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Multi-Scalar Mapping of Transit-Oriented Assemblages
Metropolitan Mobilities, Neighbourhood Morphologies and Station Design

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Keywords: Multi-scalar mapping, transport network, urban morphology, walkable access.

Abstract: With the vast expansion of cities enabled by motorised transport, the conjunction between metropolitan and neighbourhood mobilities has attracted increasing attention in transport and urban research. Within these fields, transit-oriented urbanism has become a key paradigm for environmentally sustainable, healthy and creative environments. While the importance of urban design has been acknowledged, research has generally focused on exploring correlations between metrics of built form characteristics and transport, health or environmental outcomes. However, many of these metrics are not capturing the spatial complexity of actual urban forms and are poor proxies for capacities for movement. Urban morphological studies on the other hand, while exploring historical change at neighbourhood scale with spatial precision through mapping, often neglect the importance of metropolitan transport networks. Based on case studies from Chicago and Melbourne, this research is seeking to bridge the gap between micro-, meso- and macro-scalar urban morphological studies, by focusing on metro stations as the inter-scalar interfaces between walkable neighbourhoods and rapid transit networks. In this pursuit, new mapping methods for capturing capacities for movement at multiple scales are developed. It is shown that urban mobilities are mediated by the complex assemblage of station architecture, neighbourhood form and the metropolitan transit network.

1. Introduction

As a result of rapid global urbanisation and urban expansion throughout the last century, now more than a quarter of the global population is living in cities with populations of over half a million.[1] In such large urban agglomerations, everyday social interaction is highly reliant on mechanised mobilities, including tram, train/metro, bus and car. At the same time urban sociality and economic productivity still rely on face-to-face interaction in public space (Sennett, 2007; Storper & Venables, 2004). Thus the multi-scalar relationship between local and metropolitan mobilities is becoming an increasingly important aspect of 21st century urbanisation. In this context, transit-oriented development (TOD) has emerged as a key urban paradigm (Calthorpe, 1993) and field of research for environmentally sustainable, healthy and creative

1. United Nations. (2016) The World's Cities in 2016 – Data Booklet.

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neighbourhoods. In TOD approaches the premise is that dense, mixed-use and well-connected neighbourhoods around transit nodes support walking, while also harnessing the economies of scale of large metropolitan agglomerations (Salat & Ollivier, 2017).

Within urban planning TODs have become a key policy aim with an emphasis on rail transport and land use mix, scheduling of transit services, and development mechanisms. This has been reflected in metropolitan plans such as Melbourne's '20-minute City' or Perth's 'Network City'. In streetlife studies, an area of investigation is the role of public transport stations as major attractors of pedestrian flows. The mechanical rhythms of public transport can be a key component of place-specific polyrhythms (Pafka, 2017). Thus the spatial distribution of transport stations is also important in understanding everyday rhythms of streetlife.

Much of the scholarly literature on transit-oriented design to date has been focused on exploring correlations between metrics of built form characteristics and measures of active transport, human health or carbon emissions (Cervero & Kockelman, 1997; Frank *et al.*, 2005; Newman *et al.*, 2009). However, often such metrics are based on highly simplified abstractions of built form, rather than being direct measures of urban morphology. Previous studies have shown that many of these metrics, including within space syntax approaches, are poor proxies for actual urban morphologies and capacities for movement (Pafka & Dovey, 2017; Pafka *et al.*, 2020), and that walkability is a multi-dimensional spatial property that cannot be reduced to simple indices (Dovey & Pafka, 2019). Urban morphological studies on the other hand, have been focused on capturing with spatial precision historical change at neighbourhood scale (Moudon, 1994), and generally without close examination of metropolitan transport (Vance, 1990).

Thus the main aim of this research is to bridge the gap between urban morphological studies and transport research, by focusing on transit nodes as the inter-scalar interfaces between the walkable neighbourhood and the metropolitan rapid transit network. While this multi-scalar aspect of stations as 'global' nodes as well as 'local' places has been previously recognised (Bertolini & Spit, 1998), multi-scalar urban transit research is still in incipient stages (Dovey & Woodcock, 2014). Thus this research aims to advance our understanding of multi-scalar access, by examining the nexus between metropolitan rapid transit networks, station design and neighbourhood morphologies. We seek to understand to what extent the complex assemblage of network configuration, neighbourhood morphology and station design can impact on mobilities in the 21st century.

