CHAPTER 18

CITIES AS SYSTEMS: NODE AND PLACE CONFLICT ACROSS A RAIL TRANSIT NETWORK

Ryan Falconer, Courtney Babb and Doina Olaru

INTRODUCTION

Urban growth and mobility concepts, including sprawl and car dependence, have received much attention in the transport literature. In addition, many other researchers have critiqued these concepts (Frumkin, Frank & Jackson, 2004; Holtzclaw, 2000), defined alternative forms of growth and mobility (Arrington & Cervero, 2008; Bertolini & Spit, 1998; Falconer & Newman, 2010) and developed policy and practical models that have potential to deliver more resilient outcomes for our cities and their transport systems (Dunning, 2005; Litman, 2015; van Audenhove, Dauby, Korniichuk & Rourbaix, 2014).

Chapter 17 discussed how historic transport infrastructure investment strongly influenced urban form across the Perth metropolitan area. It also discussed how investments in metropolitan rail since the early 1990s were intended to counteract sprawl and car dependence and open up opportunities for new urban growth paradigms. In particular, construction of new rail stations created potential for new forms of development within their immediate catchments and possibilities to link to areas further away and not served directly with rail transit through provision of park-and-ride (PnR) and feeder buses.

Researchers have developed a Node-Place model defining how stations operate within the context of the urban system with
respect for local development and interchange functions (Bertolini, 1996; Chorus & Bertolini, 2011). Within the model framework, analysis of the Node/Place functionality of individual stations means they are ascribed a typology relative to all the other stations being analysed. Context is vital in such analyses as the influence of rail on accessibility and development potential is rarely restricted to the immediate surrounds of a station.

Chapter 17 also presented the findings of a recent Planning and Transport Research Centre (PATREC) project, Stations In or Near Freeway Medians – reconciling Node and Place conflicts, and identifies where each of the thirteen stations in the sample is located in the continuum of the Node-Place model. Specifically, it addresses the research and policy question of whether placement of stations in freeway medians – applicable to the Mandurah and Joondalup lines – aided or limited opportunities for Transit-Oriented Development (TOD). Stations in freeway medians included in the PATREC research project sample have fewer existing transit-oriented and place-based characteristics and present much greater barriers to delivery of TOD in the future compared to stations located outside of freeway medians.

This chapter explores the research data and addresses three supplementary research questions. Firstly, in a relatively monocentric and sprawled metropolitan area like Perth, what were the intended benefits of constructing stations in freeway medians? Secondly, in recognition that the city is a system and not simply a series of nodes and corridors, should future investments in higher-order, fixed-line transit avoid major roads (highways and freeways)? Thirdly, despite the ‘best’ of policy intentions, can major roads and their district functions, unrelated to transit access and operations, affect both Place and Node potential?

The remainder of the chapter is structured in five sections. First, we discuss station typologies in more detail and define the sub-categories of interchange functionality within the ‘Node’ parameter. In particular, we discuss the different characteristics of stations supplied with park-and-ride, kiss-and-ride and feeder
transit services. Presently, none of Perth’s stations act as interchanges between metro rail and second-order transit such as light rail or bus rapid transit, so connecting transport is limited to road-based buses with limited or no prioritisation.

In the next section, we define the ‘Background Traffic’ indicator and conceptualise its relationship to the function of station precincts. The authors note that few (if any) other research pieces have explored this relationship or considered implications for Node and/or Place functionality.

The following section presents additional relevant results from the recent PATREC study examining the relationships between Place, Node and Background Traffic before unpacking our findings in more detail and relating our data to typological frameworks defined by others and the concept of the city as a system. Knowledge of individual stations is used to provide insights and interpret the Background Traffic performance.

We conclude with a range of policy implications synthesised from our data. These relate to current and potential future policy trajectories with respect for investment in transport infrastructure and services and urban growth policy. In doing so, we answer our three specific research questions posed earlier. We then broaden the discussion to consider how various findings and lessons from this research could be applied in other cities that exhibit similar land-use and transport characteristics.

A PLACE FOR ALL STATIONS

Urban and transport planners may be forgiven for thinking that TOD needs to be facilitated in all station precincts across a metropolitan rail network. There is common understanding that TOD can be a more resilient form of urban development that outperforms conventional suburban-style development on a range of transport and planning indicators (Arrington & Cervero, 2008; Trubka, Newman & Bilsborough, 2010).
Urban accessibility is affected significantly by the construction of new rail lines and especially by where stations are located. All things being equal, co-locating land development with stations on high-capacity, rapid transit lines can encourage use of public transport through walk-on ridership. Significantly, use of public transport may be higher than if access to rail was not provided and/or the land development occurred in locations where transit access was less. Co-located land development and transit (especially high-capacity, rapid transit) has been found to have positive outcomes for urban infrastructure supply and operating costs (Trubka et al., 2010; UN-Habitat, 2014).

