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Designing TOD precincts: accessibility and travel patterns

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This paper reports on a research study that investigated the travel behaviour of residents in three case study station precincts located along a new railway in Perth, Western Australia. The precincts were selected for comparison, representing the different development opportunities ranging from planned transit-oriented development (TOD) to station precincts acting primarily as origin stations or transit interchanges. Accessibility measures and the actual travel patterns of residents in each station precinct were compared, in order to consider the degree to which different station precinct designs have led residents to reduce their motorised travel and to substitute it with both public transport within the region, and walking or cycling within the local neighbourhood. We draw on two surveys: a household survey, including a travel diary, examining behaviours after the railway opened; a detailed survey measuring both local and regional accessibility using a suite of over 30 measures of multi-modal accessibility. The results highlight the dual role of public transport and land—use planning in changing mobility patterns, using a temporal perspective. We found a positive relationship between improvements to accessibility by public transport and residents reducing car-based travel. Residents also increased the spatial reach of their travel and many converted from uni-modal to multi-modal travellers. At the local level (station precinct), however, we found an accessibility mismatch between infrastructure and proximity to facilities, whereby neighbourhoods with a high standard of infrastructure for walking and cycling do not have corresponding facilities that they may walk or cycle to and vice versa.

Keywords: *accessibility, factor analysis, travel patterns, Transit-Oriented Development (TOD)***.**

1. Introduction

Access to essential goods and services is key in influencing residents' travel and location behaviours and distinguishes highly liveable areas from others. In Perth, Western Australia, for many decades, this accessibility has been achieved by car-based mobility. Since the late 80s, there has been an emergent policy seeking to offer alternatives to car travel. In addition to improvements to public transport (PT) infrastructure and services, there has been mounting support for a role for city planning in delivering more sustainable travel behaviours, including smart growth, new urbanism and transit-oriented development (TOD). These planning approaches suggest changes to accessibility at the city level (by improvements to public transport and proximity of development) and changes at the local level (by improving the infrastructure,

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amenity and development intensity and mix in order to facilitate more trips by walking and cycling). The development of a new suburban railway was accompanied by the development of new TOD precincts. In each case the design of these precincts differed both in terms of land use mix and accessibility.

The core question in this paper is whether these planning approaches, improving regional and local accessibility (enabling individuals to reach activities and destinations much easier and by more active travel modes) actually bring about travel behaviour change of residents and whether it differs according to the different TOD design. The purpose of this paper, therefore, is two-fold: a) to describe options to measure accessibility at a detailed spatial level in three TOD precincts; and b) to explore the connections between these measures and the residents' travel. We apply multivariate techniques such as factor analysis, cluster analysis and analysis of variance for quasi-longitudinal data to address the potential "causal chain" that explains the travel impacts among the TODs.

Using Perth, Western Australia as our case study, the research draws on two surveys: one, a household survey, including a travel diary, examining behaviours after a 72km railway line (Mandurah) opened in December 2007 (Figure 1); the second, a detailed survey measuring both local and regional accessibility using over 30 measures of multi-modal accessibility. We investigate the relationships between travel and accessibility to both local and city-wide urban facilities. At the city-level we apply impedance measures for the road and public transport networks to compare actual accessibility with travel. At the local level (or station precinct) we develop a multi-dimensional inventory and rating of the design features and local amenities that can be reached by public transport, walking, and cycling. Guided by van Wee and Geurs (2011) who highlighted the need for a more refined scale analysis of accessibility and drawing on Handy *et al.* (2005) as a point of departure, a suite of indicators is evaluated and then compared across precincts.

The paper offers two main contributions: first, a scale of items that can be applied in practice to identify gaps and discrepancies between various access elements (land—use and transport) and assess distribution effects of accessibility; second, empirical evidence that supports positive outcomes from improvements in accessibility both at local and city levels. The results indicate significant differences between station precincts with various degrees of accessibility and TODness, as well as changes as a result of the opening of the railway line, after accounting for socio-demographic characteristics. There are also significant differences in the travel of residents living within two clusters of distinct local accessibility.

While the empirical focus of this research is Australia, the analysis of accessibility and the findings in relation to travel behaviour in TODs is of strong relevance to other jurisdictions in Europe and North America. TOD, as a development option, is being pursued in both continents and in many cases the precincts are being developed at similar densities to the Australian cases.

The structure of the paper is as follows: after a discussion of the differences between city-wide and local accessibility measures (Section 2), the paper presents the geographical setting, the data and the methodology applied (Section 3). Results and discussion of findings follow (Section 4), and the paper concludes with some implications for practice and ideas for future research (Section 5).

2. Building accessibility measures

Density, diversity of land uses and design (the "3Ds" suggested by Cervero and Kockelman, 1997) have been shown to impact on travel by reducing car dependence and increasing more sustainable transport modes. Frank and Pivo (1995) and Handy *et al.* (2005) found that when density increases and land uses are more diverse, people drive less (or at least the single car occupancy decreases). Ewing and Cervero (2001) expanded the '3Ds' to incorporate destinations and distance, with the same common theme, of encouraging healthier lifestyles and decreased car driving. The planning response has seen TOD, the "New Urbanist" or "Compact City" principles and the "Smarter communities" introduced in many cities throughout Europe, Northern America, and Australia for new suburban development. The approaches aim to provide positive changes in the communities as a result of high levels of sustainable transport access to urban facilities, including: short distances between activity locations and the potential of increased use of public transport alternatives. Where activity opportunity intensities are high and the land use mix appropriate, fewer separate locations are needed to fulfil the daily activity needs (Khattak and Rodriguez, 2005; Chen and McKnight, 2007). Where land—use change comes with improved accessibility to public transport or other non-motorised alternatives of transport, there is potential for travel behaviour change.

TOD is expected to improve both local and regional access: at the regional (city) - level by networking station precincts across the region; at the local level by both improving the quality and amenity of cycling and pedestrian facilities and the variety and mix of neighbourhood services, clustered around the station. Positive results of TOD on more sustainable transport use have been found in USA (Lund, 2006), Europe (Aguilera *et al.*, 2009), and in China (Cervero and Day, 2008). This is clearly in contrast with the demonstrated negative impacts of sprawl (see for example Newman and Kenworthy, 1999; Ewing *et al.*, 2002; or Travisi *et al.*, 2010), which were conducive to increased travel and environmental costs.

More recently, achieving more sustainable travel has seen a resurgence of activity in accessibility planning (Curtis and Scheurer, 2010; Karou and Hull, 2014). In order to assess TOD's efficiency, there is a need to develop and evaluate measures of accessibility at both local and regional levels. At the local level, or neighbourhood, the urban design literature is strong on directing design features that provide a physical environment to encourage accessibility for walking and cycling. Appleyard and Lintel (1972), Gehl (1987), Tibbalds (2001), Jacobs (2001), Barton *et al.* (2003) all argue for particular qualities of city space based on designing at a human-scale – reducing distance between buildings, activities and across the street in order to maximise the opportunity for contact and observation. It is not just the physical distance that is important, but also the quality of the experience: the design of buildings and orientation to the street and mix of uses to serve daily activity needs.

New planning codes in North America, the UK and Australia draw on this urban design tradition. In Perth, for example, the State's Liveable Neighbourhoods Planning Design Code (2001) provides a detailed set of planning considerations for local accessibility, including detail about street cross-section design, street networks, pedestrian access, provision of footpaths, cycle paths, amenity, traffic volumes and speeds, and so on. These considerations are consistent with previous scholarly work that has identified specific objective and subjective, quantitative and qualitative characteristics of the neighbourhood that need to be considered in accessibility evaluation. If objective factors include closeness to various activity locations, street design/layout, and facilities for cycling, parking and public transport, more subjective aspects refer to the quality of facilities, atmosphere or scenery, and range and variety of opportunities (Handy and Clifton, 2001).

