Methodologies to Increase Public Transport Mode Share in Sydney and Perth

Masters Thesis

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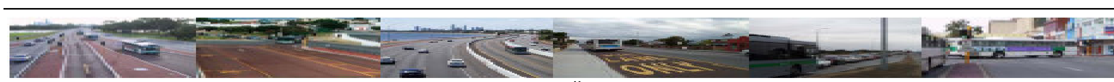

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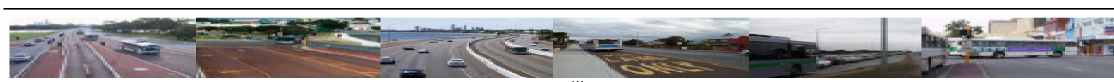

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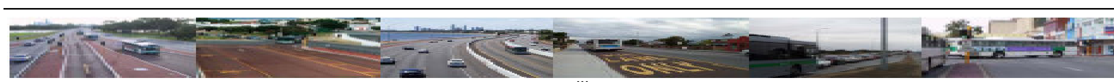

SYNOPSIS

What is this projects value to society?

Increasing public transportation mode share is important in the context of the future economic development of our cities. Given recent published greenhouse gas emissions data attributable to private transportation, it is arguable that global growth in motor vehicle usage may be detrimental to the environment and therefore to our cities' sustainable growth.

This body of work seeks to describe methodologies and theories to increase the percentage mode share of alternative forms of transport and to deter the continued growth in sole occupant motor vehicle journeys. These methodologies are the result of significant research into existing systems in Australia, and where relevant additional research in Europe and the USA. Due to the nature of the problem, the methodologies presented are not intended to be revolutionary, however are intended to show a holistic view of how behavioural science methodologies, engineering infrastructure and technology could be incorporated. This analysis and research is provided as an alternative to "reactionary" measures.

The value of this project is delivered in four ways, namely: -

- A concise listing of transportation statistical analysis from the last 25 years for both Sydney and Perth.
- An analysis of contributors to human behaviour patterns and their impact on transportation mode choice, culminating in the offering of theories involving Maslow's Hierarchy of Needs and Elliott Wave Theory.
- An analysis of transportation infrastructure engineering and it's potential to impact human behaviour and therefore impact transportation mode choice. This section culminates in an examination of passive and active signal bus priority infrastructure measures.
- The conclusions which seek to show the importance of understanding both the behavioural patterns which impact transportation mode choice decisions and the potential for engineering infrastructure to create a positive influence.

After five years of research I believe that engineering and infrastructure improvements can have an impact upon mode choices, but the underlying trend away from public transport is behavioural. Understanding and implementing schemes which target both aspects will deliver improved opportunities for success. Reduction in traffic congestion, vehicle travel times and ultimately greenhouse gas emissions are all the ultimate goals for a mode share shift from private motor vehicles to public transportation systems.

This report expands upon the material covered in the Capstone Project report "*Traffic Congestion in Australian Cities – a Summary of Transport Planning and Modal Share Targets in Four Australian Cities*".

Can I help solve problems?

I have a strong interest in the provision of public transport infrastructure and believe it is important for engineers to have formative input into projects which promote sustainable transportation objectives.

Importantly, during the research phase I have become convinced that engineers need to appreciate the behavioural science aspect of society, or simply to understand why people utilise infrastructure and public spaces. This theory commenced from an inspiring speech delivered at the UTS graduation ceremony in September 2004 by one of the guest speakers. The topic centred on designing Darling Harbour as a space where people interacted with their environment. Therefore a key success factor of the project was the slower pace which people walked through Darling Harbour than through the rest of the Sydney CBD. As Darling Harbour was a more pleasant environment, people walked slower, talked more and appeared to enjoy their surroundings more. A course syllabus covering behavioural science and transportation, or expansion of subjects such as Uncertainties and Risks or Technology Assessment could be very useful at UTS for future engineering undergraduates.

I have been involved in infrastructure design for the last 15 years and my ultimate aim is to continue to develop my career in urban transport, land development and local and state government level infrastructure. I am currently a Senior Civil engineer at TABEC in Perth which focuses on these markets. My role is to develop

and expand business, which provides a strong practical background to complete this thesis. In my previous role at WorleyParsons I was the Project Manager for the consultant appointed to provide input into the Design and Specification of a Trial of Active Signalised Bus Priority on the Perth Circle Route, which provided further opportunity for research into this topic.

I have a sound theoretical grounding after completing the subject "*Transport In The Environment"* and the aforementioned Capstone Project. I look forward to enhancing my analytical skills and knowledge in transportation and urban infrastructure engineering in the coming years.

Project origin?

The origin of the project is borne from work and study experiences over the last 5 years and working with some of Sydney's and Perth's leading transport engineers. I have always had an interest in projects involving the principles of ecologically sustainable development, and transportation is a key issue for each city in Australia to resolve, as the current trends in transport modal share arguably are not environmentally, economically or socially sustainable. In addition, it is important that the general public further develop their understanding of transportation infrastructure, how it is funded and its place in the greater environment. As an engineer with an interest in the way we integrate with the environment, particularly within the context of the urban environment, I feel this is a worthy project to dedicate time to.

Where was the work carried out?

This Masters Research Thesis has been undertaken in Perth with 6-monthly reviews undertaken in Sydney. Statistics and relevant policy information have been researched and collated, with the internet used as the primary source of information. This research is updated every 6 months to reflect latest available data and verified by contacting transportation departments in Sydney and Perth to ensure sampling techniques have not changed to the point where figures and trends are distorted. Additional transport data, policies and viewpoints have been obtained through a number of books, newspaper articles, printed material and research via telephone. All quoted material has been appropriately referenced.

It is important to note that the data sources have been checked through the duration of this research and compared to ensure that where comparisons of data sets are provided, they are on a "like for like" basis and that sample sizes, or techniques have not shown an undue emphasis or bias.

Desktop traffic modelling has been undertaken in accordance with the NSW RTA's Guide To Traffic Generating Developments, Version 2.2 October 2002 and in accordance with the data accumulated in this thesis. The author's assumptions and methodologies have been clearly noted and explained where they have been applied.

Basic goal and rationale for the project?

The key hypothesis of this work is to: -

"Discuss and analyse transportation mode share statistics and to determine behavioural science and engineering infrastructure methodologies to increase public transport modal share in Sydney and Perth."

To accomplish the key hypothesis, the work is broken into smaller goals based on a logical order of: -

- Analysis of transportation statistics;
    - Historical context.
    - Current context.
    - Comparative analysis between Sydney and Perth and opportunities for both cities to learn from successes / mistakes.
- Behavioural science aspects of transportation;
    - Analyse various behavioural science theories which impact transportation mode choice.
    - Discuss human behaviour in terms of our decision making capabilities at individual level – Maslow's Hierarchy of Needs

    - Discuss human behaviour in terms of our decision making capabilities at group (or herd) level, and the potential to predict future transportation statistical performance based on the historical context – Elliot Wave Theory.

- Transportation engineering infrastructure methodologies;
    - Analyse various engineering infrastructure theories which impact transportation mode choice.
    - Discuss the emergence of active signal bus priority technology and its potential to initiate a shift in transportation mode share.
    - Discuss the emergence of passive infrastructure bus priority and its potential to initiate a shift in transportation mode share.

- Conclusions
    - The key conclusion is to show the importance of understanding that transportation mode choice decisions are influenced by both the provision of infrastructure but also other external factors which influence human behaviour.

The goal of the historical context research is to collate a reasonable quantity of data in Sydney and Perth to deliver an accurate summary of the trend of public transportation mode share. This includes examination of land use, patronage figures and compilation of data showing why people travel to deliver an understanding of the various factors which have contributed to the historical performance.

The goal of the current context research is to collate up-to-date data which delivers an accurate summary of the factors impacting transportation mode choice today. This is reviewed in the context of recent engineering improvements which may have impacted supply / demand and the underlying behavioural trends and psychology toward various forms of transport. It may be evident that the general attitude toward public transport is more positive in Perth than in recent years in Sydney, mainly due to capacity and comfort issues. This is seen in greater patronage growth in Perth than in Sydney over the last decade. It is important however to note that patronage growth in Perth is growing off of a much lower base and that Perth has a much less complicated and more rudimentary transportation network than Sydney, making urban infill projects simpler to deploy in many cases.

The goal of the behavioural sciences research is to deliver an understanding of why people make travel choices. This is delivered through understanding existing theories and methodologies, and by developing theories and methodologies based on the data and information contained in this work. As a direct result of the research, I have developed theories associated with adapting Maslow's Hierarchy of Needs and Elliott Wave Theory to transportation.

The goal of examining and understanding engineering and infrastructure solutions is to understand the potential range of solutions available to deliver improved public transport performance. In particular, this work focuses on the development of active signal priority technology.

Progress achieved?

Over the five years of data compilation, analysis and reporting I have delivered a concise document which meets the basic goal and rationale for the project.

STATEMENT OF ORIGINALITY

I declare that I am the sole author of this report and that I have not used fragments of text from other sources without proper acknowledgment. All theories, results, designs and statistics incorporated into this report have been appropriately referenced and all sources of information and assistance have been appropriately acknowledged.

Signed

………………………………………..

………………………………………..

Colin R Kleyweg

EXECUTIVE SUMMARY

This Masters' Thesis has evolved as an iterative learning process driven initially by the compilation and understanding of transportation usage data. The research phase began with a clear goal to understand the **historical context of transportation modal share**. The initial objective and scope of the research was therefore to collate as much data as possible to deliver an understanding of the recent trends in Sydney and Perth. This data built on the "Transportation / Land Use Cycle" theories which were evident in my Capstone Project work. The scope of the data collection was to discover statistically significant trends such as links between: -

- Accessibility to the CBD and trip generation;
- Accessibility to transportation options (socio-economic status and urban location) and its impact on public transport usage;
- Whether the purpose of the trip had an impact on the mode chosen; and
- Whether household composition and dwelling densities had an impact on motor vehicle usage.

During the compilation of the Capstone Project work, I had found there were a number of useful information sources, however there wasn't a single source of information available through internet searches which delivered an in-depth understanding of patronage trends and how societies' attitudes were evolving over time to trip generation. My first goal was to provide a reference to potentially aide future students to understand the recent history of transportation in Sydney and Perth. Perth was chosen, not as a direct comparison, but to compare a city with very different transportation networks to Sydney.

The second goal has evolved throughout the research phase over the last 3 years and has culminated in the last 12 months where I have used the data to consider the behavioural science aspect of transportation. The key understanding here is **why people generate trips and why a particular mode is chosen for those**

purposes. Transportation choice is arguably a personalised commodity. Vehicle manufacturers consider their target markets carefully and purchasers associate themselves with the various stereotypes shown. Public transportation and other alternative modes are also associated with stereotyping. This has been quantified in the material from studies in NSW which provide a user profile summary. If this information is compared to questionnaires which summarise user views on potential system improvements it provides the opportunity for analysis. I have undertaken the analysis based on our short term or 'reactionary' behaviour and our longer term or 'disposition' behaviour trends as follows: -

- The short term (or 'reactionary' behaviour) is described by **price elasticity theory** and by provision of infrastructure inducing demand through accessibility; and

- The long term (or 'disposition' behaviour) is described by analysis of long term patronage trends using **Elliott Wave Theory** and adapting **Maslow's Hierarchy of Needs** for use as a tool to understand consumer transportation mode choice.

