CRC for Rail Innovation

Paper 7: Operational and Transport Issues in Rail Passenger Transport

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Table of Contents

List of Figures and Tables

Executive Summary

In Australia, rail passenger transport is predominantly urban public transport. The benefits of rail passenger transport include low pollution (including greenhouse gases), decreased congestion, and being more equitable than private car travel. Despite these benefits, it has proved very difficult to attract people to public transport in modern societies with high car ownership. The issue of urban transport has become more complicated over the past few decades. Whereas in the early 20th century the main task was to get commuters to and from the centre of a city to the suburbs, the transport task is now more dispersed both in terms of time and space.

Passenger rail services are provided by state-based and government-owned transport authorities, except in Victoria, where the urban train services are provided by a private company. In terms of size, Sydney has the largest network, followed by Melbourne, Brisbane, Perth and Adelaide. However, Perth is the only city to have significantly extended its network recently with new lines to the northern suburbs and a line to Mandurah in the south, which has just been completed. Governments provide substantial operating subsidies to all urban networks. These subsidies vary from matching fare revenue in Queensland and Victoria to twelve times the fare revenue in Western Australia.

The overall passenger transport task has increased significantly in the last 30 years with the vast majority of the increase taken up by private passenger cars. However, in the 2 years to 2007, there was a notable increase in the number of passenger kilometres on rail, whose patronage increased by nearly 13%. Despite this increase, rail is a relatively minor passenger mode in Australia. For example, if rail were to increase its modal share against passenger cars such that it doubled its share of pkm, it would reduce the share of passenger road vehicles in pkm by roughly 4%. Such a modal shift, however, would still be beneficial in broad social terms since it would reduce GHG emissions and it could have a significant impact in reducing road traffic congestion (which is sensitive to changes in traffic loads at the margin) and improving the access of many people in the community.

The energy efficiency of passenger rail can be expressed as units of energy consumed per distance travelled, i.e., mega joules per kilometre (MJ/km). Intra-city electrified rail services dominate Australian passenger rail. Passenger rail has a similar pattern of electricity consumption to power use in the residential sector. It requires a base source combined with additional power to meet daily peak use. This can be met through the interconnected electricity grid. The dominant (base) source of power in Australia is coal, with hydro-power and gas providing the peak power. Coal is the most emissions-intensive source of electricity. For passenger transport, the relative energy and emissions intensities of different modes depend on many factors, including technology, occupancy and fuel use. In current conditions, the energy intensity (in Mj/pkm) of bus and heavy rail transport is about 40% lower than that of passenger cars. The loading factors of passenger rail enable it to be up to five times more energy efficient for a fully-laden carriage compared to a car with a single occupant. Despite this, trains are seldom fully loaded (outside of peak hour), which decreases their efficiency.

New energy efficient passenger trains are lightweight but high-capacity trains. The impact of lighter weight trains would be to reduce energy consumption and therefore GHG emissions. In addition, it would also reduce the impact on rail track, fatigue load and hence track maintenance. To accompany technological change, there is a case for the extension of network coverage, capacity and frequency. In the Australian case, this involves extending electrified rail passenger routes into major suburban areas not presently covered. Other factors such as the use of travel demand management will assist in decreasing private car use. Many policy options exist such as narrowing streets, roundabouts, priority to pedestrians and public transport. The integration of urban land planning with transport planning is also an important aspect of overall urban management. It is very relevant to social access and economic efficiency and can also provide additional benefits in relation to the overall energy efficiency of transport.

Intermodality and substitutability both between different forms of public transport (such as rail and bus) and with private transport (such as through park-ride interchanges) can be increased. This would encompass transfer ticketing across different forms of transport and park-ride facilities and intermodal traffic information, as well as the timing of connections between different forms of transit services. For a

public transport system to serve the whole city, it is necessary to utilise network structures comprised of both radial and cross suburban routes. The key to a network effect is that passengers have easy and efficient transfers between services.

The competitiveness of particular passenger transport modes will depend on five main criteria: cost, timeliness, reliability, safety, and amenity. Consumers of passenger transport face a budget constraint, so the cost of a transport mode is an issue. Rising incomes enable more expensive modes that possess other positive attributes to be chosen. Rising costs may impact unevenly across particular transport modes, thereby encouraging modal shift.

Consumers of passenger transport also face a time constraint. The speed of particular modes is determined not just by average transit speeds, but also time spent waiting, time associated with intermodal transfers, time taken in parking, and time taken in walking to complete travel to and from final destinations.

The third criteria modal passenger transport competitiveness is reliability. To be judged reliable, the passenger service should not suffer cancellations, and should be able to maintain its advertised time schedule.

Safety constitutes the fourth criteria for competitiveness. The service should deliver on safety against accidents and against criminal attack. Comfort and amenity relates to (i) a smooth ride for passengers with minimised vibration and noise, and (ii) the ability to use audio equipment and mobile phones in transit.

In identifying the essential components of effective, efficient urban transportation systems, the term 'pillar' has been used. The underlying theory is that four pillars are necessary to develop a successful urban transport system. These pillars are:

- effective governance of land use and transportation;
- fair, efficient, stable funding;
- strategic infrastructure investments; and
- attention to neighbourhood design.

Passenger rail can contribute to the reduction in GHG emissions by shifting urban passenger transport from light-duty motor vehicles to urban heavy passenger rail.

1. Introduction

In recent decades, transport has had growing importance in the Australian economy, with all transport and storage products and services increasing from 4.26% of total GDP in 2001-2002 to 4.73% in 2007-2008. This trend of increasing percentage of GDP has occurred in other developed and developing countries. It is assumed this trend will continue on account of the wider distribution and mobility of populations. As a consequence, the increasing transport task and the associated energy use and emissions from transport are central to the issue of climate change.