Few empirical studies have captured the level of detail in measuring local accessibility expressed in this urban design tradition and evidenced in Perth's planning code. Handy and Clifton (2001) and Handy *et al.* (2005) come closest in identifying the full range of measures, but most travel behaviour analysis includes relatively simple measures of proximity by walking. Given the level of planning direction for urban design encompassing local accessibility, we developed a set of 35 local accessibility measures including: road type and traffic, street design features, slope, footpaths and pedestrian crossings, amenity/trees canopy, walking, cycling and public transport facilities, as well as distances to the local primary school, secondary school, shops, and park. This level of detailed measurement enables some empirical assessment of the value of policy measures put forward in planning practice.

At the regional, or city level, access is most commonly measured using a spatial separation function. Our review of approaches to accessibility measurement found a diversity of approaches, many framed around accessibility by car, rather than by public transport and led to the conclusion that there was no single perfect accessibility measure (see Curtis and Scheurer, 2010). This resulted in the development of our own measures, in particular focusing on adaption of accessibility methodologies to public transport networks across the metropolitan region and placing emphasis on the distribution land—use activities. The Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) accessibility tool (http://www.snamuts.com/) derived an impediment-based measure that uses average travel time along a route segment, weighted by the frequency of the service. While SNAMUTS has a set of seven indicators, highlighting centrality, connectivity and network performance from several angles, in this research paper we applied only one: 'Closeness centrality', which measures the average minimum cumulative impediment (travel time weighted by service frequency) for all network paths, from each node to reach any other node on the network. This indicator provided the closest comparison with accessibility by car (using distance and travel time as the measure).

3. Methodology and data

In order to assess the association between accessibility and travel, we applied a suite of multivariate techniques: 1) factor analysis (FA) of nominal and ordinal variables, describing local access - to provide reliable reflective summaries of accessibility; 2) these summaries were further analysed using correlations, without giving predictive edge to other continuous variables; 3) MANOVA analysis was then employed to compare the multiple elements of travel behaviour across space and time; 4) finally, zones of local access were cluster analysed - to test whether higher level of access is linked to more active transport modes.

As an objective of the paper was to examine the relation between accessibility and travel at two levels (city-wide and local), the data needs to be aligned to this aim. Thus, we selected three precincts with distinct design choices: Bull Creek, Cockburn Central, and Wellard (Figure 1). In Perth, the emerging TOD precincts along the new Mandurah railway line presented differing development opportunities and patronage potential. At one end of the spectrum is the precinct which acts primarily as an origin station or transit interchange, the focus here is on achieving a high level of accessibility by car and feeder bus, with little attempt to plan for land uses designed to act as a trip attractor. At the other extreme is the precinct designed around the traditional TOD concept, here the emphasis being on creating a land use mix and residential density, which will serve as a strong trip attractor, with access mainly by foot rather than car. A description of the three precincts follows:

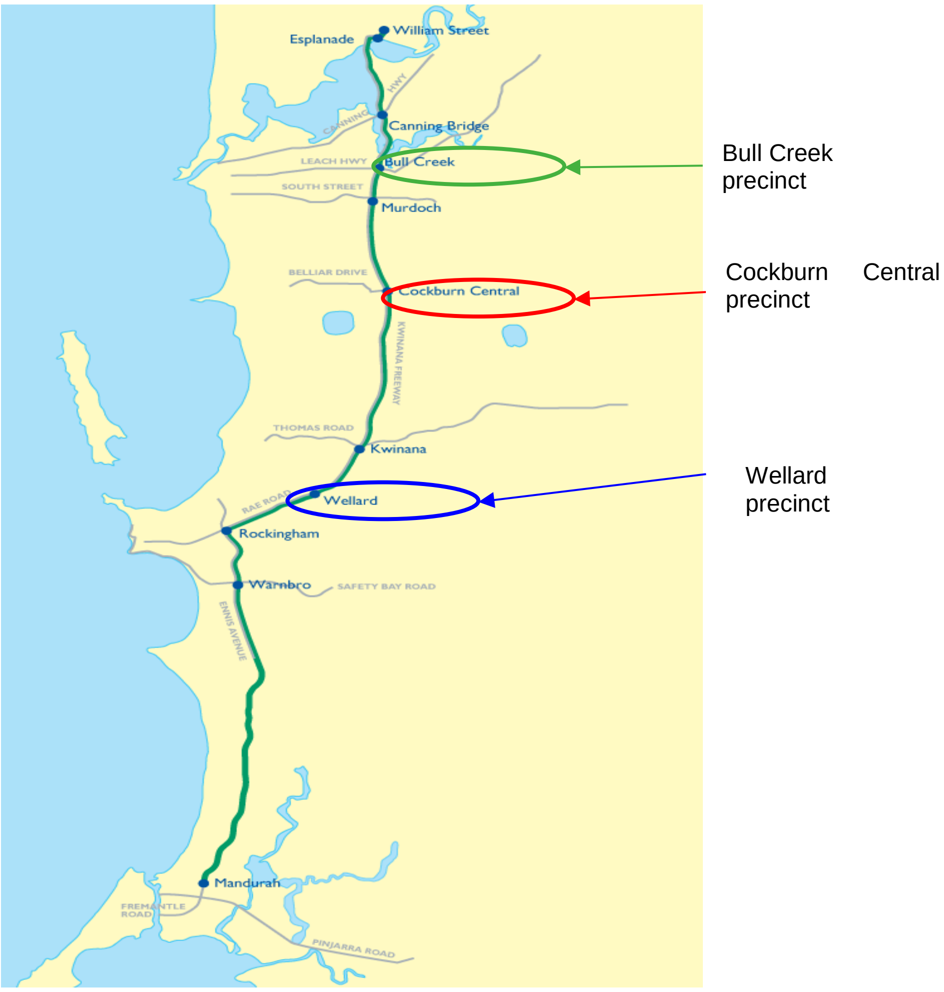


Figure 1. Railway corridor and study area

The primary focus at Bull Creek is the transit interchange. The station is located at the intersection of a primary arterial road and a freeway and is 12km from Perth city centre. The freeway reserve, at its narrowest point is approximately 100m wide, although at the off ramps this distance increases to approximately 500m, effectively constraining the opportunity for development of a pedestrian-scale precinct in close proximity of the station. At present there are no plans to promote mixed-use development. The station caters for a high volume of car access (610 car parking bays) and a feeder bus system along the arterial road serving the surrounding suburbs.

At Wellard Station (39km from the city) the design objective is to mirror both TOD and 'new urbanism' principles with a mixed-use 'main street' (including 4,070m^2 of retail space) centred on the station surrounded by higher density residential development. The street network is designed to provide a high quality pedestrian environment.

The Cockburn Central precinct (19km from the city) features aspects of both the Wellard and Bull Creek precincts. It provides for high car access (414 'park-and-ride' car bays and an estimated 928 car parks for the exclusive use of commercial premises). The precinct is dissected by a freeway reserve. Like Wellard, a mixed-use town centre is being developed centred on the station, with a range of recreational, commercial, entertainment and cultural facilities including residential apartments. There is also a suburban shopping centre located nearby.

The limits of the station precincts were established at a five-minute drive around the railway station, considering the distance between adjacent stations, the low-density urban environment (90% of the households reside outside the 1.6km "catchment area for TOD - Martinovich, 2008) and also known travel behaviour thresholds. Isochrones of actual 5, 10, and 15 minute walking distance were also drawn to identify population groups that may have different propensities to use active transport post railway opening, depending on their proximity to the railway station.

The three precincts differ not only in their TOD characteristics, but also in terms of socio-economic status and commuting patterns, as shown in Table 1.

Table 1. Profile of precincts compared to metropolitan Perth

Characteristic	Bull Creek	Cockburn Central	Wellard	Metro Perth
% Education >= year 12	47.60	33.10	20.60	36.80
% Born in Australia	59.50	68.40	65.80	64.10
% Employed	50.40	56.10	38.60	48.20
% mode split Car only – journey to work (JTW)	69.80	73.20	74.00	69.30
% mode split PT & walk/cycle - JTW	16.10	10.70	9.90	12.40
Household Car Ownership	1.67	1.69	1.36	1.51
Population density (pers/km^2)	1925	538	625	271
Dwellings/km^2	674	175	112	97
Median Weekly Household Income (AUD)	1,275	1,244	945	1,042
Median house price 2006 ('000 AUD)	$553	$394	$272	$380
Median house price 2008 ('000 AUD)	$662	$470	$301	$455

Source: ABS (2006), Census data.