The third goal is to **understand the impact of transportation engineering infrastructure on mode choice**. The purpose of this is to analyse potential infrastructure improvements to suit public transportation modes. Due to the open nature of this topic, I made a choice to focus on bus infrastructure. This has not been done to exclude other forms of alternative transportation, or to suggest that bus is in any way better than other forms of transportation – it has simply been done so that a reasonable amount of analysis and research could be undertaken on the one topic.

The fourth goal is to understand the emerging **active signal priority bus technology**, and how this technology can improve on-time running, maintenance of headway and ultimately patronage (as most bus passengers' rate on-time delivery of services as one of the highest priorities.)

Australian cities are encountering greater levels of traffic congestion which leads to a number of issues for engineers, planners, politicians and society in general.

These issues include the economic cost to society of traffic delays; damage to the environment and community health caused by vehicle exhaust fumes and the social effects upon communities coping with traffic congestion and segregation issues.

The research contained shows that growth in congestion is linked to a number of factors. These include increased percentage and number of single occupant vehicles as the primary mode of transport; population growth in outer-lying urban areas with a reduction in persons per dwelling; growth in car ownership outstripping population growth; increased urban sprawl contributing to greater travel distances and continued decline in the overall percentage share of alternative forms of transport. This research aims to provide an understanding of the reasons for the decline in public transport usage and modal share over the last 25 years.

The research focuses in particular on Sydney and Perth, as in many ways they have exhibited different growth and planning models. As such, the data sets contained provide an interesting comparison in terms of modal share percentages, patronage growth and general land-use in terms of dwelling density and household composition. In general, the research shows that while the use of public transport is greater in Sydney, growth levels are greater in Perth due to a greater un-used capacity in the public transportation system and provision of major new rail infrastructure promoting public transportation usage. It can be argued that the transportation system in Sydney operated at levels close to capacity in many areas which led to a greater level of dissatisfaction with the service in the early part of this decade. Recent improvements in service reliability and capacity however are slowly improving the situation.

The question of improving public transportation patronage is shown to be a complex issue with a variety of inputs to be considered including understanding behavioural science; providing reasonable excess capacity in the system to absorb variations in consumer behaviour; and delivering engineering and infrastructure improvements which promote increased speed of travel relative to other transport options.

The question of behavioural science is examined in detail by providing research on why people use various modes of travel, how this is changing over time and whether the reason for travel predicates an inclination to use one form of transport over another. An example of this is the general increase in trips generated for social and other purposes and the relative decline in trips generated for commuting purposes. Social, shopping and other trips tend to be discretionary in nature and as such users are biased towards using a motor vehicle for those trips. Commuting, (particularly to the CBD's in Sydney, North Sydney, Parramatta and Perth) however offers strong opportunities for mass-transit transportation modes. Information provided by various public transportation agencies shows that lower socio-economic denominations tend to utilise public and alternative transport modes for a higher percentage of their daily trips than those with a greater earning capacity. In essence, this explains the theory behind 'captive' and 'discretionary' users and points to continued latent growth in motor vehicle usage as economic conditions and availability and pricing of new motor vehicles increases accessibility to greater numbers of consumers. This is further exacerbated by an imbalance in relative travel times between public transport and private motor vehicle usage.

Behavioural sciences are further examined in terms of Maslow's Hierarchy of Needs which has been applied to transportation to show that short term variations in patronage growth and / or decline are influenced by external forces including accessibility to transportation options; variations in fuel prices and fares (price elasticity theory); and timeliness, cleanliness, frequency and degree of crowding on public transportation.

The Elliott Wave Theory is highlighted to show that short term variations in patronage are worthwhile to note, however these need to be understood in terms of the overall longer term trend which is for increasing private motor vehicle usage, unless there is a change to the phenomenon of the growing consumer market having an increased accessibility to motor vehicles and accessibility to cheap fuel and subsidised road networks. The purpose of this theory is not that it be misused as a tool to predict opportunities to cut transportation funding at various cycles. The purpose of the theory is to show potential trigger points for greater levels of investment in infrastructure and / or behavioural science programs.

Engineering and infrastructure case studies such as the Centenary Avenue Bus Lane project show the potential for engineering infrastructure improvements such as variation of road capacity to provide a net tangible benefit to the environment by promoting public transportation, whilst minimising excessive delays on other forms of traffic. It is important to note that the promotion of public transportation should not be at the expense of a net gain to the environment. The suggested infrastructure improvement shows a net travel gain to all forms of traffic.

Project expenditure is an important component, and this has been considered in the research through the delivery of active, signalised bus priority systems which utilise technology to provide time travel benefits to buses. Research in five locations shows the potential for tangible improvements in adherence to timetable for buses operating in a priority environment. The delivery of an active signal bus priority system can be achieved with minimal upgrade to existing infrastructure and has been shown to provide at least 10% improvements in on-time running. Where coupled with bus-only infrastructure such as bus transit lanes, the productivity gains have been shown to be even greater, as evidenced on the Liverpool to Parramatta Transit-Way.

In summary, this research has presented a concise understanding of the background dynamics involved in transportation engineering. For material gains to be made in alternative modal share there needs to be a consistent effort made at State and Federal Government level to promote the use of public transportation, while decreasing the access to sole occupancy motor vehicles in peak times on congested networks.

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City Rail, New South Wales

Roads and Traffic Authority, New South Wales

Sydney Buses, New South Wales

Sydney Ferries, New South Wales

Transport Data Centre (Department for Infrastructure, Planning and Natural Resources) New South Wales

1. INTRODUCTION

1.1 Key Hypothesis

The key hypothesis or aim of undertaking this research is to: -

Key Hypothesis
Discuss and analyse transportation mode share statistics and to determine behavioural science and engineering infrastructure methodologies to increase public transport modal share in Sydney and Perth.

1.2 Structure of This Work

The key hypothesis to determine *Methodologies to Increase Public Transportation Mode Share in Sydney and Perth* is reached through the analysis of the following objectives: -

- Section 1 – Introduction
  - ➢ Describe the key hypothesis or aim for the work.
  - ➢ Describe the structure of this work.
  - ➢ Describe general academic background of the report.
  - ➢ Justify the need to increase public transportation usage, (or explain the aim of the work).
- Section 2 – Transportation Statistical Analysis
  - ➢ Analyse the key performance indicators in the Sydney transport network.
  - ➢ Analyse the key performance indicators in the Perth transport network.
  - ➢ Conduct a comparative analysis of the data from the two cities.
- Section 3 – Transportation Behavioural Science Methodology

- ➢ Discuss human behaviour impacts.
- ➢ Discuss mode choice theory.
- ➢ Discuss travel purpose theory.
- ➢ Discuss time elasticity theory.
- ➢ Discuss price elasticity theory.
- ➢ Discuss Maslow's Hierarchy of Needs and how it relates to transportation mode choice.
- ➢ Discuss Elliott Wave Theory and how it may be used as a predictive tool to describe future performance and how it highlights historical changes in performance due to external factors which impact group behaviour.

- Section 4 – Transportation Infrastructure Engineering Methodology
  - ➢ Discuss how the provision of engineering infrastructure impacts transportation mode choice
  - ➢ Discuss the provision of engineering infrastructure to meet the amended Maslow's Hierarchy of Needs from Section 3, in terms of improvements to: -
    - accessibility
    - travel time
    - comfort / convenience / safety and security
    - provision of information and technology to institute behavioural change
  - ➢ Active signal bus priority schemes
  - ➢ Passive bus priority infrastructure
- Section 5 – Conclusions

1.3 Background to Thesis

This Masters' Thesis has been completed over a period of 5 years. The focus and intent of this work is to examine and compare the mode-use breakdown of all transportation modes in Sydney and Perth and to examine methods to increase public transport mode share against the use of private vehicles.

The subject title "Methodologies to Increase Public Transport Mode Share in Sydney and Perth" explains the purpose or aim of this Thesis. Public transportation modal share is shown to have decreased over the medium to long term from the early 1970's, however recently there have been improvements in mode share due to a number of factors. The purpose of this body of work is to develop an understanding of why this has happened and to provide some options which may deliver sustained increased usage of alternative modes of transport.

The work has been completed due to the authors' involvement in traffic and land development civil engineering and general interest in understanding the link between behavioural sciences and engineering implementation.

The subject matter is noted to be wide-ranging, however this has been undertaken in a deliberate manner as the issue of traffic congestion and transportation modal share is multi-faceted and mode choice is influenced by a variety of factors. Therefore it is argued that tangible benefits cannot be delivered across the system without attempting to develop a dynamic understanding of both the engineering and behavioural science aspects of transportation.

- Engineering solutions offer localised improvements based on the provision of infrastructure.
- Behavioural solutions offer system-wide improvements based on understanding consumer behaviour.

The weakness of engineering solutions when used in isolation from understanding the behavioural choices of commuters includes: -

- Major transportation projects are expensive. Subsequently any failures in service delivery or adherence to budget can attract negative press, political pressure and in extreme cases negative public reaction.

- Infrastructure improvements can be provided to suit political gain over optimum servicing location.
- Improved infrastructure leads to improved land valuations within the project catchment, leading to potential segregation from, or advantage over other communities.

1.4 The Need to Increase Public Transport Usage

The need to increase public transport usage is an ecologically sustainability need. The objective for this section is as follows: -

Objective
To document the need to increase public transport usage in terms of environmental, economic and personal health sustainability needs.

This section addresses these needs as follows: -

- Environmental Sustainability Needs (Section 1.4.1);
- Economic Sustainability Needs (Section 1.4.2); and
- Personal Health Sustainability Needs (Section 1.4.3).

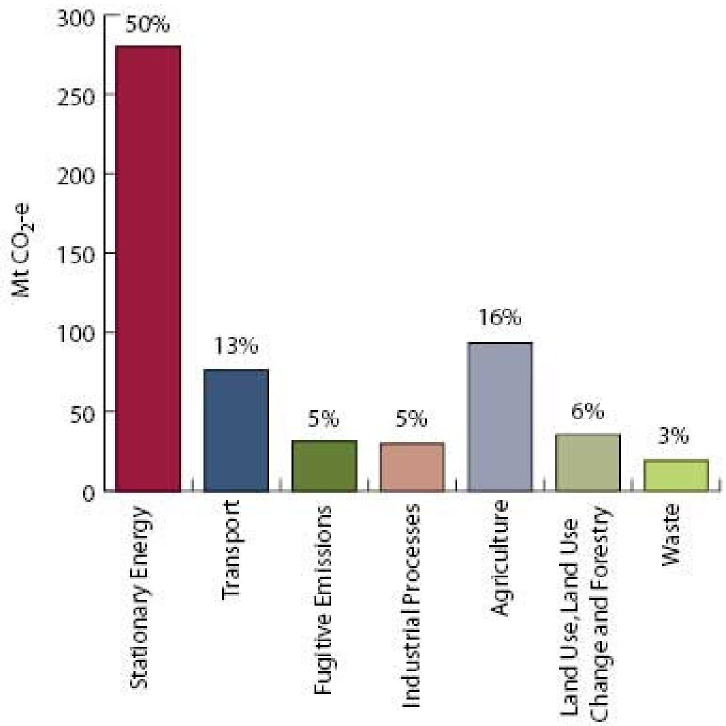
1.4.1 Environmental Sustainability

In Western Australia, the Department for Planning and Infrastructure quotes “More than 15% of Western Australia’s greenhouse gas emissions come from transport – of that, nearly half comes from cars.”

(Department for Planing and Infrastructure, 2006)

Across the country, transport represents 13% of the total greenhouse gas emissions at 2004, as shown in the following figure taken from the Australian Greenhouse Office’s National Inventory Report 2004.