In Australia, rail passenger transport is predominantly urban public transport. The benefits of rail passenger transport are generally agreed on: low pollution, decreased congestion with reduced costs to users, more equity in provision than private car travel, and low greenhouse gas emissions (Hensher 2007). Despite these benefits, it has proved very difficult to attract people to public transport in modern societies with high car ownership (Bannister 1998). The issue of urban transport has become more complicated over the past few decades. Whereas, in the early twentieth century, the main task was to get commuters to and from the centre of a city to the suburbs, the transport task is now more dispersed both in terms of time and space.

In Australian cities, which have low population densities relative to European and Asian cities, people travel to suburban malls and office parks, recreational places and educational facilities (Mees 2000). In high density European and Asian cities, public transport faces an easier task since the required amount of people to justify the system are within easy reach of the system. In fact, some commentators have suggested that public transport is incompatible with low density cities and hence is irrelevant to modern transport needs (Gordon and Richardson 1989; Cox 2006). These commentators suggest that the focus of urban transportation improvements and an associated reduction in greenhouse gas (GHG) emissions should be on cleaner and more fuel efficient engines. Other commentators suggest that Australian cities should be redesigned along European or Asian lines, with greatly increased densities that will be able to support public transport and hence decrease emissions (Newman and Kenworthy 1999). Despite this, evidence from North American cities such as Toronto suggests that some low-density cities have effective urban rail transport systems. However, international experience also appears to show that even the best public transport in the world will not result in a modal shift to rail from passenger cars unless it is also accompanied by direct disincentives for car travel such as reduced parking provision and road use charges and/or by much higher congestion or car use costs (Layard, Davoudi et al. 2001).

2. Passenger Rail Operators

In Australia, passenger rail services are provided by state-based and government-owned transport authorities, except in Victoria, where the urban train services are provided by a private company, Veolia Transport Australasia Pty Ltd (VTA) and tram services are provided by Yarra Trams. Regional train services in Victoria are provided by V/Line, which the state government assumed control of in 2002 when the private operator National Express Group withdrew from operations.

In terms of size, Sydney has the largest passenger rail network, followed by Melbourne, Brisbane, Perth and Adelaide. Governments provide substantial operating subsidies to all urban networks. These subsidies vary from matching fare revenue in Queensland and Victoria to twelve times the fare revenue in Western Australia.

3. Passenger Transport Task

The total Australian passenger transport task has increased significantly. In 1970, the total passenger movements were 139.99 billion passenger kilometres (bpkm). By 2004, this had risen to 356.79 bpkm. The main growth in the passenger task has been due to an increase in the use of passenger motor vehicles and aircraft. This is demonstrated by the relative amounts in 1970 and 2004. In 1970, passenger cars constituted 107.53 bpkm, buses 6.58 bpkm, rail 13.41 bpkm, and aviation 5.28 bpkm. As shown in Table 7.1, car travel had increased to 265.43 bpkm by 2004, buses 18.08, while rail had remained relatively static at 11.35 bpkm and aviation had increased to 40.93 bpkm (BITRE 2008). However, in the two years to 2007, there was a notable increase in the number of passenger kilometres on rail which increased by nearly 13% to 12.31 bpkm (Apelbaum Consulting Group 2008).

Hence, the passenger task, measured in passenger-kilometres, has grown at about 3% per annum over the past four decades. Data beyond 2003-04 are limited, but it seems that, from 2003-04 to 2006-07, the total passenger task continued to grow at close to 3% per annum, but with higher fuel prices leading to a shift away from passenger cars to rail and motorcycles, with continued growth in air travel. In particular, since 2004-05, the rail passenger task has grown sharply (by 6.4% per annum over the two years to 2006-07), and anecdotal evidence suggests that the rapid increase has continued since 2006-07, although increasingly constrained by supply capacity.

Despite this increase, it can be seen that rail is a relatively minor passenger mode in Australia. For example, if rail were to increase its modal share against passenger cars such that it doubled its share of pkm, it would reduce the share of passenger road vehicles in pkm by roughly 4%. However, this does not mean that such a change would not be advantageous in broad social terms. It would reduce GHG emissions and could have a significant impact in reducing road traffic congestion (which is sensitive to changes in traffic loads at the margin) and improving the access of many people in the community.

Table 7.1 Total Australia passenger transport task (billion passenger kilometres)

Year	Passenger cars	Buses	Rail	Air	Other	Total
1970–71	107.53	6.58	13.41	5.28	7.20	**139.99**
1971–72	111.21	6.72	11.65	5.70	8.40	**143.68**
1972–73	114.23	6.87	11.21	6.26	9.40	**147.97**
1973–74	121.59	6.97	10.07	7.45	10.71	**156.79**
1974–75	128.39	7.14	9.20	8.05	11.84	**164.61**
1975–76	131.84	7.18	8.57	7.87	12.58	**168.03**
1976–77	137.67	7.25	8.59	7.61	13.63	**174.74**
1977–78	142.59	7.31	8.42	8.48	14.10	**180.90**
1978–79	145.38	7.40	8.32	8.97	14.34	**184.41**
1979–80	146.82	7.85	8.74	9.90	14.22	**187.52**
1980–81	149.00	8.37	9.26	10.21	14.61	**191.44**
1981–82	157.62	8.88	9.34	10.67	14.80	**201.31**
1982–83	158.11	10.28	9.25	9.89	14.55	**202.09**
1983–84	164.94	11.75	9.14	10.29	15.36	**211.47**
1984–85	172.90	13.23	9.14	11.05	16.25	**222.58**
1985–86	178.76	14.25	9.37	11.98	15.56	**229.92**
1986–87	182.98	15.31	9.53	12.77	15.25	**235.84**
1987–88	189.83	16.30	9.97	14.05	15.30	**245.46**
1988–89	197.40	17.17	10.18	14.53	15.84	**255.12**
1989–90	200.95	17.43	9.72	10.92	15.76	**254.78**
1990–91	201.75	16.73	9.86	15.54	14.99	**258.87**
1991–92	204.72	16.19	9.85	20.23	15.09	**266.08**
1992–93	209.38	16.30	9.67	20.25	14.92	**270.52**
1993–94	213.06	15.79	9.75	24.31	15.34	**278.25**
1994–95	221.63	15.61	10.10	26.92	16.32	**290.58**
1995–96	227.30	16.41	10.18	28.91	16.42	**299.23**
1996–97	228.94	16.62	10.35	29.89	16.65	**302.46**
1997–98	232.88	16.94	9.93	30.32	17.49	**307.57**
1998–99	238.60	17.23	10.22	30.94	18.26	**315.25**
1999–00	243.06	17.34	10.71	32.71	18.35	**322.17**
2000–01	242.03	17.64	11.26	33.99	18.83	**323.74**
2001–02	251.48	17.74	11.36	32.56	19.54	**332.67**
2002–03	254.65	17.85	11.14	35.74	20.06	**339.44**
2003–04	265.43	18.08	11.35	40.93	20.99	**356.79**

