Light rail: the semi-metro concept

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Abstract

Proposals to implement Light Rail transit in Australia have been the subject of considerable debate, particularly in Sydney. The purpose of this paper is inform aspects of this debate by drawing on the reasons that Light Rail was originally developed in Europe as a distinctive 'semi-metro' rail application in the 1960s and 1970s before its international adoption. The paper has particular focus on using 'semi-metro' Light Rail as a high quality alternative to Metro rail in an environment of budget constraint, or as a means to enhance service levels of present Light Rail proposals.

The paper first presents a typology of transit systems to establish a clear understanding of the several forms of Light Rail. Secondly, it considers pertinent historic background of street tramway closures and the subsequent development and application of a respecified Light Rail Transit mode. Thirdly, the paper provides a high level analysis of the potential Sydney application of Light Rail. There are two key, related, points made in this paper. The first is that there has been a long history of demand for road space for motor vehicles that has been one factor in the removal of trams from the urban transit scene. This perceived conflict persists as a factor in today's Light Rail decision-making, despite recognition that streets should support a range of activities other than motorised transit. The second point is that street operation of transit is, in any case, often heavily compromised by motor vehicle congestion. While both of these matters may be managed to a degree by priority treatments, in certain situations the semi-metro concept – the original purpose of Light Rail – may offer advantages.

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1. Introduction

Light Rail Transit has a steadily growing presence in Australia, as it has internationally. Melbourne retained and has expanded its extensive tramway system, Adelaide has built the second extension to its Glenelg line and plans more, and the Gold Coast has committed to its Rapid Transit system using the Light Rail mode. In Sydney, extensions into the CBD and Inner West of its one line are now planned. Much of this activity, excepting the Sydney Inner West, reflects application of the Light Rail mode in a form that draws on its street tramway heritage – its ability to share road space with buses, cars, bicycle and pedestrian traffic. Ironically this contradicts the role and purpose of the original European Light Rail development, which, as we shall describe in this paper, was in part at least to take trams *off* the streets. An understanding of that role and purpose could be valuable in a broader understanding where and how Light Rail Transit may be usefully applied in Australia. This is the primary purpose of this paper.

The term 'Light Rail Transit' was given international credence in 1979 by the International Union of Public Transport (UITP) as:

> *"a rail-borne form of transport, which can be developed in stages from a modern tramway to a form operating underground or on viaducts"* (Groche 1979 p1).

UITP also allowed the terms *Stadtbahn* in German and *Métro-léger* in French. Several operators (Brussels, Antwerp, Buenos Ares) used the term *Pré-métro*, which also appeared in the literature (Goldsack, 1979). The fundamental principle was staged development to create a grade separated 'rapid transit' or Metro system; however the concept may equally be regarded as an intermediate mode with no expectation of later upgrading. For the purposes of this paper we shall term this intermediate application *'semi-metro'*. 'Light Rail' is the technically correct term for the semi-metro variant (Thompson, 2006); however this term is now used generically to describe a range of like systems.

The paper looks to the history of semi-metro Light Rail transit and the reasons that it emerged some forty years ago as a distinctive urban transport application and form of rail technology. In particular the paper examines the intentions of the original Light Rail developers in post World War II Europe, which were to progressively create high performance Metro systems from the street tramways that had been rebuilt following the War. The intention is, however, not simply to provide an historical retrospect. Rather it is, among other things, intended to draw attention to some aspects of the original application of Light Rail transit that might be informative in the debate that has emerged from time to time between proponents of the mode and its detractors in positions of power and influence, particularly in Sydney. It has been regarded among Sydney stakeholders as (on the one hand) ecologically sound urban transport (Moore, 2006) and (on the other) a solution in search of a problem (Hensher, 2006, Lee 2006).

There are two key, related, points made in this paper. The first is that there has been a long history of demand for road space for motor vehicles that was one factor in the removal of trams from the urban transit scene in North America, Great Britain and Australasia. This perceived conflict persists as a factor in today's Light Rail decision-making, despite recognition that streets should support a range of activities other than motorised transit. The second point is that street operation of transit is, in any case, often heavily compromised by motor vehicle congestion. While both of these matters may be managed to a degree by priority treatments, in certain situations the semi-metro concept – the original purpose of Light Rail – may offer advantages.

The paper does not set out to promote Light Rail, nor is there any suggestion that there may not be a role for on-street Light Rail. Further the paper does not seek to compare modes or discuss the use of Bus Rapid transit in lieu of rail modes. It assumes that there is reason to build new rail infrastructure of some type to enhance transit-based urban form and mode share, but does not seek to present that case. The focus is on using history and analysis to suggest that 'semi-metro' may be a better option for a few radial lines that are currently seen, depending on the party behind the proposal, as either full Metro at one extreme or as street tramways at the other, if they are to be built at all. It has particular focus on using the 'semi-metro' Light Rail concept as a high quality alternative to Metro rail in an environment of budget constraint, or as a means to enhance service levels of present Light Rail proposals.

The paper is structured as follows:

- First, a typology of transit systems is presented in order to establish a clear understanding of the terms that are used in the paper, where Light Rail fits, and the transit network context.
- Secondly, the paper considers the highly relevant background of historic shift away from transit that took place over the long period since the World Wars, particularly the wholesale closure of street tramway systems that preceded the Light Rail era.
- With this background we consider the emergence of Light Rail transit in the 1960s and 1970s, first in Europe and latterly in other countries, taking particular note of its purpose and evolution to what has become the current application of the mode.
- Finally, this understanding is applied to a discussion of potential application in Sydney, taking what might be described as a 'value engineering' perspective; that is seeking to provide functionality and service at initial cost significantly lower than a full Metro.

