Australasian Applicability of European Design Practice for Street Running Light Rail

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ABSTRACT:

Light Rail Transit (LRT) is defined as a medium capacity passenger rail system, operating in exclusive lanes in street or on a separate corridor. In the past decade more than 120 LRT projects have been built in OECD countries. This popularity has been based on the space efficiency, flexibility and increasing capacity of LRT and the ability to contribute to an urban form with higher amenity. In New Zealand LRT schemes are being investigated for Auckland and Christchurch.

The paper examines design trends in recent street running LRT projects and identifies critical design features that have contributed to their success from a transport viewpoint. Topics covered include an overview of LRT capacity and performance, greenhouse emissions, traffic management, signal priority, parking control, stop design, pedestrian access, design for cyclists and safety risks.

The paper will cite examples from recognised best practice LRT design in France, together with recent Australasian applications from Adelaide and the Gold Coast. Results of micro-simulation modelling of possible LRT installations in Auckland will be used to demonstrate the local applicability of the technology.

The paper will conclude by identifying recommended design practices for implementation of LRT in an Australasian context.

INTRODUCTION

Historically tram systems were the primary form of public transport in most major cities in the western world, including Australia and New Zealand, in the first half of the 20th century. The Auckland tram system comprised 21 lines and 72 km of track, carrying 270,000 passengers a day in the 1930s when the city population was under 400,000. However as car ownership grew and the demand for road space increased, street running trams were removed from most western cities in the 1950s and 1960s.

In 1985 a modern successor to trams, street running light rail transit (LRT), was introduced in the French city of Nantes. Unlike trams, light rail vehicles (LRVs) were larger, faster, able to be coupled together to achieve high capacity, and with low floors to facilitate easier access. The LRT concept was successful in achieving higher public transport patronage and capacity, and has been implemented in over 120 cities in the OECD over the past three decades.

This paper highlights the state of practice of LRT design in street running conditions, and the traffic and transport planning elements essential to its performance. French LRT systems have been identified as best practice with high system performance and patronage (Buisson 2012, Currie 2012) and closest in form to new systems planned in Australasia. Four French LRT systems (Bordeaux, Nantes, Paris and Strasbourg) are examined and key design features identified. The applicability of these design features to an Australasian environment is considered. It is hoped to facilitate an informed debate among transport engineers and planners on the relative merits of LRT as a transport mode.

This paper is confined to discussion of traffic and transport aspects of LRT projects in an Australian and New Zealand context. Other LRT issues such as constructability, social and wider economic impacts are beyond its scope.

Auckland Transport (AT) is investigating an LRT system as part of its Rapid Transit Network (RTN) from Wynyard Quarter to Auckland Airport. Jacobs, together with Arup in a joint venture, have provided advice to AT for that project. This paper does not discuss that proposal other than to illustrate design methodologies. The views expressed in this paper are the opinions of the authors and do not reflect any position by Jacobs, Arup or Auckland Transport.

STREET RUNNING LIGHT RAIL DEFINED

Street running LRT is defined as a passenger rail system designed to run in road corridors. Unlike historic trams LRT operates in exclusive lanes. This gives LRT higher capacity, reliability and average speed than trams. For purposes of this paper, street running LRT will be assumed to operate segregated from general traffic, while trams will be defined to be street-running passenger rail systems that operate in lanes shared with traffic. LRT grade-separated from traffic, more common in US and Canadian practice, is not discussed.

A light rail vehicle (LRV) is defined as a passenger rail vehicle of light axle loading, with track gauge and vehicle width suitable to be contained within a single traffic lane. Modern light rail vehicles range from 24 m to 57 m long, compared with historic trams 8 m to 16 m long. Track gauge of most modern LRVs is standard gauge (1435 mm) and vehicle width is typically 2.4 m to 2.65 m. Power is normally electric and supplied by overhead wire (OLE). LRVs can operate in the same track as historic tram systems, where it still remains. Example trams and LRVs are shown in Figure 1.

Figure 1 **Melbourne tram in traffic (left); Gold Coast LRV in segregated lane (right)**

Modern LRVs have become increasingly standardised in their design, leading to economies of scale, increased reliability and reduced capital and operating costs. The following features are common to most modern LRVs available on the market:

- Low Floor – LRV floor heights are typically 300 mm to 350 mm above street level. This allows platform stops to be integrated into footpaths or medians without stairs.
- Modular design – LRVs are assembled from modules 6 m to 9 m long. This enables LRVs of varying length and capacity to be assembled, and for LRVs to be lengthened to increase capacity as system demand increases,
- Bi-Directional – LRVs typically have a driver cabin at each end. This allows them to reverse direction to complete a return journey without requiring a turntable or loop to turn around. This makes LRT terminal space efficient and reduces lost time.