Source: BTRE (2006) and BITRE (2008).

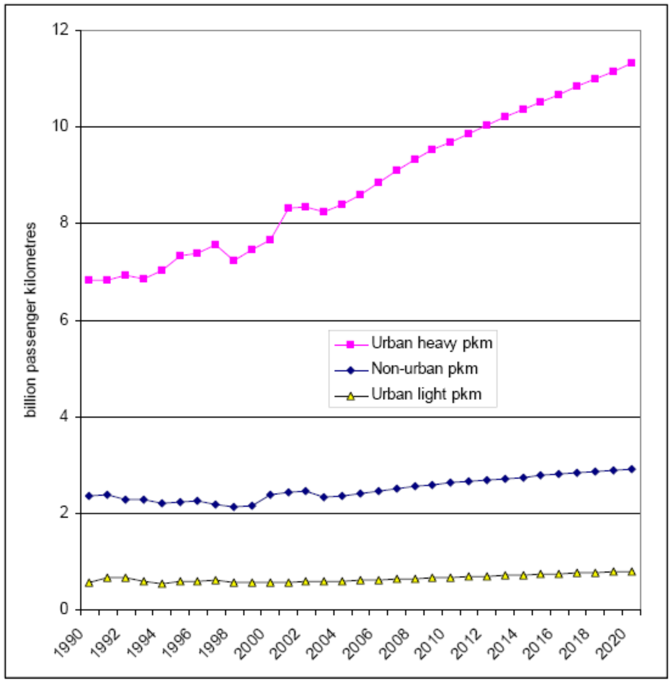
3.1. Passenger Transport Task Projections

With a projected vehicle kilometres travelled (VKT) of 289 bkm in 2020 and using a vehicle occupancy rate of 1.56, the road passenger task is forecast to be 453 bpkm in 2020. While the Bureau of Infrastructure, Transport and Regional Economics (BITRE) expects the rail passenger task to be approximately 15 bpkm and the bus task to be 23 bpkm, the aviation sector is projected to grow significantly by 2020 to 85 bpkm (BITRE 2008).

Passenger cars are currently the largest contributor to road vehicle emissions and make up around 62 per cent of road emissions in 2005, with buses and motorcycles constituting approximately 2%. Emissions from passenger cars are expected to increase from 35.2 Mt CO_2-e to 45.7 Mt CO_2-e per annum by 2020 (BTRE 2005). This increase will be driven by an increase in passenger car numbers to approximately 15 million by 2020 and a possible increase in vehicle kilometres travelled per capita (Department of Climate Change 2008).

As shown in Figure 7.1, heavy urban rail is projected to increase to between 11 and 12 bpkm by 2020, while non-urban heavy rail and urban light rail are projected to remain static (BTRE 2005). However, these projections are based on a continuation of previous trends and do not take into consideration potential modal shifts.

Figure 7.1 Projections of rail passenger tasks for Australia



Source: BTRE (2005, p. 19).

4. Passenger Transport and GHG Emissions

The generation of GHG emissions by passenger rail is determined by the energy efficiency of this transport mode, its operational efficiency, and the emission intensity of the energy sources consumed.

The energy efficiency of passenger rail can be expressed as units of energy consumed per distance travelled, i.e., mega joules per kilometre (MJ/km). Intra-city electrified rail services dominate Australian passenger rail. Powerful electrical motors are required to move the laden rail cars. These motors are very efficient, but draw a large amount of energy per kilometres travelled. The operational efficiency of passenger rail is given by the number of passengers carried per kilometre. The higher the operational efficiency, the lower the energy use per passenger kilometres (pkm). Passenger rail occupancy rates had been falling in Australia until recent years, when rising petrol prices and increased traffic congestion began to encourage a marked shift in patronage back to rail (NTC 2008).

The final element in the emissions equation for passenger rail is the emissions intensity of the energy source used. Electricity is the dominant source with diesel, used in regional and inter-city rail services, the subsidiary one. Electricity, when consumed, has zero GHG emissions. However, the generation of electricity can be very emissions-intensive. Passenger rail has a similar pattern of electricity consumption to power use in the residential sector. It requires a base source combined with additional power to meet daily peak use. This can be met through the interconnected electricity grid. The dominant (base) source of power in Australia is coal, with hydro-power and gas providing the peak power. Coal is the most emissions-intensive source of electricity, with Victorian brown coal being even more emissions-intensive than New South Wales and Queensland black coal.

For passenger transport, the relative energy and emissions intensities of different modes depend on many factors, including technology, occupancy and fuel use. In current conditions, the energy intensity (in Mj/pkm) of bus and heavy rail transport is about 40% lower than that of passenger cars, with light rail about the same as that of cars, as can be seen in Table 7.2.

This suggests that a sharp reduction in transport emissions will require both a major modal shift to rail and much reduced energy and emissions intensities in rail.