2. Multi-scalar assemblage approach

The conceptual framework is assemblage thinking as an integrative multi-disciplinary approach that avoids reductionism to the confines of any single discipline or research method (Dovey & Pafka, 2016). Such an approach is inherently multi-scalar, but hasn't been yet sufficiently explored (DeLanda 2006; 2016). In recent years assemblage thinking has been increasingly applied to urban mobilities at a conceptual level (Jensen, 2014; Kärrholm *et al.*, 2017) and also in empirical spatial analysis (Dovey & Woodcock, 2014; Duric, 2017). It has been also argued that the relationships and liaisons between spatiality and sociality are key to understand how a transit node works, as well as to explore the capacity of a transit node to produce urban intensification (Peimani, 2017). Such an understanding is also geared to a multi-disciplinary analysis, interrogating the ways in which shaping of urban morphology and public spaces at neighbourhood scale is connected to metropolitan rapid flows at larger scales.

Understanding transit-oriented assemblages is also reliant on making the distinction between actual and possible interrelations at multiple scales of both space and time. This relationship between actual/material and possible/emergent is laced throughout transit urbanism. To put it differently, rather than only studying existing objects or relationships, it is important to make sense of the yet to be realized connections. In this sense, mapping has been outlined as an abstraction that has the capacity to unravel what DeLanda (2006) calls 'real virtuality', which is a reality that has not been actualised yet. In effect, while the 'thick description' of the connections that have assembled transit nodes is important, it is also important to focus on the space of possibilities that are associated with latent capacities. In this way, mapping has an agency to produce a kind of spatial knowledge (Dovey *et al.*, 2017) which can be interrogated to explore the space of possibilities for the existing transit-related problems and embodied capacities for transformations. To explore the space of possibilities here can become a particular line of inquiry in both theory and practice where built environment professions can benefit from the process of 'design as research' (Kamalipour & Peimani, 2015).

Hence in this research we have developed new methods of mapping spatial data of street and rail networks, in conjunction with population densities and station use. We relied on transport patronage and census data for the metropolitan scale, cadastral maps for morphological analysis, and satellite imagery and street view for the station scale. We chose case studies that have simple mono-centric tree-like rail transport networks, where network effects are limited to the central node and branch bifurcations, and thus allow a focus on neighbourhood morphologies. For comparability of station usage across different cities, we selected large cities and metropolitan agglomerations with 1-5 million inhabitants, a size category comprising over 500 cities globally with over 13% of global population.[2] The final selection criteria was the availability of up-to-date reliable data. While our investigation included Stockholm, Chicago and Melbourne, in this paper we are presenting only the latter two, which are the most car dependent and where transit improvement has the potential of leading to the greatest urban transformation.

3. Metropolitan transit

As a first step towards understanding transit-oriented urban assemblages, we have retrieved the statistical data of railway station entries and exits,[3] to identify stations with high usage outside the city centre. The data for each station was ranked for each metropolitan area, then divided into septiles and mapped using a light to dark gradient (Figure 1). A typical condition of high usage we noted was at the bifurcation of branches, which may be in part due to the higher frequencies and interchange usage. We have excluded these from detailed analysis, to allow a focus on neighbourhood morphologies. Then using satellite and street view imagery we examined the stations outside the CBD with exceptionally high usage. We found that many of these highest use stations were in very low-density environments, but well connected to a bus interchange, a large car park, or a combination of the two.

A first finding at metropolitan scale is that in these car-dependent cities, the stations with the highest usage tend to be those that have an extended catchment enabled by other motorized transport modes, such as bus or car. In Chicago bus interchanges are more prevalent, while in

2. United Nations. (2016) The World's Cities in 2016 – Data Booklet.
3. Chicago Transit Authority (2017) Annual Ridership Report 2016, www.transitchicago.com, accessed 31 October 2018. Public Transport Victoria (2015) Passenger Activity by Metropolitan Station, www.ptv.vic.au, accessed 31 October 2018.

