CHAPTER 17

TRANSPORT AND LAND-USE FUNCTIONS OF FOUR RAIL STATION CONFIGURATIONS IN PERTH

Courtney Babb, Ryan Falconer, Doina Olaru, Anthony Duckworth-Smith and Richard Isted

INTRODUCTION

Successful planning and delivery of public-transport systems requires the definition of roles for the various transit stations on the network. Stations are points of access to broader catchments and feeder networks. Stations can also contribute to the identity and structure of urban areas (Hale, 2013). All things being equal, the accessibility gains provided by transit stations provide incentives for land development and opportunities for the consolidation of urban centres. Transit-Oriented Developments (TODs) are now common urban growth outcomes intended by government planning policies to mitigate the impacts of transport on liveability. They are considered sustainable forms of growth characterised by a higher intensity of residential development, employment and activities in station precincts. This intensification allows better access to public transport, reduced car driver mode share and reduced distances of travel (Renne, 2009).

In Perth, Western Australia, the Joondalup (1993) and Mandurah (2007) rail corridors have been added to the three existing heritage lines of Fremantle, Midland and Armadale, with twenty-one new stations in the Perth metropolitan region. Several more stations are planned as part of the future extension of the

Joondalup line to Yanchep and as intermediate stations on the Mandurah line (Aubin Grove and Karnup).

As major sections of both lines are co-located with the Mitchell and Kwinana freeways, over half of the existing stations are located within the freeway median. Most of these stations serve broad low-density catchments. There is relatively generous park-and-ride supply and provision of feeder bus services in reflection of the catchment size and wide average station spacing.

The 'freeway line' stations present challenges for the implementation of TOD compared to stations that have evolved with less influence from major regional road infrastructure. Greater intensity of traffic and density of road infrastructure can undermine access to the station and also present challenges to urban development. There is little published evidence regarding how different station configurations or locations relative to major road infrastructure can increase conflict between varying demands on station access and undermine the potential for development of TODs. More knowledge of the land-use and transport function in various station configurations is important for the development of effective urban policy.

This chapter is the first of two that present the findings from a Planning and Transport Research Centre (PATREC) project: *Stations In or Near Freeway Medians – reconciling Node and Place conflicts.* The project compared the land-use and transport functions of thirteen stations in the Perth metropolitan region representing four different spatial configurations of rail and road infrastructure. This chapter provides an introduction of the concept of land-use and transport integration, presents an outline of the historical geography of Perth's transport system and reports on some of the main research findings. In chapter 18, the data collected as part of the project are further explored to address supplementary research questions relating to node and place conflicts.

THE ROLE OF TRANSIT STATIONS IN SUSTAINABLE CITIES

Stations can serve a variety of functions in urban land-use and transport systems. According to Bertolini (1996), stations are both Nodes and Places. As Nodes, stations are points of connection providing access to employment and other activities. As Places, stations are catalysts for activity: places to live, to meet and to conduct business. Enhancing either the Place or Node (or both) function of transit stations is an important objective of sustainable urban policy, as stations can serve as a means to greater regional accessibility and as centres of development.

TODs have emerged as a desirable urban form in station precincts, which may be able to achieve both Place and Node policy objectives. TODs have higher land-use intensity than typical suburban developments. This intensity provides a concentration of employment opportunities and land-use mix to attract, as well as generate, public transport, walking and cycling trips, reducing the need for travel by car. TODs are intended to capitalise on the availability of high-quality transit links, improving opportunities for walk-on ridership by concentrating development within the walkable catchment of stations. The walkable catchment is often referred to as 800 metres, but may extend further than this (Burke & Brown, 2007).

There is a strong body of evidence relating to the transport benefits of TOD. These include reduced car ownership (e.g. on a per capita basis), replacement of cars with public-transport trips (particularly for work trips) and an overall reduction in the car driver mode share among residents of TODs (Arrington & Cervero, 2008; Renne, 2005). Ideally, a TOD will also support high-frequency transit operations outside of typical commuter peaks. Over time, indicators have broadened beyond transport and land-use as researchers and planning authorities have begun to embrace a sort of 'TOD-plus' scenario whereby outcomes such as energy efficiency, reduced embodied carbon and carbon emissions and public health are also being assessed (Cervero & Sullivan, 2011).

In practice, TOD is not some sort of ubiquitous urban form than can be transposed on all station precincts. Some transit stations are located in urban contexts that pose significant problems for the implementation of TOD policy. The opportunities to enhance the integration of land-use and transport at stations depends on a range of factors including the availability of land that can be developed, markets that are conducive for TOD, political support from government and local communities and the quality of the surrounding public realm.

The development of different typologies of TODs is indicative of the variety of contexts where TODs emerge (Centre for Transit Oriented Development (CTOD), 2010; Falconer & Richardson, 2010; Kamruzzaman, Baker, Washington & Turrell, 2014). The inherent difficulties of delivering high-quality developments in station precincts are reflected in the concept of Transit-Adjacent Development (TAD), where the intended performance of a TOD is not achieved. Often this is because land-use is proximal to but not integrated with a station, either due to land-use characteristics or site design (Cervero et al., 2004). Case studies of TODs presented by Curtis, Renne and Bertolini (2009) reveal that successful development at stations involves strategic planning that adapts to unique opportunities for development emerging from specific social and spatial contexts.

A greater understanding of the conflicts between different demands on a station is necessary for an informed evaluation of a station precinct's capacity to develop a TOD. These conflicts may include the station functioning as a place to live and work and as an interchange between feeder bus, park-and-ride and rail. Policy makers and planners may need to make trade-offs between varying functions to address conflict that emerges between competing demands for station access.