The paper draws both on published sources and on archival material including historic technical documentation by the relevant industry associations and operators of the time, brochures for public information by the transit operators that built the first compliant systems, outline technical data on vehicles from manufacturers, plus maps, photographs and the author's professional experience. The historic material is supplemented by a high level analysis of potential Sydney application of semi-metro Light Rail.

2. Transit modes and networks

Transit system configuration is inevitably *path dependent* (Mahoney 2000; Martin and Simmie 2008) – any one system reflects its history more than a hard and fast typology. Sydney's CityRail heavy rail system, for example, reflects its history as a state-wide passenger and freight railway within which a Metro-like central piece, Bradfield's City railway, was grafted (Raxworthy 1989), and which latterly has accommodated its commuter role with very un-Metro double-deck cars. The various rail transit modes share more attributes than differences. It is important is to recognise that transit modes merely represent applications of a technology, typically either steel wheel on rail or rubber tyre on pavement, and are not technologies in their own right. Therefore the details are transferable and boundaries blurred, including the boundary between Light Rail and Metro.

2.1 The typology of transit

Many transport texts include tables or graphics that offer a typology of transit 'modes', including Light Rail, Metro, Commuter Rail, Bus Rapid Transit etc. (Creighton 1970; Hall and Hass-Klau 1985; Gray and Hoel 1992; Vuchic 2005). These provide some useful high level data and salient characteristics such as typical capacity, commercial speed, and so on, but exceptions abound, and there is no neat fit for all systems, or indeed common terminology. However, the typology in Table 1 is presented in order to make clear where the semi-metro application sits in the continuum of urban transit applications.

For the most part the ‘Light Rail’ nomenclature is now applied loosely to a range of rail-based applications that have their origin in the electric tram – ‘streetcar’ in the more descriptive North American parlance. As suggested in Table 1 and argued in this paper, tramways and Light Rail Transit are not precisely equivalent, although there is considerable commonality, and not all forms of Light Rail are equal. In some respects the differences may be seen as simply reflecting the evolving application of the technology; however they are important to the argument presented here.

Table 1: A Typology of Transit Mode Applications

Application	Description	Examples
Road Technology		
Street Bus	Bus on ordinary streets in mixed traffic	Many in Australia and internationally
Bus Priority	Bus on ordinary streets and highways with dedicated lanes and signal priority	Common traffic engineering technique in Australia and internationally
Bus Rapid Transit – T-way	Bus on dedicated roadway (reserved right of way)over part of route, typically with bus priority in more congested sections	Sydney, Australia; Adelaide, Australia (guided – O-Bahn)
Bus Rapid Transit – Quickway (Hoffman 2008)	Bus on dedicated roadway (reserved right of way) over full route, typically in tunnel or viaduct for grade separation	Brisbane, Australia
Rail Technology		
Light Rail - Street Tramway	Light rail (tram, streetcar) on ordinary streets in mixed traffic, possibly with some level of dedicated lanes and signal priority	Melbourne, Australia; Lisbon, Portugal
Light Rail – Surface	Light rail (tram, streetcar) on ordinary streets and highways with dedicated lanes and signal priority, some reserved right of way	Gold Coast, Australia; Adelaide, Australia); US Interurban electric railways (archaic)
Light Rail – Pre-Metro or Stadtbahn ***Semi-Metro***	Light rail on reserved right of way over congested parts of line typically in tunnel or viaduct for grade separation designed to Metro standards, with priority surface light rail in other sections	Köln, Germany; Frankfurt, Germany; Pittsburgh, San Francisco (Muni), Cleveland, US
Metro	Reserved right of way over full route fully grade separated. Rapid transit multiple unit trains designed for fast loading and rapid station stops	Paris (Métropolitain), France; London (Underground, Docklands Light Railway) UK; Washington DC, San Francisco (BART), US; Hong Kong, China; Singapore.
Heavy Rail – Regional Rapid Transit	Reserved right of way over full route, multiple unit suburban trains, penetrates city core usually in tunnel	Frankfurt (S-Bahn), Germany; Paris (RER), France, Sydney (CityRail ‘CityMet’), Australia; Melbourne, Australia
Heavy Rail – Commuter Rail	Reserved right of way over full route (some grade crossings), multiple unit or locomotive hauled trains, normally to edge of city core only	London (Southeast), UK; Sydney (CityRail Intercity), Australia; Melbourne (Regional Fast Rail) Australia; San Francisco (Caltrans) US; New York (Long Island RR, Metro North), US

Source: Author, after Creighton 1970; Hall and Hass-Klau 1985; Gray and Hoel 1992; Vuchic 2005

2.2 The relevance of networks

It should also be noted (and obvious) that a single mode is unlikely to offer an entire solution to a city's transport problems. As a matter of principle, transit systems must be understood in network terms – as an interconnected web of routes that rely on each other to perform their role (Mees 2000). The concept of one line in isolation, or even of one extensive group such as the CityRail system in Sydney, is neither useful nor sound. Interchange and integration are essential, a fact recognised in New South Wales for some time (Parry 2003), albeit without material action.

Lack of integration or network perspective is often not an oversight. At best it is the result of poor governance and planning, but it can be deliberate. Yago (1984) describes the scenario of turn of nineteenth century Chicago where the city was divided between the transit companies, through services were not provided and the fare system was fragmented to maximise revenue to each company. Likewise the failure of Sydney's integrated electronic ticketing has been at least in part driven by insistence by each transit agency of retention of its own fare structure so as not to lose revenue share (Parry 2003). This point is stressed for two reasons. First, a 'single line' view of transit loses sight of the much wider range of trip types that can be, and are, accommodated by the network as a whole. Secondly, this offers evidence that initiatives can be locked out by the established (or otherwise favoured) operators, with their preferred modes, and this paradigm should not be lightly dismissed. This has been a factor in Sydney over many years, and is only now being addressed (NSW Transport and Infrastructure 2010).