Table 7.2 Energy intensity by mode

Mode	Energy intensity passenger (MJ/pkm)
Passenger car	2.7
Bus	1.4
Light rail	2.7
Heavy rail	1.6

Source: Apelbaum Consulting Group (2006).

Despite this, heavy rail remains potentially the most energy efficient for passenger tasks, especially given that it can show low energy use per pkm at high loading factors. The loading factors of passenger rail enable it to be up to five times more energy efficient for a fully-laden carriage compared to a car with a single occupant. However, trains are seldom fully loaded, which decreases their efficiency.

The emissions intensity of passenger motor vehicles remained stable, thereby reflecting the balance between factors that tended to increase emissions intensity (lower occupancy rates, the impact of catalytic converters on nitrogen oxide (N_2O) emissions, and an increased proportion of fuel-thirsty SUVs) and those that tended to reduce emissions intensity (the increased fuel efficiency of vehicles in each particular class, thereby reflecting increased average weight and other factors).

The emissions intensity of buses is little more than half that of passenger motor vehicles. While fuel consumption per kilometre is more than 2.3 times that of passenger motor vehicles, the average occupancy rate is high enough to spread the fuel load, and the increased use of natural gas as a fuel has also had a favourable impact on emissions. However, the emissions intensity of buses has increased more recently because average occupancy rates have fallen.

Emission intensities remain high by world standards for heavy rail because the technology used in Australian heavy rail is well short of world's best standards (particularly for rail track and control systems), while the emissions intensity of Australian (and particularly Victorian) electricity is high.

Non-urban passenger rail is mainly fuelled by diesel. Passenger kilometres have not changed much over the years, but there has been some contraction of services, so passenger occupancy rates may have increased. Distances travelled are very long, and for the major services, the diesel-electric locomotives used are quite efficient.

When it comes to prospects for reducing future transport-related GHG emissions, three factors related to passenger rail will be important. First, to the extent that rail services are less emissions-intensive than other competing modes, overall emissions from transport can be reduced by a strengthening of rail's competitive position against other transport modes. Second, operational improvements in rail freight have the potential to save emissions. Third, new technologies in passenger rail can also lead to emissions savings.

4.1. Transport Emissions Projections

Relative to 1990, emissions from the Australian transport sector are projected to increase 57.5 per cent by 2010, reaching 94.1 million tonnes of CO_2 equivalent. By 2020, BITRE projects the base case emissions to be close to 78 per cent above 1990 levels (at 106.3 million tonnes of CO_2 equivalent). In 2005, transport emissions were 80.8 Mt CO_2-e, 30 per cent higher than the 1990 emissions level of 62.1 Mt CO_2-e (BTRE 2006).

As described above, the bulk of emissions growth since 1990 has occurred in road vehicles, and these are projected to grow by 22 Mt CO_2-e to 2020, with emissions from road freight transport increasing especially rapidly (Department of Climate Change 2008).

5. Infrastructure Issues and Trends

5.1. Current Infrastructure Setting and Funding

5.1.1. Road

Australia had 810,641 kilometres of roads in 2004. Of these, 41.57% were bitumen or concrete. According to Austroads (2005), in 2003, 18,773 km were part of the National Highway System, 109,031 km were rural arterial roads, and 13,051 km were urban arterial roads. Arterial roads and local streets are primarily the responsibility of state and local governments respectively, albeit with some Federal funding. Over the decade to 2003-04, the total expenditure by all levels of government in Australia on roads was A$91 billion, in 2004-05 prices (Laird 2007).

5.1.2. Urban Passenger Railways

During the early decades of the twentieth century, Australia's five largest cities developed strong cores and suburbs were established around extensive urban railway infrastructure, with large patronages that steadily increased until World War II (Laird, Newman et al. 2001). However, Perth is the only city to have significantly extended its network recently with new lines to the northern suburbs, while a line to Mandurah in the south which has just been completed.

The increase in car usage in recent decades has occurred in conjunction with a rise in government spending on road infrastructure. As can be seen in Table 7.3, spending on roads has steadily risen to over A$9 billion in 2003-2004. This compares with the sum spend on rail infrastructure, which has fluctuated markedly but is negligible in comparison to the sum spent on roads.

Table 7.3 Government expenditure on roads and rail infrastructure (A$ million, 2004-05 prices)

Year	Total roads (all governments)	Total rail
1985–86	7 537.7	136.0
1986–87	7 360.4	121.5
1987–88	7 059.9	88.9
1988–89	7 209.7	77.4
1989–90	7 869.7	74.2
1990–91	8 193.8	88.6
1991–92	7 977.8	143.1
1992–93	8 362.9	159.4
1993–94	7 819.3	452.1
1994–95	7 890.0	398.0
1995–96	8 550.4	317.3
1996–97	8 502.9	150.4
1997–98	9 329.4	478.3
1998–99	9 791.8	26.4
1999–00	9 467.8	48.4
2000–01	9 454.8	741.0
2001–02	9 430.0	1039.0
2002–03	9 337.2	1483.0
2003–04	9 347.9	1677.0

Source: (Laird, Newman et al. (2001) and BITRE (2008).

5.2. Rail Technology

Part of the vision for new energy efficient passenger trains is the design of lightweight but high-capacity trains. For some countries, such as the United Kingdom, this would mean a reversal of a tendency for trains to become heavier. The impact of lighter-weight trains would be to reduce energy consumption, and therefore GHG emissions. In addition, it would also reduce the impact on rail track, fatigue load and hence track maintenance.

At present, the control systems on trains are estimated to weigh about 4 tonnes per train. In the next generation of technology, mechanical control systems will be replaced by electronic fly-by-wire systems[1] (as pioneered in the aerospace industry). As power and propulsion systems become more regenerative and efficient, kinetic energy (proportional to mass, and hence train length) becomes a progressively smaller contributor to consumed energy, and energy use becomes dominated by aerodynamic drag. Increased train length will always reduce the energy consumption per seat, but aerodynamic drag can be reduced by the better profiling of car bodies (Goodall, 2007). Improvements in the operation of accessory systems on passenger trains are possible. These include changes in HVAC systems, better thermal insulation, more energy-efficient lighting and reduced idling (Randall, 2007).