Figure 1 - Australian Greenhouse Gas Emissions by Sector 2004



(Australian Government, Department of the Environment and Heritage, Australian Greenhouse Office, 2004)

The Australian Greenhouse Office website also provides a useful calculator to compare motor vehicles for greenhouse gas emissions. Table 1 is calculated on the basis that: -

- For every litre of petrol used, 2.5 kilograms of carbon dioxide is released from the exhaust;
- The average motor vehicle user drives 15,000 kilometres per annum; and
- In congested conditions fuel economy rates are halved for most standard vehicles.

Table 1 - Annual Carbon Dioxide Emissions per Vehicle per annum

Fuel consumption	Annual carbon dioxide emissions
6 L/100km	2250 kg
8 L/100km	3000 kg
10 L/100km	3750 kg
12 L/100km	4500 kg

(Australian Government, Department of the Environment and Heritage, Australian Greenhouse Office, 2004)

Given approximately 7% of all greenhouse gas emissions are from private motor vehicle usage, a reduction in personal motor vehicle travel coupled with development of cleaner, more fuel efficient vehicles could have a major impact on lowering future greenhouse gas emissions.

The Bureau of Transport and Regional Economics (BTRE) quotes as follows: -

“Transport accounted for 14.4%, or 79 Mt, of national greenhouse gas emissions in 2002. Of this only 0.3% is contributed by rail transport.”

The BTRE quotes future trend emissions as follows: -

- 87.4 million tonnes by 2010; and
- 100.2 million tonnes by 2020.

This equates as an increase in emissions of 14.6% or 1.5% per annum, which is higher than recent population growth. Importantly, DoTARS found fuel consumption and emissions double under typical congested conditions, and current congestion accounts for around 17 per cent of all transport greenhouse emissions. Given increasing congestion on our road networks, there is an increasing importance on delivering workable peak alternative transportation options.

1.4.2 Economic Sustainability Needs

There is a substantial cost to the economy associated with traffic congestion. The BTRE provides the following quotes from Infosheet No 16 – Urban Congestion – The Implication for Greenhouse Gas Emissions: -

- Between 2000 and 2020 vehicle usage is expected to increase by 30% or 1.4% per annum;
- Approximately 50% of VKT is travelled in congested conditions; and
- Rough (order of magnitude) social expenditure for traffic congestion, based on loss of productive time and road user costs are $12.8 billion per annum in major cities across Australia.

The split for the economic costs associated with traffic congestion are shown in the Table 2: -

Table 2 - Economic Cost of Traffic Congestion in Australia by City (2000)

City	Economic Cost ($ billions per annum)
Sydney	6.0
Melbourne	2.7
Brisbane	2.6
Adelaide	0.8
Perth	0.6
Canberra	0.05

(Bureau of Transport Economics, 2000)

The Centre for International Economics recently presented an estimate of the economic cost of traffic congestion in Sydney of $18 billion per annum in 2005. (Centre for International Economics, 2005)

It can be argued that this economic imposition is impacting the economy of New South Wales and that significant investment in infrastructure is required to improve traffic flows and to improve public transport usage as an alternative to increased motor vehicle congestion.

1.4.3 Personal Health Sustainability Needs

The choices that Australians make about their use of transportation can result in important health benefits, as our reliance on car travel may encourage a more sedentary lifestyle.

Travel Smart programs promote the concept of 'Active Transport'. This includes the promotion of alternative modes such as walking and cycling which can be done alone, or combined with catching public transport. Walking or cycling can provide 30 minutes of moderate physical activity which is required on a daily basis for good health. Travel Smart notes that many car trips can be less than 2km, and can be easily replaced by walking or cycling, which helps to save time and costs by combining needs for exercise with needs for travel.

(Travel Smart 2006)

Physical activity provides preventative and protective benefits for a wide range of health conditions including: -

- Preventing cardiovascular disease;
- Decreased mortality rates;
- Cancer prevention;
- Improved psychological health (relief of symptoms of anxiety and depression); and
- Reduced risk of obesity, adult-onset diabetes and osteoporosis.

(Australian Government, Department of Health and Family Services, 1998).

The idea that we combine our fitness and personal health with getting to and from work, school or the shops may sound revolutionary given the advertising associated with the many weight loss products available. I undertook some research to quantify the health benefits associated with walking: -

- An 80kg adult can typically burn around 180 calories by walking for 30 minutes (this varies based on weight of the person, pace of walking, longitudinal grades, weather factors etc); and
- Low-intensity training burns about 50% fat for energy while high-intensity training burns about 40% fat for energy. Therefore if walking for 20 minutes burns 100 calories, then 50 fat-calories are burned.

(Nilsson, N. 2006)

The importance of behavioural change away from excessive every day motor vehicle usage is important in so many levels of our lives and provides benefits on personal, environmental and economic levels. Given personal trip rates of around 3.5 trips per day per person, if we could make one less trip per day by motor vehicle the contribution to society would be massive in terms of reduced congestion, reduced greenhouse gas emissions and increased personal health and fitness. It can be argued the economic impact of this would be extremely positive.

2. TRANSPORTATION STATISTICAL ANALYSIS

This section provides a detailed compilation of transportation statistics from Sydney and Perth. The purpose is to collate a wide variety of data and to assess and analyse the trends.

Objective

1. *To research and collate data for Sydney and Perth which describes our recent historical travel patterns and trends – providing statistical and scientific basis.*

The scope of this section examines: -

- Travel patterns and trends in Sydney and Perth (Section 2.1);
- Mode choice theory (Section 2.2); and
- Examples where public transportation patronage has increased (Section 2.3).

2.1 Sydney Transport Key Performance Indicators

This section examines key data relating to transport patterns in Sydney, and provides the basis for decisions on future campaigns to improve public transport mode share in Sydney.

Quotation of key performance statistics delivers the historical precedent, enabling conclusions to be drawn regarding areas for potential growth in the system and importantly to determine areas of success and failure within the system.

The key performance indicators examined in this section include: -

- Public Transport Yearly Patronage statistics from 1997 / 1998 to 2005 / 2006;
- Sydney Rail Network Statistics, split by line 1997 / 1998 to 2002 / 2003;
- Liverpool to Parramatta Transitway, Monthly Patronage 2003 to 2005;
- Historical Modal Share comparisons;
- Population, Trip Rate and vehicle kilometres travelled (VKT) Growth;
- Cycling as an alternative mode of transport; and
- Summary of Key Performance Indicators.

Public Transport Yearly Patronage

Sydney Buses, City Rail and Sydney Ferries publish annual reports based on performance over the previous financial year in accordance with their regulations. Table 3 shows the recent historical trends in public transport patronage with information dating back to 1997 / 1998. Information for light rail is difficult to attain as the system is run by private operators.

Table 3 - Sydney Public Transport Yearly Patronage

Year	Western Sydney Bus ('000)	STA Bus ('000)	Train ('000)	Ferry ('000)	Lt Rail ('000)	Total ('000)
1997 – 1998		183,792	266,500	13,068		463,360
1998 – 1999		185,762	270,500	13,080		469,342
1999 – 2000		191,855	278,700	13,258		483,813
2000 – 2001		195,380	302,600	14,912*		512,892
2001 – 2002		187,307	276,400	13,733	2,730	480,170
2002 – 2003		187,306	273,400	13,341	2,610	476,657
2003 – 2004		187,000	272,900	13,900	2,572	477,372
2004 – 2005	1,687	186,480	266,970	14,100	2,500	471,737
2005 – 2006	2,015	186,000	273,720	14,071	2,500*	478,306
2006 – 2007	2,279	189,000	281,250	14,133	2,500*	489,162
Avg % Growth	**17.5%**	**0.31%**	**0.61%**	**0.91%**	**n.a.**	**0.62%**

(State Transit Authority NSW Annual Reports, 1998 to 2007)

(Sydney Ferries NSW Annual Reports, 2004 / 2005 and 2005 / 2006)

(State Rail NSW, Annual Reports 1998 to 2005) and

(CityRail, 2006)

Note: * Patronage for light rail for 2005 / 2006 has been assumed by the author to be static. (The operator has been reluctant to provide any new operational figures since 2004/2005).

The 2000 – 2001 figures have been influenced by public transportation usage during the Olympic Games held in September. As an example, Sydney Ferries

carried 96,000 passengers on the 29th of September 2000, breaking the previous record patronage set on Foundation Day 1901.

Private bus figures are not included, however the 2000 Transport Data Centre's 'Bus Users in Sydney' document shows that private bus companies carry approximately half the average patronage per day for weekday trips and a quarter of the average patronage per day for weekend trips of the Sydney Buses network. In 2000 there was an average of 921,000 bus trips per day across Sydney.

(Transport and Population Data Centre, 2003.)

The 2005 / 2006 figures show a reversal of the declining patronage numbers over the last 5 years. This is largely due to the improved performance of the City Rail network and the continued strong growth in usage on the Liverpool to Parramatta Transit-way. Further system expansions in rail and new bus transit-ways between 2007 and 2010 should assist this trend.

Sydney Rail Network Statistics

This section examines the City Rail network split by rail service within the overall network to determine which lines were winning or losing patronage between 1997 and 2003. Any changes in patronage are assessed against external factors such as provision of major infrastructure, which may have created the impetus for behavioural change.

Table 4 presents patronage information by line across the City Rail network.

Table 4 - Sydney City Rail Network Statistics Boardings per Annum (Split by Line)

Total Passengers ('000) p.a.	1997 - 1998	1998 – 1999	1999 - 2000	2000 - 2001	2001 - 2002	2002 - 2003
Illawarra	23,650	24,329	25,183	25,599	24,897	24,745
East Hills	7,908	8,124	8,352	8,248	7,682	7,626
Bankstown	15,303	15,440	16,132	16,287	15,260	14,508
North Shore	21,486	22,083	23,058	24,119	23,021	22,832
Eastern Suburbs	11,485	12,090	12,076	11,750	11,119	10,656
Main North	14,221	14,704	15,185	15,468	15,048	14,636
West	30,884	30,814	32,104	32,789	32,403	32,152
South	25,043	25,452	26,792	27,343	26,985	26,856
Inner West	18,298	19,247	20,387	20,874	20,331	20,066
Total	**168,278**	**172,283**	**179,269**	**182,477**	**176,746**	**174,077**

(Department of Transport NSW, 2003.)

This table shows differing values for yearly train boardings to Table 14 due to the Department of Transport NSW's counting of Sydney metropolitan boardings only. The State Rail data includes boardings within the full State Rail zone comprising Illawarra, the Blue Mountains, the Central Coast and Newcastle.

Key external events which have impacted patronage over the timeframe shown in this table includes: -

- Patronage on the East Hills and Bankstown lines was affected by the opening of the M5 East in 2002;

- Patronage on the Eastern Suburbs line was impacted by the closure of the Bondi Junction shopping centre for major renovations and improvements to some eastern suburbs bus services through the provision of peak bus lane infrastructure;
- Growth was maintained on the inner west line and on longer haul lines such as the South, West, Illawarra and North Shore lines.

In general there was a marked decline in patronage up to 2005 due to the decline in on-time running performance and high levels of customer dissatisfaction. CityRail however issued a press release on Friday 3rd March 2006 showing that patronage was up by 90,000 per week on a year-on-year basis based on improved timetabling, schedule adherence and the impact of rising petrol prices. By line these increases are broken down as follows: -

- CBD up 4.2% or 24,000 passengers a week;
- Western Line up 3.8% or 21,400 passengers a week;
- Inner West up 4.0% or 14,700 passengers a week;
- South Line up 2.8% or 12,300 passengers a week;
- Main North Line up 3.5% or 9,000 passengers a week;
- East Hills Line up 4.8% or 6,400 passengers a week; and
- Bankstown Line up 2.4% or 5,800 passengers a week.