Low-density urban areas provide unique opportunities for, and barriers to, development at stations. Many stations on Perth's

Joondalup and Mandurah rail lines are co-located with major freeway infrastructure; several stations are sited within the freeway median. Stations in areas dominated by low-density development and significant road infrastructure service a large catchment of potential transit riders. Access is provided by feeder buses that require an efficient functioning road-transport system and cars, through park-and-ride, with a large opportunity cost through consumption of land. The configuration of stations, that is the spatial arrangement of their road and rail infrastructure relative to land-development opportunities, could be one important factor in the performance and potential of stations to integrate their transport and land-use functions.

The next section outlines a brief overview of the history of Perth's land-use and transport system to illustrate the contextual factors that have led to the emergence of various station configurations in the Perth metropolitan area (e.g. various statutory planning documentation of the WA government, including *Directions 2031 and Beyond*, and *Development Control Policy 1.6: Planning to Support Transit Use and Transit Oriented Development*). The historical development of Perth's land-use and transport systems is described in more detail elsewhere (Curtis, 2008; Curtis & Low, 2012; McManus, 2003; Newman, 1992).

THE EVOLUTION OF PERTH'S RAIL TRANSPORT SYSTEM

The first metropolitan passenger railway lines appeared in Perth in the late 1800s. The first line linked the port city of Fremantle to Central Perth and then through to the inland centre of Guildford. In 1881 the metropolitan rail network was extended via a south-eastern corridor to Armadale. Stations on these 'heritage lines' (known later as the Fremantle, Midland and Armadale lines) were either sited near or adjacent to major arterial roads, which often run parallel to the railway. Early urban development around stations on these heritage lines therefore proceeded with little impact from significant road infrastructure or traffic, especially within the part of the station catchment unburdened by the parallel road.

Urban development in the decades following World War II established Perth's reputation as a car-dependent city. The growth in car ownership and use necessitated the implementation of recommendations in Gordon Stephenson and Alistair Hepburn's report in 1955 and shaped the 1970 Corridor Plan for Perth. Government support for the prioritisation of bus services over rail and the neglected maintenance of the rail network led to the closure of the Fremantle line in 1979.

The following decade saw political support for rail increase in Perth. A campaign led by Friends of the Railways successfully gathered community and political support for the reopening of the Perth to Fremantle rail line, which occurred in 1983 (Newman, 1992; see chapter 8). This marked the beginning of a period of capital expenditure to expand the urban rail system. Electrification of the rail line in 1992 was followed by the introduction of the Northern Suburbs Transit System (NSTS) in 1993. The rail line connected the Perth CBD to Currambine in the north-west metropolitan corridor, linking Perth with the newly planned major northern metropolitan centre of Joondalup. The railway line is situated within the median of the Mitchell Freeway on land that was reserved in the statutory zoning plans of the 1950s and 1960s (McManus, 2003). The NSTS emerged from planning studies that were based on a bus rapid-transit corridor and buses still played a role in the function of the corridor, feeding patrons to and from rail via station interchanges.

In addition to the NSTS, in 1992 the Western Australia state government announced support for a south-west urban passenger rail line linking Perth to Rockingham and Mandurah. The original alignment plan of the South West Mandurah Railway (SWMR) was via the Thornlie spur on the Armadale line to Jandakot; however, the approved and constructed alignment was within the median of Kwinana Freeway between Perth CBD and Anketell. The line deviates west from the

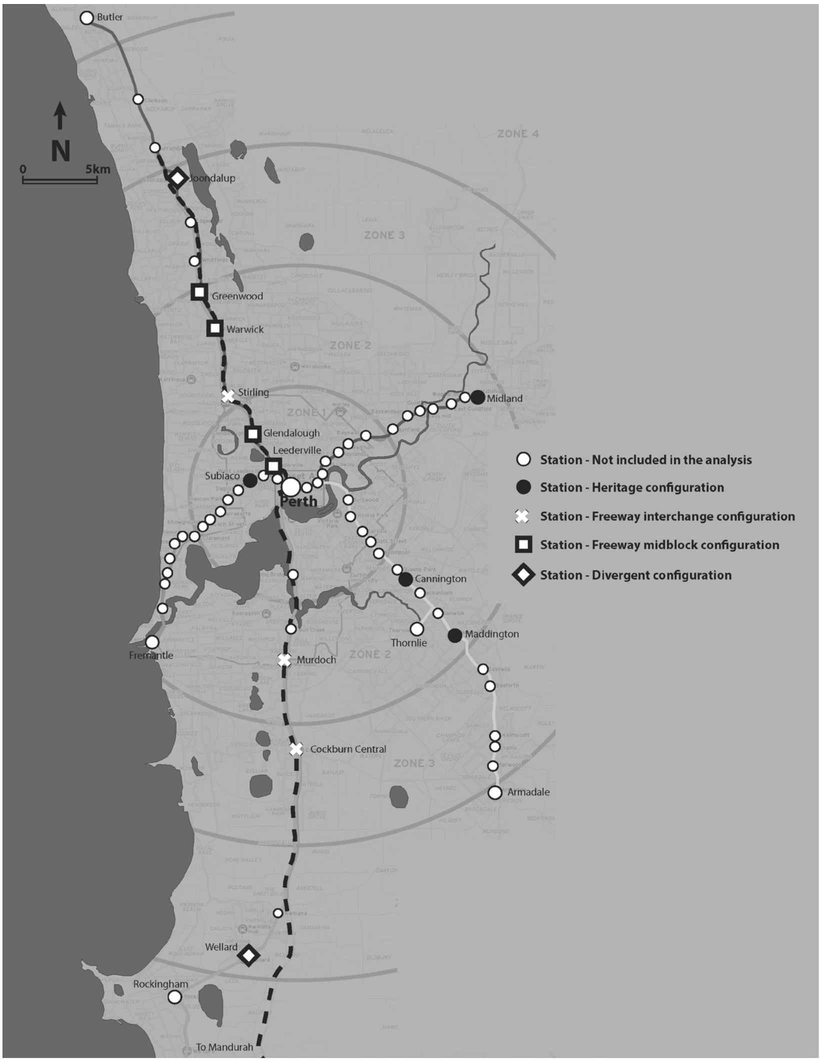

Figure 1: Rail and freeway systems in the Perth metropolitan area.

freeway south of this point. Like the NSTS, the SWMR was underpinned by an objective to deliver travel times competitive with car travel and also wide station spacing, resulting in large station catchments. Figure 1 illustrates the railways, stations and freeway system in the Perth metropolitan area.