Bertolini (1996, p. 332) defines transit stations as both ‘node of networks’ and ‘places in the city’. He argues that Node/Place functions influence each other and that this needs to be accounted for in metropolitan planning. For example, land-use policies that target strategic co-location of development with transit stations that already have strong nodal functions may compromise the land-use outcome and functionality of the station as an interchange. Bertolini’s Node-Place model is explored in more detail in chapter 17.

Other studies have developed station typologies although these tend to have a common, independent variable: distance from the CBD. They also tend to focus more on land-use than interchange functionality as the key condition (Arup, 2005; Centre for Transit Oriented Development (CTOD, 2010; Kamruzzaman, Baker, Washington & Turrell, 2014; Thorne-Lyman et al., 2011).

A study in the US by Kittelson & Associates (Semler & Parks, 2011) assessed how access to stations could be best promoted depending on context and what the implications of new development and transport investments might be (e.g. a shift in emphasis from PnR to walk-on patronage through TOD). The study defined eighteen different station types on the basis of existing land-use and transport data and combinations thereof.

Another Arup (2008) study evaluated the potential for different types of investment around transit stations that form part
of the Bay Area Rapid Transit (BART) system in San Francisco. Much like Kittelson & Associates’ approach, this research considered how functions differ between stations and that a singular development blueprint will not apply in all instances. The Arup (2008) study defined five types of stations based on the following performance criteria: ridership and access to the station by foot and car (PnR and feeder buses). They included:

- **Urban**: high volume of boardings/alightings, a walkable station precinct, limited parking (particularly PnR) and significant feeder bus services
- **Urban with parking**: moderate–high volume of boardings/alightings, relatively walkable station precinct, less limited parking (particularly PnR) and significant feeder bus services
- **Balanced multimodal**: moderate volumes of boardings/alightings, less walkable station precinct, small to moderate supply of PnR and moderate to significant feeder bus services
- **Multimodal – auto reliant**: moderate volumes of boardings/alightings, suburban road network within station precinct, good access to freeways, moderate to significant PnR supply and fewer feeder bus services
- **Auto dependent**: low to moderate volumes of boardings/alightings, suburban road network within station precinct, adjacent to freeways, moderate to significant PnR supply, and few feeder bus services.

A combination of access characteristics was central to show how stations fare within the Node-Place model. Policy implications of the work included a consideration that future investments in transport infrastructure and TOD need not be limited strictly by current form and function, e.g. a car-reliant precinct could be transformed given the right investment program and assuming such investment would represent value for money.
The various studies, either implicitly or explicitly, assumed that a balanced situation is desirable and therefore, even if a station functions as a strong Node in the short or medium term, over the long term a planning prerogative should be to increase Place functionality. In particular, PnR is often categorised as a temporary provision to generate transit patronage until such time as the market is ready to deliver TOD and car arrivals can be replaced by walk-on ridership.

In practice, the complexity of the urban system means there will be no uniform urban transect or typographical model applicable to each and every rail line. Conditions at stations along different lines may change depending on their location with respect to the CBD but the decaying distance effects may be dominated by other factors. For example, the location of suburban activity centres and major interchanges will influence the Node-Place balance on some rail lines differently to others. This means that scholarly work, which has focussed more on typical monocentric cities using CBDs as urban centroids, needs to be expanded and become more reflective of contemporary urban dynamics. In addition, by considering a city as a system, there may be good reasons to retain strong ‘Node’ functions at stations rather than pursuing strategies to increase ‘Place’. This may be because of the catchments these stations serve and reductions to station access that investment in Place could yield. Furthermore, some major physical or operational constraints cannot be addressed in a cost-effective way to increase Place functionality, and isolation of the station in a freeway median may be precisely such a constraint.

Chapter 17 described that the two ‘freeway’ lines (Joondalup and Mandurah) in Perth, built in the past two decades, are significantly longer than the three ‘heritage’ rail lines (Fremantle, Midland and Armadale). This reflects Perth’s strong north–south orientation along the Western Australian coastline: the ‘freeway’ lines are north–south, while all the ‘heritage’ lines have much stronger east–west orientation.
Table 1 summarises the characteristics of the five railway lines: length (km), number of stations, average station spacing, PnR supply and number of interchanging bus services per station. The Joondalup and Mandurah lines were intended to serve broader catchments and were constructed with more PnR, integrated feeder bus services and greater station spacings. Even with two new stations planned and committed to on the Mandurah line (after 2017–2018) – Aubin Grove and Karnup – average station spacing will remain close to 6 kilometres. More detailed statistics at the individual-station level, including relationship of Node functionality to actual boardings and alightings, are explored later in the chapter.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Midland</th>
<th>Fremantle</th>
<th>Armadale/Thornlie</th>
<th>Joondalup</th>
<th>Mandurah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>16</td>
<td>19</td>
<td>31(^*)</td>
<td>41(^*)</td>
<td>71</td>
</tr>
<tr>
<td>Number of stations</td>
<td>12</td>
<td>15</td>
<td>17</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Average station spacing (km)</td>
<td>1.33</td>
<td>1.27</td>
<td>1.82</td>
<td>3.73</td>
<td>7.1</td>
</tr>
<tr>
<td>Average park-and-ride supply (bays)</td>
<td>163</td>
<td>37</td>
<td>136</td>
<td>737</td>
<td>794</td>
</tr>
<tr>
<td>Average number interchanging bus services</td>
<td>1.86</td>
<td>1.60</td>
<td>2.28</td>
<td>7.55</td>
<td>9.56</td>
</tr>
</tbody>
</table>