Melbourne there are also a large number of park-and-ride interchanges. The stations with such facilities often attract more potential drivers. Interchanges with high patronage often appear at end of lines and mid-way between the CBD and network end. Thus in these cities, rail infrastructure is to a significant extent supporting the mobilities of suburban dwellers, rather than simply being a driver of urbanisation. The implication is that an uncritical assumption that investment in rail automatically leads to more sustainable urban forms is problematic. Rather a more nuanced understanding of the conditions under which synergies between metropolitan rail transport and urban neighbourhoods emerge is required.

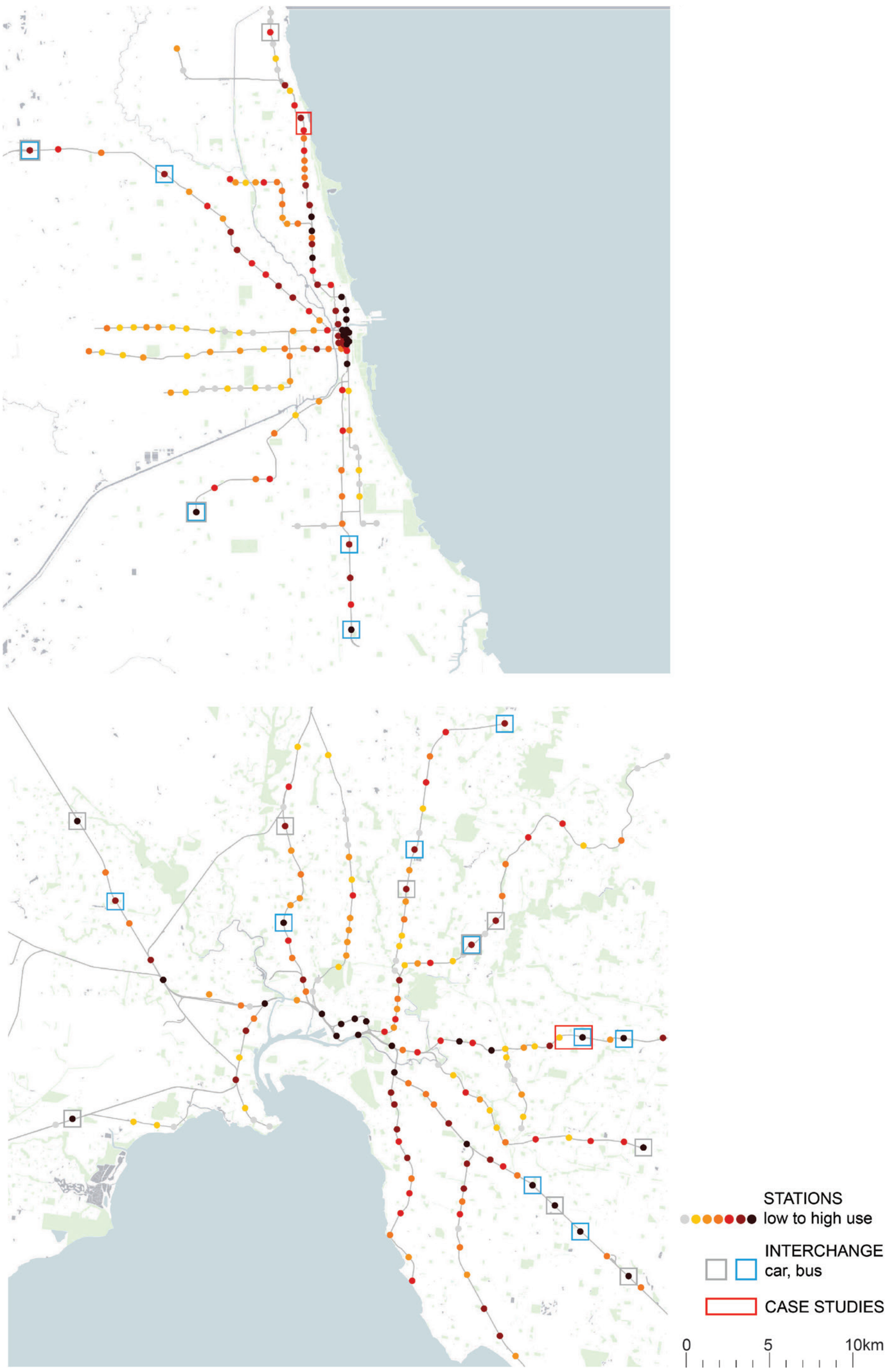

Figure 1. *Railway stations in Chicago and Melbourne by passenger patronage.*

4. Walkable catchment densities

Metropolitan-scale studies of transport and urban form attributes have long identified a general relationship between population densities and public transport patronage (Newman *et al.*, 2009). Yet the empirical evidence so far relied on administrative and statistical areas of variable sizes, which can heavily bias the results (Dovey & Pafka, 2014). Thus in this study we used a regular grid cell of 1x1km as reference area to analyse residential densities across the metropolitan area. The population data has been extracted from fine-grain census data at the level of census blocks[4] and mesh-blocks.[5]