Strategic land-use planning outlined in state plans since 2004 – *Network City: Community planning strategy for Perth and Peel* (WAPC, 2004) in 2004, *Directions 2031* (WAPC, 2010) in 2010 and the recent draft *Perth and Peel@3.5million* (WAPC, 2015) – has emphasised the objective of consolidated and well-connected urban growth, with higher density and mixed land-use development in activity centres and along activity corridors. State policies such as *Development Control Policy 1.6 Planning to Enhance Public Transport Use 1999* (later *Planning to Enhance Transit Use and Transit Oriented Development* 2005 (WAPC, 2006)) and *State Planning Policy 4.2: Activity Centres for Perth and Peel* (State of Western Australia, 2010) were developed to guide development of TODs in station precincts.

The transport and land-use outcomes of NSTS and the SWMR have been mixed. The new rail lines have seen great success in attracting ridership (BITRE, 2009; Martinovich, 2008); however, this has occurred in the absence of significant TOD at stations (Falconer, 2014), irrespective of what some commentators have argued (Hemsley, 2009). This is due to barriers to the delivery of TOD rising from integration of stations on the Joondalup and Mandurah lines with existing, low-density suburban areas.

To understand the current Place and Node function of differently configured stations, this research addresses two questions: 1) What lessons can we draw from how various station configurations function according to their land-use and transport performance and potential? and 2) How do different station configurations aid or restrict TOD? We explore these questions through our research approach, which we discuss in the next section.

RESEARCH DESIGN AND FINDINGS

The research team adapted Chorus and Bertolini's (2011) Node and Place model to evaluate thirteen stations in the Perth metropolitan area as an exploration of this issue. Chorus and Bertolini's model is illustrated in Figure 2.

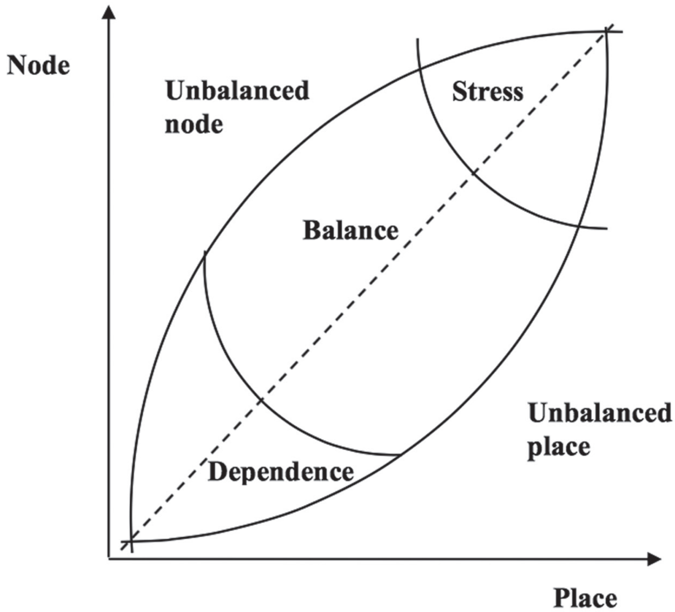

Figure 2: Node/Place Model (Chorus & Bertolini, 2011).

The model proposes five different conditions for Node and Place relationships. *Balance* refers to a synergy between land-use and transport dynamics. *Dependence* is a situation where there are lower values of both Place and Node. *Stress* occurs when there is high value of both Node and Place indicators, suggesting that conflict between land-use and transport function is likely. *Unbalanced Node* refers to a situation where there are high values of Node indicators and lower values of Place. This situation could be represented by a station with very good access by feeder systems and car, yet a surrounding hostile environment for pedestrians dominated by major roads. *Unbalanced Place* refers to a situation where there are high values of Place indicators and lower values of Node. This situation can be found in high-amenity Places with transport interchange functions.

The stations selected for analysis reflect various station configurations, depending on their relation to the freeway. Nine are from the two new freeway lines (Joondalup and Mandurah) and four are located on the heritage lines (Fremantle, Midland and

Armadale). Figure 1 illustrates the location of the thirteen stations in the Perth metropolitan region.

Station	Rail line	Location relative to freeway/ highway	Distance from CBD in km (via rail network)
Cannington	Armadale	Heritage – separated	12.3
Maddington	Armadale	Heritage – adjacent	17.7
Midland	Midland	Heritage – adjacent	16.1
Subiaco	Fremantle	Heritage – separated	3.6
Cockburn Central	Mandurah	Freeway median – interchange	20.8
Murdoch	Mandurah	Freeway median – interchange	13.9
Stirling	Joondalup	Freeway median – interchange	8.8
Glendalough	Joondalup	Freeway median – midblock	5.6
Greenwood	Joondalup	Freeway median – midblock	17.5
Leederville	Joondalup	Freeway median – midblock	2.3
Warwick	Joondalup	Freeway median – midblock	14.5
Joondalup	Joondalup	Divergent	26.2
Wellard	Mandurah	Divergent	37.2

Table 1: Stations included in project sample including line, location relative to freeway/ highway and distance from CBD.