Table 1: Summary metrics for Perth’s metro rail lines. \(^*\)Does not include Belmont Park, which is for events only. \(^*\)Does not include Showgrounds, which is for events only. \(^*\)Length for Armadale line specified, not including Thornlie spur. \(^*\)Includes extension to Butler.

Unlike the heritage lines, the freeway lines were planned and constructed to provide already-developed areas with a higher level of transit accessibility. As major urban retrofits, they were located for much of their length within the Kwinana (Mandurah line) and Mitchell (Joondalup line) freeways (see example Figure 1). These alignments meant the lines could be constructed relatively easily and cheaply, being on land reserved already for transport and yielding limited impacts on existing built form. Furthermore, a number of stations could be tied into perpendicular road interchanges and PnR constructed on available public land nearby, allowing for access by both feeder buses and PnR patrons.

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These investments in rail have had pronounced impacts on travel behaviour in Perth. Figure 2 presents private and public

Figure 1: Mandurah line from north of Canning Bridge (outlook towards Perth City).

Figure 2: Annual trends in metropolitan rail passenger kilometres in Perth, 1977 to 2008 (BITRE, 2009).
transport statistics reported initially by the Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2009) covering a period from the late 1970s to 2008 (the year following the opening of the Mandurah line). Comparatively, there has been growth overall in both private and public transport kilometres; however, the rate of increase in private kilometres has declined relatively consistently over the thirty-year reporting period while the rate of growth in public transport kilometres is influenced significantly by major rail improvement projects.

Scheurer and Curtis (2008) have measured the increases in regional accessibility in Perth following the opening of the Mandurah rail line, thereby providing the context for people to choose to live in new locations made accessible by the new service. Others have validated these findings through travel diary research (Botte & Olaru, 2012). Indisputably, the infrastructure also benefitted those within station catchments, underserved previously by public transport.

Figure 3: Warwick Station catchment, 2012.
Analysis of catchments supports these findings further and an example from the Joondalup line, Warwick Station, is provided (Figure 3). Based on 2012 numberplate survey data, Warwick has a catchment area of about 7,450 hectares, substantially larger than on the ‘heritage’ lines.

Two major studies in Perth, both executed on behalf of the state government, have assessed opportunities for investment in stations to yield better Node and/or Place outcomes. The earlier work, completed in 2007, only assessed ‘readiness for TOD’ based on a variety of existing land-use and public realm characteristics (Syme Marmion & Co, 2007). The study did not look at nodal functions and, accordingly, was of limited use with respect for both current and potential roles for stations within the city as a system. Specifically, it did not acknowledge the very different conditions (urban transects) along the ‘heritage’ compared to ‘freeway’ rail lines.

The later work assessed a sample of ten stations for both node and place function and developed policy recommendations that were cognisant of the role of these stations within the broader urban environment (Arup, 2012). In particular, the study identified differences between ‘freeway’ and ‘heritage’ line stations and recommended investment in more interchange functionality in certain locations because of:

- Significant constraints imposed on development because of presence of major transport infrastructure;
- Opportunities to attract more transit users from the station’s hinterland; and
- Opportunities for the station to anchor a new secondary transit (e.g. light rail or bus rapid transit) alignment, which in turn could facilitate TOD in new locations.

Arup’s work was an important precursor to PATREC’s recent research. It was one of few studies to examine how major road transport infrastructure can encumber stations. By implication, it led to a rethink of land-use policy at a state level that then aimed
to direct infill development to some stations encumbered in this way. PATREC’s research has fleshed these issues out in much more detail and across a comprehensive set of indicator variables, with the objective to:

- Assess differences in performance and potential across Node/Place indicators with location in or separation from major road infrastructure (freeway medians, particularly) being independent variables; and
- Identify the impacts of Background Traffic on performance and potential. Background Traffic and transport infrastructure proximity are interdependent, but the former is difficult to measure.