In Sydney, the 'Metro' mode was briefly promoted heavily as the 'future of Sydney's transport' (MetroLink, 2008; Sydney Metro Authority 2009a). Light Rail has also been promoted by its supporters (Moore 2006; EcoTransit 2009; Glazebrook 2009; Metro Transport Sydney 2009). Little has been offered by way of network integration to date. The current Light Rail line ticketing is separate to that for the government services, even with new MyZone arrangements. The initial study of the Dulwich Hill extension (GHD Group Pty Ltd 2010) specifically examined physical interchanges with other transit links as part of the assessment criteria. Nevertheless, lack of integration coupled with a highly anti-directional route that skirts the CBD leads to the present Sydney light rail line's limited mode share compared to CityRail's lines (Norley and Peters 2010). Equally, the concept embodied in the once-proposed Sydney Metro that the CityRail system should not be expanded in the city, or the idea that bus passengers should transfer to Light Rail on the edge of the CBD, would result in major transfer penalties at the point of peak ridership. This has been recognised even where heavy rail has historically had limited CBD penetration. Paris, where the Métropolitain is synonymous with the city, has a nearly 600km Réseau Express Régional (RER) Rapid Transit system developed since World War II that includes substantial parts through the central city.

> *"The authorities worked from the premise that the metro is like a prisoner within its own straitjacket... while the suburban lines ended in a cul-de-sac at the main Paris stations, which prevents an efficient diffusion of passengers" RER, cited in (Schofield 2004).*

London is building its new Crossrail link to add to its Thameslink cross city suburban rail. Many of the European cities have built new cross-city heavy rail lines (notably S-Bahn in Germany and Zurich) as well as extensive Metro and Light Rail networks. San Francisco is currently planning to extend its Caltrain commuter railroad lines two kilometres from the current Caltrain terminus to the new Transbay Transit Center closer to the Central Business District to overcome a similar failing in its heavy rail network. Adelaide's Light Rail City West extension recognises this, and Melbourne relies on the CBD penetration of both its tram and rail systems. These cities have recognised that a single mode is not the answer, and that there are high penalties for failing to offer quality access into and through the main economic zones in the cities, whether by Light Rail, Metro or Heavy Rail.

Two further examples stress the importance of any Light Rail proposal, or any other transit infrastructure, being seen as part of a network. The first is the 'Zurich Model' of strong integration of the public transport network, effective marketing and ticketing. Zurich uses high-frequency operation of the tram system in the inner areas and co-ordinated interchange elsewhere and with the S-Bahn, using an even-interval pulse ('Taktsystem') model that had been developed for the longer-distance Swiss trains. This 'Zurich Model' has been very successful in retaining market share to public transport (Mees, 2010; Cervero, 1998). The second is the success of strong integration and co-ordination in Vancouver Canada. Vancouver has no Light Rail of consequence, but has applied the strong network principle (Greater Vancouver Transportation Authority, 2005) with some success (Stone 2009).

3. Metamorphosis – tramways to light rail

We now turn to the origin of Light Rail and the semi-metro application. To do so it is necessary to understand the long history of competition with private car travel that led to the progressive decline of the transit systems that once heavily influenced urban form. The fact that the decline was led by the movement against the street tramway is a key factor in the development of Light Rail transit. This history highlights the factors that contributed to decisions to abandon tramway systems and which ultimately led to development of Light Rail Transit in its modern form. It also makes clear some of the reasons that Light Rail engenders such debate and polarisation forty years after its emergence and international recognition as a distinctive transit mode. The fundamental issue here is the acceptability or otherwise of trams – whether called Light Rail or not – on streets.

3.1 The decline of the street tramway

In the latter part of the nineteenth century, railways facilitated relatively affluent new settlements in the countryside outside of what were, until then, compact urban areas (Sort 2006). Electrification of tramways (Middleton 1972) also increased urban mobility and development in allowing workers to live away from their work. Together they facilitated what we know today as suburbia; albeit not suburban sprawl. The electric tram did not require the heavy engineering and separate right of way of the steam railway – electric tramways could be built on existing streets, as had their more primitive horse, steam and cable forebears. To the extent that the trams were impeded by other vehicles and themselves added to the congestion, the street operation was not at first seen as problematic, since they were faster than the horse-drawn and ambulatory road users with which they competed for space.

The decline in transit use that showed its first symptoms after the First World War and took hold after the Second is essentially the decline in the same street tramway networks that had grown over the previous fifty years. In the US and western countries particularly, the car became generally available and bus transit became more common. Cars and trams began to interfere with each others' progress along their shared right of way. Wherever cars required street space, there was pressure on the tramways to vacate it. In the interwar years the tramways began to lose the support of the communities that they had served over fifty years, and their plight was exacerbated when the finances of the tramway operators and the need for reinvestment began to become problematic (Yago 1984; Hall and Hass-Klau 1985). It was early in those years that the tramways reached their maximum extent, and the decline set in. In the US this may have been driven by conspiracy between major car manufacturers, petroleum and chemical companies (Bernick and Cervero 1996), although this has not been established; however, there can be no question that it was at least in major part induced by the conflict between 'automobility' (Mees 2000) and streetcars. Hall and Hass-Klau (1985) suggest that the abandonment of trams in Britain at least was a deliberate policy, fortified by accounting that favoured buses ('free' track), a strong pro-car view (where trams caused congestion) that had emerged in city engineers' and planning departments, and councillors' prejudices. In Sydney, the poor state of the infrastructure – which was less of an issue in Melbourne – had a bearing on the decision (Quince 2006).