PERFORMANCE OF STREET RUNNING LIGHT RAIL

Speed

Average speed for street running LRT is determined primarily by whether the track is segregated and the degree of signal priority. A sample of European and Australian street running LRT and tram systems were inspected in 2016 and performance data obtained for each line (46). Average speeds for measured tram and LRT lines are shown in Table 1.

City	Length (km)	Stops	Lines	Stop Spacing (m)	Corridor	Signal Priority	Average Speed (km/hr)
Bordeaux	44	90	5	488	Segregated	Yes; Pre-emption	23 km/hr
Nantes	44	83	3	534	Segregated	Yes; Pre-emption	21 km/hr
Paris	105	186	9	566	Segregated	Yes; Pre-emption	20 km/hr
Strasbourg	43	75	6	573	Segregated	Yes	18 km/hr
Adelaide	15	22	1	681	Segregated	No	17 km/hr
Gold Coast	13	16	1	813	Segregated	Yes; Pre-emption	23 km/hr
Melbourne	250	1763	20	142	Shared	No	16 km/hr
Sydney	13	23	1	565	Segregated	Yes	23 km/hr

Table 1 **Average speeds for street running LRT and Tram systems**

Average speeds in the sampled LRT systems with a segregated corridor varied from 20 to 25 km/hr (average 22 km/hr). Speeds for trams and LRT operating in a shared corridor varied from 15 to 20 km/hr (average 17 km/hr). The only exception among the segregated systems was Strasbourg (18 km/hr), which is slowed by lines passing through a large pedestrianised CBD, lack of pre-emption at traffic signals and slow opening doors on LRVs. On average, LRT in the segregated corridors observed is up to 29% faster than in shared lanes with traffic. As dwell time at signals is an important variable in LRT running time, LRT systems with segregated track should also have more reliable travel times than trams in shared track.

Capacity and Patronage

LRT capacity depends on vehicle capacity and service frequency. The latter is controlled by the limiting factor of track geometry, signalling, traffic priority, or stop (boarding) capacity. Modern trams and LRVs have multiple double doors with high boarding capacity. This means that signalling and traffic priority are generally the limiting factor on capacity, rather than stop or terminal capacity. Operational capacity on selected LRT and tram lines was analysed with the results shown in Table 2.

City & Line	Frequency (LRVs/hr)	Vehicle (pass/veh)		Line Cap. (Pass/hr/dir)	2015 Patronage (pass/day)	Track
		Length (m)	Capacity (passengers)			
Bordeaux Ligne B	15	45m	310	4550	52,000	Segregated
Nantes Ligne 1	30	36m	250	7500	114,000	Segregated
Paris T3A	30	45m	310	9100	210,000	Segregated
Strasbourg Ligne A	20	45m	310	6200	80,000	Segregated
Adelaide	10	33m	200	2000	30,000	Segregated
Gold Coast	8	45m	310	2480	23,000	Segregated
Melbourne Rt 109	15	23m	150 (C Class)	2250	43,000	Shared
Melbourne Rt 96	15	33m	210 (C2/E)	3150	42,000	Shared
Sydney	8	33m	200	1600	18000	Segregated

Table 2 Line Capacity and patronage for sample LRT and tram systems[1]

Note: pass/hr/dir. = passengers per hour per direction.

In the sampled LRT and tram lines the highest frequency (shortest headway) observed was 2 minutes (30 LRVs/hr) in segregated corridors and 4 minutes (15 LRVs in shared corridors). The ability to run at higher frequency gives segregated LRT lines higher capacity. In-service capacities recorded ranged up to 9000 passengers/hr/direction for segregated LRT, compared with up to 3200 passengers/hr/direction for shared tram lines. Patronage of the segregated lines sampled is also higher, with the busiest segregated lines in France (Nantes and Paris LRT) more than double the patronage of the busiest shared lines in Australia (Melbourne trams). Many other factors influence patronage, and it should be noted that correlation does not prove causation.

System utilisation and population density

System efficiency can be measured by comparing the patronage with the length of track to determine the utilisation of the system. This is shown for the sample systems in Table 3. Utilisation for French LRT systems is strikingly higher than (triple that of) Australian systems.

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1. Data sourced from Semitan, Keolis, RATP, Yarra Trams, G:Link, TransAdelaide and Transdev

City	Patronage[3] (pass/day)	Length (km)	Utilisation (pass/km/day)	Population Density (persons/km^2)
Bordeaux	282,000	59	4780	700
Nantes	285,000	41	6951	1100
Paris	960,000	105	9143	3800
Strasbourg	317,000	43	7372	1352
Adelaide	30,000	15	2000	852
Gold Coast	23,000	13	1769	414
Melbourne	560,000	250	2233	1536
Sydney	18,000	13	1385	1998

Table 3 LRT system utilisation and population density in 2015

These differences cannot be explained by differences in metropolitan population density alone. The results for utilisation (passengers per track km) are plotted against population density in Figure 2. The performance of the French (in blue) regional city LRTs (Bordeaux, Nantes and Strasbourg) is notable. These cities have populations (700,000 to 1.1 million) and population density comparable to Australian state capitals (similar to Adelaide; lower than Melbourne and Sydney). Yet system utilisation for the French LRT networks is 3 to 4 times the Australian LRT utilisation. As Table 2 shows, French LRT frequency is also higher.