In the long term, consideration is likely to be given to significant expansion of Remote Train Operation (RTO) or 'manned driverless' trains. RTO is being approached through incremental steps. The first step – auto-reversing – is being assessed in some countries. The principal rolling stock requirements for RTO are intelligent door control, high train system reliability, enhanced communication facilities, remote recovery, and back-up manual driving controls.

Automated Train Protection and Control Systems (TPC) interfaces the signalling system of railways and transmits relevant data to the train. It can supervise actual train speed and location against the movement authority generated by the signalling system and apply brakes automatically if the driver fails to respond to movement authority limits.

5.3. Capacity

To accompany technological change, there is a case for the extension of network coverage, capacity and frequency (OECD 1997). In the Australian case, this involves extending electrified rail passenger routes into major suburban areas not presently covered (a process that will be encouraged by increasing population densities in many of these areas), investing in infrastructure improvements that increase the quality of regional train services (as in the case of recent initiatives in Victoria), and improving interstate rail services. In the latter case, there is the longer-run possibility of developing an electrified Very Fast Train service between Melbourne and Sydney and, eventually, Sydney to Brisbane.

5.4. Intermodal Passenger Transportation

Intermodality and substitutability both between different forms of public transport (such as rail and bus) and with private transport (such as through park-ride interchanges) can be increased. This would encompass transfer ticketing across different forms of transport and park-ride facilities and intermodal traffic information, in addition to the timing of connections between different forms of transit services.

Intermodal operations have become a key aspect of the shipping, railroad, trucking and air cargo businesses, and have resulted in a much more integrated and efficient freight transportation system. Intermodality has been a less prominent feature of passenger transport systems. Nevertheless, there is great potential for increased integration of local transit, intercity bus and rail, and international air transport, and several cities in Australia have made significant progress in this regard.

[1] Note Cooper (2007).

Europe has made the greatest advances in integrating passenger transport modes. The Europeans have made great strides in linking the individual systems of intercity rail, bus and local transit, as well as air transport. The classic example is the intercity rail stations located in the lower levels of major European airports linking airlines with the Trans-European High Speed Rail Network.

Applications of passenger transport intermodality include the following:

- Bus-rail, bus-air. As the most flexible of the passenger transport modes, bus transport is able to adjust its schedules and routes to meet the requirements of its intermodal partners, whether they be urban rail inter-city rail or air (or park-ride). Cooperation can extend to shared passenger information systems, integrated ticketing systems and code-sharing.
- Rail-air, rail-passenger vehicles. Linking rail stations with airport terminals, the transport of passengers with their cars, intercity/local transit rail. Checking luggage through intermodal systems. Other aspects of cooperation as listed above.
- Rail/bus-private transport. The provision of park-ride facilities at transit interchanges.

The successful application of intermodal principles to transportation relies on three critical factors: infrastructure, information technology, and cooperation.

Passenger intermodal facilities need to be optimised at railway stations, particularly those that service major transport nodes, in terms of comfort, accessibility, security, weather protection and parking. Of particular importance is the need to provide a physical interconnection between rail and air passenger services at airports. The accommodation of surface transportation at airports requires recognition at the overall regulatory level for airports, as individual terminals are separately owned.

Information technology can be harnessed to improve passenger information systems, providing aids to security (such as CCV cameras) and intermodal computer reservation systems. The deployment of the above systems requires cooperation between the different transport modes, and that of local and regional planning bodies (Goetz and Vowles nd).

6. Operational Issues and Trends

For a public transport system to serve the whole city, it is necessary to utilise network structures comprised of both radial and cross suburban routes. The key to a network effect is that passengers transfer efficiently between services. Networks are used by airlines in the US in an environment of dispersed demand. They rely on 'hubbing' to reduce operating costs (Hansen and Kanafani 1989). A similar approach is used by the Zurich and Paris public transport systems. In a network system, passengers trade off the inconvenience of having to transfer between services and some indirect journeys against a high level of service and low fares; this results in a go anywhere, anytime service that resembles the convenience of a car. While the busiest routes may be high-capacity rail routes along radial lines to the central business district (CBD), each route must provide a high-quality service. Since it is impossible to provide public transport from every origin to every destination, it is necessary for such a system to make use of a high number of transfers. When densities are low, trip ends dispersed and networks laid out on a grid, transferring becomes necessary. Straightforward transfers between modes are thus crucial if motorists are to change to public transport (Vuchic 2007).

For this to be successful and increase modal share, timetabling appears to have to be supply led, not demand led. Traditionally services have been demand led, where if patronage increases, more services are provided, if patronage decreases fewer services are run. However, for a system to gain as much modal share as possible, services must be set to maximise opportunities for travel and the possibilities for connections. The traditional demand-led approach locks public transport into a declining role. Efficient timetables with easy transfers need to be supported with transfer-friendly fares; this means the transfer must be free (Vuchic 2005). This is currently the case in all Australian cities except Sydney (Apelbaum Consulting Group 2006).

6.1. Competitiveness

The competitiveness of particular passenger transport modes will depend on five main criteria: cost, timeliness, reliability, safety, and amenity.

Consumers of passenger transport face a budget constraint, so the *cost* of a transport mode is an issue. Rising incomes enable more expensive modes that possess other positive attributes to be chosen. Rising costs may impact unevenly across particular transport modes, thereby encouraging modal shift.

Consumers of passenger transport also face a time constraint, so *timeliness* or *speed* also becomes an issue. The speed of particular modes is determined not just by average transit speeds, but also time spent waiting, time associated with intermodal transfers, time taken in parking, and time taken in walking to complete travel to and from final destinations.