Case Study - Liverpool to Parramatta Transit-way

The Liverpool to Parramatta Transit-way has been selected as a case study, to shown what I believe is an example of a successful public transport infrastructure project. Western Sydney Buses forecasted patronage of approximately 40,000 persons per week within 10 years. Figures below show that has been achieved within 2 and a half years of construction. The reasons for success arguably include: -

- Provision of bus priority in the form of signal priority and bus only transit lanes, speeding up travel times;

- Provision of bus stop information including expected arrival time of buses;
- High frequency service allotment during peak and off-peak times; and
- New buses providing an increased level of service and comfort to passengers.

Table 5 presents the patronage figures per month from project inception, to the latest available figures in July 2005.

Table 5 - Liverpool to Parramatta Transit-way Monthly Patronage

Month	2003	2004	2005	Avg % Growth p.a.
January	-	96,370	118,052	22.5%
February	-	112,601	136,310	21.1%
March	60,765	134,706	158,462	69.7%
April	63,507	116,593	150,526	56.4%
May	74,775	130,859	163,505	50.0%
June	75,335	124,760	153,590	51.9%
July	86,056	129,716	154,560	39.8%
August	91,453	136,357		49.1%
September	100,363	137,297		36.8%
October	102,019	131,349		28.7%
November	97,198	140,992		45.1%
December	105,038	134,443		28.0%
Total	**856,509**	**1,526,043**	**1,035,005**	

(Western Sydney Buses, 2003 to 2005.)

Western Sydney Buses have revised targets for usage of the Liverpool to Parramatta Transit-way to 80,000 passengers per week and 3,900,000 passengers

per annum by 2011 given further integration with train and bus services. The service is already attracting around 37,000 passengers per week.

It is important to note that this service is an amalgamation of a number of previous shorter bus routes. The service connects a number of residential catchments to employment generating land uses, schools and shopping precincts. In addition the service connects two major western suburbs CBD districts.

Anecdotally however the Liverpool to Parramatta Transit-way is attracting ex-train passengers from the City Rail services between Liverpool and Parramatta due to improved travel times, service frequencies and overall adherence to schedule.

Further transit-way projects are currently being developed for Parramatta to Castle Hill and Blacktown to Rouse Hill.

Historical Transportation Modal Share

This section examines the historical context of the mode share performance of each form of transportation.

Sydney is experiencing a decline in public transportation mode share up to 2005 due to: -

- Growth in single occupant motor vehicle journeys;
- Increased trip generation for social / recreational purposes and weekend journeys;
- Capacity issues with major peak public transport infrastructure in existing built-up areas;
- Poor quality / reliability problem on rail network and introduction of a slower timetable; and
- A lack of appropriate services to new urban districts in the north-western and the south-western outerlying suburbs.

The Transport and Population Data Centre publishes passenger-km's travelled information for the Sydney network as follows: -

Table 6 - Public Transport Passenger Km's, Sydney (2002 / 2003)

Mode	Average Distance Travelled per Passenger (km's)	Average No of Passengers per Weekday	Average Weekday Passenger Km's
State Transit Authority Buses	6.2	550,000	3,410,000
Private Buses	8.8	367,000	3,229,600
City Rail	18.4	900,000	16,560,000

(Transport and Population Data Centre, 2002 & 2003)

Growth in public transport mode share may be possible in 2006 due to the impact of higher fuel prices curbing growth in motor vehicle travel and improvements in reliability and on-time running of rail services.

Table 7 shows the deterioration in alternative transport modal choice as a percentage of all trips undertaken from 1981. Earlier data provided for 1901 and 1946 is provided to show travel patterns prior to the widespread use of motor vehicles and private transportation.

Table 7 - Historical Transportation Modal Share

Total Passengers (%)	1901	1946 - 1947	1981	1991	1999	2000	2001	2002	2003	2004	2005
Bus	19%	62.6%	7.2%	6.7%	6.2%	5.9%	5.6%	5.5%	5.4%	5.2%	5.6%
Rail	11%	22.0%	5.8%	5.0%	4.9%	5.0%	4.9%	4.8%	4.7%	4.6%	4.8%
Car as Driver	n.a.	12.6%	86.6%	66.9%	48.0%	48.1%	48.3%	48.9%	49.0%	49.1%	48.3%
Car as Passenger					21.8%	21.9%	21.8%	21.3%	21.1%	21.5%	21.1%
Total Car					69.8%	70.0%	70.1%	70.2%	70.1%	70.5%	69.4%
Other	14%	2.8%	0.4%	1.8%	1.8%	1.9%	2.1%	2.3%	2.4%	2.3%	2.3%
Walking	56%	n.a.	n.a.	19.6%	17.4%	17.4%	17.2%	17.3%	17.4%	17.2%	17.9%

(New South Wales Department of Transport, Transport & Population Data Centre. 1991, 1999, 2000, 2001, 2002, 2003, 2004 & 2005.)

The following points are worth noting in addition to the information provided in Table 7: -

- Walking and cycling trips have been included from the 1991 data series. The trend shows a decline in walking mode share from 1991 to 2001, however there has been a slight gain in mode share in both 2002 and 2003 and a major gain in 2005. This may be due to increasing development in the CBD and inner city areas providing opportunities to walk to work and for social trips or may be due to improved sampling and data collection.

- The growth in peak hour congestion in Sydney can be shown incrementally by the growth in peak hour trips from 1946 (8% of peak hour trips by car), to 1981 (66% of peak hour trips by car) to 1991 (69% of peak hour trips by car);

- Bus and tram travel has dropped rapidly, mainly due to private operations losing substantial market share in the outer suburbs. However in 2005 the trend has changed with a marked increase in bus travel as mode;

- After a long period of holding modal share, rail trips appeared to be heading toward 4.5% due to operations at capacity and low consumer approval ratings after 2004, however in 2005 rail trips increased to 4.8%; and

- Car and passenger journeys appear to be holding around 70% over the medium to long term. This stagnation of growth is due to Sydney's existing congested inner city road networks and a lack of viable alternative infrastructure to accommodate greater levels of future economic growth. A drop in vehicle usage in 2005 has been claimed to be in line with a drop in the Gross State Product (GSP) by the TDC, showing a strong correlation between economic conditions and discretionary motor vehicle usage.

Measuring the growth in traffic congestion is not as simplistic as the above numbers suggest. The New South Wales Transport Data Centre collates data on a yearly basis to find trends in transportation usage; vehicle kilometres travelled and trip duration times which deliver additional measures of traffic congestion.

Population, Trip Rate and VKT Growth

This section examines growth in population, household composition and changes to number of people per household, with growth in trip rates, average trip lengths and vehicle kilometres travelled in Sydney. This information provides a potential matrix of data comparisons which will provide a clear picture on the trip generation and modal choice trends in Sydney.

Table 8 shows a collation of Transport and Population Data Centre statistics.

Table 8 – Population, Household and Travel Statistics, Sydney

Key Transport Indicator	1991	1999	2000	2001	2002	2003	2004	2005	% Growth p.a.
Population ('000)	3,600	3,957	4,007	4,066	4,108	4,139	4,169	4,191	**1.17%**
No of households ('000)	1,300	1,451	1,473	1,499	1,514	1,514	1,538	1,545	**1.35%**
No of trips avg weekday ('000)	13,100	15,112	15,152	15,206	15,552	15,807	15,829	15,737	**1.44%**
No of trips avg weekend	11,400	12,991	12,878	13,012	13,410	13,497	13,701	13,703	**1.44%**

day ('000)									
Trip rate per person avg weekday	3.68	3.82	3.78	3.74	3.78	3.82	3.80	3.75	**0.14%**
Trip rate per house avg weekday	10.17	10.41	10.28	10.14	10.27	10.36	10.30	10.18	**0.01%**
Total kilometres travelled (mil)	119.9	141.21	143.63	143.96	146.76	147.18	147.85	147.64	**1.65%**
Total km /person (mil)	33.6	35.7	35.8	35.4	35.7	35.6	35.5	35.2	**0.34%**
Trip length av weekday (km)	9.1	9.3	9.5	9.5	9.4	9.3	9.3	9.4	**0.24%**
Total VKT av day per person		20.1	20.3	20.0	20.4	20.4	20.3	19.7	**-0.40%**
Avg duration to work (min)	31	31	32	31	32	31	32	33	**n.a.**
Avg	17	18	18	18	18	18	18	18	**n.a.**

duration to non work (min)									
Total travel time per person (min)	73	79	79	79	79	79	79	79	**0.59%**

(Transport and Population Data Centre, 2002, 2003, 2004, 2005, 2006 & 2007)

The Key Transport Indicators shown above were collated by the New South Wales Transport and Population Data Centre and are packaged under the title of the ‘Household Travel Survey’ (HTS). The HTS is a continuous survey conducted by the Transport and Population Data Centre of the travel patterns of residents of the Sydney Statistical Division. Every year approximately 3,500 households (10,000 individuals) are interviewed about their travel on a particular day through a face-to-face interview. Each year, the HTS data set consists of data collected on an annual basis which is weighted to the latest population characteristics from the Australian Bureau of Statistics to represent total travel in each year.

The main findings from the 2005 HTS together with comparisons of travel by Sydney residents in 1991, 1999, 2000, 2001, 2002, 2003, 2004 and 2005 for the Sydney Statistical Division are presented in the above Table of Key Transport Indicators and are summarised below: -

- In 1991 Sydney residents made 13.2 million trips on an average weekday. Over the decade trip rates increased at a faster rate than population growth. The recent trend from 2002, 2003 and 2004 shows a continuation of accelerated weekday trip growth at a rate greater than population growth, however weekend trip rates appear to have slowed from the longer term trend, possibly due to sluggish economic conditions in New South Wales in comparison to other parts of Australia and due to congestion issues – this has been continued in 2005 with economic conditions further limiting discretionary motor vehicle travel;

- The weekday trip rate per person shows a drop in 2001, with growth in trip rates increasing by 0.04 in 2002 and 2003 and drops of 0.02 trips per person in 2004 and 0.05 per person in 2005. The weekday trip rate shows a marked decrease from a peak of 3.90 in 1998, however this may be cyclical based on prevailing economic conditions;
- Total kilometres travelled per person have been relatively stable since 1999;
- From 1999 to 2005 there has been a plateau in average kilometres travelled per person; and
- From 1999 to 2005 there has been little or no change in average durations travelled however there is a decrease in average trip length since 2000 which may represent potential behavioural change due to traffic congestion conditions.

Summary and Analysis

Sydney residents are showing signs of behaviour change in their use of transportation due to congestion and capacity issues; quality of life; continual population growth in existing urban areas adding to capacity constraints and choice of residential and employment locations within the city. Average trip rates and average trip distances travelled per person have remained relatively constant since 1999. Given the recent increases in fuel pricing, this trend should continue to accelerate in the latter part of this decade. The 2005 figures are testament to the impact of prevailing economic conditions on discretionary travel choices.

The decline in public transportation mode share to 2004 needs to be addressed to capitalise on potential increased shift in behaviour by improving capacity in public transport services, as public transport services are also suffering from congested road networks and are overcrowded in the peaks.

The impact of higher fuel prices is yet to be seen in the figures presented, however anecdotal evidence received in 2006 shows that higher fuel prices are impacting both trip rates per person and vehicle kilometres travelled, and is providing an impetus for increased usage of public transport, particularly buses and rail. These positive issues are inhibited by Sydney residents' continuing negative perception of public transport due to poor management by recent state governments and peak bus and train services still operating close to, or exceeding capacity in peak periods.