The research also considers the city as a system and highlights that implications should be evaluated not only at the individual station level or railway line, but rather across the network. At the individual station level, there may be sense to maintaining strong Node functionality and avoiding investment in the Place dimension; however, consequences of Node function dominating lines or even the network include potential for urban sprawl and acute passenger tidal flow issues at peak times.

Weekday average boarding and alighting data from 2011 for the AM peak period (7am to 9am) show uneven boarding and alighting patterns across the network (Figure 4, a) to e)). This discrepancy is more pronounced on Perth’s ‘freeway’ lines. This data illustrates the tidal flow issues evident on the metropolitan rail network, which impact negatively on the cost of rolling stock and operations, and cost recovery through the fare-box (Infrastructure Partnerships Australia, Arup & Veolia Environment, 2012).

The data shows that a more detailed taxonomy of stations is required to better understand their functions in the urban transport system. We start this analysis with the Background Traffic, conceptualised in the next section, and subsequently investigate the relationships between Background Traffic and Node and Place factors.
Background Traffic is a complex construct to develop and apply. This is because Nodes (and Places) generate road traffic and it is difficult to separate this traffic from vehicle trips that occur through station precincts. Additionally, road traffic can reflect land-use activity within a station precinct and the trips to and from the precinct that are generated.
Road capacity and design dimensions are expected to influence Node and Place functionality. For example, basic assessment of roadway level-of-service and degree-of-saturation may reveal similar states within a sample of precincts; however, some environments may feature major arterials, grade-separations and wide-intersection spacings, while others have a flatter and denser internal street hierarchy, with much less capacity per link and significantly more intersections.

The Background Traffic indicator applied in the recent PATREC study encompassed the following variables:

- Peak hour volume-to-capacity;
- Peak hour average level of service;
- Capacity of road(s) parallel to the station (measured based on number of lanes);
- Capacity of road(s) perpendicular to the station (measured based on number of lanes);
- Intersection spacing along road(s) parallel to the station.

The researchers hypothesised that these road capacity and design dimensions were appropriate items to differentiate precinct environments and their performance. Similar to the other components of Place and Node, each variable was scored across a normalised scale (0–1) and received the same weighting in generating the indicator. This matched the process for generating the Place and Node indicators, although alternative weighting scenarios were also evaluated for these (see chapter 17). Results across the sample of stations are reported in the next section and reveal insights into the relationships between Place, Node and Background Traffic. The Background Traffic construct also provides context and a baseline for future studies that may consider different constituent variables.
THE PLACE, NODE AND BACKGROUND TRAFFIC NEXUS

The aggregate Place, Node and Background Traffic values for the thirteen stations in the sample were shown in chapter 17 (see Tables 2, 3 and 4). The indicator values are reproduced here in Table 2. We reiterate that four different station configurations: ‘heritage’, ‘freeway interchange’, ‘freeway midblock’ and ‘divergent’ (e.g. stations on the freeway lines located away from the freeways) were compared.

The interpretation for the Background Traffic indicator is distinct from the other two. High aggregate scores on Place and Node indicators suggest high functionality, while a high score on Background Traffic implies, *ceteris paribus*, constraints on station performance. Plainly the relationships are not this simple, a point we explore shortly.

The Node-Place model identified stations that were Place-dominant (Subiaco, Leederville and Joondalup) and Node-dominant (Murdoch, Warwick and Cockburn Central). The remaining stations were more balanced in their Node-Place functions. On closer inspection, at the domain level, the findings reinforce that stations can have conflicting functions depending on where the station is located within the broader urban system.

The research yielded three main findings with respect to station location: 1) stations located away from freeway medians or on the heritage lines perform more successfully as Places or have greater capacity to develop the Place function than stations located within freeway medians; 2) stations located within freeway medians function more successfully as Nodes, due primarily to historic transport planning that has endowed them with generous PnR and/or feeder bus services; 3) stations located in the freeway median have a lower potential to develop as TODs.

There is an evident relationship between the directionality of train trips (e.g. inbound versus outbound across an average weekday) and Place performance. Higher Place performance corresponds to higher contra-flow as they are both trip generators and attractors. Median stations, with the exception of Leederville
and, to some extent, Glendalough, make a very small contribution to contra-flow and generally exhibit very high boarding-to-alighting ratios in peak hours. This effect seems more powerful than distance/time from the CBD, which correlates weakly with morning peak boarding-to-alighting ratios (Figure 5).