The residential densities of Chicago and Melbourne have been mapped within a consistent frame of 40x40km, using a base-scale of 1x1km (100 hectares) roughly corresponding to walkable neighbourhoods (Figure 2). The maps show non-urban densities (below 5p/ha) in white and suburban densities (below 50p/ha) in light grey. The gradients of grey darken as densities increase from 50 to 150p/ha typical of row-housing and low-rise or scattered apartment buildings, and then darken further above 150p/ha in higher-density neighbourhoods. Both Chicago and Melbourne are dominated by suburban sprawl (below 50p/ha), with only few patches of higher densities of 100-200p/ha, and no areas with densities over 200p/ha.

The walkable densities shown here capture the patchwork of different neighbourhoods that form the metropolis, bringing together the territorial reach of walking and motorised transport. The densities of 100-hectare grid cells are relevant to capacities for face-to-face encounter, but also to transit station catchments. Residential densities in Chicago follow a mono-centric and radial pattern, while in Melbourne a mono-centric pattern with some gaps around it due to large parklands between the central city and the inner suburbs.

The use of overlayered mapping here provides indication of whether differences in transit station use are correlated with residential densities (Figure 2). In Chicago the clusters of high usage along the northern lines converge with the clusters of higher residential densities. In Melbourne the convergence between higher residential densities and higher station use is concentrated in the CBD and along the south-eastern line. The more one gets further away from the CBD, the less noticeable any increase in residential densities around high-use stations. At the same time, in both cities, within the low-density suburban areas there are significant fluctuations from low to high station use. As discussed in the previous section, much of this can be explained by modal interchanges rather than local densities and morphologies. In the following section we will examine cases where the increased station use did not appear to be simply a result of such interchanges, but instead local morphologies may be a contributing factor for high station usage.

5. Station access

To explore the role of neighbourhood morphologies and station design on railway use, we have selected pairs of stations in each city, with a large gap in patronage between consecutive stations, and that also stood out from the metropolitan patterns related to residential densities described in the previous section. In this paper we present one such pair from each city. In Chicago we focus on two elevated stations: Loyola with a weekly patronage of 34,000 people en-

4. US Census Bureau (2010) Census, https://www.census.gov/, accessed 31 October 2018.
5. Australian Bureau of Statistics (ABS) (2016) Census of Population and Housing, http://www.abs.gov.au/, accessed 31 October 2018.