A typology of four station configurations was developed based on these stations: a) heritage line stations, adjacent or separated by major arterial roads; b) stations in the freeway median located at major road interchanges; c) stations in the freeway median located in midblock locations; and d) stations located nearby or divergent from the freeway. Table 1 notes key station characteristics including line, station type and distance from Perth CBD via the rail network.

Our research method incorporated three key steps to generate an adapted Node and Place model. Firstly, a multi-layered analysis was undertaken, separating indicators into different domains in order to identify conflict between various station functions. This approach enabled analysis of the multi-functional nature of station precincts.

Secondly, indicators and domains were identified as reflecting the current performance of the station in regards to land-use and transport metrics or as indicative of the potential for Node or

Place functions to emerge. TODs are more than a physical set of characteristics. It is of great benefit to planners to isolate factors that reflect a station's potential to become a TOD.

Finally, a 'Background Traffic' indicator was introduced. This indicator captured the traffic flow and road capacity surrounding stations. The indicator was designed to provide insight into potential traffic and road network factors that may constrain Place and Node functionality of stations.

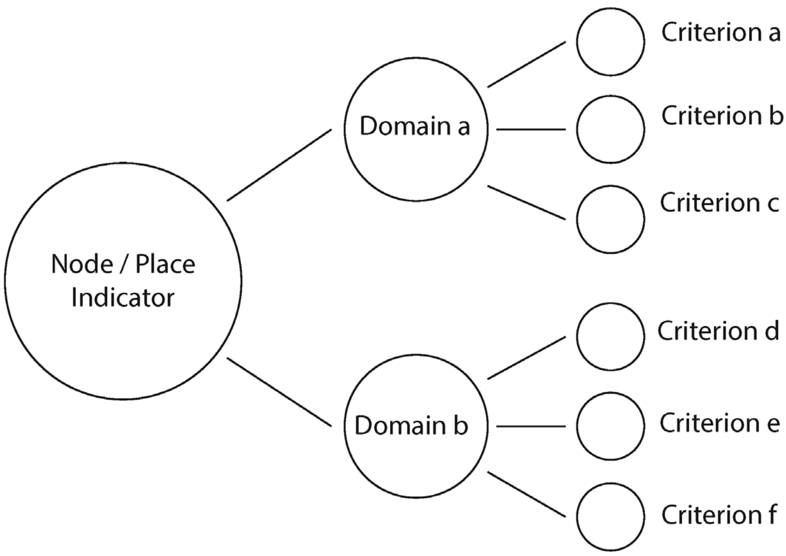

Figure 3: Indicator, Domain and Criteria Relationships.

A set of forty-three criteria was analysed and organised according to the defined Node, Place, and Background Traffic indicators and domains. The criteria were established from an initial review of the literature. The multi-layered conceptual framework is illustrated in Figure 3.

The criteria were categorised according to whether they contributed to or detracted from Node or Place function. Background Traffic criteria were treated differently (see below).

For each criterion, raw data was standardised into a score between 0 and 1, with 0 reflecting the lowest performing station and 1 the highest. Stations other than the highest or lowest performing were assigned a relative value between 0 and 1. Weighted average scores for the criteria in each domain and domain in each indicator were established.

Criteria that represented Place function were categorised into a series of seven domains. These domains then made up aggregate indicator variables. The first indicator captured *Density and Diversity of Land-use*. This indicator included four domains relating to population density and land-use diversity (including economic activity and the intensity of development), as well as the presence of developable sites and underlying socio-economic characteristics of the immediate station precinct.

		Heritage				Interchange			Midblock				Divergent	
Indicator	**Domain**	**Cannington**	**Maddington**	**Midland**	**Subiaco**	**Cockburn Central**	**Murdoch**	**Stirling**	**Glendalough**	**Greenwood**	**Leederville**	**Warwick**	**Joondalup**	**Wellard**
Density and Diversity of Land Use	Density	.23	.02	.04	.78	.13	.23	.23	.50	.28	.68	.26	.51	.14
	Land use intensity and diversity	.28	.44	.58	.89	.34	.25	.46	.56	.11	.78	.21	.82	0.0
	Development potential	.48	1.0	.44	.36	.30	.06	.53	.72	.03	.35	0.0	.58	.13
	Socio-economic level	.17	.03	.37	.85	.32	.56	.51	.25	.55	.68	.53	.37	.32
	Average	**.29**	**.37**	**.36**	**.72**	**.27**	**.27**	**.43**	**.51**	**.24**	**.62**	**.25**	**.57**	**.15**
Quality of Place	Amenity and comfort	.32	.33	.39	.60	.38	.33	.49	.41	.76	.33	.53	.68	.44
	Urban Structure	.59	.64	.89	.89	.17	.18	.44	.38	.31	.89	.36	.71	.74
	Walkability	.28	.24	.54	1.0	.25	.34	.32	.35	.31	.83	.44	.64	.33
	Average	**.40**	**.40**	**.61**	**.83**	**.27**	**.28**	**.42**	**.38**	**.46**	**.68**	**.44**	**.68**	**.50**
Overall Place function		**.34**	**.39**	**.48**	**.78**	**.27**	**.28**	**.42**	**.44**	**.35**	**.65**	**.35**	**.62**	**.33**

Table 2: Place indicator and domain scores.