Table 2: Aggregate Place, Node and Background Traffic Scores across research sample

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Place score</th>
<th>Node score</th>
<th>Background Traffic score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannington</td>
<td>Heritage</td>
<td>0.34</td>
<td>0.51</td>
<td>0.52</td>
</tr>
<tr>
<td>Maddington</td>
<td></td>
<td>0.39</td>
<td>0.30</td>
<td>0.50</td>
</tr>
<tr>
<td>Midland</td>
<td></td>
<td>0.48</td>
<td>0.40</td>
<td>0.44</td>
</tr>
<tr>
<td>Subiaco</td>
<td></td>
<td>0.34</td>
<td>0.51</td>
<td>0.52</td>
</tr>
<tr>
<td>Cockburn</td>
<td>Freeway interchange</td>
<td>0.27</td>
<td>0.53</td>
<td>0.43</td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murdoch</td>
<td></td>
<td>0.28</td>
<td>0.63</td>
<td>0.56</td>
</tr>
<tr>
<td>Stirling</td>
<td></td>
<td>0.42</td>
<td>0.41</td>
<td>0.44</td>
</tr>
<tr>
<td>Glendalough</td>
<td>Freeway midblock</td>
<td>0.44</td>
<td>0.45</td>
<td>0.37</td>
</tr>
<tr>
<td>Leederville</td>
<td></td>
<td>0.65</td>
<td>0.36</td>
<td>0.31</td>
</tr>
<tr>
<td>Warwick</td>
<td></td>
<td>0.35</td>
<td>0.62</td>
<td>0.45</td>
</tr>
<tr>
<td>Joondalup</td>
<td>Divergent</td>
<td>0.62</td>
<td>0.26</td>
<td>0.88</td>
</tr>
<tr>
<td>Wellard</td>
<td></td>
<td>0.33</td>
<td>0.25</td>
<td>0.65</td>
</tr>
<tr>
<td>Greenwood</td>
<td>Control (away from activity centre)</td>
<td>0.35</td>
<td>0.47</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Figure 5: Station location relative to CBD compared to average weekday morning peak hour boarding-to-alighting (b/a) ratio (March 2014).
Chapter 18

With respect to AM peak boardings, there is compelling evidence that Node functionality, not Place-related, walk-up ridership, is the source of the most peak-hour patronage. The bi variate relationship between the combined PnR supply and feeder bus availability versus boardings is strong ($R^2$ value 0.97 in Figure 6).

Table 3 compares the thirteen stations with respect to distance from the CBD, Node indicator score, feeder bus catchment and PnR catchment. The stations are ranked in ascending order on the distance variable. Catchments were derived using the same method as described in Falconer (2014). There are moderate associations between all factors except with the distance from the CBD. Tellingly, most stations have significant catchment areas, which far exceed the commonly accepted, 200-hectare ‘walkable’ catchment suggested by Newman and Kenworthy (2006).

![Figure 6: AM peak hour boardings on an average weekday compared to park-and-ride supply and feeder bus service component measure (March, 2014).](image)

Relatively weak relationships between Background Traffic, and Place and Node are also manifest. Subiaco has the highest Place performance and a moderate Background Traffic score. Joondalup, with a reasonably good Place score, has by far the highest Background Traffic score despite being a divergent
Node and Place Conflict Across a Rail Transit Network

Station | Distance from CBD in km (via rail network) | Node indicator score | Feeder bus catchment (ha) | Park-and-ride catchment (ha)
---|---|---|---|---
Leederville | 2.3 | 0.36 | - | -
Subiaco | 3.6 | 0.51 | 1,146 | -
Glendalough | 5.6 | 0.45 | 1,390 | 1,561
Stirling | 8.8 | 0.41 | 4,391 | 3,454
Cannington | 12.3 | 0.51 | 3,243 | 1,033
Murdoch | 13.9 | 0.63 | 5,559 | 7,175
Warwick | 14.5 | 0.62 | 4,615 | 7,456
Midland | 16.1 | 0.40 | 8,083 | 7,125
Greenwood | 17.5 | 0.47 | - | 2,129
Maddington | 17.7 | 0.30 | 1,124 | 1,033
Cockburn Central | 20.8 | 0.53 | 4,624 | 3,035
Joondalup | 26.2 | 0.26 | 3,116 | 2,267
Wellard | 37.2 | 0.25 | 410 | 625

Table 3: Distance of stations from CBD, Node indicator score, and feeder bus and park-and-ride catchments.

Warwick has a weak Place score and a surprisingly low Background Traffic score. Wellard is a poor performer across both the Place and Node indicators and yields the second-worst Background Traffic score.

These and other outwardly inconclusive results can be explained better through careful inspection of the Background Traffic constituent variables and a deep understanding of context. Performance across constituent variables is shown in Table 4. Again, scores for all variables are normalised to values between 0 and 1. Some scores are coarse – for example, for Level of Service (LoS) – because raw values were coarse. Three LoS scores were observed at each location: 0.2, 0.4 and 0.6.