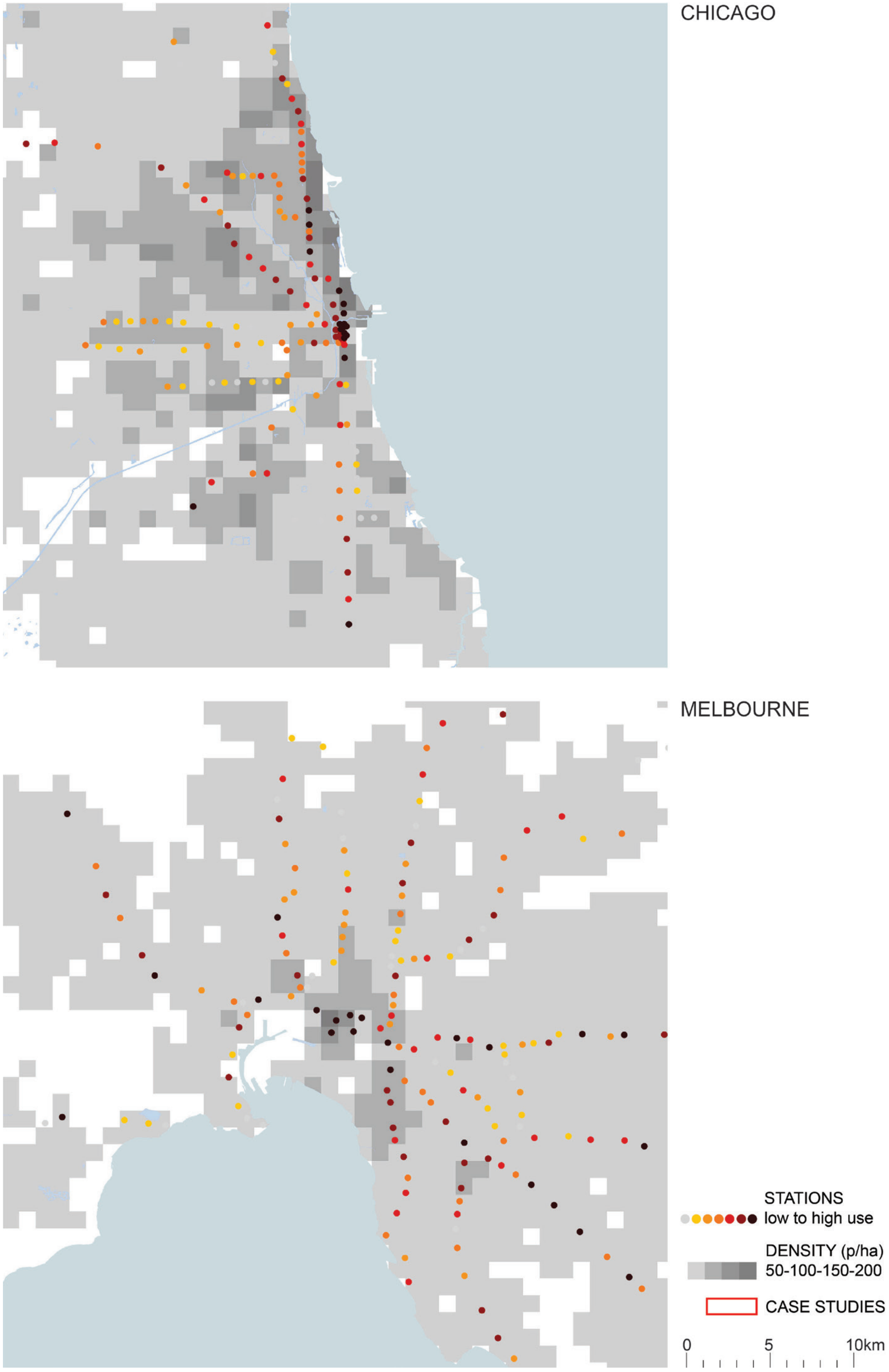

Figure 2. *Railway station patronage and residential densities.*

tering and existing the station, and Granville with a patronage of 26,000 despite being located closer to the CBD. In Melbourne we focus on the underground station at Box Hill with a weekly patronage of 66,600 and Mont Albert, a station at grade, with tenfold lower patronage of 6,500 despite its location closer to the CBD. At this stage of the research we have only focused on the vertical access configuration of the railway stations. The vertical location of stations in relation to their associated streets (i.e. the extent to which the station is well connected to the surrounding street network) have a significant impact on pedestrian access and potential for higher-density redevelopment (Dovey & Woodcock, 2014). In Chicago the elevated platforms at both case study stations allow direct access to the street via escalators and lift. At Box Hill the access is through the internal lanes of the shopping mall, which we included in the mapping of the area, as in a Nolli map. At Mont Albert access to the north is through an underpass, which was accounted for by subtracting the length of the ramps from the overall walking distance threshold of 400m.

We analysed the neighbourhood around each station according to the capacity of the urban morphology to allow through movement and attract to-movement (Figure 3). The measures of these properties are the area-weighted average perimeter (AwaP) of urban blocks for access through the urban fabric, also known as permeability, and interface catchment (IC) for access to potential attractors, as developed by Pafka & Dovey (2017). Jacobs' principle of short blocks, often expressed as a rule of thumb for urban blocks to be shorter than 100m in length, corresponds to an AwaP of 400m. Higher AwaP scores indicate a lower permeability. The area-weighting based average of block perimeters accounts for the major effect a single large block can have on the permeability of a neighbourhood. Interface Catchment measures the total length of public/private interfaces, within a given walking distance. The total length of interfaces relates to the capacity of the urban fabric to incorporate a mix of attractors, such as entries to various buildings with various functions. Combined AwaP and IC can distinguish between traditional central-city morphologies with high-permeability and high catchment, labyrinthine morphologies with low-permeability and high catchment, modernist morphologies with high-permeability and low catchments, cul-de-sac suburbs with low permeability and low catchment.