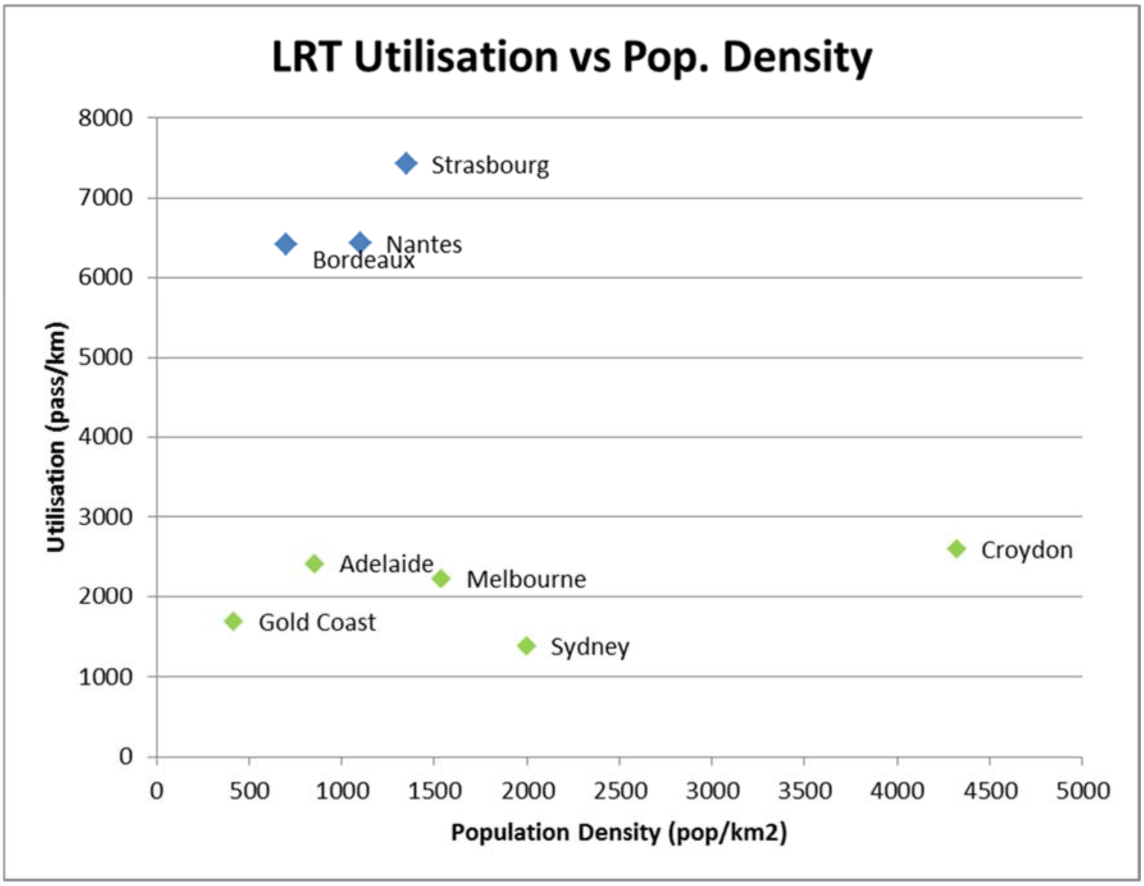

Figure 2 LRT system utilisation and city population density in 2015

Other policy and economic factors may influence these outcomes. Car ownership in France (578 cars/1000 persons) is lower than Australia (736 cars/1000 persons), and has plateaued in the last decade[2]. In French regional cities car ownership rates are up to 20% higher. This is not sufficient to explain the difference in LRT utilisation. There are insufficient city data points with comparable population densities in France and Australia to isolate causes. We can only note that, within each jurisdiction, segregated track LRT systems have higher speed and utilisation.

Greenhouse Emissions

Energy consumption per passenger for public transport in a given geography depends on the vehicle efficiency plus the vehicle occupancy, PT (Public Transport) schedule and demand profile across the day. Greenhouse emissions from transport depend on the energy consumption per vehicle plus the emission intensity of the source. Consequently estimates of energy and emissions per passenger vary considerably.

Passenger rail is consistently found to be the most efficient land motorised transport mode for energy and emissions per passenger kilometre. Light rail is not always reported separately to heavy passenger rail but where it is LRT is found to be similar to or slightly less efficient than heavy rail. The energy use and emissions of LRT is found to be one third to one quarter that of private cars and half that of an equally modern bus (Puchalsky 2006). Recent LRV models fitted with regenerative braking technology promise to reduce this further. Emission intensity for urban transport modes by different agencies are shown in Table 4.