The coarse nature of some scores may be argued to have an unreasonable influence on overall scoring, however, the researchers accounted for this, at least partly, by including a range of reasonable variables and applying weighting factors. The effect must also be acknowledged as a consequence of the normalised assessment framework.

In general, scores are expected to be higher where stations are within proximity to wider and busier roads, which tend also to feature wider intersection spacings. For example, the road network around Murdoch is very high capacity. South Street
(which is perpendicular to the station) is a major arterial, has three lanes in each direction and very wide intersection spacing. The station itself is situated in the middle of a diamond interchange between Kwinana Freeway and South Street. Yet, South Street has relatively high residual capacity in peak hours, due to recent major upgrades to intersections and addition of lanes to Kwinana Freeway to reduce delays on the access ramps. Also, there is no influence from the parallel road variable, which pulls the indicator score even lower.

In contrast, Wellard station, located away from Kwinana Freeway, has a high Background Traffic score. The score is influenced significantly by nearby road congestion in the evening peak hour.

Subiaco is near no major roads but local network congestion in peak hours – a natural by-product of an inner-city location – means a higher Background Traffic indicator score than may be anticipated. We discuss these and other contextual factors in more detail in the next section as part of a review of strategic policies applicable to our sample of stations and to better understand the city as a system.

<table>
<thead>
<tr>
<th>Station</th>
<th>V/C (AM peak hour)</th>
<th>V/C (PM peak hour)</th>
<th>AM LoS average</th>
<th>PM LoS average</th>
<th>Parallel road number of lanes (one way)</th>
<th>Parallel road intersect. spacing over 10km</th>
<th>Perpend. road number of lanes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannington</td>
<td>0.72</td>
<td>0.13</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.33</td>
<td>0.52</td>
</tr>
<tr>
<td>Cockburn Central</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>0.25</td>
<td>0.33</td>
<td>0.43</td>
</tr>
<tr>
<td>Glendalough</td>
<td>1.00</td>
<td>0.82</td>
<td>0.00</td>
<td>0.50</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.37</td>
</tr>
<tr>
<td>Greenwood</td>
<td>0.16</td>
<td>0.51</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.49</td>
</tr>
<tr>
<td>Joondalup</td>
<td>0.82</td>
<td>0.91</td>
<td>1.00</td>
<td>0.50</td>
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Table 4: Station performance across Background Traffic variables and in aggregate for the indicator.
DISCUSSION

The Strengths and Weaknesses of Freeway Median Stations
In a medium-sized sprawled city – particularly where urban rail has been retrofitted – many stations can be expected to exhibit strong Node functions. In Perth, this is evident especially on the Joondalup and Mandurah lines because of the way most stations are embedded in freeways and their spacing. They are also new lines: the Joondalup line was opened in December 1992 while the Mandurah line was opened in December 2007.

Our data shows substantially higher morning peak boardings at almost all stations on the freeway lines in comparison to the heritage stations. Moreover, with one exception (Leederville), these stations all have high boarding-to-alighting ratios. As expected, the opening of the ‘freeway’ lines triggered a significant uplift in passenger transit kilometres, exceeding both private vehicle kilometres and population growth. Collectively, the data seem to vindicate the decision to construct both freeway lines.

The freeway lines may have been politically and economically infeasible if constructed outside of the primary road reserves. In their absence, Perth’s northern and southern suburbs would likely have had experienced a lower level of access, continuing to rely on bus services, which simply could not compete with the higher door-to-door speeds of car travel. Under current network conditions – especially in peak hours and in the peak direction of travel – rail services are significantly faster than average freeway speeds within 15 to 20 kilometres from the CBD and, on some occasions, even further. Undoubtedly, passenger transit kilometres would not have grown as they have without the rail investments.

The state government has made significant investments in feeder modes – buses and PnR – which have also contributed to growth in patronage. Station precincts had little existing land-use that would generate or attract transit trips and were unlikely to accommodate significant new land development in the short-to-medium term. Additionally, proximity to interchanges (in many
cases) has provided some access for feeder buses and PnR users, while residual space within the primary regional road reserve has been available readily for bus facilities and PnR bays.

Provision of PnR has yielded short-term patronage and farebox return while in the longer term, ceteris paribus, potential for land development and walk-on patronage. Yet, there is no uniform effect across the lines. Leederville is one of these exceptions. Leederville does not have high patronage in relative terms but functions as a destination more so than an origin. There is no existing, strong TOD around the station, nevertheless, it is on the edge of the CBD and provides access to mixed-use development within a relatively short street network distance. There is also good accessibility to employment and destinations in three suburbs surrounding the CBD (Northbridge, North Perth and West Leederville) via bus services, including free Central Area Transit (CAT). While not feeding the station, these buses are close enough by to facilitate fairly convenient transfers.