The city is delicately poised regarding its future sustainable growth and immediate steps should be taken to address the balance and reverse the decline.

Cycling as an Alternative Mode of Transport

It is important to understand the broader context of cycling within the Greater Metropolitan Area of Sydney and overall targets set at a State Government level.

The NSW Government 10 Year Plan Action For Bikes – BikePlan 2010 is a fourpoint plan describing the wide range of actions that can be taken to improve facilities for cyclists and make it safer to cycle. To encourage more people to take up cycling the NSW Roads and Traffic Authority (RTA) organises Bike Week and publishes cycleways maps. Transport NSW is quoted as having over 500 secure bicycle lockers at transport interchanges across Sydney.

The following points provide a snapshot of cycling in Sydney: -

- In 2000 Sydney households' owned a total of 1.15 million bicycles;
- 1.0% of Sydney residents' cycle each day;
- Bicycles account for 0.5% of all trips by Sydney residents on weekdays and 0.9% on weekends;
- 0.6% of trips to work are by bicycle (2001 JTW);

- The largest group of bicycle users are male and aged between 11 and 20 years;
- 79% of all bicycle users in Sydney are male;
- Bicycle trips tend to be longer on weekends than weekdays;
- The duration of the average bicycle trip is 17 minutes on weekdays and 23 minutes on weekends;
- One third of bicycle trips are less than five (5) minutes in duration;
- 40% of bicycle users are students and 38% are full time employed;
- Inner Sydney has an increased ownership rate of 0.5 bicycles per household; and
- 1.7% of resident trips in inner Sydney to work are by bicycle.

State Governments in New South Wales and Western Australia are promoting the benefits of cycling and walking as alternative transportation modes due to the health and lifestyle benefits to society. Recent programs in Western Australia promote finding 30 minutes to exercise daily to improve and sustain quality of life and health. In Perth there has been a significant push to improve infrastructure for cyclists and pedestrians through the Dual Use Pathways and Perth Bicycle Network programs. This appears to have been justified by recent gains in mode share for both cycling and walking. Mode share gains are also occurring in Sydney as evidenced by the data collated in Table 7.

Summary of Key Performance Indicators – Sydney

There are a number of important summary points regarding current trends in trip generation and mode choice in Sydney: -

- A combination of congested peak public transport networks and negative customer perception appears to be aiding the decline in public transport mode share and pushing the growth in motor vehicle usage toward and through the 70% barrier of all total trips.

- The medium to long term trend for motor vehicle usage appears to be holding at around 70% of all trips, due to significant road congestion issues in the inner city.
- Due to minimal short term improvements in service capacity, public transport patronage in Sydney will arguably continue to grow at a slower rate than in cities such as Perth and Brisbane which are yet to experience this level of comprised capacity in their public transport networks. It is important to note however that the Rail Clearways will overcome some of the constraints on the rail network, with the Bondi Junction turnback recently completed. The Epping to Chatswood rail service is expected to commence operations in 2008 and there are reports that an investor may be willing to purchase the Airport Link and potentially reduce the fare pricing structure. The commencement of the integrated ticketing system across the Sydney network and the deployment of bus active signal priority on the Unsworth listed major Bus Corridors should provide additional benefits. For buses, additional capacities are being added to cope with peak level demands. Light rail proposals for inner city regions are also being pushed by sections of the community;
- After the initial patronage growth on the Liverpool to Parramatta Transit-way, the development of bus transit-ways and improved rail services should be a priority to improve public transport links in the north-western and south-western suburbs where provision and access to public transport is currently poor. Development of additional public transport infrastructure provides a positive impetus for patronage growth, as long as the growth does not negatively impact another form of public transport, or replace a poorly performing mode;
- Additional capacity to rail and bus systems is needed in the inner west with the rail network noted as highly congested between Strathfield and Central;

- Limited urban sprawl in Greater Sydney, in comparison to Melbourne, Brisbane and Perth is limiting growth in VKT. Therefore improvements to public transport infrastructure in Sydney, particularly to poorly serviced areas should have a strong positive impact upon modal share splits and patronage, as there is already a behavioural shift away from increasing time spent in motor vehicles;
- Smaller households, greater access to motor vehicles and greater trip generation for social purposes are the major reasons for increased vehicular travel, producing vehicle occupancy levels around 1.1 persons per vehicle. There is a limit to this reduction in vehicle occupancy levels, (the number cannot be less than 1). I believe it is therefore reasonable to assume that a slowing in the trend toward greater sole occupancy trips has the potential to have a strong positive impact upon mode share figures;
- Public transport provides a strong alternative for commuting and education trips, particularly for customers in the State Transit Authority serviced inner city areas and for outer-lying residential areas in the north-western and south-western suburbs;
- Travel by rail has declined sharply in 2004 / 2005 due to maintenance issues and reduced on-time running performances. The poor performance in rail is the leading reason why Sydney’s perception of public transport is poor and why growth will continue to be stagnant in overall patronage unless the situation is quickly improved;
- Improvements in customer satisfaction levels on the City Rail network have been noted since the commencement of the Rail Clearways program and the adjustment to the timetable schedule in 2005, with greater on-time running and higher customer satisfaction levels compared to 2004;

- The impacts of higher energy prices have not been seen in the data provided in this report. Due to the levels of congestion on Sydney public transport networks in the peak, the long term potential for patronage growth is expected to be negligible, unless greater future price rises are coupled with a sustained effort to improve service capacities. As customers become accustomed to higher fuel prices there is a risk that these patronage gains may be temporary; and
- Negative impacts regarding potential terrorism threats against public transport are expected to be limited, unless there is a significant targeted action in Australia.

The following average annual growth rates provide a snapshot of transportation usage in Sydney between 1991 and 2004: -

- Population 1.17%
- Number of Households 1.35%
- Vehicle Journeys – Car as Driver 0.05%
- Vehicle Journeys – Car as Passenger 0.05%
- Number of Vehicles Registered 2.2%
- Vehicle Kilometres Travelled 1.65%

During the compilation of this work it was stated that "*it is expected that the Vehicle Kilometres Travelled growth will slow over 2005 and 2006 due to the impact of higher fuel prices.*" This has been proven with the recent release of the 2005 HTS Data from TDC.

2.2 Perth Transport Key Performance Indicators

This section examines key data relating to transportation usage patterns in Perth, in terms of the historical and current context. Understanding historical data enables examination of external factors that have delivered increased

growth in the past, or those which require counter-balancing measures to inhibit loss of growth.

The key performance indicators examined in this section include: -

- Public Transport Yearly Patronage from 1997 / 1998 to 2005 / 2006;
- Westrail Average Weekly Boardings;
- Perth Circle Route patronage;
- Historical transportation modal share;
- Population and trip rate growth; and
- Summary of Key Performance Indicators, Perth.

Public Transport Yearly Patronage

This section provides details of recent historical public transport performance in the Perth Metropolitan area. Table 9 shows yearly patronage for bus, train and ferry in Perth from 1997 / 1998 to 2006 / 2007.

Historically, strong growth in rail travel occurred in the period from 1991 (8 million boardings) to 1996 (28 million boardings). This increase was due to electrification of the service in 1991 and the commencement of the Perth to Currambine service in 1993. From 1999 there has been strong growth in bus patronage.

Table 9 – Public Transport Yearly Patronage (Perth)

Year	Bus ('000)	Train ('000)	Ferry ('000)	Total ('000)
1997 – 1998	46,491	28,374	500	**75,566**
1998 – 1999	44,681	29,099	493	**74,273**
1999 – 2000	48,103	29,693	475	**78,270**
2000 – 2001	52,011	31,127	558	**83,696**
2001 – 2002	54,561	31,009	499	**86,069**
2002 – 2003	56,341	31,303	477	**88,121**
2003 – 2004	58,998	31,115	465	**90,578**
2004 – 2005	61,873	32,652	460	**94,985**
2005 - 2006	63,891	34,133	502	**98,526**
2006 - 2007	64,623	35,758	545	**100,926**
Avg % Growth	**4.33%**	**2.89%**	**1.0%**	**3.73%**

(Western Australia, Public Transport Authority, 1998 to 2007.)

Note: Total patronage includes all free travel in Perth City Free Travel Zone, transfers (within 2 hour limit) and travel on Perth and Fremantle CAT services.

Perth public transport has exhibited strong growth over the last 9 years, including: -

- 39.0% increase in bus patronage; and
- 26.0% increase in train patronage.

Strong growth is anticipated to continue, particularly in rail patronage with the addition of the Thornlie and Greenwood railway stations and in 2007 / 2008 with the addition of the Perth to Mandurah rail service.

Continued growth in passenger place kilometres was also found in 2005 / 2006 as the Perth Metropolitan region continues to expand.

Table 10 - Public Transport Passenger Km's, Perth (2004 / 2005 and 2005 / 2006)

Mode	2004 / 2005	2005 / 2006
Bus	3,545,300	3,559,800
Rail	2,293,600	2,823,300

(Public Transport Authority WA, Annual Report 2005 / 2006)

Westrail Average Weekly Patronage

Table 11 shows average weekly journeys on the Westrail network split by line and urban location. For the purposes of this table, I have made the following assumptions: -

- Inner city is deemed to be within approximately 5km of the CBD;
- Middle ring suburbs are deemed to be between 5km and 15km from the CBD; and
- Outer ring suburbs are greater than 15km from the CBD.

Table 11 – Perth Westrail Network Statistics Average Weekly Boardings (Split by Line)

Year	Urban Location	1996	1998	2002
Armadale	**Inner**	21,793	22,726	25,828
	Middle	19,284	19,071	19,191
	Outer	44,270	40,999	36,932
	Total	**85,347**	**82,796**	**81,951**
Fremantle	**Inner**	23,919	21,182	30,026

	Middle	55,699	51,403	59,157
	Total	**79,618**	**72,185**	**89,183**
Midland	**Inner**	19,987	18,999	20,265
	Middle	11,740	11,274	11,010
	Outer	30,840	28,874	28,194
	Total	**62,567**	**59,147**	**59,469**
Joondalup	**Inner**	11,626	11,841	11,898
	Middle	15,362	14,772	16,104
	Outer	76,069	71,632	72,793
	Total	**103,057**	**98,245**	**100,795**

(Western Australia, Public Transport Authority, 2003.)

Note: This data does not include boardings at Perth City station as this data was not made available in the 2003 cordon survey.

Anecdotal evidence provided in a telephone conversation with Public Transport Authority estimates patronage split by line for 2004 as follows: -

- Armadale line 22.8%;
- Midland line 19.9%;
- Fremantle line 26.0%; and
- Joondalup line 34.3%.

Note: The Joondalup line is expected to increase strongly with additional stations and rolling stock to be added. Future figures for the Armadale line will be impacted by the removal of existing stations from the Armadale line onto the new Thornlie to Perth service. The reduction in travel time however for the Armadale to Perth service (with the train running express where the Perth to

Thornlie duplicates the existing service) should have a positive impact on patronage.

I believe future Perth to Mandurah line patronage will be in the order of 25,000 boardings per day.

Case Study – The Perth Circle Route

The Perth Circle Route generates the highest patronage of all Transperth bus routes. Similar to the Liverpool to Parramatta Transit-way, the service is an amalgamation of a number of smaller routes and forms an orbital network as opposed to the standard radial services which operate from a series of residential catchments through to one major CBD. The Circle Route operates through Perth's inner and middle ring suburbs connecting a number of entertainment, employment and education precincts to residential catchments and also provides connectivity to major transportation hubs including train and bus stations.

Table 12 shows the growth in patronage of this service since July 2003.