The third criteria of modal passenger transport competitiveness is *reliability.* To be judged reliable, the passenger service should not suffer cancellations, and should be able to maintain its advertised time schedule, or operate so frequently that publicly advertised schedules are unnecessary.

Safety constitutes the fourth criteria for competitiveness. The service should deliver on safety against accidents and against criminal attack.

Finally, *comfort and amenity* relates to a smooth ride for passengers with minimised vibration and noise, and the ability to use audio equipment and mobile phones in transit and many other characteristics of the transport experience. The quality of the customer interface is also important, including the furnishing of real-time passenger information.

The importance of rail passenger transport varies greatly between countries. Rail can be used for journeys of many different distances, but has historically lost market share to air for longer journeys. Rail's competitiveness is aided by high population densities because they provide a large potential passenger pool that helps spread the cost of the significant infrastructure overheads associated with rail transport. Rail passenger transport enables commuters to avoid congestion problems in the road network (and therefore provide quicker transit times than rival forms of transport) and can, if there is sufficient capacity in the system, provide a very comfortable means of travel. The problems for rail are its lack of flexibility, time penalties associated with travelling to rail stations and waiting times, and the high costs of providing rail infrastructure.

Income elasticities of demand for rail services are generally assumed to be low or even zero by transport economists, although this reflects the implicit assumption of supply factors being fixed. Rising incomes along with urban densification may lead to a combination of supply growth (based on readier financing capabilities) with demand growth. Rail benefits from increased road congestion if supply flexibility is assumed. Price elasticities are usually low, but big changes in relativities with car travel combined with flexible rail supply capability would qualify this assumption. Cross-price elasticities with cars are usually low, but could become significant in the above situation.

Five major strategies are required if the competitiveness and flexibility of rail passenger transport is to be increased substantially in the future. They involve the harnessing of new technologies to improve passenger transport services, the increase in the capacity of the passenger transport infrastructure, increased operational flexibility, the strengthening of intermodal passenger transportation, and greater economic development along public transport corridors.

6.1.1. Impacts of Factors on Rail Competitiveness

Increased Capacity

The capacity of passenger rail transport can be increased for a given rail infrastructure through:

- New car technology up 6% in capacity on current technology.
- Semi-trailer vehicles providing up to 10-15% more capacity than enhanced conventional cars.
- Dealing with increased capacity – platform management, increased door numbers to decrease station dwell times, train length, digital in-cab signalling and increased standing capacity.

Reduction in Costs

The operational costs of passenger rail can be reduced in the following ways:

- New track technologies could result in reduced interruptions to freight movements because of track defects. Increased life for track and track components associated with these technologies helps to spread capital costs and also reduces maintenance costs.
- The adoption of advanced network traffic controls can reduce the fuel costs of the freight operator and improve the utilisation of vehicles and staff, and thereby reduce both the variable and fixed cost of operations. Improved logistics facilitate economies in both fuel costs and the cost of equipment through more efficient vehicle operation. For example, Automated Train Protection and

Control Systems will decrease signalling infrastructure, operations and maintenance costs.

- Improved light rail vehicles requiring lower maintenance.

Speed

The average speed of passenger rail services can be increased in a number of ways:

- New passenger rolling stock have faster average speeds and acceleration.
- Very fast rail may have long-term potential for intercity rail.
- Light rail vehicles will have faster acceleration, faster exit and entry, perhaps traffic signal priority.
- Average rail freight speeds would be boosted by more consistent track conditions as a consequence of new track technologies.
- Advanced network traffic controls can reduce stoppages and thereby increase average speeds.

Reliability

The reliability of passenger rail services can be boosted:

- Improved track conditions increase the reliability of services.
- More advanced track maintenance methods result in quicker restitution of damaged track.

Safety

Passenger rail safety can be increased:

- Improvements in security technology such as through the use of CCV cameras.
- Light rail: lower floors, easier entry and exit especially for people with disabilities. Stronger vehicles, increased security.
- Improvements in track and control technologies, including the use of automatic train protection (ATP), could increase safety.

Comfort

Comfort to rail passengers can be increased:

- Minimised vibration.
- Low noise.
- Integrated tilt and active lateral suspension control may solve motion sickness issue.
- Wi-Fi technology, internet access and 'infotainment' services.

6.2. Efficient Timetables

Best practice in urban rail timetabling is about providing service patterns that:

- are easy to operate reliably,
- make the most efficient use of infrastructure and rolling stock,
- are easy to understand and remember for passengers; and
- simplify the task of providing connecting bus services (Vuchic 2005).

The pre-eminent approach, as set out in manuals such as *Urban Transit: Systems and Technology* (Vuchic 2007) and applied in 'best-practice' cities like Zurich and Copenhagen, is to adopt a regular service pattern using a recognised model like 'skip-stop' or 'zonal' operation. A regular service pattern is recommended because it is easy for operators and passengers to remember, facilitates the timetabling of connecting bus services and allows the development of recovery strategies to deal with delays (Vuchic 2007).

6.3. Operational Efficiency

Some transport organisations have a tendency to develop operational procedures that decrease efficiency over time owing to the convenience of personnel and loss of corporate memory. There appears to be some evidence of such a phenomenon with the train operators in Melbourne. This is detailed in a supporting document to the *East West Link Needs Assessment* by Sir Rod Eddington. The document by SKM details complicated patterns of services currently running, crew changes and layovers at the busiest stations during peak hour (SKM 2008). In addition, headway times of 3 minutes are currently used, but 2-minute headways are commonplace internationally, with the Moscow Metro having headways in the order of 90 seconds (Moscow Metro 2008). This pattern implies that operational efficiencies have fallen within the organisation.

6.4. Travel Demand Management

Travel demand management programs will often be directed at trip reduction programs, but can also aid in the decrease of private car use. Many policy options exist such as narrowing streets, roundabouts, and giving priority to pedestrians and public transport. Other examples of disincentives for car use include increased car parking charges, parking capacity reduction, road capacity reduction, road pricing, and fuel taxes (Luk 2003).