As lines, the main success factors for Mandurah and Joondalup have also become their greatest weaknesses, through the rebound effects. Although transit is a critical part of the ‘smart growth’ agenda, the accessibility gained through speed and alleviated congestion may be converted into increased travel distances (Curtis & Olaru, 2010). Consequently, while they have met clear needs, the Mandurah and Joondalup lines have also contributed to expansion of the metropolitan footprint because they have significantly altered travel time equations: people can travel further in the same time. Land-use and urban growth policy have not managed this sprawl effectively.

Government and the private sector also need additional work to deliver ‘gold standard’ Places around stations. The Cockburn Central development west of the station has some strong TOD characteristics, however, other medium-density housing is actually separated from the station by a six-lane major arterial (Beeliar Drive) and Gateway Shopping Centre – a vast, car-oriented box.
Murdoch is designated in growth policy as a Strategic Centre, second only in eminence to Perth CBD. The Centre incorporates Fiona Stanley Hospital – the state’s largest – and ancillary health facilities, St John of God Hospital Murdoch (private) and Murdoch University. High activity intensity, mixed use is also planned. Yet, the hospitals are separated from the station by at-grade PnR and are well supplied with commuter parking (Figure 7).

South Street is a major barrier to crossing movements from the north and Murdoch Drive, another four-lane major arterial, severs the university from the station. The proposed Roe Highway extension is likely to funnel more traffic down Murdoch Drive and the state government has committed to facilitating more through-traffic through road upgrades. Despite its policy status, Murdoch Station scores poorly on Place.

According to Thomas and Bertolini (2014), TODs need to be thought of as a regional strategy with individual TODs interacting with others. Others have called this polycentrism, and a desirable outcome of a Smart Growth agenda (Newman, Beatley & Boyer, 2009). A ‘network’ or holistic approach to TOD is not evident along the freeway lines where there are weak Places in absolute
terms and instead, overwhelming Node functionality. This limitation explains the peak demand management issues Perth is now grappling with.

**Should Situating Stations in Freeway Medians Be Avoided in Future?**
The evidence suggests that Perth should avoid future rail alignments within freeway or highway medians because they constrain Place potential and performance. All things being equal, stations within freeway medians represent very difficult contexts for delivery of TOD, meaning that Node-focused policy is the cheapest and most effective way to generate patronage.

On the one hand, Node functionality is important because it can provide transit access for those otherwise served poorly. On the other hand, it incentivises new urban development in greenfield areas because new residents enjoy a level of access they would not otherwise have. The Mandurah and Joondalup lines met these particular purposes. In practice, the challenges associated with the operation of these lines and unintended urban growth consequences are more consequences of transport policy in general (e.g. other transport investments that have and have not been made) and suboptimal urban growth strategy and implementation. We consider these matters in more detail in the next section.

**Does Background Traffic Compromise Place and Node Functionality?**
Based solely on the seven quantitative variables (Table 4), our study of a Background Traffic indicator is inconclusive. The total indicator shows no strong association with Place or Node performance. Using contextual knowledge helps us better understand associations between Place and Node and individual Background Traffic variables and to question the findings at the aggregated level.

In practice, Background Traffic has major bearing on the function of stations and, generally, more of a negative impact on Place. The relationships are two-fold:
1. Where multi-lane, high-capacity and high-speed major arterials are part of the station precinct they exert a strong negative influence on Place functionality and potential. The effect is more pronounced when the roads experience a low service level due to high vehicle demands (especially where these are through-trips).

2. Depending on road network characteristics, network busyness may have a considerable effect on performance. This means that transport network priorities within a station catchment must be orientated away from private vehicles, which means constraining capacity along individual streets, ensuring good intersection density and limiting vehicle travel speeds.

Murdoch illustrates clearly the first effect. Opportunities for improved Place performance are compromised significantly by the orientation of current transport policy towards delivering a good level of service for future forecasted through-traffic, particularly that associated with the Roe Highway extension.

Subiaco is a fine example of the second effect. Despite relatively low overall development density (two to three-storey low-rise) and excessive parking by international benchmarks, Subiaco has been lauded as the best example of TOD in Perth (Howe, Glass & Curtis, 2009). Some of its favourable characteristics include significant mixed-use in its immediate hinterland and the sinking of the Fremantle rail line, which means no severance of the catchment by rail infrastructure.

The Node-Background Traffic association is much less clear. In hindsight, a study of the Node and Background Traffic relationship should have controlled for bus priority access. When feeder services are delayed because of general network congestion, Node functionality will be affected negatively.

Intuitively, general network congestion would associate negatively with PnR accessibility and use: the higher the congestion,
the lower the accessibility and PnR use (Curtis & Olaru, 2010; van Wee & van der Hoorn, 2002). Still, higher scores on V/C (e.g. worse congestion) are associated with Joondalup, Glendalough and Midland.