Bull Creek residents have the highest income and level of education, but a significant proportion of them are retired or skilled immigrants, Cockburn Central is an emergent area with high employment, primarily in the resources area, whilst Wellard, has the lowest employment and income and the largest use of car for commuting.

3.1 Data collected – survey 1 (Household survey)

The first data source is a quasi-longitudinal household survey, which was conducted over four years (2006-2009). We collected data for household and individual characteristics, car ownership, travel behaviour, location, physical activity and mobility restrictions in the surveys (Table 2). Here we focus on the "established" travel behaviour (trip diaries).

Table 2. Household Survey Information collected

Section	Information
Household (hh):	Size, type of dwelling and tenancy, when moved to the residence, number of cars, bicycles, scooters, motorcycles, parking bays (income and contact details asked at the end of the interview).
Household vehicles:	Type, make, age, fuel, costs amount and who bears them.
Household members:	Age, gender, education, work/education place, number of weekly hours involved in work and voluntary work, flexibility of work program, types of driving licenses possessed, mobility restrictions due to physical condition (or imposed by parents on their children), physical activity, height and weight.
Travel diaries:	Collected as daily logs of all trips made by each hh member on the specified Wednesday (origin, destination of locations, departure and arrival time, purpose/activity, mode of travel, route, party size, out-of-pocket cost, parking, transfers). The activities in which the individuals were engaged were recorded in five main categories: work/study, shopping (for groceries or for other), personal business (personal care, banking, institutional appointments, etc.), recreational (spectating or participating in sporting events, cultural/public events, visiting friends/receiving visitors, eating out, sightseeing, fitness/exercise), pick-up/drop-off or accompanying someone, plus returning home. The trip diaries recorded separately transfers between travel modes and waiting times. The trip diaries were manually geo-coded after data collection.

The study started with more than 1,000 households interviewed in 2006 and panel attrition resulted in about 500 households in the fourth and last survey in 2009. In this paper we report only on the 2006 and 2009 data – before opening and "settled-in" behaviour after railway opening. The two samples 2006 and 2009 did not differ significantly in their socio-demographic characteristics; therefore we deem their comparison valid.

3.2 Data collected – survey 2 (Regional and local accessibility)
Accessibility was evaluated at two levels: regional (city-wide) and local (neighbourhood). As indicated, the regional accessibility measure was determined by the transport network and its services to reach destinations, with greater accessibility by car and by PT corresponding to lower values (Table 3). Bull Creek has the highest access and Wellard the lowest. This is mainly due to their geographical location in regard to Perth CBD and in the case of public transport a product of a radial rail network centred on Perth city. All three precincts witnessed substantial improvements in public transport following the opening of the rail corridor (in fact for the city as a whole Bull Creek's regional accessibility became second to the Perth city). Moreover, the metrics dropped significantly in all three precincts immediately after the railway opening, but policy measures of a 3% cut in services (taken in 2008 as a result of the in-coming liberal government economic policy aimed at cutting the cost of government), meant reduction of the frequency of public transport services and the access measures worsened (not shown here). The highest improvement in access was for Cockburn Central (33%), followed by Bull Creek (15%) and Wellard (12%). Table 3 also shows no significant changes in the road distance access as a result of the new railway corridor. Anecdotal evidence suggests significant deterioration of the time access on the road network between 2006 and 2009 (especially peak time), however data on traffic congestion was not available for this analysis. The alleged decrease in attractiveness of car travel is due primarily to the population changes in Perth. Due to the boom in the resources sector, WA has been the "powerhouse" of Australia - even during the recent global financial crisis - which has led to a growing number of vehicles on the road and consequently to an increase of the congestion.

Table 3. City-wide access by precinct

Access variable	Bull Creek	Cockburn Central	Wellard	Bull Creek	Cockburn Central	Wellard
	Before railway opening			After railway opening		
City-wide road distance accessibility (km)	24.1	30.2	39.9	24.1	28.9	38.3
City-wide public transport time accessibility (non-dimensional)	45	70	112.9	38.1	46.9	99.2

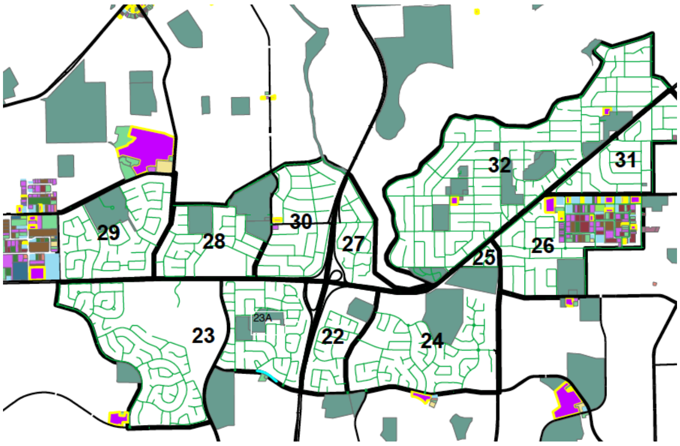
Note: We used here the Closeness Centrality, one of the seven core SNAMUTS indicators described in Curtis and Scheurer (2010) and designed to highlight different aspects of accessibility by public transport and road network performance. SNAMUTS refer to the ease of movement between a set of activity nodes, representing points on the public transport network where one or more land uses exist (residential, employment, recreational, health, etc.).

This paper uses closeness centrality, based on the shortest paths between two nodes using a generalised cost/time function as spatial separation or impedance. The measure represents the average generalised cost (including travel distance or time for road network and travel time and frequency of services for public transport) between one activity node and all the other activity nodes in the network (89 in the case of Perth). The smaller numbers are better and they can be interpreted as follows: the average distance by road from Bull Creek to any of the activity centres in Perth is 24.1km and the average 'time' by public transport (accounting for frequency) is 45 min.

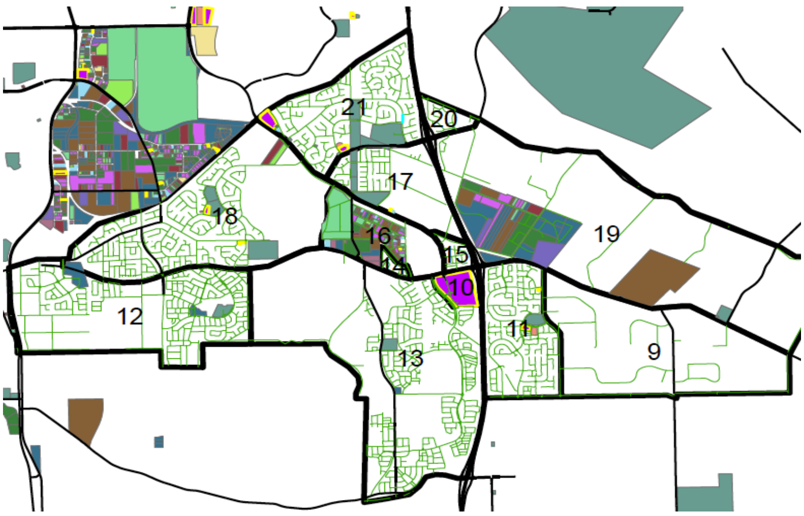
We selected one of the SNAMUTS measures, purely to illustrate the differences in precinct accessibilities. Other SNAMUTS measures account for the relative role of activity centres across the metropolitan area, in terms of activities and transport connections. Amongst others, degree centrality is a proxy measure for transfer intensity, whereas network coverage and contour catchments illustrate the opportunities available for individuals at a particular node. Future research will assess the link between these measures and changes in travel behaviour.