The second indicator captured the *Quality of Place*. Of the three constituent domains, amenity and comfort included the level of background noise, shade and thermal comfort. Urban structure represented basic urban design elements (public spaces, landmarks and degree of road space) that indicate potential for enhanced Quality of Place. Walkability incorporated the permeability of street networks, destinations to walk to and pedestrian access to the station via prominent and direct radial routes. The scores for each domain and indicator scores for Place are illustrated in Table 2.

		Heritage				Interchange			Midblock				Divergent	
Indicator	**Domain**	**Cannington**	**Maddington**	**Midland**	**Subiaco**	**Cockburn Central**	**Murdoch**	**Stirling**	**Glendalough**	**Greenwood**	**Leederville**	**Warwick**	**Joondalup**	**Wellard**
Public Transport Access	Potential demand	.52	.28	.13	.59	.36	.59	.69	.59	.07	.67	.59	.45	.32
	Supply	.72	.12	.33	.05	.65	.90	.73	.54	.24	.38	.72	.54	.15
	Station Activity	.18	.13	.32	.11	.51	.57	.38	.25	.38	.12	.49	.33	.57
	Journey-to-work	.38	.14	.27	.50	.36	.67	.35	.73	.19	.44	.53	.50	.25
	Average	**.45**	**.17**	**.26**	**.31**	**.47**	**.68**	**.54**	**.53**	**.22**	**.40**	**.58**	**.45**	**.32**
Vehicle Access	Potential demand	.80	.68	.77	.89	.56	.74	.72	.94	.53	1.0	.74	.15	0.0
	Interchange	.15	.12	.53	0.0	.72	.76	.48	.13	.31	0.0	.73	.17	.23
	Average	**.48**	**.40**	**.65**	**.45**	**.64**	**.75**	**.60**	**.53**	**.42**	**.50**	**.74**	**.16**	**.12**
Cycling	**Average**	**.62**	**.36**	**.31**	**.16**	**.50**	**.46**	**.09**	**.30**	**.77**	**.19**	**.56**	**.17**	**.33**
Overall Node Function		**.51**	**.30**	**.40**	**.30**	**.53**	**.63**	**.41**	**.45**	**.47**	**.36**	**.62**	**.26**	**.25**

Table 3: Node indicator and domain scores.

The Node function (Table 3) comprised three indicators: *Public Transport Access*, *Vehicle Access* and *Cycling*. The public transport and vehicle access indicators were aggregations of six distinct domains representing accessibility and the supply of services and facilities. *Public Transport Access* contained four domains capturing the potential demand for station access (regional travel time from the stations and feeder bus catchment area), the quality of feeder bus and rail services, station activity (boardings and alightings) and journey-to-work data. *Vehicle Access* to the station was captured by the potential demand for vehicle access to stations, park-and-ride supply and utilisation, and kiss-and-ride facilities. *Cycling* incorporated a single domain, which included the amount of cycling infrastructure, bike parking at stations and bike mode share as constituent criteria. The standardised scores for Node indicators and domains are illustrated in Table 3.

The Background Traffic indicator comprised two domains. The first represented road congestion and performance within the station's immediate catchment. Constituent criteria include Level-of-Service (delays) and volume/capacity ratios at key intersections in the AM and PM peak hour. The second domain related to existing road capacity measured by the number of lanes and intersection spacing along major parallel and perpendicular roads.

The Background Traffic metrics require careful interpretation. Higher aggregated scores (free-flowing traffic and wide roads) do not necessarily reflect an optimal outcome and may not have a positive association with high Node or Place station functions. An evaluation of Node and Place function in relation to the domains that make up Background Traffic provides a more meaningful reflection on potential of stations to function as TODs or interchanges. Findings relating to the Background Traffic measures are introduced in this chapter and explored in more detail in chapter 18. The Background Traffic scores are provided in Table 4.

		Heritage				Interchange			Midblock				Divergent	
Indicator	**Domain**	**Cannington**	**Maddington**	**Midland**	**Subiaco**	**Cockburn Central**	**Murdoch**	**Stirling**	**Glendalough**	**Greenwood**	**Leederville**	**Warwick**	**Joondalup**	**Wellard**
Background Traffic	Traffic function	.59	.77	.78	.77	.50	.62	.58	.46	.42	.63	.57	.93	.86
	Road capacity	.44	.22	.11	.28	.36	.50	.31	.28	.56	.00	.33	.83	.44
Overall Background Traffic function		**.52**	**.50**	**.44**	**.52**	**.43**	**.56**	**.44**	**.37**	**.49**	**.31**	**.45**	**.88**	**.65**

Table 4: Background Traffic indicator and Node scores.

A further feature of the analysis is the weighting of criteria, domains and indicators to manage the influence of single or aggregate variables on overall performance. One weighting scenario is presented in Babb et al. (2015), which was calibrated so Node and Place *potential* criteria received higher weightings than those that reflected current performance. The purpose of this scenario was to reveal stations that had greater capacity to develop as TODs or as interchanges.

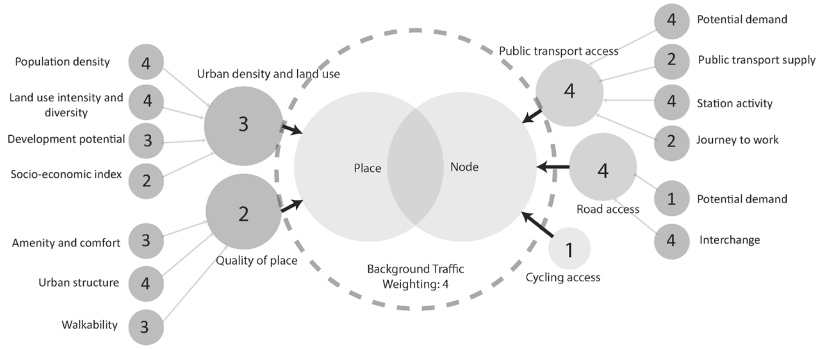

Figure 4: Node and Place indicator and domain weightings.