Joondalup and Glendalough have relatively low PnR and bus feeder transit supply scores, which influence their overall Node indicator scores. Midland has a relatively low Node indicator score but a reasonable quantum of PnR and good feeder bus supply. In addition, commuters who use PnR at Midland Station also appear willing to accept delays associated with travelling along and/or crossing Great Eastern Highway based on the efficient sub-regional accessibility that the Midland line affords.

These examples suggest that while the Background Traffic indicator provides some good clues as to effects on Place and Node functionality and potential of stations, its structure has to be further refined and explored.

CONCLUSIONS: POLICY AND PRACTICAL IMPLICATIONS

Our research provides insights into the development of Perth’s newest rail lines – Joondalup and Mandurah – and the regional accessibility that they have generated. The data collected and analysed demonstrates that there is a strong bias towards Node functionality on these lines. While not unique to ‘freeway line’ stations, the dominant Node feature seems to be a product of both policy intent and the rail alignments themselves.

The state government established many stations to serve large catchments by setting wide station spacings and investing in significant PnR and feeder bus services. Long sections of the lines were established in freeway medians (especially close to the CBD) and this appears to have suited Node rather than Place performance.

Freeway medians did represent opportunities from a deliverability perspective and the establishment of the lines addressed clear gaps in transit service provisions; however, the freeway lines have also perpetuated urban sprawl and there has been very limited
success with respect to TOD delivery. The relatively easy deliverability of the lines has become one of their greatest constraints.

Future transit investments in Perth have to yield greater opportunities for TOD and facilitate walk-on ridership. Land-use and urban growth policy also needs to deliver TODs that incorporate jobs to avoid increased future peak-demand management issues on the network. This will require hard decisions by state government to diverge lines from major roads (freeways and highways) and into areas where there is the greatest potential for land-use intensification. In some cases, tunnelling will be needed. It is beyond the scope of this chapter to postulate where these lines should go, but current discussions regarding an eastern Wanneroo line to the north of Perth City and a circumferential line should learn from our research.

Furthermore, as part of delivery, the consequences of alignment decisions will need to be better appreciated and addressed. For example, a line that extends to the edge of greenfield areas may perpetuate Perth’s sprawl issues whereas a line that serves the existing built environment (e.g. the circumferential line) may assist with urban containment policy.

Additionally, our research demonstrates that rail investments have not necessarily considered Perth as an integrated system. Government struggles to deliver strong ex-CBD centres that attract significant land-development intensity and are well connected to each other. The Joondalup and Mandurah lines have not really yielded results in this respect. We recommend a statutory planning and funding policy review to help stimulate land development around future transit stations constructed away from freeways and highways, considering density bonuses, relaxation of parking standards and tax credits in return for delivery of affordable housing. Such a review may have little relevance now to the freeway lines.

Equally important, government policy needs to emphasise the most desirable functionality at stations and avoid trying to deliver outcomes that conflict with each other and therefore undermine
performance. Murdoch represents one of the cases where conflict has occurred because of conflicting emphases on district traffic operations and land-use intensification. Not all precincts need to meet the Place, Node and Background Traffic functions to the same extent. Nodal functions should not be forced into ‘good places’ such as Subiaco, nor Place functions to Warwick and Glendalough.

Our study of the Background Traffic indicator (as an aggregate measure) was limited in demonstrating how road network operations can influence both Node and Place functionality, however, interrogation of constituent variables and understanding of context was revealing. As indicated, high-capacity and high-speed major arterials have a strong negative impact on Place functionality and potential. When the transport network within a station catchment does not prioritise cars (e.g. provides good intersection density and constrains vehicle travel speeds), access by public transport and active travel is enhanced and the Node functionality is increased. We recommend that further research refines our Background Traffic dimensions. In particular, a measure of bus priority and better differentiation of busy sub-arterial roads and busy major arterials should be included in the framework.

**CONCLUSION**

Overall, the study allows a good appreciation of current rail network opportunities and challenges in Perth, and opens up some strong lines of enquiry regarding the influences of co-location of rail lines with major road infrastructure and high Background Traffic on station operations. It also provides meaningful lessons for other cities with similar characteristics. For example, several lines of the Bay Area Rapid Transit (BART) System in San Francisco are partly co-located with major freeways. Like Perth’s ‘freeway’ lines, stations on BART were delivered originally for PnR to capture ridership within the low-density urban catchment. BART and government partners have been struggling
with transitioning many PnR facilities into TODs (Willson & Menotti, 2007). Like the Public Transport Authority of Western Australia, BART has a service ethos to grow transit mode share while not disadvantaging current patrons (Duncan, 2010). Perhaps the strongest policy lesson from our study does not relate to how to deliver Place functionality on existing lines, but how to avoid the same problems when future transit alignments are planned and delivered.

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