At the local level our interest was to capture in detail the ease of movement within the precincts when using public transport, walking, or cycling (see section above for rationale). The data was compiled from various sources: GIS data for proximity measures provided by Department of Transport WA, traffic volume provided by the Main Roads Department, public transport routes and schedules provided by Public Transport Authority WA, and field work observations for amenity and walking, cycling, and public transport facilities. The three precincts were split into sub-zones of accessibility (32 zones in total for all three precincts), defined by natural boundaries, major arterials, internal road layout and the distribution of land-uses. Figure 2 presents these sub-zones and Tables 5 to 7 in the following section describe in more detail the local access indicators.

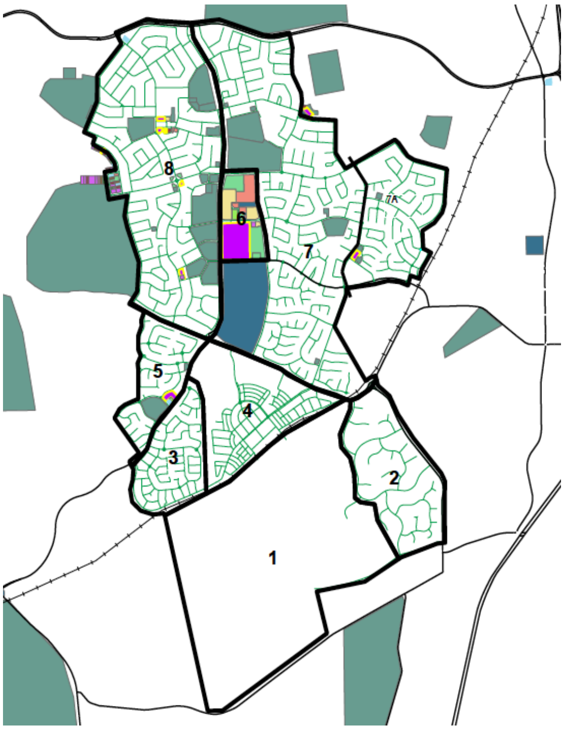
The different colours in Figure 2 indicate various land uses in the precincts. It becomes apparent that the street layout, distribution and mix of land-use differ across the three precincts.



a) Bull Creek local accessibility zones



b) Cockburn Central accessibility zones



c) Wellard local accessibility zones

Figure 2. Local accessibility maps including roads and land use

Note: Magenta denotes offices, yellow and orange various types of retail, brown manufacturing, and green public reserves.

4. Results

4.1 Household sample characteristics

The selected socio-demographics confirm the distinctive profile of the precincts, but do not indicate considerable changes in their 'social fabric' after railway opening (Table 4).

Table 4. Descriptive statistics by precinct (socio-demographics)

Variable	Bull Creek	Cockburn Central	Wellard	Bull Creek	Cockburn Central	Wellard
	Before railway opening 2006			After railway opening 2009		
Family size	2.85	3.0	2.76	2.79	2.92	2.59
# bedrooms	3.63	3.73	2.75	3.68	3.70	3.13
Weekly working hrs/person	31.2	30.7	28.7	32.5	31.4	31.9
Car availability	1.95	1.94	1.83	1.86	1.98	1.69
Parking space	2.86	3.14	3.15	3.02	3.13	3.18
Number of adult bicycles/household	1.26	0.92	0.72	1.21	0.98	1.13
Number of children bicycles/household	0.47	0.70	0.64	0.59	0.76	0.87
N households	317	369	348	201	161	137

Consistent with population data, Cockburn Central has the largest families and houses, Bull Creek the residents with the highest number of working hours (excluding domestic activities), and Wellard the lowest car availability.

4.2 Local access measures

A comprehensive audit of local access used 35 characteristics or measures (see discussion p.3). To summarise these local accessibility measurements factor analysis was performed. The reasoning for this is that each single measure is unlikely to be very informative about the level of access by a mode; also many indicators go hand-in-hand (because of the design practices or agglomeration economies) or complement each other. In Cervero's (2003, p. 120) words: *"dimensions of built environment tend to operate in tandem and synergistically"*, thus discrepancies represent a diagnostic tool for weak planning practices.

By using factor analysis we created composites (or summaries), likely to mirror the accessibility requirements residents consider. Each summary/construct has a measure of reliability, so instead of the 35 individual local accessibility measures, we use a reduced number of measures, based on their commonality, beneficial for model complexity. The factor analysis provides loadings, which reflect the strength of relationship between the construct and the individual measure and show how consistent the items are within a construct. Some items are strongly related to the construct, others are weak. Loadings show the relative importance/contribution of the items within the construct based on the objective planning practices applied in these zones. In addition, these summaries are continuous variables, providing an advantage in modelling over binary or ordinal variables, which require special approaches.

Following an exploratory stage, our confirmatory factor analysis (CFA) has shown a number of seven uni-dimensional constructs (summary measures). Six of them have reliabilities above 0.55, with only one exception of the construct of bicycle facilities. Table 5 presents the factor loadings for these constructs.

Table 5. Measures of local accessibility – factor loadings

Construct – variance explained	Items	Factor loadings
Walking distance to neighbourhood facilities – 0.684	Walking distance to the park	0.920
	Walking distance to basic shop	0.869
	Walking distance to the nearest high school	0.782
	Walking distance to the nearest primary school	0.723
Walking facilities /Footpaths – 0.883	Width of the footpaths	0.974
	Surface quality	0.956
	Presence footpaths (one or both sides)	0.887
	Tree canopy	0.815
Street design/geometry – 0.577	Distance in m from kerb to kerb	0.799
	Street crossing b (designated crossing)	0.767
	Street crossing a (one or two stage crossing)	0.676
	Active frontage	0.661
Cycling distance to neighbourhood facilities – 0.588	Cycling distance to basic shop	0.843
	Cycling distance to the park	0.658
	Cycling distance to the nearest high school	0.614
	Cycling distance to the nearest primary school	0.571
Bicycle facilities – 0.378	Terrain	0.738
	Bike parking at the shops	-0.712
	Off-road designated bike paths	0.283
PT amenities – 0.758	Bus stop seats	0.884
	Bus stop shelter	0.884
	Bus stop	0.856
	Bus stop information	0.667
PT local services - 0.846	Frequency bus services to shopping centre	0.906
	Bus route to primary school	0.895
	Frequency bus services to primary school	0.883
	Bus route to shopping centre	0.881

Note: All models have non-significant X^2 tests, CFIs>0.83 and RMSEAs<0.06. Eight items with very low loadings were removed from the factors. They included: the road type and traffic and street design features such as radius, slope.

We notice that the public transport level of service factors, the comfort and convenience of pedestrian facilities and the impedance (distance) factors all have loadings above 0.7, confirming the appropriateness of using construct measures to evaluate the impacts of access in the TOD developments on travel behaviour. In relative terms, walking and cycling to shops (0.869 and 0.843) and recreation spaces (0.92 and 0.658) seem to have higher contribution to the constructs than access to schools (lower values for loadings). The width of footpaths (0.974) and the surface quality (0.956) are determinant for the easiness of walking. The presence of benches and shelters (0.884), along with more frequent bus services to shops (0.906) and schools (0.883), are vital to public transport users, as they affect the quality of waiting time. The loadings provide an indication on how current planning practices in Perth incorporate these elements in the overall access to primary social goods.

The factor scores coefficients were then applied to characterise the local accessibility for the 32 access zones in the three precincts. Figure 3 shows the standardised local access values for each of the local access zones displayed in Figure 2. Negative values indicate a lower level of combined access or facilities, whilst a positive value indicates that the zone has a higher level of access and of the quality of services. The 30 radar charts provide two types of information: a) similarity between zones, assisting us to gauge the homogeneity of a precinct in terms of local accessibility; b) inconsistencies between walking, cycling, public transport features and the presence of urban facilities within the precinct zones (such as shopping, health, recreational, or educational establishments). Similar shapes in a precinct would suggest some cohesion in the planning practices applied to that precinct. Shapes closer to a regular heptagon would indicate consistency between the presence of facilities and the infrastructure to access them, whereas asymmetric, unusual shapes with “spikes” would suggest a certain level of incongruity between design features or walking and cycling facilities and the availability of urban facilities (such as shopping, health, recreational, or educational establishments). In these zones, the indicators of amenities or proximity frequently have a positive value, whereas the available facilities display negative values, as highlighted in the matrix of radar charts below.