Mode	European Energy Agency 2013	International Energy Agency 2009	National Atmospheric Emissions Inventory (UK) 2008	US Department of Transportation 2010
Rail	40	20 to 50	60	62
LRT	40	20 to 50	65	100
Bus/BRT	115	30 to 90	89	179
Passenger Cars	115	80 to 290	125 to 250	268
Air	120	220 to 260	175	Not assessed

Table 4 Emission intensity of urban transport modes (CO2 in g/pass-km)

There are significant differences between energy sources for LRT in Australia and New Zealand. In New Zealand approximately 75% of electricity is from renewable sources, while in Australia more than 50% of electricity is from coal. Rail (and LRT) would be the most energy efficient form of urban motorised transport in both countries. Rail and LRT would be the lowest carbon emitting mode by a larger margin in New Zealand.

EUROPEAN (FRENCH) LIGHT RAIL TRAFFIC DESIGN FEATURES

Specific LRT design features in the four French cities (Bordeaux, Nantes, Paris and Strasbourg) studied have been identified that influence their transport performance.

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[2] Eurostat and Australian Bureau of Statistics (ABS) data for 2014.

Insertion into key activity centres

French light rail, as opposed to heavy rail, depends heavily on the “walk up” catchment for patronage. Therefore it is placed directly into the middle of the city centre and near activity centres, to be within walking distance of major destinations (Buisson, 2012). Typically it is placed in the main commercial street in the CBD, and connects directly to hospitals, universities and business centres in the rest of the city. This pattern was observed in all of the sample systems.

Exclusive LRT Lanes

Light Rail networks running in their own exclusive lanes, segregated from car traffic, benefits the speed, capacity, reliability and safety of the LRT. From 1985 to the present, France has built 28 new LRT systems with a total of over 700 km of track, of which only 2 km is not segregated from car traffic. Furthermore, under French road regulations LRVs have right of way over all other vehicles (Bertrand 2016). This law, in combination with segregated track, means that LRVs only halt at passenger stops and rarely at signalised intersections.

Segregated track means that LRVs are not delayed by queued traffic, and LRVs stopping to pick up passengers do not delay cars. LRV services can operate at shorter headways, giving higher frequency and capacity. Segregated track also allows the use of longer or coupled LRVs. A segregated LRT track has capacity equal to two to four freeway lanes.

LRV travel times in segregated track, allow greater efficiency in fleet utilisation for the LRT operator. That is, with segregated track, a given sized fleet of LRVs can run more services per hour. This creates an operating cost saving for the LRT operator.

Reallocation of Road Space

Adding space for light rail tracks exclusive of traffic requires that space for some existing traffic functions be reduced. French practice is to remove on street parking and/or traffic lanes to achieve this. In CBD areas car traffic is often removed entirely to create a pedestrianised zone with only LRVs and service vehicles (where permitted) to enter.

French LRT practice does not attempt to maintain existing road capacity for general traffic. It is accepted that adjustment will be required in road user behaviour, when the LRT is introduced. This may be a combination of travel mode shift, redistribution of traffic (i.e. fewer cars driving into treated areas and corridors), and reassignment to parallel routes. LRT systems have typically achieved mode shifts from cars on opening of +10% to +30% (Semaly and Faber Maunsell 2003). The shift is both to public transport, and to active modes. Traffic congestion does not necessarily reduce with the addition of LRT, but traffic volumes generally do. The opening of Paris Tramway T3A saw traffic reductions of up to 40% in the corridor, which was formerly a six lane arterial road and reduced to four traffic lanes.

Signal Priority and Pre-emption

Allied with segregated LRT lanes, priority for LRVs at traffic signals also contributes to improving the time-competitiveness of street running LRT. For European LRT practice, this has moved from priority to pre-emption. LRT priority is defined as traffic phasing minimising delay for an LRV when it arrives at a signalised intersection. LRT pre-emption, is defined as traffic phasing adjusting prior to the arrival of an LRV to avoid delay to the LRV. This may occur via switching to an LRV inclusive phase, or extending an existing phase to allow the LRV to clear the intersection without stopping.

Using pre-emption, modern LRT systems are able to reduce intersection dwell time to an average of 2% to 4% or less of total journey time (Brilon 1994). It is rarely possible to reduce intersection dwell time to zero, since some signal phases such as crossing pedestrian movements may not be cut short for safety reasons.

Pre-emption may be achieved through several methods, all of which rely on integration between the LRV control system and the traffic signal control system. LRVs may be detected approaching a signalised intersection by conventional loop detectors, or communication systems on board the LRV. Recent advances include on-board LRV systems that can monitor schedule adherence and request increased signal priority in real time. An example signal pre-emption system diagram is shown in Figure 3.

