37 **	0.44 ***	-0.39 **	-0.32 *	-0.47 ***	-0.57 ***
Place classification[c]	0.15	-0.21	0.26	0.30	0.19	-0.18	0.64 ***	-0.75 ***
Activity centre characteristics								
Size of activity centre (ha)	0.01	0.23 *	-0.23 *	-0.27 **	-0.10	0.07	-0.10	0.75 ***
Network distance to nearest train station (m)	-0.04	0.14	0.05	0.00	-0.02	0.03	-0.16	-0.03
Network distance to nearest supermarket (m)	-0.27 **	0.17	0.23 *	0.04	0.13	0.26 **	0.08	0.08
Network distance to nearest pharmacy (m)	-0.38 ***	0.43 ***	0.27 **	0.08	0.16	0.48 ***	-0.07	0.18
Distance to CBD (km)	-0.02	-0.45 ***	0.11	0.27 **	-0.08	-0.25 **	0.51 ***	-0.46 ***
Car sharing vehicle within 400 m (0=no, 1=yes)	0.21	0.42 ***	-0.19	-0.41 ***	0.03	0.30 **	-0.28 **	0.31 **
Total intersection density (intersections / sq. km)	0.14	0.40 ***	-0.12	-0.14	-0.02	0.39 ***	-0.20	0.02
4+ way intersection density (intersections / sq. km)	0.24 *	0.26 **	-0.27 **	-0.13	-0.16	0.10	-0.21 *	0.13
Employment density in local area (jobs / sq. km)	0.14	0.05	-0.20	-0.15	-0.15	0.09	0.04	0.24 *
Residential population density in local area (persons / sq. km)	0.17	0.20	-0.19	-0.04	-0.06	0.09	-0.32 **	0.03
Employment + residential population density in local area (jobs + people / sq. km)	0.16	0.08	-0.22 *	-0.15	-0.15	0.10	-0.02	0.23 *
Average car ownership in sub-region (cars / household)	-0.17	-0.49 ***	0.26 **	0.30 **	0.10	-0.36 ***	0.05	-0.40 ***
Median household income in sub-region ($ / week)	-0.11	-0.05	0.10	0.09	0.06	-0.14	-0.49 ***	0.02
Average resident age in sub-region (years)	-0.12	-0.35 ***	0.20	0.16	0.14	-0.15	-0.09	-0.27 **

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

[a] Pearson correlation coefficients are quoted for street/activity centre characteristics that are continuous with a t-test used to indicate statistical significance; eta coefficients are quoted for street/activity centres characteristics that are categorical with a one-way ANOVA test used to indicate statistical significance. Signs for eta coefficients were derived through visual comparisons of means across categories.

[b] Movement classifications range from 1 (mass movement of state/national significance) to 5 (local movement only).

[c] Place classifications range from 1 (state/national significance) to 5 (local significance only).

5. Discussion and conclusions

Using a case study of Melbourne's activity centres, the aim of the research underlying this paper was to understand how much street space is allocated and used by each mode of transport, and to explore factors that are associated with the use of each mode of transport.

Key results showed that on average, based on the principle of egalitarianism, pedestrian space in the form of footpaths was significantly undersupplied, while bicycle lanes, car parking and shared general traffic/bus lanes were greatly oversupplied. However, when viewed across individual sites, considerable variability was found in street space allocation vs. use. These results contrast previous street space allocation studies, where the amount of space for pedestrians was generally similar to, or exceeded, the amount of people walking (Lefebvre-Ropars et al. 2021a; Nello-Deakin 2019) – the exception to this being a previous study undertaken in Melbourne's Central Business District (CBD) were footpath space was significantly undersupplied (Daly 2018). Previous studies also found that space for cyclists was undersupplied (Creutzig et al. 2020b; Gössling et al. 2016; Nello-Deakin 2019), contrasting the finding from this research in which the average mode share for cycling was only 2%.

The results from this research also showed a number of street/activity centre characteristics that were associated with use of the street space by mode. Among others, these included footpath width, clearways, movement and place classifications, distance to the CBD, presence of car sharing, car ownership, income and age. These characteristics are consistent with previous research that has assessed the influence of built environment and socio-demographic factors on travel behaviour (Boulange et al. 2017; De Gruyter et al. 2020; Ewing & Cervero 2010), plus variables relevant to planning complete streets (Dehghanmongabadi & Hoskara 2020).

There are three key implications arising from this research. First, street space for pedestrians could be increased in many of the activity centres that were surveyed, potentially through conversion of existing on-street car parking, as is the case with 'parklets' (City of Melbourne 2020). While space for bicycle lanes was found to be oversupplied, caution would need to be taken in reducing or eliminating cycling facilities as this would not necessarily progress a sustainable transport agenda (Nello-Deakin 2019). Any reallocation of space would of course also need to be considered against minimum width requirements for different modes of transport. Second, various street/activity centre characteristics that were shown to be associated with use of the street space by more sustainable transport modes (e.g. walking, cycling, public transport) should be encouraged and planned for where possible. Third, the use of averages to denote street space allocation and use across sites should be avoided as these can mask differences found at individual sites where changes to street space allocation may be implemented in practice. This is not to discredit previous studies that quote average (city-wide) results, but rather to highlight the importance of considering the local context.