The mapping and measures have been calculated in QGIS with the AwaP and IC plugins developed by Majic & Pafka (2019). These plugins use innovative algorithms that empower urban morphological analysis with the computational capacity of GIS. The interface catchment has been calculated for a 400m walking distance, calculated from the middle of the platform. While the interface catchment takes various spatial configurations for each station, the cumulative length for each station is remarkably similar, around 10,000m, with variations of 10% only. On the other hand permeability varies more significantly. The highest permeability is around Loyola with an AwaP of 571m, followed by Granville with 644m. Both Melbourne case studies have very poor permeability, with AwaP of 800m and 740m. Thus the significant differences in patronage between these two pairs of adjacent stations are not linked to street network, and as shown previously neither to residential density.

Walkability is however a more complex property that emerges from the synergies between density, mix and access (Dovey & Pafka, 2020). Looking at functional mix the major differences between the railway stations become apparent. In Chicago the area around Loyola station incorporates a university campus, while Granville only has a small local shopping street. In Melbourne the Box Hill station is at the core of a shopping mall which is connected to two short retail streets, while Mont Albert only has a small local shopping strip. Thus the differences in station patronage seem to have less to do with station design or neighbourhood street configuration, but rather with the regional attractors (university and mall) located next to the station.

6. Discussion

In this research we aimed to better understand transit-oriented assemblages in large metropolitan areas. Our approach was informed by assemblage thinking and involved a multi-scalar exploration of mobilities at metropolitan, neighbourhood and station scale. We developed new mapping methods to capture station usage and neighbourhood capacities of movement in metropolitan areas. While one of our key goals was to uncover emergent transit-oriented neigh-