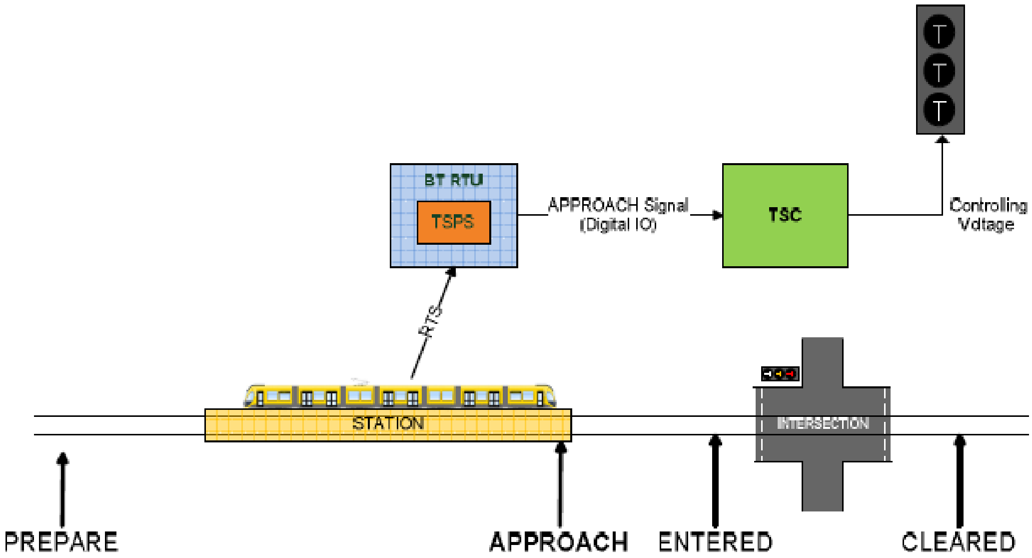

Figure 3 LRT Signal Pre-emption within Traffic Control System

Integrated Platform Stops for Low-Floor LRVs

The introduction of low-floor LRVs has facilitated the implementation of platform stops as part of LRT projects. These are typically integrated into the footpath or median for minimal impact. Typical boarding height of a low floor LRV is 300mm to 350mm. This enables most LRT stops to be built with minimal ramps and without stairs.

LRT stop platforms with level boarding gains three major advantages for the LRT system: safety, equity and capacity. The LRT stop platform protects waiting passengers from conflicts with car traffic. The level boarding height is convenient for all passengers regardless of level of personal mobility. Level boarding reduces boarding time per person and increases system capacity. This enables high service frequency in CBD locations.

High Quality environment for Active Transport

Street running LRT is reliant on the walk-up catchment for the majority of patronage. French LRT design focuses on the quality of pedestrian infrastructure to maximise the size of catchment for each LRT stop. Design techniques used include:

- Placing LRT tracks adjacent to a footpath (rather than centrally) in arterial roads.
- Bicycle lanes can be placed between the LRT track and footpath to be protected.
- Reducing traffic lanes, with consequent reduction in traffic volume.
- Removing left-turn slip lanes to improve pedestrian safety.
- Removing kerbside parking, which creates space for safe cycle lanes.
- Narrowing the width of signalised intersections.
- Breaking up wider roads into separate carriageways, with median refuges.
- High quality paving on footpaths to provide easy walking.
- Use of textured pavement on LRT track (e.g. cobblestone finish) to deter pedestrians and cyclists in locations where it may be dangerous to walk or cycle.

French LRT systems include streetscapes and landscaping to create a high quality urban environment in the LRT corridor. Typical treatments include planting of street trees, use of grass-track, and iconic architecture for featured locations. Recent innovations such as in ground induction power supply (APS) or battery or capacitor powered LRVs allow the introduction of wire-free sections of track where visual amenity is critical.

These measures add to system cost, but have benefits for the project and wider urban planning objectives. From a public transport perspective, they make the environment of the LRT corridor an attractive place, and encourage passengers to walk to the LRV stops. From an economic viewpoint, they enhance amenity and the value of land in the urban corridor, which encourages business investment. This increases activity in the corridor and further grows the patronage over time. The economic value of the wider economic benefits created by LRT has been shown to exceed the value of transport benefits (Jacobs 2012).

Figure 4 Paris T3 corridor with paved pedestrian paths and segregated track

From a traffic viewpoint these features suggest that LRT should not be “squeezed” into a corridor by reducing footpath widths or stop platform widths. Removing on street parking or traffic lanes is a more appropriate design treatment.