Figure 3 signals substantial heterogeneity within the precincts and helped us in identifying neighbourhoods with deficiencies in accessibility and suggesting possible solutions. An example of this planning inconsistency may be the industrial area in Jandakot, opposite to the Cockburn Central railway station (zone 19), where the access to local facilities is nil; another one is the Wellard suburb, with good walking and cycling access, but no retail, recreation, community services available on the Main Street Complex (zone 4). Zones 19 and 4 are highlighted in Figure 3 by round rectangles.

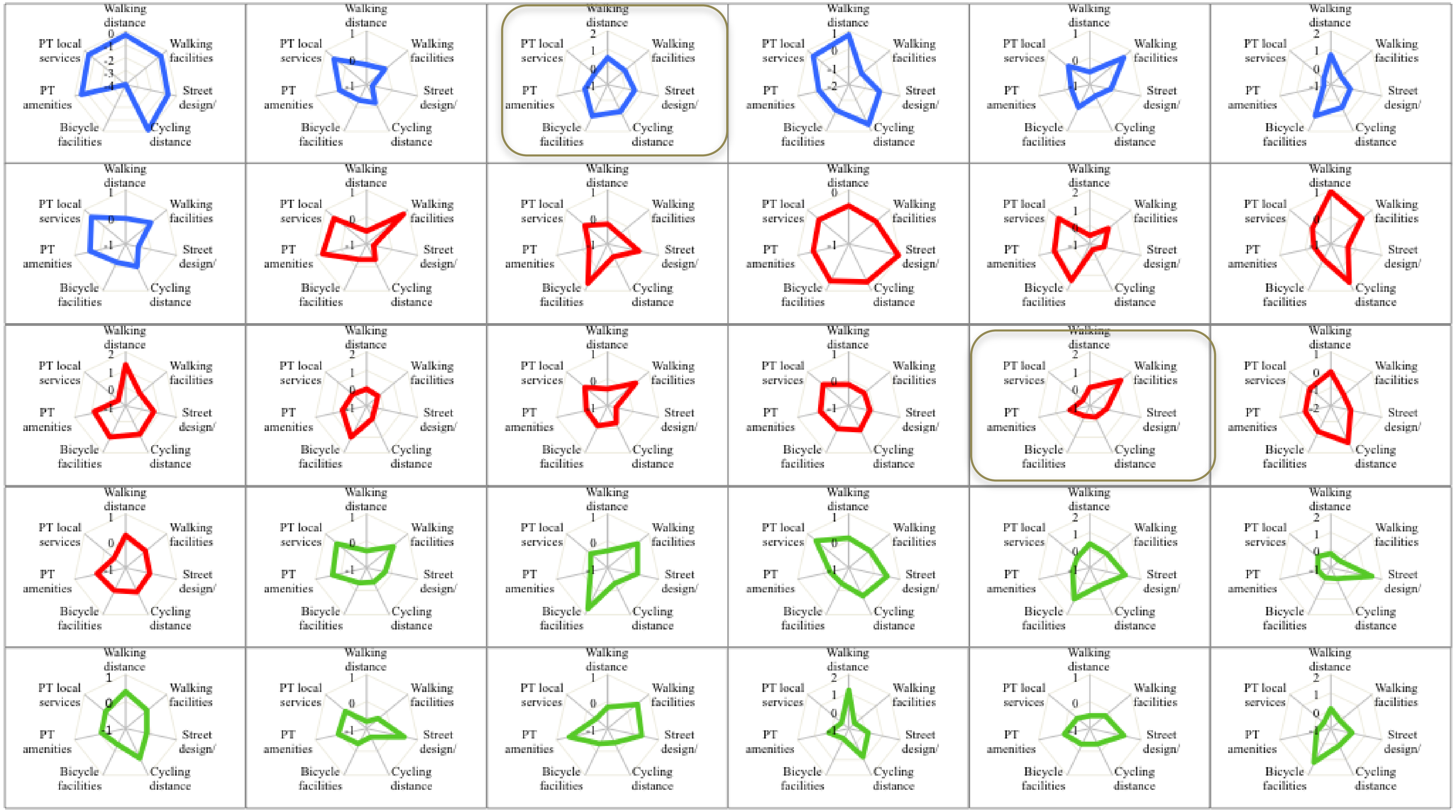


Figure 3. Local accessibility by zone (left to right and top-down, zones 2 to 8 Wellard, 9, 11 to 21 Cockburn Central, 22 to 32 Bull Creek)
Note: Colour code: Wellard – blue, Cockburn Central - red, and Bull Creek - green.
Zone 1 is a reserve and zone 10 is the local town centre, without residential use and therefore not included in the analysis.

Table 6 presents correlations between the seven factors/constructs of local access. These results further attest to the mismatch between the provision of facilities or opportunities for local activities and the network features enabling more sustainable transport (walking, cycling, public transport). For example, the insignificant correlations (p>=0.05) between the walking distance to facilities and the pedestrian orientation of the zones and the street design, or between the bicycle facilities and cycling distance to local amenities. Ideally, the matrix would include significant positive associations, such as between the PT amenities and local services, but in the case of the three precincts there are numerous 'anomalies'. As suggested, this has implications for planners, who can use this type of information and analysis to find gaps in the availability and quality of urban services at the neighbourhood level.

Table 6. Correlations between local access constructs (Pearson correlation and p-value)

	Walking distance to facilities	Walking facilities/ footpaths	Street design/ geometry	Cycling distance to facilities	Bicycle facilities	PT amenities	PT local services
Walking distance to facilities	1						
Walking facilities/footpaths	-0.146 (0.074)	1					
Street design/ geometry	-0.103 (0.215)	***0.509*** *(<0.001)*	1				
Cycling distance to facilities	***0.921*** *(<0.001)*	-0.149 (0.067)	-0.121 (0.145)	1			
Bicycle facilities	0.083 (0.307)	0.132 (0.106)	0.111 (0.179)	0.037 (0.652)	1		
PT amenities	-0.146 (0.074)	***0.548*** *(<0.001)*	***0.577*** *(<0.001)*	-0.131 (0.109)	0.132 (0.105)	1	
PT local services	-0.128 (0.117)	***0.448*** *(<0.001)*	***0.455*** *(<0.001)*	-0.105 (0.199)	0.125 (0.125)	***0.609*** *(<0.001)*	1
N	152	151	147	152	152	152	152

When aggregated at the precinct level[3] (Table 7), we observe that Bull Creek has better distribution of local shops, parks, and schools that are accessible by walking and cycling, and superior cycling facilities. Wellard displays the best street geometry/design out of the three precincts, attesting to its intended traditional TOD design, although local shops are yet to be constructed. Cockburn Central appears to be served by superior public transport amenities and to offer good bus services to local urban facilities (likely the result of one major shopping precinct which includes a bus station).

3 The aggregation takes into account the number of households in each local access zone, reducing the potential bias towards large size areas and reflecting the fact that accessibility is measured for households residing in the area. Nevertheless, the underlying assumption is that access is equally important for all households regardless of their needs and/or restrictions.