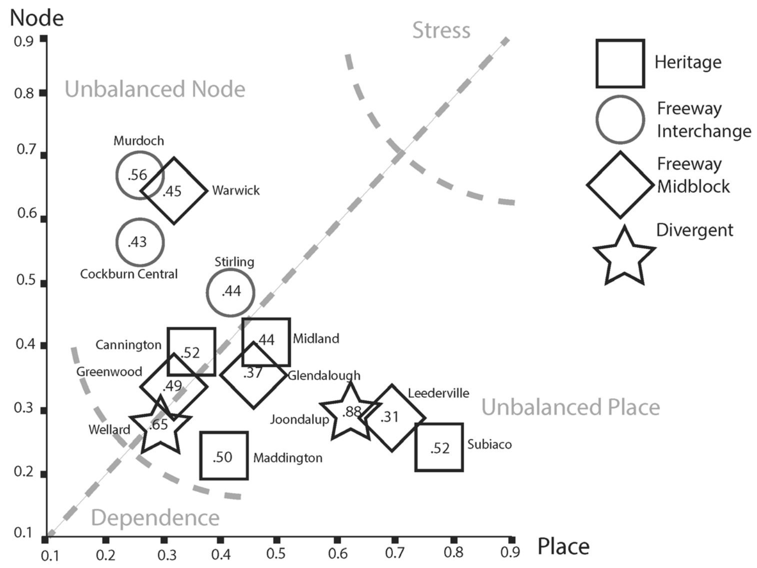

Figure 5: Station Node and Place model, with Background Traffic scores.

In this chapter, the scenario presented incorporates weightings agreed by the research team. The team applied professional experience to weight criteria and domains on a scale 1 to 4, depending on their relative influence on overall current Place and

Node functionality. The weighted values of each indicator and domain are illustrated in Figure 4.

Following the application of weightings, the overall Node, Place and Background Traffic scores for each station were incorporated into a matrix (Figure 5). Place is represented on the x axis and Node on the y axis. Background Traffic is indicated by the value in each of the station circles.

The analysis shows three clusters of stations: those that are Node-dominant (Murdoch, Warwick and Cockburn Central), Place-dominant (Subiaco, Leederville and Joondalup) and the remaining seven relatively balanced stations. Referring to Chorus and Bertolini's model (Figure 2), the aggregate station scores indicate that there are no stations that are under stress, although several stations are approaching dependence (Wellard, Greenwood and Maddington).

The following section discusses the findings in more detail, comparing the role station configurations have in Node and Place functions. Some consideration is also given to the influence of Background Traffic variables: this is covered in detail in chapter 18.

STATION CONFIGURATIONS: PLACE, NODE AND BACKGROUND TRAFFIC FUNCTIONS

Four station configurations were used to frame selection of stations for inclusion in the study. To reiterate, these configurations are stations:

1. On heritage lines, either adjacent to or separated from a highway or arterial road;
2. In a freeway median at a major road interchange;
3. In a freeway median midblock;
4. At divergent sites in proximity to a freeway.

Firstly, stations on the heritage line were higher performers on average with regard for Place function. Subiaco was the outstanding performer, with high metrics for density, employment, urban structure and walkability. Proximity to the CBD is likely a key factor shaping the Place metrics at Subiaco.

The other three heritage line stations produced less-consistent scoring across the indicators and domains. Maddington had the highest amount of developable land, reflecting the large lots inherent in the light-industrial area in the station precinct. All stations had a high degree of urban structure suggesting that there is potential for enhanced Place functionality, assuming application of supportive policy.

With regard for Node function, heritage line stations did not perform as well. There are few feeder bus services to Subiaco reflecting its inner-city location and emphasis on walk-on patronage. Cannington, which is located in the middle suburbs and in a less intense land-use context has much more interchange functionality. The heritage line stations generated consistently low Background Traffic scores, but this appears more to do with the limit capacity of road networks, reflective of the absence of freeway infrastructure, rather than traffic congestion.

We note that recent Perth-focussed research has revealed some interesting facts. Using a hedonic price model, the researchers found significant uplift for both residential and commercial land-uses in proximity to the so-called 'heritage' rail lines (McIntosh, Newman & Glazebrook, 2013).

The stations located at freeway interchanges were poor performers overall with regard for Place function both in terms of Density and Diversity of Land-use, and Quality of Place. These stations – particularly Murdoch and Cockburn Central – have limited potential to develop as Places. Both have a lack of developable land and poor urban structure within the broader station precincts. Given the spatial footprint of road infrastructure within the 800-metre station catchment, the configuration of the station within the freeway median is a limiting factor for the station's Place function.

Proximity to the 'new lines' (Joondalup and Mandurah) is reflected in a commercial land-use price premium (McIntosh, Newman & Glazebrook, 2013). Tellingly, *close* proximity (e.g. ≤400 metres) appears to impact negatively on residential land values. This may be a function of the poor amenity adjacent to stations given considerable park-and-ride in many locations, and the situation of the lines within freeway reserves for much of their length. This evidence supports the view that at least some station precincts along these rail lines would benefit more from investment in interchange facilities than land development. Park-and-ride supply and feeder bus services provide access potential for people in the broader station catchment compared to those within 400 metres of stations who can 'walk on', without the poor amenity associated with proximity of the freeway and other major transport infrastructure.

However, significant investment in infrastructure, including land bridges and grade separation, is likely needed to enhance Place factors at stations in the freeway median. In contrast, interchange stations performed comparatively well as Nodes; especially in terms of vehicle-to-rail transfers. This reflects relatively generous park-and-ride and feeder bus provisions. These issues are discussed further in chapter 18.