6.5. Operational Flexibility

The operational flexibility of public transport should be increased with customisation being the primary objective. Specific attention should be given to:

- the provision of clear and accurate customer information, including dissemination of information via the internet and through road linkages;[2]
- improved service reliability and comfort;
- addressing personal safety issues;
- focusing on customer demands;
- tailoring vehicle mixes to customer demands; and
- better designed transit interchanges (in terms of comfort, accessibility, security and weather protection) with customer-focused services.

[2] Including whether timetables, maps and other information are provided at every stop, and whether the system is actively marketed and sold through innovative advertising campaigns and marketing strategies such as specialised destination maps for different purposes.

7. Urban Form and Planning Issues

7.1. Transport and Urban Development

The integration of urban land planning with transport planning is an important aspect of overall urban management. It is very relevant to social access and economic efficiency and can also provide additional benefits in relation to the overall energy efficiency of transport. Key aspects of the required policies are:

- encouraging higher urban density and mixed-use development in high income cities;
- improving the scope for walking and cycling to achieve mobility requirements;
- integrating land use planning with the development of transit infrastructure (while this is mainly aimed at intermodal substitution from light-duty vehicles to rail or bus transport, improvements in transit infrastructure can facilitate savings in vehicle kilometres by facilitating more direct linkages for travellers); and
- managing parking supply in order to discourage certain types of vehicle trips (APEC 2000).

The integration of urban and transport planning in a way that addresses the issues raised by sustainable transport as an objective requires two essential areas of competency. The first is effective governance systems for the region under question. The second is the provision of adequate information on current transport requirements and data relevant to constructing scenarios of future transport movements so that planning models can be based on rigorous empirical analysis.

The integration of urban land planning with transport planning provides an opportunity to coordinate the upgrading and extension of rail corridors with intensive residential and commercial development. Japan provides a good example of such an approach. The development rights to transport corridors provide a valuable asset that can be leveraged to facilitate the growth of transit infrastructure.

Compact city policies are justified in part as means of conserving rural land and saving on the costs of urban infrastructure like water mains and schools; however, they also reduce car travel by promoting walking, cycling and public transport (Kohn 2000; Soltani 2006). City area has been correlated with passenger car use, vehicle emissions and fuel use. Cities with smaller areas are more transport efficient, regardless of the transport system, culture, affluence, age, layout or anything else (Hughes et al. 2003).

7.2. Minimum Densities for Public Transport

Close proximity to key amenities and activity centres such as shopping centres, schools and parklands are crucial to reduce the need to travel for a long distance as well as make alternative modes (i.e., walking, public transport) more feasible. A suburb’s self-sufficiency can be improved not by organising job places, but through closeness to key amenities. Each key amenity has its own supporting area, enabling a residential area to benefit in different ways. The larger the proportion of the area with proximity buffer, the more likely that a suburb is favourable for those interested in walking/cycling activities (Soltani 2006).

8. Institutional Factors

The most important requirement is for a single transport agency to be established with oversight of urban transport. It should be detached from any operational responsibility for transport. Furthermore, transport operators should be subject to overall regulation that specifies community service obligations and sets goals for service provision and overall efficiency.[3] The corporatisation or privatisation of transport operators may be seen as being necessary to secure the above goals (APEC 2000).

There are many constraints to increase public transport patronage. Significant difficulties lie in the way funds are allocated to transport. In the second half of the twentieth century, the vast majority of funds has been allocated for road infrastructure. In addition, generous tax incentives exist for private car use (Luk and Richardson 1997). Thus, for funds to be allocated more evenly, a new process needs to be implemented.

8.1. Four Pillars

In identifying the essential components of effective, efficient urban transportation systems, the term 'pillar' has been used. The underlying theory is that four pillars are necessary to develop a successful urban transport system. These pillars are:

- effective governance of land use and transportation;
- fair, efficient, stable funding;
- strategic infrastructure investments; and
- attention to neighbourhood design (Kennedy, Miller et al. 2005).

For example, fixed rail urban transit systems have the potential to make cities more environmentally sustainable, but unless they are supported with effective land-use policy, transit systems might be financially unsustainable. Conversely, establishing a neo-traditional neighbourhood in a sea of suburban sprawl may do little to promote transport by sustainable modes. Without suitable governance, it is difficult to see how either integrated land use planning or sustainable funding mechanisms can be achieved. Sustainable urban transportation arguably requires all four pillars (Kennedy, Miller et al. 2005).

[3] It may also oversee the introduction of a ticketing system integrated across different modes of transit services.

9. Modal Shift

The major way that passenger rail can contribute to the reduction in GHG emissions in the short-to-medium-term is by increasing its competitiveness against more emissions-intensive forms of passenger transport. By far the biggest opportunity is to shift urban passenger transport from light-duty motor vehicles to urban heavy-passenger rail. There are even bigger emissions savings in shifting passenger traffic from air to rail, and it is noteworthy that the present environmental advantages possessed by buses are reversed in the medium- and long-term. But this would be very costly and raises issues beyond the scope of this paper.

10. Urban Rail Case Studies

With respect to system configuration, the extensive transit systems found in cities such as Copenhagen, Seoul, Hong Kong and Singapore could be considered very good models. Such systems are of sufficient extent that direct rapid transit service is not limited to the traditional central business district. High degrees of mobility and accessibility are achieved at high-capacity levels. By comparison, transit systems in North American cities are generally less extensive, typically having CBD-oriented rapid transit with supplementary street transit routes in the city and suburbs. Expanding the existing rapid transit systems in North American and other similar urban regions is obviously an expensive endeavour that would only be cost effective at high passenger volumes. This requires the development of high-density land use at nodes and along corridors outside the traditional CBD (Kennedy, Miller et al. 2005).