Competition for road space was not the case with the Metro, regional and commuter railway systems, which ran on their own rights of way (with a few exceptions) and still do. While some rationalisation of railway networks took place, this was a reflection of railroad consolidation (in the US) and grouping (in the UK), and of the inevitable failure of minor lines for which there was never a commercial case. The Great Depression reduced revenue kilometres and railway revenue, but the networks largely remained. Indeed the interwar years were characterised by major developments in the railway sector. This was the period in which urban electrification took place in Sydney, Melbourne, the Southern Railway commuter network in South East England and in many other cities on both sides of the Atlantic. It was also when the great Metro networks of London and Paris were firmly established (Sort 2006).

Paris was one of the first world cities to walk away from trams, in its case closing its entire network save some lines in the Versailles area in 1937. The role of the Parisienne tramways was thus assumed by buses and the growing Metro system before World War II. In the US, 250 systems were abandoned over the five years to 1934 (Bernick and Cervero 1996). The UK had first stopped extending tramway systems between the wars and abandoned trams altogether between 1949 and 1961 (Hall and Hass-Klau 1985) everywhere except Blackpool, which had been one of the first British systems and the last survivor, as it continued to operate a slightly eccentric Victorian-era system along its seafront.

Australian cities followed the North American pattern of tramway abandonment in the 1950s, except of course in Melbourne. The Adelaide system (except the Glenelg Line, largely on its own right of way) was closed in 1958, as was that in Perth. Hobart's went in October 1960 and Sydney's in 1961. Brisbane lingered until 1969. Nowhere is the logical disconnect of replacing rail with car lanes more evident than occurred with the demise of the Sydney tram system. With the closure of the North Sydney system, which used the eastern railway lines on the Harbour Bridge to enter Wynyard station, the railway lines were ceded by the Railways Department to the then Department of Main Roads in conjunction with the building of the Cahill Expressway. This single decision reduced the passenger carrying capacity of the Bridge by 40% (from 180,000 to little more than 100,000, author's calculation). Every proposal to provide additional cross-harbour rail capacity since has involved an extraordinarily expensive and impractical deep tunnel or a second Bridge deck, unlikely to be built in the foreseeable future.

3.2 The development of Light Rail – the semi-metro

Outside of Europe, the abandonment of tramway systems became more systematic in the years following World War II. Only those lines such as several in San Francisco, Boston, Pittsburgh and Cleveland, and Adelaide South Australia, that had significant off-street operation impeding direct conversion to bus survived. In Australia all of the capital city tramway systems, except that of Melbourne and the Glenelg line in Adelaide, had been shut down by 1969, as discussed above. A large number of European cities, on the other hand, retained, restored and developed tramways as an important form of urban transit. Much had been destroyed in the latter part of WWII, but was quickly restored as part of the urban reconstruction effort.

The key development, however, was the creation early in the 1970s of modern Light Rail by the German Association of Public Transport Operators (Verband öffentlicher Verkehrsbetriebe, or VöV).

> *"When problems of traffic congestion began to arise in the German cities – later than in Britain because car ownership started from lower levels – the logical answer was to put them underground" (Hall and Hass-Klau 1985 p20).*

VöV published of a code of practice that went beyond the standards of the street tramway, written for semi-metro application (Verband öffentlicher Verkehrsbetriebe 1971, updated 1977). This standard offered an alternative to the earlier tramway standard (Verband öffentlicher Verkehrsbetriebe 1965). The differences between the two involve the use of railway rather than tramway standards that reflect the higher line speeds of the planned Metro, and tolerances that reflect the rapid transit or Metro environment (Norley 1979). These documents show how the standards were changed to meet the intent of the operators concerned. Publicity material progressively released during the 1970s adds further evidence in the form of visually-enhanced engineering drawings of the transitional steps from tramway to Light Rail to Metro and other material.

West German cities grew their U-Bahn and Stadtbahn systems from 191km to 278km between 1970 and 1978. The term 'Light Rail Transit' first appeared in the early 1970s when North American interests observed this phenomenon. Influential scholars and practitioners observed tram system upgrades in several northern European cities that had advanced programs of grade separation, traffic priority, increased vehicle size and multiple-unit operation (Thompson 2006). Capital costs for what had hitherto been known in the US to provide 'rapid transit' characteristics were contained in the European systems by using heavy infrastructure only where it was particularly needed. The US observers saw this as a 'new transit mode'. These observations had been closely associated with individuals involved with the Bay Area Rapid Transit System – itself very much a heavy Metro, but which indirectly led to creation of what is classic semi-metro Light Rail in a US city, the San Francisco Muni Metro. We shall return to that later.