Table 7. Aggregated local access by precinct (weighted by number of households)

Access variable	Bull Creek	Cockburn Central	Wellard
Walking distance to facilities	*0.273*	-0.203	-0.043
Walking facilities	-0.085	-0.110	-0.052
Street geometry/design	-0.041	-0.190	*0.293*
Cycling distance to facilities	*0.200*	-0.238	-0.037
Bicycle facilities	*0.417*	0.254	0.294
PT amenities	-0.087	*0.158*	-0.078
PT services to local facilities	0.175	0.186	-0.186

4.3 Clusters of local access

Cluster analysis assisted us to classify areas with similar local access features into groups without preconceptions of their defining attributes. Euclidean distance measures between the access zones were used to group the zones that are more similar with one another in the same cluster. The relatively homogenous resulting clusters were further used in comparing travel behaviour with the composite of access score. In each precinct we distinguished between zones with lower (Cluster 1, in red) and higher access (Cluster 2, in green) for pedestrian, cycling, and public transport features (Figure 4). The evidence suggests that the local access metrics were significantly different between the two clusters (at 0.05 level), with the exception of the street layout and cycling distance to the nearest high school.

The clustering shows that in each precinct, there are areas of high access by one mode or another, but not necessarily by all modes. In fact only two zones have high access by all three active travel modes (4 and 13) and six have low access in walking, cycling, and PT walking (2, 6, 8, 9, 12, and 17). This type of analysis can promptly and without much effort indicate areas where synergies may be missed and thus decision-making becomes a priority.

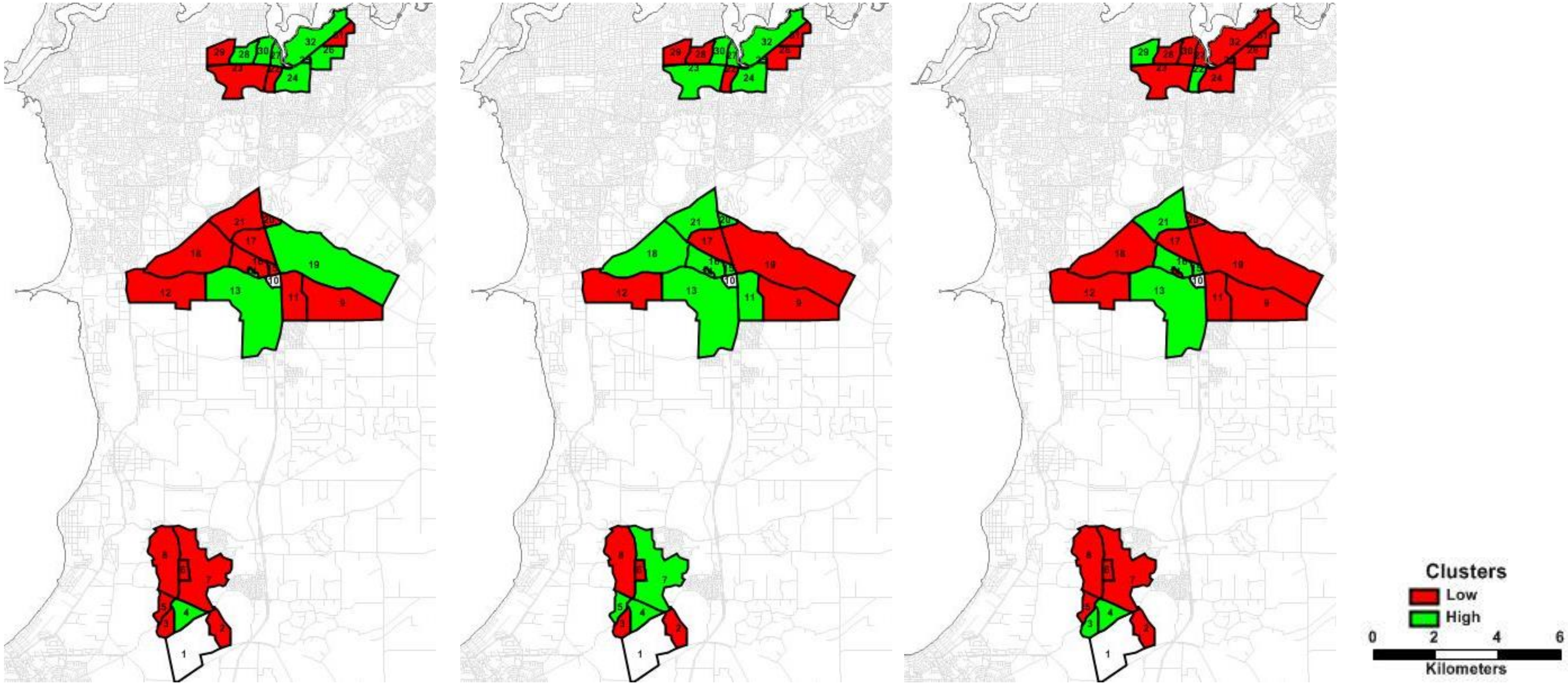


Figure 4. Clusters of high and low access for walking, cycling and PT access

4.4 Travel behaviour

To explore the associations between travel behaviour and accessibility indicators we have undertaken a series of comparisons: i) changes in travel behaviour before and after the railway opening; and ii) differences in travel patterns by cluster of local accessibility. The first one provides insights into likely changes in travel due to the new railway line (city-level access) and TODs, whereas the latter looks into the travel behaviour at local level. Table 8 presents the results of a MANCOVA analysis, including household size, car availability, income as covariates.

Table 8. Descriptive statistics by precinct (travel behaviour – averages and standard deviations)

Variable	Bull Creek	Cockburn Central	Wellard	Total	Bull Creek	Cockburn Central	Wellard	Total
	Before railway opening (2006)				After railway opening (2009)			
Daily travel distance (km)	28.75 (25.11)	34.21 (29.98)	44.58 (40.26)	31.39 (30.27)	24.18 (23.44)	26.09 (24.84)	39.31 (43.97)	28.84 (31.26)
Daily travel time (min)	71.85 (48.41)	73.32 (52.65)	87.35 (70.70)	76.96 (61.74)	71.77 (53.06)	68.02 (66.93)	81.52 (85.56)	73.11 (67.71)
N trips	1,853	1,289	1,984	3,936	1,618	1.081	864	3,563
# trips/day and person	3.95 (2.40)	3.78 (2.84)	3.76 (2.54)	3.85 (2.73)	4.72 (3.07)	3.63 (2.34)	3.81 (2.95)	4.12 (2.86)
% trips by mode:								
- private motorised	77.07	81.80	83.46	80.34	67.60	75.72	72.23	70.20
- public transport	6.29	5.20	4.19	5.54	11.04	6.79	12.08	11.24
- cycling & walking	16.23	11.22	9.88	12.60	17.89	16.65	14.99	16.42
Trips under 5km:								
% private motorised	63.60	66.45	82.84	69.23	61.39	66.93	61.88	63.30
% walking and cycling	27.90	24.89	14.71	24.58	29.72	28.18	22.80	27.52
N persons	913	1,095	967	2,975	484	414	284	1,182

Note: Cycling and walking trips combined both utilitarian and recreational activities.

We noticed a significant drop in the use of motorised modes in all precincts and the corresponding increase in alternative modes such as walking-cycling and public transport. This concurs with the improved city-wide accessibility by PT, as a result of the developments on the corridor and TOD precincts (Table 3). These changes are substantially higher than the changes in commuting mode shares at the Perth city level and changes in patronage on other public transport corridors. Using aggregate Census data (http://www.abs.gov.au/websitedbs/censushome.nsf/home/data, http://profile.id.com.au/perth/travel-to-work) and from the Western Australia Departments of Planning and Transport as well as the Public Transport Authority (http://www.pta.wa.gov.au/NewsandMedia/TransperthPatronage/tabid/218/Default.aspx) it appears that between 2006 and 2009, the % of private motorised trips decreased by 0.4% in Perth, whereas the use of public transport increased by 0.7% and the use of active transport by 0.32%. In terms of ridership, the number of boardings increased by 1.3 times, but the train boardings increased by a factor of 1.577, mainly as a result of the introduction of the Perth-Mandurah corridor. These statistics, although not directly comparable, indicate that the changes in city-wide access and travel brought by the rail corridor are not trivial.