LRT Cross Sections in Streets

French LRT designs vary with available road space, but typically adopt a functional approach to road cross sections. In all cases LRT track is segregated. In city centre main streets the corridor is likely to be pedestrianised, with general traffic removed, and footpath widths increased. In arterial road, one or two traffic lanes in each direction will be retained, sufficient for off-peak travel demand, but with capacity reduced. In non-arterial roads, a single traffic lane will be retained in one or both directions, to maintain connectivity and accessibility. In both arterial and non-arterial roads where there is additional road space available, it will be allocated towards increased space for active transport and urban design, rather than maximising traffic capacity. Typical treatments are defined in Table 5 and an example of LRT in a narrow corridor is shown in Figure 5.

Road Type	Width	Cross Section pre LRT			Cross Section post LRT		
		Traffic	Parking	Footpath	traffic	Parking	Footpath
CBD Main Street	20m to 30m	2 to 4 lanes	2 lanes	5m+ each	2 LRT No traffic	Shared space only	7m+ each
Arterial Road	24m to 30m+	4 lanes	Off Peak 2 lanes	4m+ each	2 LRT 2 lanes	Move to side streets	5m+ each
Sub-Arterial Road	20 to 24m	2 lanes	2 lanes	4m+ each	2 LRT 1 lane	Move to side streets	4m+ each
Collector Street	15 to 20m	2 lanes	2 lanes	3m each	2 LRT 1 lane	Move to side streets	4m+ each

Table 5 Typical Cross Section Treatments for street running LRT

Figure 5 Bordeaux LRT in a narrow street (15m) with a single traffic lane

Traffic Regulations for Light Rail

In 2008 France issued a new Street Use Code (traffic regulations), that defined several new categories of traffic management regimes that would suite LRVs operating in street running (Bertrand, 2016). These classifications create clear rules for all road users so that the status and rights of way of pedestrians, cyclists, public transport and private cars are clear in each type of street. In all cases, LRVs have priority over other forms of traffic, including pedestrians and cyclists. The categories of traffic operations permitted are shown in Table 6:

Classification	Pedestrian Area	Pedestrian Priority Zone	30 km/hr Zone	Urban Area	70 Section
Speed Limit	5 to 10 km/hr	20 km/hr	30 km/hr	50 km/hr	70 km/hr
Functional balance between traffic/ local life	5/95	20/80	50/50	80/20	95/5
LRT Priority?	Yes	Yes	Yes	Yes	Yes
Priority Rule	Pedestrians, PT, service vehicles only; cars banned	Cars permitted; Priority for pedestrians	Cars permitted, Priority as signed	Cars permitted, Priority as signed	Cars permitted, Priority as signed
Traffic Management	Through traffic prohibited	Through traffic discouraged	Through traffic permitted	Through traffic permitted	Through traffic permitted
% of road network	0-10%	2-15%	60-90%	10-40%	0-5%
Austroads Equivalent	Pedestrian mall	Shared Zone	Traffic calmed street	Local road	Arterial road

Table 6 French Street Use Code Street classifications (Bertrand 2016)

APPLICABILITY IN AUSTRALASIA

Most historic trams systems in Australasian cities ran in street, shared with traffic. All but Adelaide, Christchurch (only small sub-section preserved) and Melbourne were removed by the 1960s. Since the 1990s two new LRT systems have been built (Gold Coast and Sydney) and two historic systems (Adelaide and Melbourne) have been fully or partially upgraded to an LRT standard.

The performance of Australasian LRT and tram systems demonstrates the benefits of track segregation and signal priority. Consistent with European experience, tram systems running in mixed traffic operate at an average of 17 km/hr. LRT systems on segregated track operate at an average speed of 23 km/hr. With the exception of the first stage of Sydney, all LRTs built or extended in Australia in the past 20 years have met or exceeded forecast patronage targets (Elaurant and Louise, 2015).

There have been some difficulties in Australian implementations to date. There is a lack of consistently agreed design standards and regulatory regimes for LRT comparable to Austroads guides for road design and operation. Depending on the jurisdiction, separation of road and public transport management into different agencies has complicated the ability to achieve track segregation and signal priority. The Gold Coast G:Link is the only Australian system to date to have full signal pre-emption at intersections.

There is currently significant activity in the development of new LRT systems in Australasia. New LRTs are being built in Canberra and Sydney. Extensions are occurring in Adelaide, Gold Coast and Melbourne. New systems are being planned in Newcastle, Parramatta and Perth. New systems are being investigated for Auckland, Christchurch and Hobart.

TRAFFIC ANALYSIS FOR STREET RUNNING LRT

To plan and design street running LRT, there is a need to change traffic engineering methodology, although the same analytical tools may still be used. The focus of traffic management needs to shift from maximising vehicle capacity to person capacity. This means that road capacity for general traffic will be lost, but should be exceeded by gains in total passenger capacity via adding the LRT to the corridor.

Micro-simulation transport software packages are a common tool used in transportation engineering to inform planning decisions. They are also capable tools to evaluate operations and impacts for LRT design concepts. This section will describe as an example micro-simulation modelling undertaken for planning the Auckland LRT. The S-Paramics and Aimsun software packages were used to demonstrate the potential application of specific LRT design arrangements in an Auckland, New Zealand context. In UK and Europe the VISSIM software has also been used for the same purpose.