Table 12 - Perth Circle Route Monthly Patronage, 2003 / 2004 and 2004 / 2005

Month	2003 / 2004	2004 / 2005	Avg % Growth p.a.
July	353,959	331,881	-6.24%
August	417,845	429,188	2.71%
September	408,085	408,209	0.03%
October	417,657	378,257	-9.43%
November	349,992	376,394	7.54%
December	277,944	279,696	0.63%
January	252,297	250,242	-0.81%
February	341,067	348,153	2.08%
March	497,975	465,397	-6.54%
April	360,461	401,503	11.39%
May	433,499	468,145	7.99%
June	353,613	356,252	0.75%
Total	**4,464,394**	**4,493,317**	**0.65%**

(Patronage data received by email request to PTA, 2005 and 2006)

The Perth Circle Route is a highly cyclical route in terms of patronage due to its servicing of multiple universities and places of education. Differences in monthly patronage on a yearly basis are largely due to variations in school periods and holidays. Particular reference should be paid to March and April which show the variations in school holidays due to Easter.

Historical Modal Share

The following table shows historical transportation modal share in Perth, starting in 1991.

Table 13 - Historical Modal Share – All Trips, Perth

Total Passengers (%)	1976	1986	2003
Public Transport	8.0%	7.4%	5.5%
Walking Only	15.7%	11.6%	10.8%
Car (As Driver)	69.8%	59.1%	62.5%
Car (As Passenger)		14.8%	18.0%
Cycling	3.0%	5.3%	1.6%
Other	3.5%	1.8%	1.6%

(Sourced via email – Department for Planning and Infrastructure, 2005)

The variation in cycling figures has been acknowledged in conversations with staff from the Department of Planning and Infrastructure as “noisy” due to variations in sampling techniques employed.

Recently, The West Australian reported strong growth in cyclist numbers per day in a cordon count conducted by the Public Transport Authority.

Table 14 - Daily Average Number of Cyclists, Perth (2005 / 2006)

Location	2005	2006	% Increase
Aberdeen St (west of Oxford St)	238	438	84.0%
Subiaco Rd (west of Thomas St)	307	398	29.6%
Mounts Bay Rd cyclepath	455	771	69.5%
Narrows Bridge (west side)	233	374	60.5%
Narrows Bridge (east side)	250	390	56.0%
Goongoonup Bridge	141	242	71.6%
Causeway	527	836	59.0%

(The West Australian, 2006)

The Census Journey to Work statistics makes an interesting comparison to the data presented above.

Table 15 - Census Journey to Work Mode Share, Perth

Total Passengers (%)	1981	1986	1991	1996	2001
Public Transport	10.8%	10.1%	8.9%	8.5%	9.1%
Walking Only	2.8%	2.6%	2.5%	2.1%	2.1%
Car (As Driver)	69.0%	70.9%	72.4%	73.7%	73.7%
Car (As Passenger)	10.4%	9.4%	8.1%	7.6%	6.6%
Cycling	1.1%	1.3%	1.4%	1.0%	1.1%
Other	1.8%	1.8%	2.4%	2.3%	2.7%
Work at Home	4.2%	3.8%	4.3%	4.7%	4.7%

(Australian Bureau of Statistics, 1981, 1986, 1991, 1996 & 2001.)

The following points are noteworthy regarding variations in mode share over the last 25 years in Perth: -

- Public transport showed a strong decline between 1986 and 1991, however the rate of decline eased between 1991 and 1996 coinciding with the re-opening the Fremantle rail line and there has been a slight increase to 2001;
- Walking journeys have shown a steady decline between 1981 and 1996, however recent government promotions may provide a stabilisation of the mode share as seen in the recent results in Sydney;
- Car (as driver) results continue to be the dominant mode share in Perth due to lower dwelling densities, continued urban sprawl and strong economic conditions;
- Car (as passenger) results continue to decline, mainly due to increasing car ownership, licence holders and changes in age structures; and
- Commentary regarding cycling as mode in Perth is difficult as the quoted mode shares for cycling are openly criticised as incorrect by government officers, however anecdotally it is believed there has been some growth between 2001 and 2006 due to infrastructure upgrades. A slight increase is noted between 2001 and 2006.

Population versus Trip Rate Growth

This section provides a comparison between rates of population growth and total average daily kilometres travelled across Perth. The comparison shows Perth's sprawling suburbs are having a disproportionate impact on motor vehicle usage.

Table 16 – Population versus Total Daily Kilometres Travelled Growth, Perth

Key Transport Indicator	1991	2001	% Growth p.a. 1991 / 2001
Population (‘000)	1,188	1,397	**1.76%**
Total av daily kilometres travelled (mil)	25.8	41.5	**6.09%**

(Sourced via email – Department for Planning and Infrastructure, 2005)

Summary of Key Performance Indicators for Perth

The following is a summary of the key performance indicators provided for the Perth metropolitan region: -

- Growth in kilometres travelled is almost 3.5 times greater than the rate of population growth. This is the biggest issue to address in Perth;
- Public transport patronage is growing strongly from a low base, due to provision of new rail infrastructure, a positive marketing campaign and high levels of customer satisfaction;
- Whilst some recent urban developments in outer-lying and inner city areas have promoted Transit Oriented Design (TOD) principles, vehicle trip rates are high and form the dominant mode of travel due to urban sprawl in Perth extending northward to Yanchep and southward to Mandurah coupled with low relative housing densities and infrastructure planning which is geared toward motor vehicle usage;
- Road traffic congestion is a major issue to address on radial road networks such as the Mitchell and Kwinana Freeway’s during peak periods with vehicle speeds averaging around 20% of the signposted speed limit for growing sections of the journey;

- Smaller household numbers, accessibility to transportation and a booming economy are providing an inflationary impact on discretionary travel, which may maintain sustained high levels of motor vehicle usage;
- Behavioural change programs focussing on re-allocating single occupant vehicle trips to walking, cycling, public transport and sharing vehicle travel have resulted in positive responses over relatively small sample sizes in a number of local government areas in the metropolitan region; and
- Travel by rail is expected to grow strongly between 2006 and 2011; however this may partly be at the expense of bus travel as bus users in the southern suburbs transfer to the forthcoming Perth to Mandurah rail network. The Perth to Mandurah rail network will promote park and ride journeys, similar to the Perth to Joondalup rail line which may have an impact on bus trips. Purpose-built TOD developments however such as Cockburn Central should have a strong impact on alternative transport mode shares due to the design intent focusing on walkable catchments and mixing commercial land uses with higher density urban living.

2.3 Comparative Analysis

The comparative analysis is an important phase in this research. Sydney and Perth were chosen for analysis due to a number of diametrically opposed external factors. But this highlights the reason for the choice as it can be argued both cities represent opportunities for mutual learning based on their differences.

The purpose of this section is to determine how consumers travel in Sydney and Perth and to analyse recent trends in transportation mode choice. The most important of these include: -

- Population and population densities, including rate of change per annum (Section 2.3.1);

- Household composition (Section 2.3.2);
- Urban location (inner, middle or outer suburban) and its effect on modal choice (Section 2.3.3);
- Employment catchments (Section 2.3.4);
- Key performance indicators for Sydney (Section 2.3.5);
- Key performance indicators for Perth (Section 2.3.6); and
- Comparison matrix – Perth / Sydney (Section 2.3.7)

2.3.1 Population and Population Densities

This section compares the dynamics of population composition in both Perth and Sydney.

Due to geographical constraints in Sydney it is expected that population growth will mostly be through higher density development in existing urban and brownfield's areas, (recent newspaper reports suggest that 60% to 70% of Sydney's population growth over the next 20 years will be in existing metropolitan areas). This is confirmed in the NSW Government's current Metropolitan Strategy.

Population and Population Density Comparisons

Table 17 below shows approximate population and population density comparisons between Sydney and Perth in 1996. The numbers have been rounded as various data sources show different figures for area and population based on differing geographical assumptions.

Table 17 - Population and Population Density Comparisons (1996)

Item	Sydney	Perth
Population	3,276,207	1,096,829
Area (ha)	200,000	120,000

Persons per ha	16.2	9.1

(Kenworthy, J. 1996 / Census, 1996.)

As shown above population density is approximately 80% greater across the metropolitan region in Sydney than in Perth.

Population Growth Comparisons

Recent Australian Bureau of Statistics data shows the rate of population growth in Sydney and Perth.

Table 18 - Population Growth Comparisons (1996 to 2001)

Item	Sydney (Statistical Division)	Perth (Statistical Division)
1996	3,276,207	1,096,829
2001	3,948,015	1,325,392
2005	4,254,900	1,477,800
Growth	29.9%	34.7%
Growth Rate p.a.	3.0%	3.5%

(Census 1996, 2001) and (Australian Bureau of Statistics, 2005)

Note: The size of the Statistical Division catchments for both Sydney and Perth has increased between 1996 and 2005, which contributes to the annual population growth rates as shown above: -

- The 1996 figures for Sydney do not include Wollongong.
- The 1996 figures for Perth do not include Rockingham and Mandurah.

Given the anecdotal evidence available however, the reasons for Perth's greater population growth have historically included greater land affordability, coupled with comparable economic benefits. Recent strong growth in land prices in Perth however may limit future growth in Perth based on affordability

criteria, particularly once the current resources boom is completed. Population growth in Sydney is constrained by the lack of greenfield land available for development on the periphery of the city.

Population Density Growth Comparisons

The Australian State of the Environment Report quotes the following growth in population densities (in persons per square kilometre) between 1986 and 1996: -

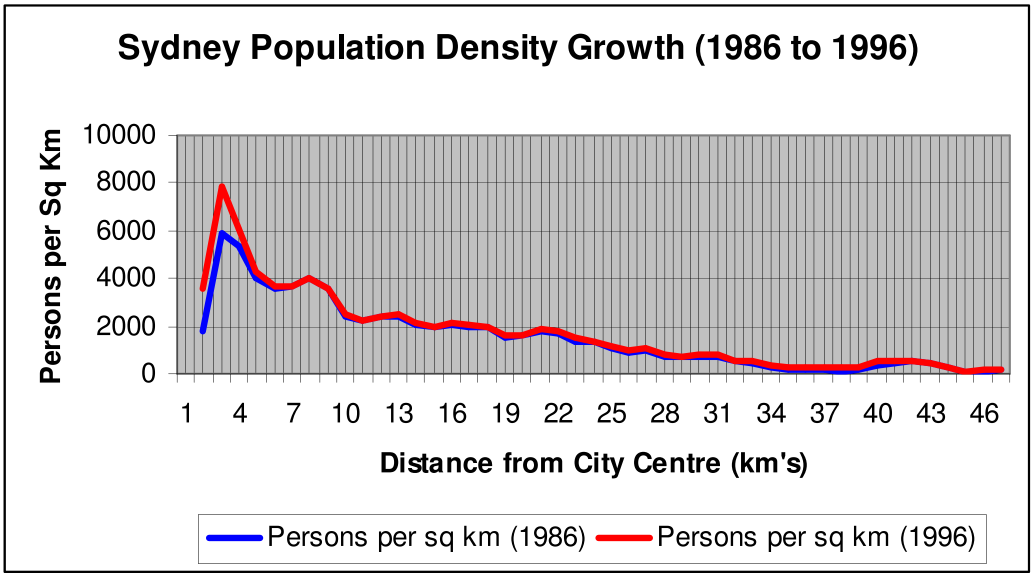
- Sydney 620 to 690 persons per sq km (an increase of 11.3%); and
- Perth 141 to 164 persons per sq km (an increase of 16.3%).