The contribution of this research is an understanding of street space allocation and use, specifically in activity centres where movement and place objectives are often in conflict with one another. As part of this, the research accounted for differences in travel speeds by mode through using a measure of concentration, rather than flow, and also shed light on factors associated with use of street space. However, this research is not without limitations. The surveys were undertaken at a limited number of sites during limited time periods, including during COVID-19 restrictions. Also, while informed by previous studies, the analysis assumed an average travel speed for each mode, rather than directly measuring speeds at the sites. In addition, the correlation analysis was limited to bivariate comparisons and therefore did not include any regression analysis to control for other variables, while noting the relatively small sample of sites. Future research should seek to address these limitations where possible.

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Appendix A: List of survey sites

ID	Activity centre	Survey location	Survey date	Survey period 1	Survey period 2
1	Hawthorn	667 Glenferrie Road	1/10/2020	8:00am - 6:00pm	-
2A	Kew Junction	210 High Street	6/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
2B	Kew Junction	146 High Street	6/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
3A	Camberwell Junction	206 Camberwell Road	7/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
3B	Camberwell Junction	795 Burke Road	7/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
4A	Box Hill	Opposite 35A Carrington Road	8/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
4B	Box Hill	605 Station Street	8/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
5A	Malvern/Armadale	1125 High Street	13/10/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
5B	Malvern/Armadale	177 Glenferrie Road	13/10/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
6A	Toorak Village	451 Toorak Road	14/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
6B	Toorak Village	533 Toorak Road	14/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
7A	Prahran	473 Chapel Street	15/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
7B	Prahran	137 Chapel Street	15/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
8A	Richmond	170 Swan Street	20/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
8B	Richmond	258 Swan Street	20/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
9A	Richmond	185 Bridge Road	21/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
9B	Richmond	415 Bridge Road	21/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
10A	Bentleigh	464 Centre Road	22/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
10B	Bentleigh	358 Centre Road	22/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
11A	Brighton	76 Church Street	27/10/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
11B	Brighton	327 Bay Street	27/10/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
12A	Glen Huntly	1134 Glen Huntly Road	28/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
12B	Glen Huntly	1190 Glen Huntly Road	28/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
13A	Elsternwick	481 Glen Huntly Road	29/10/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
13B	Elsternwick	324 Glen Huntly Road	29/10/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
14A	Balaclava	262 Carlisle Street	4/11/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
14B	St Kilda	99 Acland Street	4/11/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
15A	South Melbourne	270 Clarendon Street	5/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
15B	South Melbourne	338 Clarendon Street	5/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
16A	Port Melbourne	245 Bay Street	10/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
16B	Port Melbourne	67 Bay Street	10/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
17A	Melbourne	Middle of Princes Bridge	11/11/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
17B	Melbourne	St Francis Church, Elizabeth Street	11/11/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
18A	Carlton	249 Lygon Street	12/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
18B	Carlton	181 Elgin Street	12/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
19A	Fitzroy	201 Brunswick Street	17/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
19B	Fitzroy	261 Smith Street	17/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
20A	Brunswick	317 Sydney Road	18/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
20B	Brunswick	649 Sydney Road	18/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
21A	Coburg	409 Sydney Road	19/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
21B	Coburg	87 Bell Street	19/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
22A	Thornbury	687 High Street	24/11/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
22B	Northcote	243 High Street	24/11/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
23A	Preston	437 High Street	25/11/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
23B	Preston	303 High Street	25/11/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
24A	Heidelberg	120 Burgundy Street	26/11/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
24B	Ivanhoe	189 Upper Heidelberg Road	26/11/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
25A	Footscray	132-134 Hopkins Street	1/12/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
25B	Footscray	166-168 Barkly Street	1/12/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
26A	Flemington	329 Racecourse Road	2/12/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
26B	Kensington	503 Macaulay Road	2/12/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
27A	Ascot Vale	191 Union Road	3/12/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
27B	Ascot Vale	103 Maribyrnong Road	3/12/2020	2:00pm – 2:45pm	4:30pm – 5:15pm
28A	Essendon	Opposite 41 Rose Street	8/12/2020	1:00pm – 1:45pm	2:00pm – 2:45pm
28B	Moonee Ponds	85 Puckle Street	8/12/2020	3:30pm – 4:15pm	4:30pm – 5:15pm
30A	Williamstown	19-21 Douglas Parade	10/12/2020	1:00pm – 1:45pm	3:30pm – 4:15pm
30B	Williamstown	27 Ferguson Street	10/12/2020	2:00pm – 2:45pm	4:30pm – 5:15pm