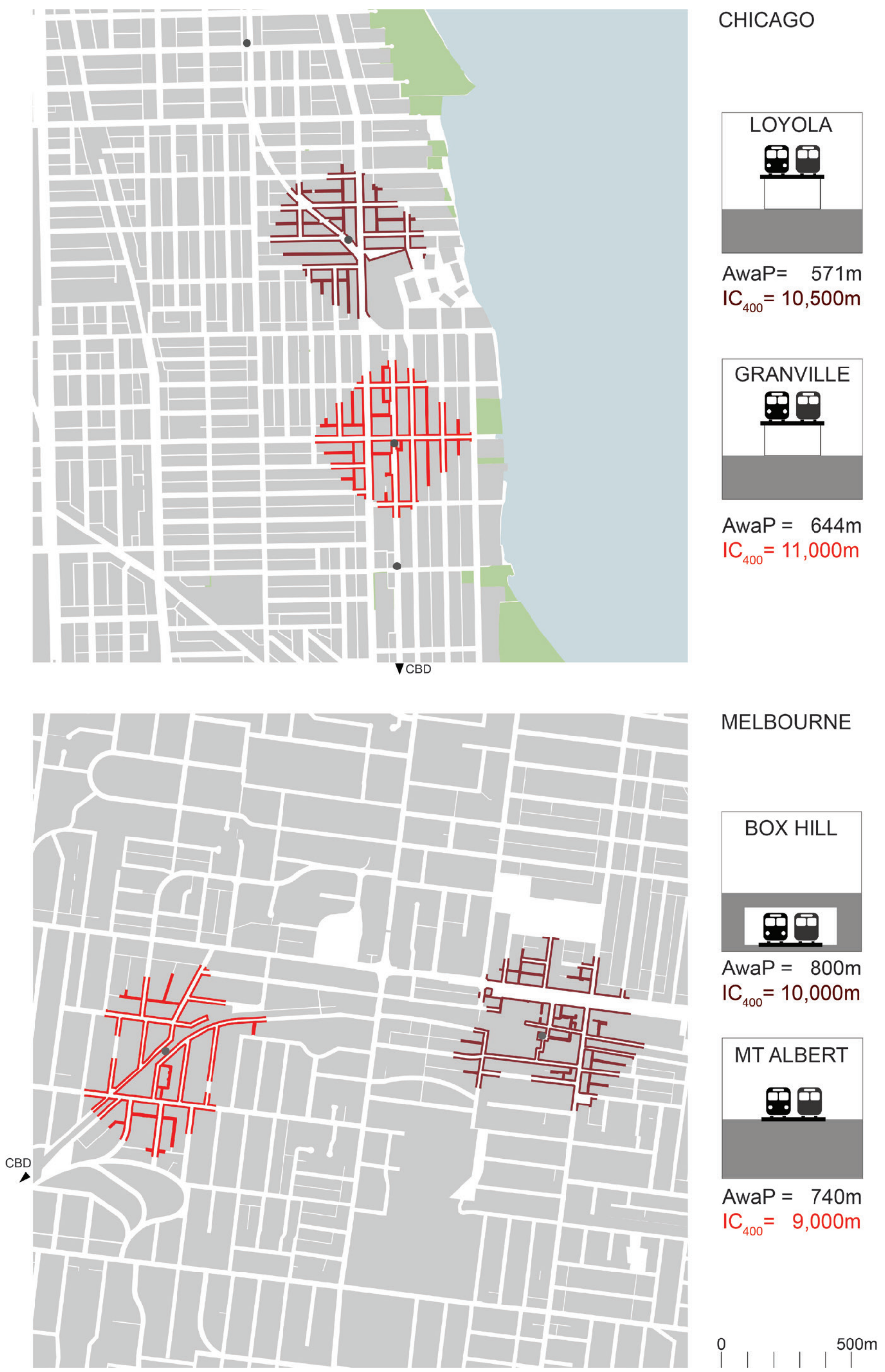

Figure 3. *Walkable access of railway stations.*

bourhoods as envisioned in the literature (Bertolini & Spit, 1998; Calthorpe, 1993; Dovey & Woodcock, 2014) we haven't discovered any station area that would neatly fit the TOD model. Instead we found that many non-CBD stations with high levels of patronage are either linked to bus or park-and-ride interchanges, and thus support suburban mobilities within car-dependent cities. In the few exceptions where the high station patronage could not be simply linked to extended catchment through other motorised transport modes, we found regional or metropolitan scale attractors, such as university campuses or shopping malls located in close proximity of stations.

In our multi-scalar analysis of station patronage we found three key factors for high usage: (1) the necessity to pass through the station in order to get somewhere else, as in the case of a bus, car or train interchange (i.e. station acts as a multi-modal hub), (2) the desires and needs of residents in high-density residential areas to access other functions of the city and leave their neighbourhoods, and (3) the desire to access a key visit or work attractor located within walking distance of the station, such as a CBD, university campus, shopping mall or stadium. The two stations with higher use we focused on in this paper fall in multiple categories. In the case of Loyola in Chicago, the station is next to a university campus as a work destination, while it is also within a higher-density residential area. In the case of Box Hill in Melbourne, the shopping mall on top of the station is a key regional visit destination, while there is also a major bus interchange above it. Most stations with high use outside the CBD we found in these car-dependent cities are seemingly dull places that serve utilitarian purposes only, such as interchange, mono-functional residential or work district, or an occasional major attraction such as a stadium. However, high station usage in some cases can be related to a more intensive place of encounter, when it is part of a mixed-use neighbourhood, with visitor attractions as well as higher-density residential spaces.

The effective integration of private shopping malls with their suburban hinterlands has been considered as multimodal transit hubs embodying potentials for transit-oriented intensification within low-density car-dependent cities particularly those that characterise North America and Australia. Hence, there is no prospect of simply wishing them away. However, different forms of shopping malls considering their associated morphologies (e.g. permeability within the malls, connection to the surrounding street network and local neighbourhood, connection to the large car parks) as well as their multi-modal nature can be further investigated to better understand the extent to which such major attractors can encourage or constrain transit-oriented urbanism. This is also linked to the question of how to leverage such developments (e.g. shopping malls) to fund better public transport connections.

The diagrammatic representation of the metropolitan organisation of rail, bus, park-and-ride catchments in Chicago and Melbourne (Figure 4) shows how their spatial logic is linked to the simple radial network structure. The further the rail station from the centre, the bigger the gap to the next rail branch, and the greater the opportunity for radial bus connections to increase the catchment of a station. Once a station is designed to accommodate a bus-interchange, multiple bus routes can be directed to that station, covering the metropolitan interstices between the rail branches.