3.2.1 International Recognition

During the 1970s, German cities began to create overarching public transport authorities or *Verkehrsverbund*. Building of new underground lines had commenced in the decade before, and by 1962 rapid rail and light rail systems had been planned or commenced in nearly all German cities with more than 500,000 inhabitants (Hall). The notable post war Stadtbahn/U-Bahn systems included München (Munich), Frankfurt, Hannover, Stuttgart and Köln (Cologne). Three German Cities stood out in development of the prototype Stadtbahn configured light rail systems that became the international models. These were:

- Frankfurt-am-Main; and
- The linked networks of Köln and Bonn

Frankfurt was one of the first cities to adopt the new standards and to commence construction of its Stadtbahn system (now marketed as *U-Bahn*, or Metro). The initial configuration of the Frankfurt A lines, designated U1, U2, and U3, was to commence in a metro-like subway at Theaterplatz (now Willi-Brandt-Platz) in the city centre, traverse the median of an arterial road through inner suburbs on a heavily-engineered exclusive right of way that sported un-metrolike at-grade road crossings, before branching into comparatively low density suburban territory on lines that, at the time, resembled road-side rural tramways. One even carried freight out of hours. The vehicles, which could run in sets of up to four articulated cars, operated to medium height platforms marginally lower than a full Metro but, in the inner area, closely resembling one. It is significant that virtually identical cars were used for the first of the North American systems in Edmonton (DüWag c.1980) and then for Calgary and San Diego. Figure 1 overleaf illustrates a train of the original Frankfurt U2 light rail vehicles in the arterial road surface alignment mentioned above.

The role that Frankfurt had in the development of light rail is somewhat ironic. Frankfurt has arguably been among the most car-focussed cities in Germany. By the end of the post-World War I Weimar period, Frankfurt had become the centre of the German oil, rubber and automobile industry, and early signs of the motorisation of Frankfurt were evident (Yago 1984), and Frankfurt ultimately became the centre of both the motor car lobby and the Reichsautobahn network. Despite this and the destruction of half of the city's buildings in World War II, for the decade and a half after the second war Frankfurt's rail transit played a major role in the recovery of the city. Nevertheless huge increases in car ownership and Frankfurt's legacy as a car industry-driven metropolis led to another spate of highway construction and strains on the transit system. The solution described above, as had occurred earlier in the city's history, was to use transit for commuter traffic to clear the streets and highways for trucking and business rather than as an end in itself, and associated plans to clear the streets of trams.

Figure 1: DüWag U2 car, surface alignment, Frankfurt

(Photo: Author, October 1979)

The city of Köln and its immediate neighbour Bonn provides the second case of the prototypical Light Rail system, and one that definitively illustrates the process of progressive upgrading. Bonn was the capital of West Germany at the time of the early Stadtbahn deployment and it was accordingly seen that it should have a full-scale U-Bahn system. This was created in concert with Köln by undergrounding the tramways in the central city areas. In 1962 Köln decided to build its Stadtbahn system, based on the existing tram network. This led to 42km of new Light Rail, 90km of exclusive tram right of way and only 30km of on-street track. Köln and Bonn now have linked extensive U-Bahn systems developed in this manner, although in Köln the process did not encompass the full extent of the urbanised areas. There was a major shift in policy in 1979; the city government chose to develop its system as a "Mischbetrieb" (mixed system) rather than a full U-Bahn configuration (Hall).

Figure 2: Past (surface) and present (underground) Bonn Bad Godesburg semi-metro stations

(Photos: Author, October 1979; V. Brückel, March 2006)

3.2.2 Other Cities

Other cities in Europe also developed Metro systems along the semi-metro path. Brussels, Belgium is an important example. Like Bonn, its status as the European Community capital warranted construction of a Metro System and, like Bonn, this was to be achieved by progressive upgrading of its tramways. During this process the Brussels Metro Authority

Société des Transports Intercommunaux de Bruxelles (STIB) published an extensive series of pamphlets and other documents to illustrate this. The Brussels model differed in that it maintained separate configuration of its vehicles such that its semi-metro ('*Pré-métro*') lines resemble underground tramways and use tramway-type cars, while the full Metro lines and vehicles are fully configured as such.

The city of Zurich, mentioned previously for its highly integrated network, is important for its rejection of the semi-metro option. Planners in Zurich took a similar view to the German cities and proposed to put the main tram routes underground and to convert much of the network to buses. This was put to referendum in 1962 and soundly rejected, despite political support on all sides. A full Metro scheme was similarly rejected in 1973. Eventually an S-Bahn scheme found favour in 1981 (Mees 2010).

With the European prototypes established, North American cities began building Light Rail; however typically not in the semi-metro configuration. The Muni Metro in San Francisco is, however, a very important North American example (and one of a very small number) of true semi-metro systems. A small group of that city's streetcar lines had survived because they were in tunnel under the Twin Peaks area to access the downtown part of the City from the Pacific Ocean side of the City, and were not directly convertible to bus operation. As noted earlier, US Light Rail has San Francisco connections through BART; however there were other options for the second pair of tracks (the others are BART) in the Market Street subway. The use of these tracks transformed the residual Muni streetcars into a Light Rail system that for the interested rider is a dramatic demonstration of the semi-metro mode. On the streets of the ocean-side districts of the City of San Francisco the Muni is no more than a streetcar – tramway – network, albeit operated by coupled car-sets. Moving into the subway, the trains undergo a dramatic transformation - the floor in the car doorways lifts to platform height, the ride quality improves, speed increases, station announcements are automated, and the rider senses that some external force has assumed control. It has. In the subway the trains are under automatic (driverless) moving-block train control (ATC) and are operating as a true Metro.

Among the Australian 'Light Rail' systems, none has true semi-metro characteristics in the sense that they have been designed as part-metro applications. Melbourne calls two of its lines 'Light Rail' when in fact they are extensions of the tramway system over old railways with no Metro aspirations - these lines revert to street tramways in the city. Sydney's one light rail line has the technology and off-street characteristics but no Metro aspirations beyond its name. The new Gold Coast line has no metro characteristics beyond some grade separation. The Adelaide Glenelg line has a new grade separation at South Road. Its origins, however, are consistent with the configuration of the US interurban railway; street running in the built up areas and reserved right of way between, grade-separated from the 'mainline' railway network.