Yet, the changes in driving and use of public transport in the three precincts did not match the changes in closeness centrality: Cockburn Central had the biggest improvement in public transport access at the city-level (33%, compared to 15% for Bull Creek and 12% for Wellard), but the lowest percentage point reduction in car trips (-6%, compared to -10% in Bull Creek and -11%

in Wellard) and the lowest percentage point increase in PT share (+1.5%, compared to +5% in Bull Creek and +6% in Wellard) – indicating that other factors may affect the mode shifting. There are also reduced distances travelled daily, although the travel time expenditures remained unchanged. This is because we witnessed a change in trip-making, many residents becoming multimodal travellers (i.e., city-level access facilitated a larger number of legs in the travel chains).

The analysis of the data also showed significant changes in the travel destinations (included in Curtis and Olaru, 2010). In Bull Creek we noted strong local focus with many destinations within 0-15kms radius, Perth CBD representing a strong magnet for trips generated in Bull Creek. Cockburn Central displayed more dispersed destinations, with Perth CBD becoming easier to reach, as well as Mandurah. Wellard presented the most scattered map of destinations, but again this is explained by the corridor's attractiveness. Wellard's increased accessibility at the city level means that residents can now reach Perth and Mandurah city centres faster, with significant implications for commuting. Interestingly, the shopping destinations have changed to a certain extent as a result of the opening and extension of the Cockburn Gateway Shopping Centre. The new shopping centre includes: supermarkets, liquor stores, chemists, bank offices and food courts, but also electronics, furniture, florists, fitness centres, etc. Residents in the Cockburn Central and Wellard precincts now shop at Gateway instead of Garden City and Kwinana Hub (respectively), the closest retail areas to each precinct prior to the TOD developments. The percentage of trips made within the precinct (self-contained) increased in relation to the extent of TOD design (i.e. Wellard shows greatest local trips while Bull Creek the least) and there is more sustainable travel (walking and cycling) in all three precincts.

Table 9 contrasts the two clusters of access in each precinct in their travel, using multiple analysis of variance (MANOVA). The purpose was to test if travel behaviour indicators are the same between the lower and higher access clusters at household, individual, and trip level.

Table 9. Travel behaviour by local accessibility (Cluster 1 – low, Cluster 2 – high access)

Variable	Walking		Cycling		Public transport (PT)	
	Cluster 1	Cluster 2	Cluster 1	Cluster 2	Cluster 1	Cluster 2
Household level						
Daily travel distance (km)	**69.06**	*53.74*	61.76	64.58	63.41	64.56
Daily travel time (min)	*148.89*	**168.26**	*154.19*	**164.74**	*158.80*	**168.84**
N trips	9.19	8.92	8.85	9.2	8.98	9.41
N motorised trips	**6.37**	*5.72*	6.25	6.11	*6.00*	**6.52**
N trips walking & cycling	*1.72*	**2.07**	1.73	1.9	*1.8*	**1.96**
N trips by PT	0.89	0.93	*0.72*	**0.99**	*0.69*	**0.99**
Individual level						
Daily travel distance (km)	31.73	*23.32*	28.42	28.82	28.95	28.03
Daily travel time (min)	**77.31**	*64.61*	*70.94*	**74.38**	72.5	73.28
N trips	**4.22**	*3.87*	4.07	4.11	4.10	4.08
N motorised trips	**2.93**	*2.48*	2.87	2.72	2.74	2.83
N trips walking & cycling	*0.79*	**0.89**	0.79	0.84	0.82	0.85
N trips by PT	0.40	0.41	*0.33*	**0.44**	0.41	0.38
Trip level						
Distance (km)	**8.13**	*6.16*	7.60	7.37	7.45	7.39
Trip duration (min)	**18.81**	*16.78*	18.19	18.06	18.15	17.94
% motorised trips	**72.50**	*66.69*	**73.35**	*69.11*	72.21	71.35
% trips walking & cycling	*16.32*	**22.68**	17.03	18.94	18.28	18.47
% trips by PT	11.18	10.63	*9.62*	**11.91**	*9.51*	**10.18**

Note: Bold and italic values indicate the largest and smallest values for statistically significant comparisons at 0.05 level.

When we compared individual travel and mode shares between the public transport access clusters (last two columns of the table), the findings were less conclusive. However, the proportion of walking and cycling trips was higher in the Cluster 2 zones of higher local access, and the percentage of motorised trips lower. In Cluster 2 zones with better pedestrian facilities and closer to local recreation, shopping services, and schools, the daily travel distance and time and trip distances and durations were significantly lower. Another interesting finding is that public transport use appears higher in cluster 2 zones of better access by bicycle. For households, the findings indicate that areas of higher access are associated with higher daily travel time, which may be reflective of the higher use of slower modes.

5. Summary of findings

As highlighted by Handy & Clifton (2001: 76), *"developing a comprehensive neighborhood accessibility database, consisting of detailed data about a wide range of accessibility indicators requires a significant commitment of resources..."* as data is readily available for only a small subset of factors. In this respect, this research contributes to both body of knowledge and the local planning practice by compiling a detailed database of quantitative and qualitative factors. We take this work further by identifying the most relevant indicators in the given context (through commonality of metrics), and showing how to use these constructs to highlight the uneven distribution of facilities in order to guide improvements in neighbourhoods planning. Our findings in the Perth case study indicate that the comfort and convenience of pedestrian facilities (as measured by width of footpaths and the surface quality) and the impedance/distance are determinants for walking and cycling to shops and recreation spaces. For public transport, the presence of benches and shelters, along with more frequent bus services to shops and schools are vital to public transport users.

The second contribution is represented by the analysis of travel behaviour by accessibility (city-wide and within the precinct) within the context of different TOD designs. The results confirm our expectations. Measures that enhance the access to non-residential activities and improve the quality of transport infrastructure, contribute to residents' reduced car-based travel, consistent with the traditional concept of TOD. Better cycling and walking access are associated with higher proportion of walking and cycling trips and improvements of the city-level public transport access are converted in higher public transport ridership. At the same time, greater access at the city level means increased spatial reach of the residents' travel, as demonstrated by their spread of activity destinations. We also found that TOD precincts designed around the traditional TOD concept, which promotes good local accessibility, are most able to deliver local travel behaviour change. At the local level (station precinct), however, we found accessibility mismatches between infrastructure and proximity to facilities, whereby neighbourhoods with a high standard of infrastructure for walking and cycling do not have corresponding facilities that they may walk or cycle to and vice versa. This emphasises the need for planners to recognise the dual nature of access, determined simultaneously by transport system and patterns of land use. Transport alone is not enough to ensure high accessibility, an aspect clearly understood in the traditional TOD definition, but at the time of these surveys had yet to come to fruition (land use changed lagged transport infrastructure change).

Better access (measured both by transport services and distribution of urban features), therefore, is expected to reduce the need for car travel and encourage alternative transport modes. Nevertheless, urban design and planning for TOD alone will not be translated automatically in travel behaviour changes. Many households select residential locations consistent with their travel and lifestyle preferences (Mokhtarian and Cao, 2008; Kamruzzaman *et al.*, 2013). It is argued therefore, that researchers should consider the self-selection process when quantifying the contribution of access changes to travel changes. While self-selection may be evident, it is not an argument, however, against making changes to accessibility by more active travel modes. Whether residents move to locations selected for their transport choices or not, where more sustainable travel behaviour results, there is a positive outcome. Here, the comparison of before-after data, with more than 50% of the households included in both sets of data, limits the contaminating effect of self-selection and further supports the effectiveness of the land use and transport policies.

While, theoretically, TOD holds a promise for more sustainable travel, its implementation in real places may be challenging for multiple reasons. In places where TOD is retrofitted within an existing city structure it is not always possible to control the distribution and density of activities (Curtis, 2008). Furthermore, in Western Australia land use change appears to be asynchronous with transport accessibility across the full range of accessibility measures, and vice versa.