A primary benefit of using micro-simulation to model LRV operations is the ability to simulate the interactions between general traffic and LRVs. This understanding is critical for street running LRT arrangements where interactions with general traffic can directly impact the performance and travel time of LRT systems. Another key benefit of the micro-simulation model is that decision makers can visually see how LRT could potentially operate in the particular setting and location they are interested in. This visualisation provides more context and can often be more meaningful than output values presented in a report format.

Both the physical and dynamic properties of LRVs can be set within the model to represent the design LRV. Factors such as length, boarding rate (stop dwell time), maximum speed, acceleration and deceleration influence LRV operation and can be individually modelled in S-Paramics or Aimsun. Examples of typical dynamic parameters used for modelling Auckland LRT are shown in Table 7.

Parameter	Value
Acceleration	+ 0.9 m/s^2
Deceleration	- 0.8 m/s^2
Pedestrian area top speed	30 km/hr
Street running operational speed	50 km/hr
Street running top speed	70 km/hr

Table 7 Typical dynamic micro-simulation parameters for LRV

For analysis of running time for street running LRT, traffic micro-simulation packages have proven superior to rail simulation packages such as Railsys or OpenTrack. The latter require delays from traffic signals to be determined and added separately, whereas traffic simulation software can determine running times directly.

Early on in the investigation of LRT in Auckland, S-Paramics was used to demonstrate the performance of different LRT stop arrangements. S-Paramics modelling compared two stop options, LRT “side running” (LRT track adjacent to footpath) and LRT “time segregated running” (LRT in central track with LRV and general traffic time-segregated by signal phasing) and determined travel time and delays for both general traffic and LRVs. This enabled traffic impacts of the LRT to be quantified, and a preferred option to be determined. The two stop options as shown in the S-Paramics model are shown in Figure 6.

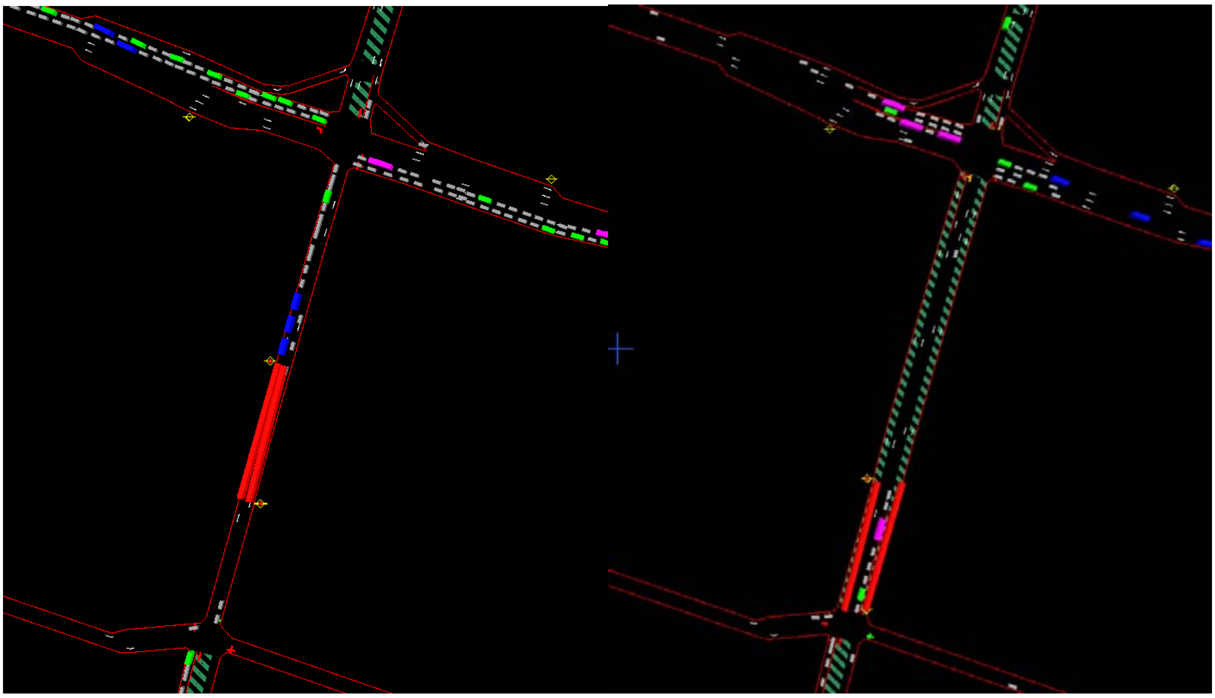

Figure 6 S-Paramics time segregated running (left) and side running (right) stops

Travel times were combined for the stop locations comparing the overall performance of the side running and time segregated running stop options. An example of this comparison is shown in Figure 7.