Stations at *mid-block* locations – while performing marginally better as Places than stations located at freeway interchanges – yielded mixed results when assessed at the domain level. The metropolitan context of the station seems to be a key factor for Place function at midblock stations. Proximity to Perth's CBD associates moderately with higher metrics for density, development intensity and urban structure, as found at Leederville and Glendalough.

Despite some potential for TOD at Glendalough, opportunities are constrained by low quality of Place as a consequence of the existing regional road network. In contrast, the other midblock stations, Warwick and Greenwood, yielded good quality Place scores but feature limited development potential because of low-density, small residential lots in single ownership dominating their immediate catchments.

The midblock stations were mixed performers with regard for Node function. For example, Leederville and Glendalough feature a limited supply of park-and-ride and few feeder bus services. Much like interchange stations, the influence of the freeway remains a significant barrier to improving Place function, while access to the stations for park-and-riders and feeder buses is extremely limited.

Joondalup, as a divergent station, is emerging as a destination. Despite its long distance from the CBD, the Joondalup line was deviated deliberately from the Mitchell Freeway to permit the station to be unaffected by major road infrastructure. Unfortunately, from a strategic urban-growth perspective, it was embedded in the forecourt of a regional 'big box' shopping centre with conventional car-oriented characteristics. Its historic underperformance is being addressed through recent growth of the surrounding town centre with much more transit-orientation than transit-adjacency (see Renne & Ewing, 2013).

Wellard station is a major underperformer with respect to Place and points to some of the difficulties associated with delivery of TOD in outer Perth. This is despite its design as an excellent example of TOD (Hemsley, 2009). The Mandurah line deviates from the Kwinana Freeway a few kilometres north of Wellard station, meaning the station precinct is not encumbered by major road infrastructure. Nevertheless, the developer responsible for the entire, immediate walkable catchment has managed to deliver very limited low-medium density mixed use, and only R20/R30 housing (e.g. 330 to 500 square metres plus single dwelling blocks) even within a five- to ten-minute walk of the station's front door. Wellard is second only to Maddington with respect to having the lowest boarding and alightings in the sample.

The lessons to be drawn from the analysis are limited by three factors. Firstly, there is no measure capturing station-to-station travel. Although the Public Transport Authority in Western Australia collects SmartRider data based on tags-on and tags-off from the system, with the vast majority of movements on the network being completed using payment via SmartRider cards, this source was not fully mined to date, especially analysis of movements that are part of linked trips that include other travel modes.

Secondly, application of our scoring and weighting system allowed some exploration of relativities and a degree of standardisation. On one hand, this reduced the influence of outlying variables, which could skew results in unintended and unhelpful ways. For example, some stations have significantly more cycle parking than others, but in the broader scheme of things this has very little impact on true Node or Place functionality. On the other hand, the fact that skewness on one variable can be washed out by standardisation or scale is ignored, which can mean it does not receive the emphasis it may deserve. Scale is a great example of this: a standardised score of 0.75 may represent a rating of 3 for landmarks, but 1,800 persons per square kilometre in terms of density. This limitation also applies when trying to compare freeway and heritage line stations as sets.

Relative scoring presents a further issue with respect for Place and Node performance. A high overall score infers good performance, although this may only be true in relative rather than absolute terms. The sample is limited to Perth's metro rail network and, accordingly, there is no external benchmarking.

Finally, we have attempted to define an indicator (Background Traffic) by aggregating a series of traffic-related variables. These variables were selected because they were measurable and discrete. In practice they may yield limited evidence relating to how stations are or are not affected by surrounding road network operations. Yet, by the same token, we are not aware of more robust or informative measures that could be generated with reasonable effort instead. As indicated, the implications of Background Traffic and its relationship with Place and Node functions are discussed in more detail in chapter 18.

Despite these limitations, the findings presented in this chapter provide evidence that Node and Place functions can be in conflict with each other. From a policy perspective, a thrust towards delivery of TOD is hindered by the constraints imposed by station locations in freeway medians and existing Nodal functionality. By implication, trade-offs may be necessary between different policy objectives such as transit ridership, employment and residential density targets and maintaining a service catchment. A clearer role for each station is required, based on underlying land-use and transport functions and their role within the broader urban system.

CONCLUSION

The findings presented in this chapter illustrate the Node and Place function of stations depending on their spatial configuration with regard to regional road infrastructure. The introduction of a Background Traffic indicator is a distinctive feature of the study methodology. To our knowledge there are no other studies that have incorporated an indicator of Background Traffic in the evaluation of station land-use and transport functions. This reflects a significant gap in the knowledge of the interaction of land-use and transport systems in low-density and car-dependent cities like Perth.

The research findings regarding the role of station configurations are indicative but not definitive. Stations on heritage lines either perform well or have greater relative potential to perform as Places, and are therefore better candidates for TOD. In contrast, stations located in freeway medians are Node dominant due primarily to their encumbrance by major road infrastructure, integrated feeder bus services and demand for access from a large catchment of transit riders. Whilst the station performance is shaped by regional context, there is a clear indication that development in station precincts in the freeway median will be characterised by the ongoing constraint by broader metropolitan regional transport demands.

Chapter 18 advances the findings presented in this chapter by addressing urban policy questions relating to the judiciousness of locating rail infrastructure within freeway medians and implications for TOD at stations within freeway medians.

ACKNOWLEDGEMENT

The research presented in this chapter was supported by the Planning and Transport Research Centre (PATREC).