The paper presents indicators useful to evaluate policy options aimed at reducing car-based travel. However, there is an inherent assumption that access to facilities is equally important to all residents. Utility-based measures (Geurs *et al*., 2010) at the household level would enable a more complex and deeper understanding of the human needs for activities and the importance of TOD, providing a bundle of transport and mixed land use in the vicinity of the railway stations.

Similarly, more longitudinal analysis (Handy *et al*., 2005; Mokhtarian and Cao, 2008) would assist in examining changes in behaviour related to changes in accessibility at a disaggregated level and complex latent growth models, accounting for the individual preferences for transport and urban facilities before considering travel behaviour, would eliminate the overestimation of the built environment impacts. In addition, accessibility can represent a measure of performance only if it is consistent with residents' needs and wants, and their changes through time.

Finally, we acknowledge that our conclusions are context specific, linked to the characteristics of the TOD developments in lower density urban areas, such as the Australian cities. While we would suggest that caution needs to be exercised when considering translating these findings to other conditions, we would also assert that TOD development has emerged as an option for suburban development in many cities across North America and Europe, where low density car-served development is prevalent.

Nevertheless, our results support the view that TOD policies, designed to provide viable alternatives to car travel and multiple facilities closer to residents, will actually lead to less reliance on driving and more use of public transport, cycling and walking.

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References

Aguiléra, A., Wenglenski, S., and Proulhac, L. (2009). Employment suburbanisation, reverse commuting and travel behaviour by residents of the central city in the Paris metropolitan area. *Transportation Research A*, 43, 685–691.

Appleyard, D. and Lintel, M. (1972). The Environmental Quality of City Streets. *Journal of the American Planning Institute*, 38(2), 84-101.

Australian Bureau of Statistics (ABS) (2006) Census data, Available at http://abs.gov.au/websitedbs/censushome.nsf/home/historicaldata2006.

Barton, H., Grant, M. and Guise, R. (2003). *Shaping Neighbourhoods: a guide for health, sustainability and vitality*, Spon Press, London.

Cao, X.(J)., Mokhtarian, P.L., and Handy, S.L. (2009). The relationship between the built environment and nonwork travel: A case study of Northern California. *Transportation Research A*, 43, 548–559.

Carr, D. (1979). 'Metropolitan Design', In Gentilli, J. (ed) *Western Landscapes*, University of Western Australia Press, Perth.

Cervero, R. and Kockelman, K. (1997). Travel Demand and the 3Ds: Density, Diversity, and Design. *Transportation Research D*, 2(3), 199-219.

Cervero, R. (2001). Efficient Urbanisation: Economic Performance and the Shape of the Metropolis. *Urban Studies*, 38(10), 1651–1671.

Cervero, R. and Day, J. (2008). Suburbanization and transit-oriented development in China. *Transport Policy*, 15, 315–323.

Chen, C. and McKnight, C.E. (2007). Does the built environment make a difference? Additional evidence from the daily activity and travel behavior of homemakers living in New York City and suburbs. *Journal of Transport Geography*, 15, 380–395.

Circella, G., Mokhtarian, P. and Handy, S. (2008). Land use, attitudes, and travel behaviour relationships: A cross-sectional structural equations model for Northern California. Paper presented at the *88th Annual Transportation Research Board Meeting*, January, 13-17, Washington DC, USA.

Curtis, C. (2008). The evolution of the TOD model for low density cities: A case study of Perth's new railway corridor. *Planning Practice and Research*, 23, 285-302.

Curtis, C. and Olaru, D. (2010). The Relevance of Traditional Town Planning Concepts for Travel Minimization. *Planning Practice and Research*, 25(1), 49-75.

Curtis, C. and Scheurer, J. (2010). Planning for Sustainable Accessibility: Developing tools to aid discussion and decision-making. *Progress in Planning*, 74, 53-106.

Ewing, R. and Cervero, R. (2001). Travel and the built environment–synthesis. *Transportation Research Record*, 1780, 87–114.

Ewing, R., Pendall, R. and Chen, D. (2002). *Measuring Sprawl and Its Impact*, Vol.1, Available at http://www.smartgrowthamerica.org/documents/MeasuringSprawlTechnical.pdf.

Frank, L. and Pivo, G. (1995). Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking. *Transportation Research Record*, 1466, 44–52.

Gehl, J. (1987). *Life Between Buildings - Using Public Space*, Van Nostrand Reinhold Company, NY.

Geurs, K., Zondag, B., de Jong, G., and de Bok, M. (2010). Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. *Transportation Research* D, 15, 382–393.

Handy, S. and Clifton, K. (2001). Evaluating Neighborhood Accessibility: Possibilities and Practicalities. *Journal of Transportation and Statistics*, September/December, 67-78.

Handy, S., Cao, X. and Mokhtarian, P. (2005). Correlation or causality between the built environment and travel behaviour? Evidence from Northern California. *Transportation Research D*, 10, 427-444.

Jacobs, A.B. (2001). *Great Streets*, MIT Press, Cambridge, Massachusetts.

Kamruzzaman, M., Baker, D., Washington, S., Turrell, G. (2013) Residential dissonance and mode choice. *Journal of Transport Geography* 33, 12-28.

Karou, S. and Hull, A. (2014). Accessibility modelling: Predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK. *Transport Geography* 35, 1-11.

Khattak, A.J. and Rodriguez, D. (2005). Travel behaviour in neo-traditional neighborhood developments: A case study in USA. *Transportation Research A*, 39(6), 481-500.

Lund, H. (2006). Reasons for living in a transit-oriented development, and associated transit use. *Journal of the American Planning Association*, 72(3), 357–366.

Madanipour, A. (2001). How relevant is 'planning by neighbourhoods' today? *Town Planning Review*, 72(2), 171-191.

Martinovich, P. (2008). The Integration of Rail Transit and Land Use in western Australia. *Paper presented at the Conference on Railway Engineering (CORE)*, 7-10 September, Perth, Australia.

Meurs, H. and Haaijer, R. (2001). Spatial structure and mobility. *Transportation Research D*, 6(6), 429–446.

Meurs, H. and van Wee, B. (2003). Land Use and Mobility: A Synthesis of findings and Policy Implications. *European Journal of Transport and Infrastructure Research*, 3(2), 219-233.

Mokhtarian, P.L. and Cao, X. (2008). Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. *Transportation Research B*, 42, 204-228.

Newman, P. and Kenworthy, J. (1999). *Sustainability and Cities: Overcoming Automobile Dependence*, Island Press, Washington DC.

Sanchez, T.W. and Dawkins, C.J. (2001). Distinguishing City and Suburban Movers: Evidence from the American Housing Survey. *Housing Policy Debate*, 12(3), 607-631.

Scheurer, J. and Curtis, C. (2008). *Spatial Network Analysis of Multimodal Transport Systems: Developing a Strategic Planning Tool to Assess the Congruence of Movement and Urban Structure - A Case Study of Perth before and after the Perth-to-Mandurah Railway*, Available at http://abp.unimelb.edu.au/files/miabp/5GAMUT2008_JUN_02.pdf.

Schwanen, T. and Mokhtarian, P.L. (2005). What if you live in the wrong neighborhood? The impact of residential neighborhood type dissonance on distance travelled. *Transportation Research D*, 10(2), 127–151.

Tibbalds, F. (2001). *Making People Friendly Places: Improving the public environment in towns and cities*, Spon Press, London.

Travisi, C.M., Camagni, R. and Nijkamp, P. (2010). Impacts of urban sprawl and commuting: a modelling study for Italy. *Journal of Transport Geography*, 18(3), 382-392.

Urban Task Force (1999). *Towards an Urban Renaissance*, E & FN Spon, London.

Van Acker, V. and Witlox, F. (2010). Car ownership as a mediating variable in car travel behaviour research using a structural equation modelling approach to identify its dual relationship. *Journal of Transport Geography*, 18, 65–74.

Van Wee, B. and Geurs, K. (2011). Discussing Equity and Social Exclusion in Accessibility Evaluations. *European Journal of Transport and Infrastructure Research*, 11(4), 350-367.