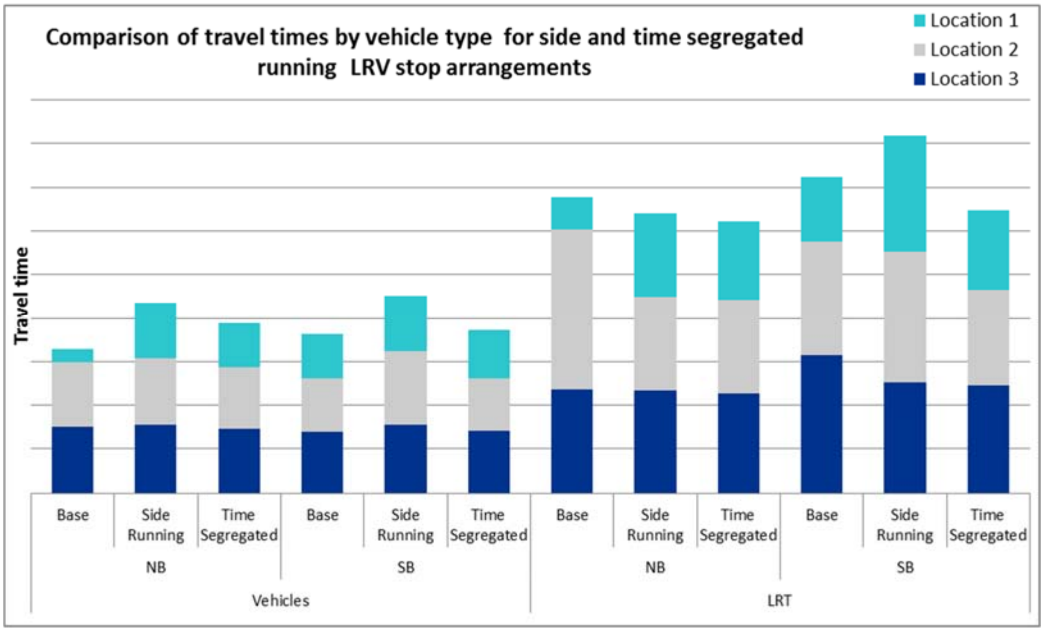

Figure 7 Combined LRT travel times for side running and time segregated running stop options

The following key conclusions were noted from the results of the stop option modelling:

- Travel times for general traffic are faster for time segregated running stop options than for side running stop options. Both are slower than the base case for general traffic.
- Travel times for LRT are also faster for time segregated running stop options than for side running stop options. LRTs with time segregated running are faster than the base case for buses.
- These conclusions are similar for different LRT frequencies.

Micro-simulation is continuing to be a beneficial tool in planning LRT, allowing complex concepts to be modelled prior to being further progressed.

CONCLUSIONS

Street running LRT has been proven in European (French) practice to be an effective and space efficient urban travel mode well suited to retrofitting into existing (brownfield) urban road corridors. Examination of a sample of LRT systems in medium sized French cities demonstrates that the street running LRT mode can greatly increase public transport capacity and patronage in a corridor while having beneficial impacts on urban amenity.

The sample cities (Bordeaux, Nantes and Strasbourg) have comparable or lower population densities to Australasian cities. This suggests it should be possible to implement street running LRT systems in Australasia, provided the key design, planning and regulatory features that have contributed to the success of the French systems are retained.

Critical elements of street running LRT include segregated track, signal pre-emption at intersections, low floor LRVs, stop platforms integrated into streetscapes, and high quality pedestrian access. With these features street running LRT has been shown to have very high capacity, reliability and safety.

Traffic microsimulation software packages such as Aimsun and S-Paramics can be used to simulate LRVs operating in street running. These allow detailed definition of characteristics of LRT vehicles and schedules to be analysed so that accurate LRV travel times may be determined. The scope of LRT works can then be designed within these packages, and traffic operational impacts determined.

Perhaps the greatest change required for the effective implementation of street running LRT systems in Australasian cites is the need for a change in thinking and methodology on the part of traffic engineers and transport planners. Traffic engineers and transport planners focused on public transport have typically been two different groups of individuals. The traffic engineers have traditionally been focused on maximising vehicle speed, capacity and safety. The public transport planners have traditionally been focused on improving the existing public transport level of service.

Planning effective street running LRT in France has seen the thinking of both groups merge and change. The focus has become maximising the capacity and utilisation of the public transport system by giving the LRT a high degree of priority, integrating it into the streetscape for convenient access and achieving close proximity to major trip generators. The general traffic system is then focused on maintaining connectivity and access, particularly for commercial and service traffic. Traffic capacity is adequate, but not maximised. The final barrier that requires addressing is to update road traffic regulations to better recognise the capabilities of large LRVs moving near traffic.

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