Comparisons of population densities over time are difficult as the Statistical Division boundaries of Sydney and Perth (as used in Census information) have significantly expanded over the last 20 years. In addition, there are a number of different geographic definitions of the size of “Sydney” and “Perth” therefore it is difficult to compare data from different sources with any degree of accuracy.

A more accurate measure of population density growth is to look at the persons per square kilometre by distance from each city over two time periods, and to show this information graphically.

Figures 2 and 3 show the varying population density growth rates across the metropolitan regions in Sydney and Perth, and makes an interesting comparison. Figure 4 shows a comparison of Sydney and Perth together on the same graph over the same time periods, highlighting the differences in urban densities.

Figure 2 - Sydney Population Density Growth Graph (1986 to 1996)

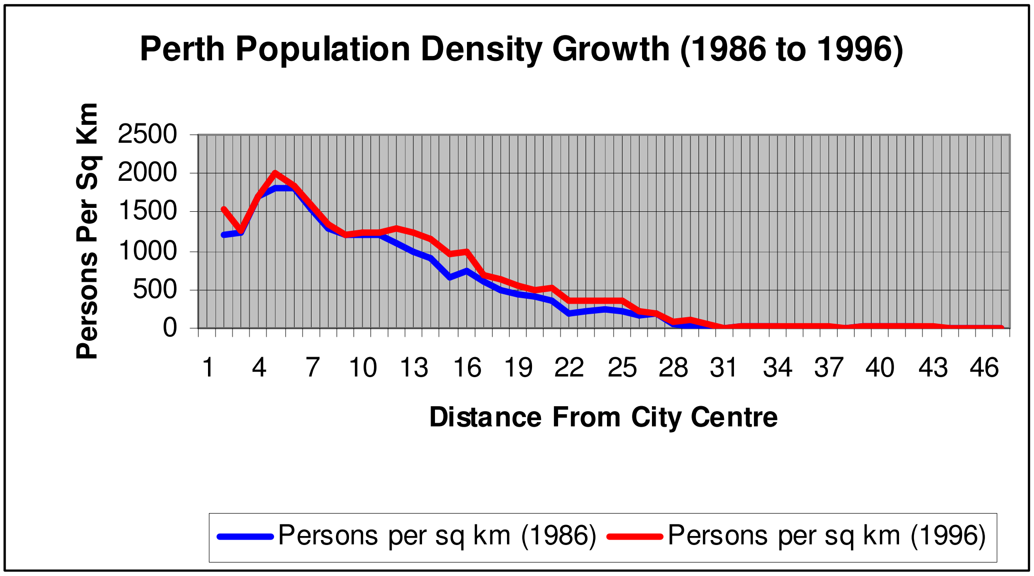


(Newton Professor P.W. (CSIRO) 2001)

The greatest rate of population density growth in Sydney is within 5 kilometres of the city centre. Over the period quoted, development of high density unit dwellings was accelerated through the CBD and in the Pyrmont / Ultimo area. This growth is expected to continue between 1996 and 2006 with growth expected in the North Sydney, Sydney and South Sydney local government areas. Minimal changes in population density in outer-lying areas show that apart from the north-western sector (Baulkham Hills LGA), development of Greenfield sites in Sydney has been minimal over the five-year period.

Figure 3 shows the variation in persons per square kilometre in Perth between 1986 and 1996.

Figure 3 - Perth Population Density Growth Graph (1986 to 1996)

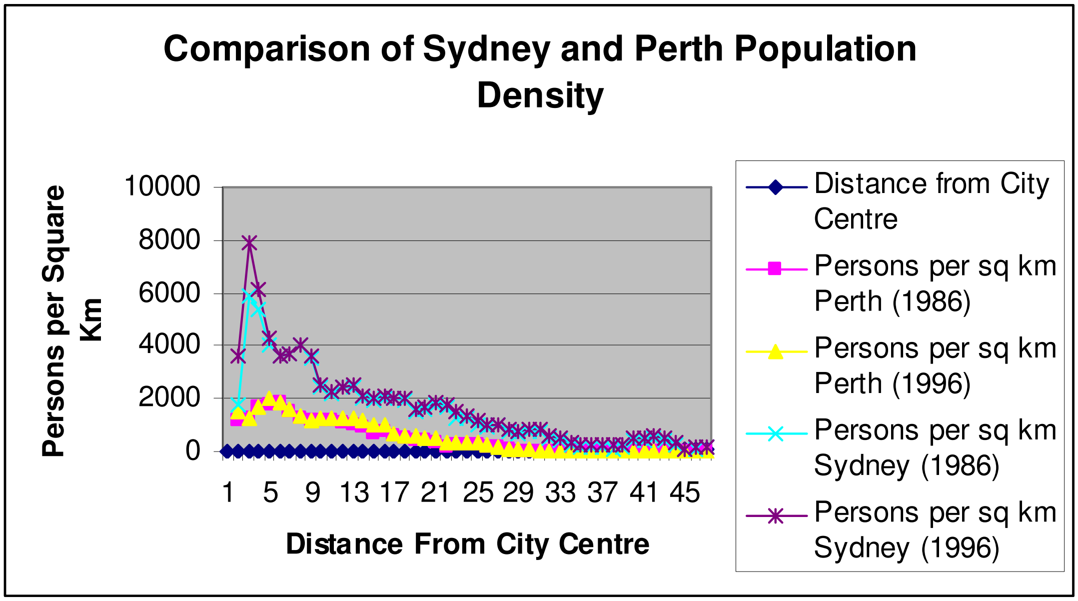


(Newton, Professor P.W. (CSIRO) 2001)

The rate of change of population density growth in Perth is wider spread than in Sydney over the same period. This is due mainly to Perth's lower densities enabling consolidation of development from low to medium densities through a number of middle and inner ring suburbs. Development in the period 1986 to 1996 centred on subdivision of larger landholdings in the Wanneroo, Stirling, Swan, Melville and Fremantle local government areas. This population density growth is expected to continue between 1996 and 2006 with growth in the CBD and East Perth in the form of higher density unit development and urban consolidation spreading to other middle and outer ring local government areas such as Belmont, Canning, Rockingham, Joondalup and Cockburn.

The figure below shows a comparison of population density growth throughout the metropolitan regions of Sydney and Perth between 1986 and 1996.

Figure 4 - Comparison of Sydney and Perth Population Densities



(Newton, Professor P.W. (CSIRO) 2001)

The densities which are approximately 20km's from the Sydney CBD are relative to the inner city densities in Perth.

2.3.2 Household Composition

The purpose of this section is to develop an understanding of household composition in each city.

Household composition, in the terms of this Thesis is the broad descriptor of the following factors: -

- Number of persons per household;
- Number of vehicles per household;
- Socio-economic status of the occupants of the household; and
- Age of the occupants of the household.

Household composition impacts accessibility to transportation modes and therefore influences modal choice and trip generation.

Transportation choice can be linked to data such as number of persons per household, number of vehicles per household, age group and socio-economic status as there are a number of potential factors in a persons' choice to use a motor vehicle or alternative transport forms. This section describes these factors and quantifies the recent historical impact that each has on transportation modal choice.

Persons per Household

The 'persons per household' category is the average number of persons residing within a household. Averages for inner, middle and outer suburbs tend to vary with the number of people per household generally tending to increase with lower dwelling densities and distance from the CBD. In general, this is a function of higher density living in inner city areas corresponding to lower numbers of persons per dwelling.

The number of people per household is steadily dropping across Australia. The average persons per household in Perth and Sydney are 2.5 as surveyed in

2001. The recent change in birth rates in Australia may however see a change to this trend. Table 19 shows the average number of people per household by year across Australia.

Table 19 - Number of People per Household

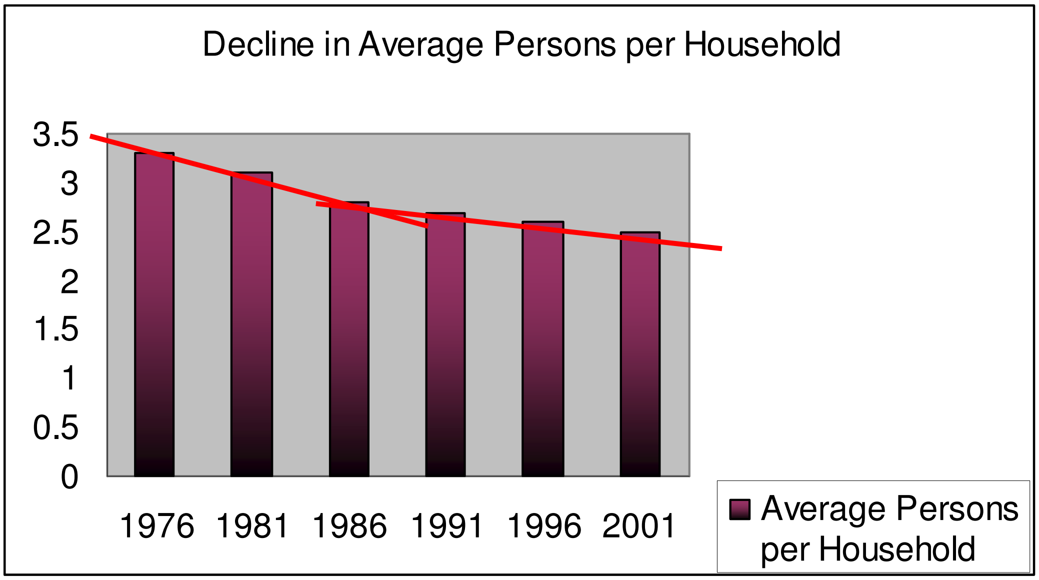
Year	Average Persons per Household
1976	**3.3**
1981	**3.1**
1986	**2.8**
1991	**2.7**
1996	**2.6**
2001	**2.5**

(Australian Bureau of Statistics, 2001)

It can be argued that the declining trend is a combination of economic (housing affordability) and socio – demographic (ageing, divorce rates, less families) factors.

The trend is highlighted in Figure 5 below.

Figure 5 - Decline in Average Persons Per Household



(Australian Bureau of Statistics, 2001)

Providing this information in graphical format shows the declining trend, however at some point in the future it is reasonable to expect that the rate of decline will continue to slow and reverse as shown by the red trend lines overlying the graph.

Table 20 shows household composition data based on family type in Sydney between 1991 and 2001.

Table 20 - Household Composition - Sydney

Family Type	1991	1996	2001
Single-parent families	8.8%	15.9%	16.5%
Childless couples	31.4%	36.5%	39.8%
Couples with dependent children	53.9%	45.8%	41.9%
Other	5.9%	1.8%	1.8%

(Australian Bureau of Statistics, 2001)

The household composition data shows the drop in average persons per household and growth in single parent families and childless couples. There is a large change in the "Other" grouping which may be due to variations in the definition.

Motor Vehicles per Household

Statistics from the Transport Data Centre show that the number of motor vehicles in a household has an inflationary impact on the number of trips generated per day by persons within that household. Access to a motor vehicle increases mobility and therefore allows greater discretionary travel, particularly over shorter distances. Table 21 shows the number of vehicles per household and the impact upon trip generation rates per person.

Table 21 – Motor Vehicles per Household and Trip Rates - Sydney

No of Vehicles per Household	Percentage of Total Households	Trip Rate per Day per Person
0	15%	2.74
1	43%	3.57
2	32%	4.10
3 or more	10%	4.10

(Department of Infrastructure, Planning and Natural Resources, TPDC 2002)

Supporting this, the number of motor vehicles per household has risen from 1.3 to 1.4 in Sydney between 1991 and 2001. Growth in car usage is up an average 2.7% per annum from 1991 to 2000, with subsequent growth in kilometres travelled up an average 2.0% per annum from 1991 to 2000.