4. Application to Sydney, Australia

Sydney has serious issues in providing infrastructure to suit the vision in the published current centres-based strategy for Sydney *City of Cities* (NSW Department of Planning 2005, Property Council of Australia 2010). The paradigm that has emerged in Sydney is one of reliance on the use of the existing rail transit and strategic bus networks as the basis for primary interregional non-car travel, of indefinite delays to new metropolitan transit infrastructure in growth areas, and of *inter alia* targeting aggressive densification, in some cases at the expense of the heritage railway villages (Duffy 2006), to limit the need for expansion of the metropolis. Where infrastructure is inadequate and development has been allowed or encouraged to occur, redressing the situation involves retrofitting, which is inevitably more costly than construction on a green-fields site. The cost of belatedly providing the necessary transit infrastructure is demonstrably higher than building it contemporaneously with the development.

4.1 Current Rail transit proposals

There is now a new Metropolitan Transport Plan (NSW Transport and Infrastructure 2010) that excludes the Metro proposals of the previous two years, but now includes proposals for Light Rail lines to Barangaroo and to Summer Hill/Dulwich Hill. These have the long-held support from the City of Sydney (City of Sydney, 2008) and the current light rail operator (Metro Transport 2009). There have also been proposals, official and unofficial, for Light Rail or Metro to the South and East of Sydney, including the Anzac Parade corridor, lines to Bondi Beach, Randwick and Green Square (Glazebrook 2009; EcoTransit 2002, 2010). This is not a new proposal. It was raised by transport economist Robert Caldwell at the time that the tramway system was closed, but firmly rejected by the government of the day (Collins 1983). The surface Light Rail proposals have varied in how they would handle distribution in the city; however the tidiest and best articulated suggestion is the Glazebrook suggestion (p54) of a loop around George, Market and Elizabeth streets, intersecting with the City of Sydney intra-city loop that would run between Central and Circular Quay. Current Light Rail proposals for Sydney are all surface proposals, either on-street or using existing railway lines (the Dulwich Hill proposal). This immediately places most of them at odds with one intention of semi-metro – to take trams off the street. As such, the history described above suggests that most will meet with opposition from the car and bus protagonists. The George Street proposal (City of Sydney 2008) for example continues to be excluded from the State Government plan.