10.1. Melbourne

Melbourne's electrified suburban rail system is very extensive by world standards. It is similar in size to the London Underground and larger than the Paris Metro.

In contrast with its physical extent, the Melbourne rail system carries low passenger volumes by international standards, with 179 million trips made in 2006/07. Tokyo's rail network carries more passengers in a week than Melbourne's does in a year. Tokyo's system is bigger than Melbourne's, but the Paris Metro has less track and smaller trains, but carries around 6 times as many passengers as Melbourne's. Toronto's subway and Montreal's Metro, which together form approximately half the size of the Melbourne system, carry 317 and 274 million passengers per annum (Mees 2008).

The rail patronage growth predicted in the 1920s did not eventuate, because of the rise of the car: by 1964, annual patronage was only 170 million trips, less than half the level predicted. Moreover, the number of trains serving Flinders Street Station in the busiest hour of the day had actually fallen, from 113 to 108 (SKM 2008).

The 1969 transport plan predicted that rail patronage would nearly double, to around 300 million, by 1985. The predictions, however, turned out to be incorrect: patronage actually declined until the early 1980s, and did not begin a significant recovery until the early 1990s. Although patronage is now higher than two decades ago, it remains much lower than the planners of the 1960s expected, and the number of suburban trains in the busiest hour has fallen to only 94 (Eddington 2008).

10.2. Perth

The Perth suburban railway system was opened in 1881 together with the establishment of trams in Fremantle and Perth. This rail system remained dominant in the first part of the twentieth century with urban growth clustering around railway stations. However, after World War II, urban growth began to be built away from the railway and in conjunction with roads used by private vehicles. In fact, the city grew along the north and south of the Swan River instead of on its previous rail-based east-west axis. Subsequently, as in Sydney, the tram service was terminated. For the same reasons, the Fremantle line was terminated in 1979 and replaced by a bus system (Curtis 2006). However, community efforts to restore the rail service culminated in success in 1983, when the Fremantle line was re-opened and examined for possible electrification. In late 1985, the project was awarded for work and track upgrading on the Fremantle line. The electric trains attracted an increase of twenty per cent in patronage (over the operating figure before closure) immediately after the line's re-birth .The apparent success story of the Fremantle line opened the debate on the northern suburbs rail option in 1988. Eventually, the state government allocated A$220 million in 1989 for the construction of northern suburban lines (Carlton 2006).

Since the early 1990s, Perth has invested heavily in urban rail. The A$1.6 billion New Metro Rail project, which doubled the size of the city's rail system and funded new rolling stock thoughout the network, was completed late last year with the opening of the new Southern Railway to Mandurah. This new 72-kilometre line, incorporating an underground section through the city centre, was built in less than four years, for around A$1 billion. It is already attracting 80% of its projected daily patronage of 50,000. Rail patronage across Perth has increased sixfold in the last 20 years. New trains have been ordered to cope with rising demand, while a second round of rail extensions is planned, with six new or extended lines proposed, including a new link to Perth Airport (Muhammed, Low et al. 2006). Many other successful public transport initiatives have also been undertaken in Perth in recent years.

10.3. Toronto

Public transit was one of the essential services identified by Metro Toronto's founders in 1953. On January 1, 1954, the Toronto Transportation Commission was renamed the Toronto Transit Commission and public transit was placed under the jurisdiction of the new Municipality of Metropolitan Toronto (Filey 1996).

The Toronto Transit Commission (TTC) is a public transport authority that operates buses, streetcars (trams), subways and rapid transit lines in Toronto, Ontario, Canada. The TTC operates 149 surface transit routes, of which 148 routes make 243 connections with a subway or rapid transit station during weekday rush hours. In 2007, the TTC carried 1.5 million passengers per day, and there were 459,769,000 passenger trips in total.

The TTC operates the third most heavily used urban mass transit system in North America (after the New York City Transit Authority and the Mexico City Metro). As of 2006, there are three subway lines and one elevated rapid transit line (see Toronto subway and RT) with a total of 69 stations. The average daily usage exceeds 2.46 million passengers: 1,197,000 through bus, 328,700 by tram, 35,300 by intermediate rail, and 901,400 by subway (TTC 2008).

The Toronto subway system consists of the Yonge-University-Spadina Line, a U-shaped line started in 1954 and last extended in 1996; the Bloor-Danforth Line, an east-west line started in 1966 and last extended in 1980; the Scarborough RT, a partly elevated light rail line built in 1985 that continues from the Bloor-Danforth Line's eastern terminus; and the Sheppard Line, opened in 2002 (TTC 2008).

In addition to the subway, tram and bus systems, a commuter service also exists. This service is called GO (Government of Ontario) Transit. The GO Transit system serves the Greater Toronto and Hamilton Area (GTHA), which consists of the City of Toronto, the City of Hamilton, and the surrounding Regions of Halton, Peel, York and Durham. In total, GO trains and buses serve a population of 7 million in an 8,000 km² (3,000 sq.mi.) area radiating in places more than 100 km from central Toronto. The GO system consists of seven routes, all departing from Toronto's Union Station.

Most of the GO Train route network operates only in peak rush-hour periods and then only in the primary direction of travel (GO Transit 2008).

The TTC's system is an interconnected network of direct high-frequency services with an easily understood grid network of trains, trams and buses. The system offers most of the residents of Toronto the ability to travel to their chosen destination at a time of their choosing, cheaply and comfortably in reasonable time. Feeder buses to the rail system also serve local and cross suburban needs. The rail system is of sufficient quality that a substantial number of passengers choose to use the feeder buses, which are then able to provide the level of service which enables bus-only users to be attracted to the system. The combination of these streams of patronage permits a high-quality system. The system's success is also due to the simple route network and intermodal coordination, which reduce duplication and overlapping, thus producing a seamless service that serves spatially and temporally diverse needs (Mees 2000).

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