REFERENCES

Arrington, G.B., & Cervero, R. (2008). Effects of TOD on Housing, Parking, and Travel, *Transportation Cooperative Research Program Report (TRCP) 128*, Washington, D.C. Retrieved from http://www.reconnectingamerica.org/assets/Uploads/finalreporttcrp128.pdf

Babb, C., Duckworth-Smith, A., Falconer, R., Isted, R., Olaru, D. & Biermann, S. (2015). The Performance and Potential of Rail Stations In and Outside Freeway Medians: The application of a Node/Place model to Perth. *Australasian Transport Research Forum*. 30 September–2 October. Sydney, NSW.

Bertolini, L. (1996). Nodes and Places: Complexities of railway station redevelopment. *European Planning Studies, 4*(3), 331–45.

Bureau of Infrastructure, Transport and Regional Economics (BITRE). (2009). Urban Passenger Transport: How people move about in Australian cities. *Information Sheet 31*. Canberra, ACT: Department of Infrastructure and Transport.

Burke, M. & Brown, A.L. (2007). Distances People Walk for Transport. *Road and Transport Research, 16*(3), 16–29.

Centre for Transit Oriented Development (CTOD). (2010). *Performance-Based Transit-Oriented Development Typology Guidebook*. Retrieved from http://www.cnt.org/sites/default/files/publications/CNT_TODTypologyGuidebook.pdf

Cervero, R. & Sullivan, C. (2011). Green TODs: Marrying transit-oriented development and green urbanism. *International Journal of Sustainable Development & World Ecology*, *18*(3). 210–18.

Cervero, R., Murphy, S., Ferrell, C., Goguts, N., Tsai, Y.H., Arrington, G.B., Boroski, J. et al. (2004). Transit-Oriented Development in the United States: Experiences, challenges and prospects. *TCRP Report 102*. Washington, DC. Retrieved from http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_102.pdf

Chorus, P. & Bertolini, L. (2011). An Application of the Node Place Model to Explore the Spatial Development Dynamics of Station Areas in

Tokyo. *Journal of Transport and Land Use*, 4((1), 45-58. Curtis, C. (2008). Evolution of the Transit-Oriented Development Model for Low-Density Cities: A case study of Perth's new railway corridor. *Planning Practice & Research*, *23*(3), 285–302.

Curtis, C. & Low, N. (2012). *Institutional Barriers to Sustainable Transport*. Burlington, Vermont: Ashgate.

Curtis, C., Renne, J.L. & Bertolini, L. (2009). *Transit Oriented Development: Making it happen*. London, United Kingdom: Ashgate.

Falconer R. (2014). Smarter Centres: Lessons from Perth regarding assessment of transport and access contexts. *Australian Planner*, *52*(2), 90–102.

Falconer, R. & Richardson, E. (2010). Rethinking Urban Land-use and Transport Planning – opportunities for transit oriented development in Australian cities case study Perth. *Australian Planner*, *47*, 1–13.

Hale, C. (2013). History and Prospects of the Rail Station. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 6*(1), 72–91.

Hemsley, W. (2009). The Commercial Reality of TOD in Australia. In C. Curtis, J. Renne & L. Bertolini (Eds.). *Transit Oriented Development: Making it happen*, London: Ashgate, 201–8.

Kamruzzaman, M., Baker, D., Washington, S. & Turrell, G. (2014). Advance Transit Oriented Development Typology: Case study in Brisbane, Australia. *Journal of Transport Geography, 34*, 54–70.

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, WA, 9–24.

McIntosh, J., Newman, P. & Glazebrook, G. (2013). Why Fast Trains Work: An assessment of a fast regional rail system in Perth, Australia. *Journal of Transportation Technologies, 3*, 37–47.

McManus, P. (2003). Your Car is Welcome as You Are: A history of transportation and planning in the Perth metropolitan region. In A. Gaynor, M. Trinca & A. Haebich (eds.) *Country: Visions of land and people in Western Australia*. Perth, WA: WA Museum.

Newman, P. (1992) The Rebirth of Perth's Suburban Railways. In D. Hedgcock (ed.), *Urban and Regional Planning in Western Australia*. Perth, WA: Paradigm Press.

Renne, J.L. (2005). *Transit-oriented Development: Measuring benefits, analyzing trends, and evaluating policy*. PhD thesis, Rutgers University, Ann Arbor, MI.

Renne, J. (2009). From Transit-Adjacent to Transit-Oriented Development.

Local Environment, 14(1), 1–15.
Renne, J. & Ewing, R. (2013). *Transit-Oriented Development: An examination of America's transit precincts in 2000 & 2010*. UNOTI Publications, Paper 17. Retrieved from http://scholarworks.uno.edu/unoti_pubs/17
State of Western Australia. (2010). State Planning Policy 4.2: Activity Centres for Perth and Peel. *Western Australian Government Gazette 166*, Perth, WA. Retrieved from http://www.planning.wa.gov.au/publications/1178.asp
Western Australian Planning Commission (WAPC). (2004). *Network City: Community Planning Strategy for Perth and Peel*. Perth, WA. Retrieved from https://books.google.com.au/books/about/Network_City.html?id=2IbVAAAACAAJ
Western Australian Planning Commission (WAPC). (2006). *Development Control Policy 1.6 Planning to Enhance Transit Use and Transit Oriented Development*. Perth, WA: WAPC. Retrieved from http://www.planning.wa.gov.au/publications/798.asp
Western Australian Planning Commission (WAPC). (2010). *Directions 2031 and Beyond. Metropolitan planning beyond the horizon*. Perth, WA. Retrieved from http://www.planning.wa.gov.au/publications/826.asp
Western Australian Planning Commission (WAPC). (2015). *Perth and Peel@3.5million*. WA: WAPC. Retrieved from http://www.planning.wa.gov.au/publications/3.5million.asp