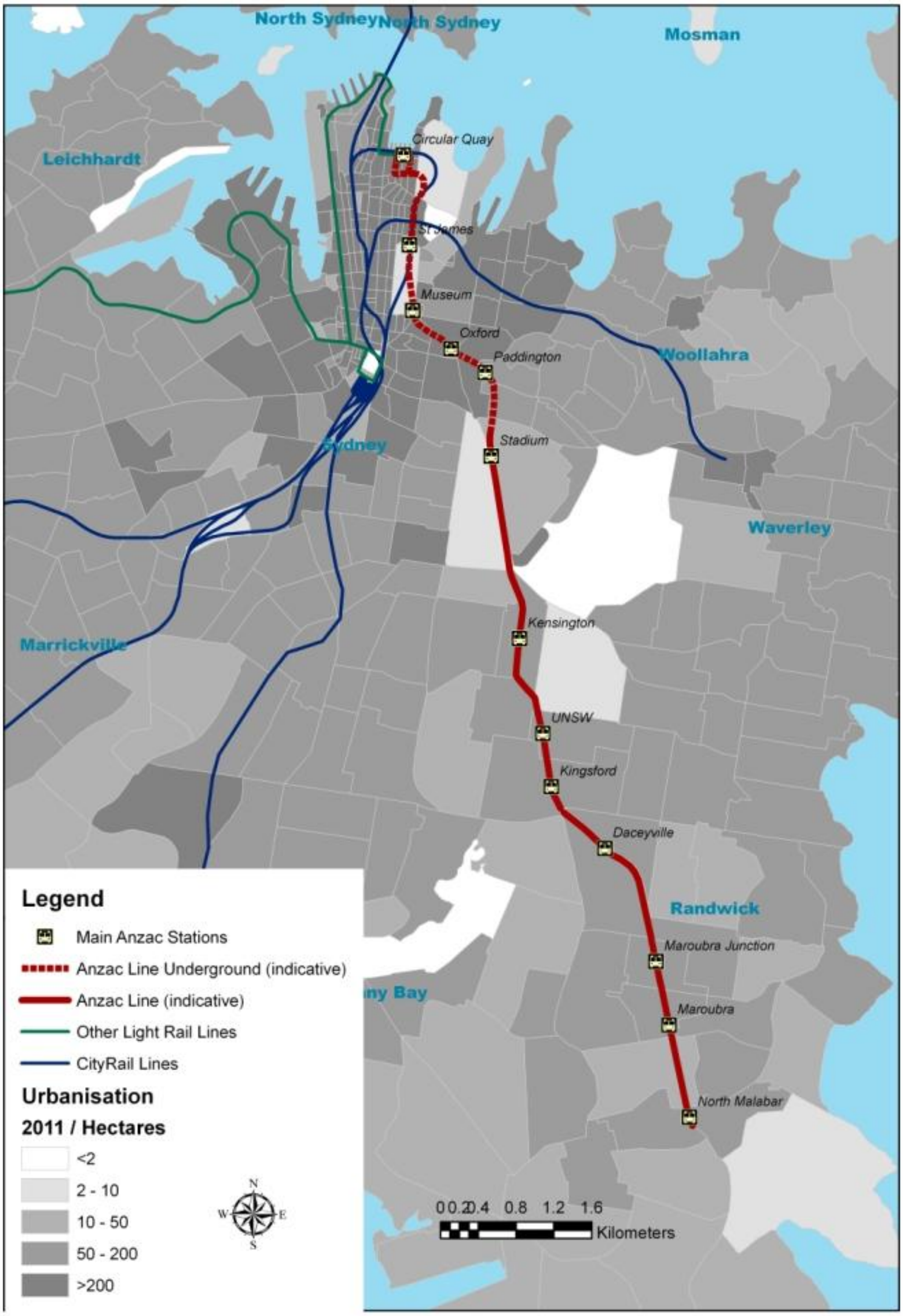
4.2 Semi-metro potential

Of the current proposals, those extending in to the south-eastern suburbs stand out as Light Rail options. The Anzac Line, as it has been dubbed, has been proposed on various occasions as noted above. A Metro proposal for the 'City East Line' to extend from Malabar through Randwick and the City to the Northern Beaches was briefly included in State Government documentation (Sydney Metro Authority 2009a). There is no detail available; however, the route suggested through Randwick would presumably be built in tunnel as was to occur with the other Sydney Metro lines. Such a route has significant surface opportunities outside of the CBD and thus potentially suits a Light Rail application. Figure 3 overleaf suggests the semi-metro option for an Anzac line, and further details follow in this section.

In its semi-metro form, the City East/Anzac line would be built as an underground Metro line in the CBD proper and through the heavily built-up precincts immediately adjacent. As was envisaged at one stage for the CBD component of the North West Metro (MetroLink 2008), this line could potentially use the empty railway platforms at St James and tunnels under Macquarie Street and Hyde Park. Using these and former tramway right of way in the Moore Park entertainment precinct and in Anzac Parade could create a semi-metro with as little as three kilometres of new tunnelling. The major engineering challenge for the new tunnel sections would be conflict with the Eastern Distributor road tunnels. The line would emerge near the Moore Park entertainment precinct ('Stadium' on the map) to assume a surface alignment that might replace the existing bus road. In the more constricted University of New South Wales/Kensington area it would need to adopt dedicated lanes to avoid further tunnelling except to grade separate the line at some locations. The Anzac Parade section is a similar environment to the outer extensions of the Melbourne network.

As noted earlier there are inevitably some potential criticisms that might be levelled at such a proposal, notably that St James and other CBD stations are not central to the CBD shopping precinct; however much can be done to enhance accessibility with good urban design. In the other direction the old tunnels continue for some distance north from St James (Oakes 2003), and several options exist that would provide connections at Circular Quay.

Figure 3: Anzac Semi-metro Line



Source: Map, Author; Urbanisation (jobs plus residents), Transport Data Centre 2009a, b

Some measure of the cost advantages of limiting new tunnelling is evident from current Light Rail projects and Sydney's Metro proposals. The Gold Coast Rapid Transit line – largely street-based light rail with traffic priority – is budgeted at about $70 million per kilometre (Australian Government 2010). The reported cost of Sydney's Metro tunnel proposals ranged from $320 million to well over $600 million per kilometre (International Review Panel 2008; West 2010).

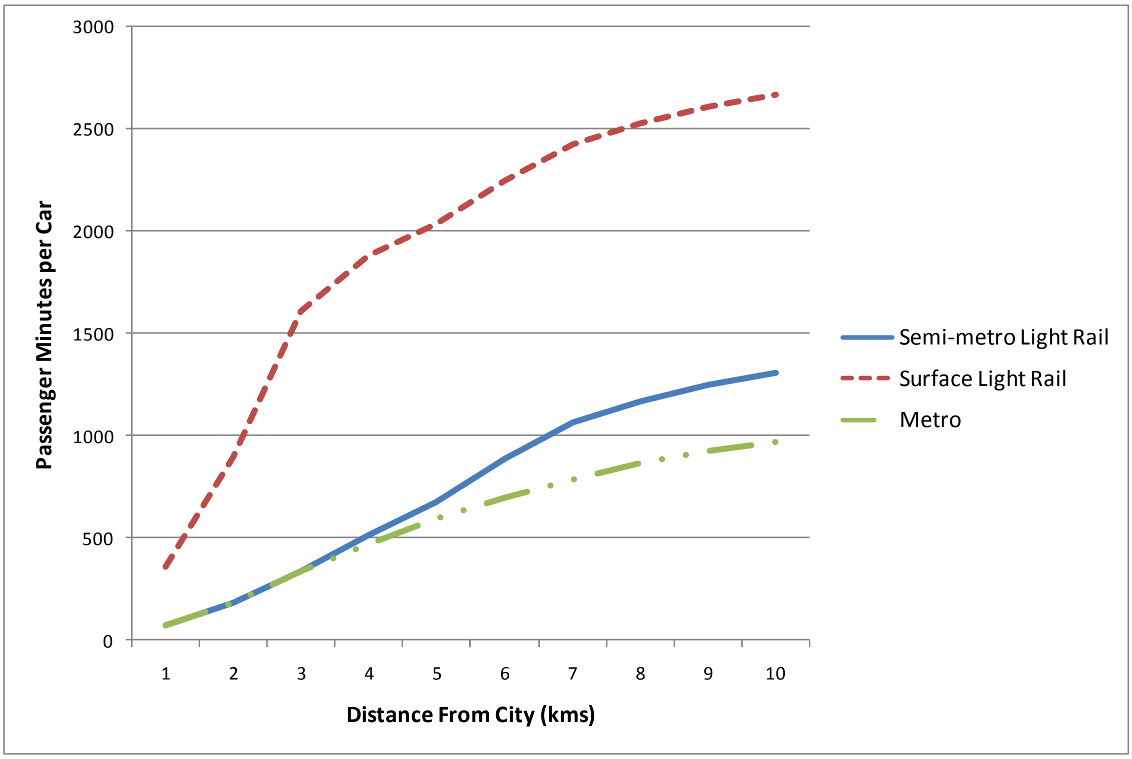
4.3 Service levels

While at this stage the operation of such a semi-metro Anzac line has not been modelled by this author, it is possible to readily demonstrate that service levels close to that of a full Metro option are feasible, and also that these significantly exceed those of a street-based line. If the travel times are compared, weighted by the ridership on a normalised basis, the effects of providing unconstrained operation in the most congested parts of the route (as offered by semi-metro) can be shown. This results from the higher speeds of an exclusive right of way where passenger numbers (vehicle occupancy) are highest, and allowing some interaction with road traffic at grade crossings and traffic lane operation elsewhere. For this demonstration it is assumed that:

- The Metro option is completely grade separated over the full route (City to North Malabar) and operates in accord with Metro principles.
- A conventional Light Rail option would be on-street from the City to Stadium/Moore Park with priority where feasible, but largely with road traffic interfaces at-grade. Freer travel is feasible once clear of the central City/Paddington areas through Kensington, with the same operating conditions afforded semi-metro in these sections.
- The semi-metro option enjoys the same operating conditions as Metro over the City section of the route and the same conditions as the conventional street-based option over the outer section.
- Inbound loading builds to the CBD outskirts thence reduces as loading is discharged; outbound is the reverse.
- Station/stop spacing is treated as identical for each option.
- Timings are based on Sydney and Adelaide timetabled and Cervero (1998).

In order to take out the effects of capacity differences between the options, calculations have been done on a 'per vehicle' basis. Capacity issues are discussed later. For this purpose passenger minutes per vehicle, that is the time taken to traverse the section multiplied by the number of passengers in the vehicle at that time, is used as the performance penalty measure. Figure 4 illustrates service levels from each of these options, based on in-vehicle passenger minutes for a nominal 100 person maximum car loading.

Figure 4: Indicative Cumulative Passenger Minutes per Vehicle – Anzac Options



It can be seen that that cumulative in-vehicle time for the slower on-street option increases much faster than the options that are operating under Metro conditions in the CBD and peripheral areas. Over the middle section of the route near 'Stadium' on the map, the semi-metro line begins to diverge from the Metro – although exclusive right of way is assumed it is a surface alignment with some conflicts. Once Kensington is reached, both Light Rail options are subject to impacts from road traffic and this slows them in equal measure, but the street-based option by this point has accumulated significantly more delay than either of the other options. However as all options are at this stage progressively unloading passengers, this factor slows the rate of passenger minute growth. The measure used suggests that the transit times for the average passenger from semi-metro would be lower than full metro by about one third, but better by a factor of two than an on-street Light Rail Line. On the matter of capacity, the Metro option, allowing two minute headways of five car trains as proposed by Sydney Metro (Sydney Metro Authority, 2009b) is 29,000 per hour. At similar loading standards the slightly longer but narrower Light Rail vehicle (based on the Köln Flexity K5000) operating in three car trains could carry approximately 20,000 per hour in semi-metro mode. Operating singly, as with street-car operation, but with increased frequency, and indicative capacity on similar assumptions for on-street Light Rail might be of the order of 10,000 per hour, although higher figures are often quoted.

The application described has two major advantages. It would remove around one hundred peak hour bus movements entering and leaving the Sydney CBD without adding to the congestion by tram movements and without requiring passengers to transfer on the outskirts. And it would do so at significantly lower capital cost than a full Metro solution. While there is an argument that supports the environmental benefits of trams rather than buses on Sydney's streets, the operational performance is limited to 40kph (max) stop-start movement and less in pedestrian zones. Moreover, they expose Light Rail service to service delays and traffic conflict no matter what traffic priority is offered. This is tolerable for intra-city hop-on/hop-off applications, but it rapidly erodes any value for Light Rail to act as a distributor for routes that extend beyond the city. It also limits the vehicle configuration, and hence capacity, to single unit consists (albeit articulated) rather than trains.

5. Conclusion

As a leading Melbourne transport researcher suggested to a Sydney audience in no uncertain terms 'Beware the Streetcar!' (Currie 2006), semi-metro offers a number of pointers on the effective application of Light Rail that appear to have been dismissed both by proponents of Light Rail and by those favouring Metro construction. Light Rail was originally intended by its earlier generation European developers as the beginning of a Metro system that would free the streets for other purposes and not merely create a new generation surface tramway. The fact that some did not succeed in completing their full Metro plans should, in an ironic way, be seen as a success, in that plans for full Metro systems might just be unaffordable, and alternatives may be needed. The problem with compromise in these circumstances is that a typical response is not to build the difficult sections, which are usually those that offer the greatest benefit. Hence the 'T-Way' rather than the 'Quickway' in Bus Rapid Transit (Hoffman 2008) and on-street Light Rail rather than semi-metro in rail.

In this paper we have seen that much of the decline of street-based rail transit systems over nearly a century has been the result of car-dominance that in turn has been part of deliberate and considered policy – it hasn't 'just happened'. It has triggered by conflict between philosophies and by positions taken by powerful enterprises, both public and private. These factors have conspired to limit the role that rail transit of all kinds has in many cities and Sydney in particular. Light Rail is an application that is among the more flexible of rail modes – it can operate in a wide variety of environments and project an attractiveness that allows it to be welcomed into spaces that other modes are not. Semi-metro Light rail takes advantage of this. Ensuring it is there for a purpose as part of an effective transit network, with the key metro-like characteristics applied where they are needed, is fundamental to its application.

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