This research advances methodological tools for a multi-scalar understanding of the neighbourhood morphology – station design – transport network nexus, contributing to a novel approach to studying urban mobilities. Innovative methods of mapping and diagramming multi-scalar mobilities have been developed. We hope that these methodological tools can help advance urban research across disciplinary boundaries, bridging between morphological and transport studies. Such an endeavour will require a non-reductionist approach that includes the broader assemblage of urban elements at multiple scales. It also requires a socio-spatio-temporal thinking, that avoids the pitfalls of reductionism in the pursuit of capturing urban phenomena with ever greater precision.

7. Acknowledgement

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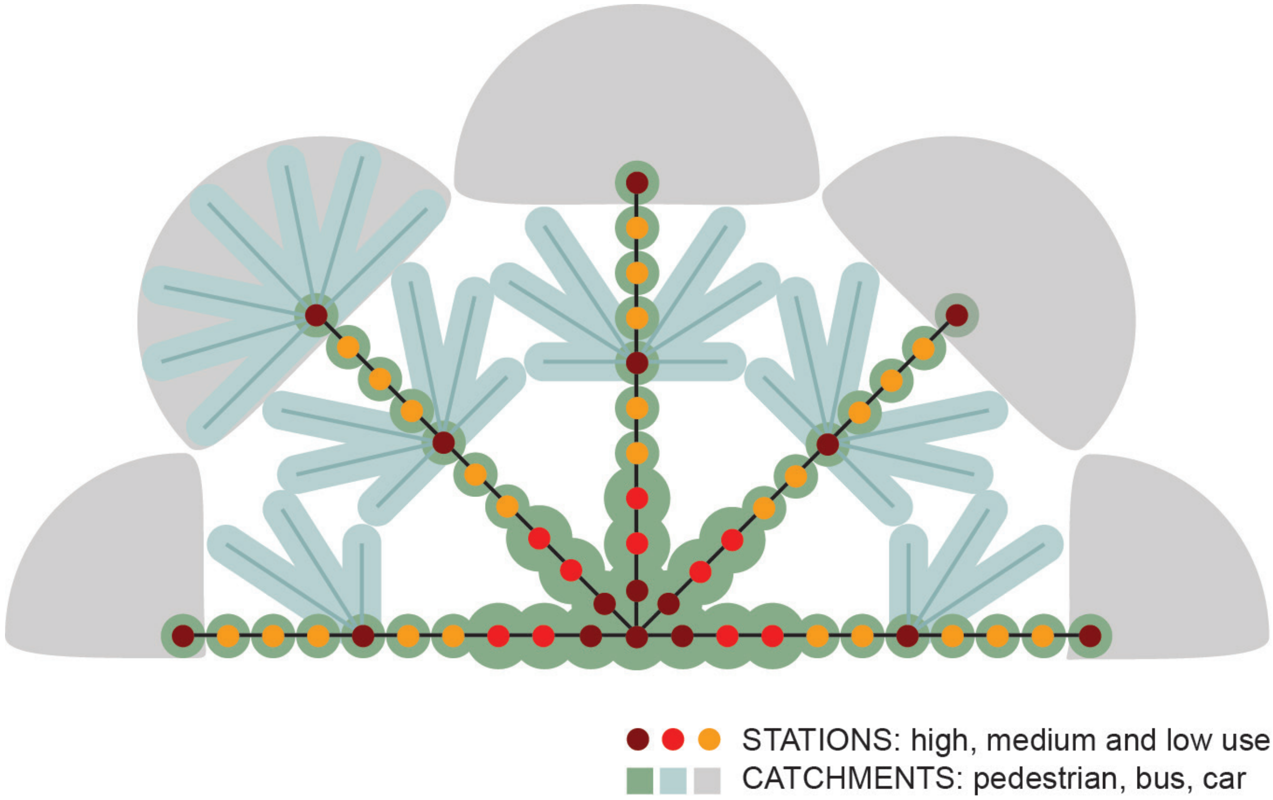

Figure 4. *Pedestrian, bus and rail catchments – a diagrammatic representation.*

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