(The Committee for Sydney Inc, 2002.)

Interestingly, overall trip rates tend to increase commensurate with an increase in the number of vehicles per household. In 2000, the average trip rate per person per day in Sydney was 3.77.

Table 21 presents an interesting set of statistics in that it does not concur with the findings of respected researchers, such as James and Brog et al, 1999 who argue that accessibility to transport alternatives did not necessarily equate to increased trip generation. I contend that accessibility to motor vehicles tends to increase discretionary or non-necessary trip making such as social and shopping journeys. This is covered in further detail in Section 3.2 – Mode Choice Theory.

Socio- Economic Status

Socio-economic status has a bearing upon trip generation through the theory of accessibility to transportation options. As a general rule, lower socio-economic status equates to greater percentages of captive or necessary travel and lower percentages of discretionary travel. Travel is therefore a "superior" good and therefore it can be argued that travel increases with increased income.

Socio-economic status is a combination of cultural heritage, financial position and earning capacity. One simplistic example is the growth in vehicles per household. The ability to pay additional vehicle costs indicates a reasonable proportion of household income can be directed away from the necessities of daily life. I describe this as "Increased vehicle usage for discretionary travel can be an indication of surplus income".

Statistics provided by the Transport and Population Data Centre of NSW show that generally public transport is utilised by people within lower wage brackets, with bus patrons shown to have a lower average wage than train users in Sydney. City Rail statistics back this theory and show that 46% of train users, compared with 62% of bus users, have an annual income of less than $20,800.

Socio-economic status and mode choice theory is examined in further detail in Section 3.2 – Mode Choice Theory.

Age

Age profiles tend to be an indicator of socio-economic status, as public transport users for school purposes and senior citizens utilising day time bus

services tend not to be higher income earners. Table 22 shows the split of bus users by age in Sydney.

Table 22 - Profile of Bus Users by Age (Sydney)

Age Group	% Users by Age Group
10 or less	14%
11 to 20	15%
21 - 30	14%
31 - 40	18%
41 - 50	17%
51 - 60	10%
61 – 70	6%
70 +	6%

(New South Wales, Sydney Buses 2001.)

From the figures above for Sydney, we can reasonably assume that a minimum of between 25% and 33% of bus users may not have a vehicle license and also have limited wage earning capacities, therefore their mobility is limited to alternative and public transportation modes and passenger journeys by motor vehicle.

2.3.3 Urban Location and Accessibility to Transportation Options

Hypothesis
Does urban location impact transportation modal choice?

It is reasonable to assume that different suburbs generate varying trip rates and mode uses. However, is there a link between increasing distance from the CBD and increased vehicle usage?

For the purpose of this Thesis, urban location describes whether the dwelling is located within inner, middle or outer suburban areas.

Growth in VKT Travelled by LGA

Table 23 shows a selection of the average vehicle kilometres travelled (VKT) per person by local government authority region for 1991 and 2001 and highlights the percentage changes in VKT.

Table 23 – Growth in Vehicle Kilometres Travelled (VKT) per Person by LGA

Local Authority	1991 (VKT)	2001 (VKT)	% Change p.a.
Auburn	9.4	12.9	**3.8%**
Baulkham Hills	27.3	27.6	**0.1%**
Botany	11.2	13.3	**1.9%**
Burwood	9.3	11.7	**2.5%**
Camden	24.9	36.1	**4.5%**
Campbelltown	24.8	28.7	**1.6%**
Canterbury	11.3	11.4	**0.1%**
Drummoyne	9.2	13.5	**4.8%**

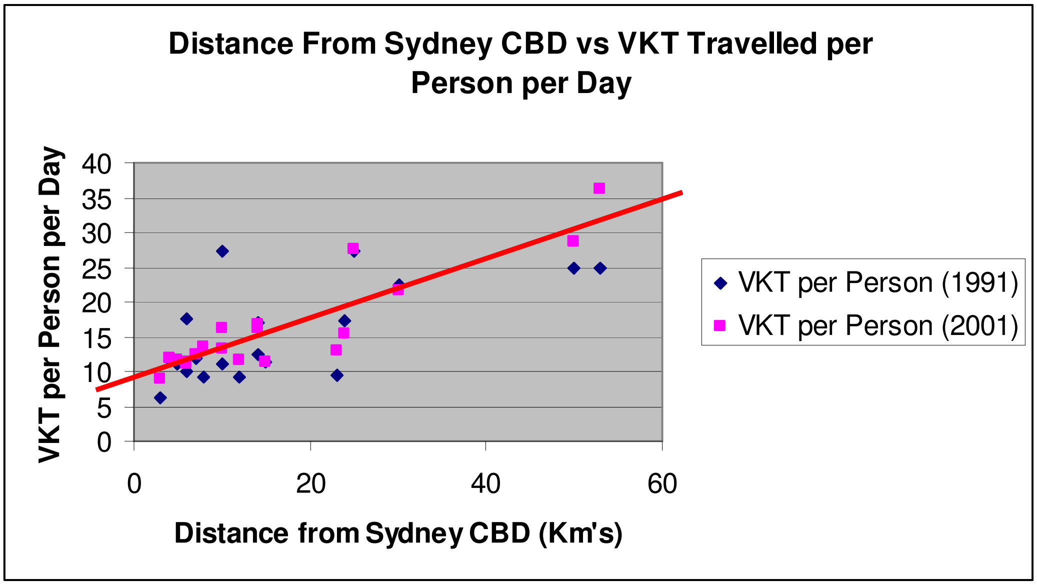
Hornsby	22.5	21.7	**-0.4%**
Hunters Hill	27.2	16.1	**-4.1%**
Kogarah	17.0	16.7	**-0.2%**
Leichhardt	17.7	11.3	**-3.6%**
Manly	12.3	16.2	**3.2%**
Marrickville	12.0	12.4	**0.3%**
Mosman	11.1	11.5	**0.4%**
North Sydney	11.0	11.7	**0.7%**
Parramatta	17.4	15.3	**-1.2%**
Randwick	10.1	11.0	**0.9%**
South Sydney	6.3	8.8	**4.0%**
Woollahra	11.7	11.8	**0.1%**

(Transport Data and Population Centre, 2004)

The following can points are made with relation to Table 23: -

- The greater the distance from the CBD, the greater the average VKT travelled per person per day, as shown in Figure 6 below and highlighted by the red trend line. (This information is collated from Table 23);

Figure 6 - Distance From Sydney CBD vs VKT Travelled per Person per Day



- Areas undergoing major population growth between 1991 and 2001 such as Camden (greenfields development and lack of viable alternative transport options), South Sydney, Drummoyne, Auburn and Burwood (infill development and / or major socio-economic change i.e. gentrification) experienced large increases in VKT;

- Areas serviced with strong inner suburban public transport and experiencing congestion in major road networks due to increased vehicle traffic from outerlying areas sustaining modal shift such as Leichhardt and Hunters Hill experienced large decreases in VKT;

- Areas such as Woollahra and Mosman have experienced minimal socio-economic change, minimal increase in development, minimal increase in provision of new road infrastructure and minimal increase in new public transport infrastructure and as such have maintained similar VKT results;

- Development of major employment generating businesses within an LGA promotes employment opportunities within local residential

catchments. Parramatta offers an interesting case study in this regard; and

- There appears to be no discernible pattern relating to growth in VKT based on urban location.

Areas which are closer to employment generating areas and major public transport hubs offer more choices to the public and tend to exhibit greater trip rates with higher modal splits for alternative mode choices. In these areas accessibility to multiple transportation modes provides a greater range of mobility options.

Journey to Work by Private Vehicle by LGA

The accessibility theory is also tested in Table 24, which examines the percentage of private drive to work trips based on local government area. The third column summarises in general terms the authors' interpretation of accessibility to alternative transport and socio-economic status as collated earlier in this section.

Table 24 - Journey to Work by Private Vehicle (Split by LGA)

Local Authority	% Private Vehicle Uses (Journey to Work)	Notes (Authors Analysis)
Auburn	**59%**	STA buses and City Rail. Increasing densities with some employment and mixed use zones.
Baulkham Hills	**86%**	Private buses and no rail. Large urban catchments with poor alternative modal choices.
Blacktown	**73%**	Private buses and City Rail. Expanding low density outer suburban developments

		with limited transport options.
Blue Mountains	**71%**	Private buses and City Rail. Lower dwelling densities and steeper topography limit walking and cycling.
Burwood	**52%**	STA Buses and City Rail. Good coverage of service. Some employment and mixed use zones.
Canterbury	**59%**	STA Buses and City Rail. Good coverage of service. Some employment and mixed use zones.
Drummoyne	**66%**	STA Buses with good coverage through area, no rail.
Fairfield	**77%**	Private buses with limited coverage and City Rail offering long haul travel with varying frequencies. Lower socio-economic region.
Hawkesbury	**81%**	Private buses with limited coverage. City Rail offering long haul travel with varying frequencies.
Holroyd	**75%**	Private buses with some access to City Rail network.
Hunters Hill	**61%**	STA Buses with strong coverage and City Rail network with some permeability. High socio-economic region with considerable congestion issues.
Leichhardt	**50%**	STA Buses with strong coverage and frequency. Light rail system with limited permeability. Highly congested road

		networks.
Liverpool	**74%**	Private buses plus LPT and City Rail. Expanding residential catchments to south west with limited services.
Marrickville	**48%**	Good coverage with City Rail and STA Buses. Highly congested inner city road networks. Lower inner city socio-economic population.
Parramatta	**71%**	Major City Rail hub. Mixture of STA and Private Bus networks. CBD attracts work trips.
Penrith	**74%**	City Rail network plus private buses. Growing suburban regions poorly serviced by public transport.
Sydney, South Sydney	**25%**	Strong STA Bus and City Rail networks. High density development and street layout highly geared to walking trips and alternative transport.

(Australian Bureau of Statistics, 2001)

Summary and Analysis

In summary, there is a clear trend showing increased alternative transportation usage dependent upon urban location. This is based on the proximity of the location to the destination and the end-users' accessibility to viable transportation modes.

The local government areas closest to the CBD such as Sydney / South Sydney, Marrickville and Leichhardt offer the greatest mode share splits for alternative transport modes for commuting. An outer-lying area such as

Baulkham Hills which is poorly serviced by public transport has a very low modal split for alternative transport.

Highlighting the Baulkham Hills results is a recent New South Wales Government approach for development of new greenfield areas: -

- Minimum of 15 dwellings per hectare;
- Maximum of 5 kilometres from an existing or proposed mass transit (bus or train); and
- Minimum 15 minute frequency for local public transport in peak periods.

The combination of 15 minute peak frequencies with R15 development densities in greenfield sites, coupled with distances of up to 5 km to access viable public transport, (given a walkable catchment is defined as 400 metres), is not appropriate and will do little to improve the take-up of alternative modes of transport. As such, this vision should be revised and replaced with a more appropriate vision immediately.

An interesting statistic provided by the TDPC is that on average, people spend more time getting to/from the train and waiting for it than they spend travelling on the train itself. This will be exacerbated by planning which provides a distance of up to 5km to a high frequency service.

Perth – Mode Split by Location

In Perth, modal share split by location also shows greater alternative transport mode use as the location approaches the CBD. Table 25 provides a contrast between inner, middle and outer ring suburbs and shows a comparison between mode splits in 1986 and 2000.

Table 25 - Modal Split By Urban Location – All Trips, Perth (1986 / 2000)

Item	Inner		Middle		Outer	
	1986	2000	1986	2000	1986	2000
Car (As Driver)	54%	57%	58%	60%	55%	55%
Car (As Passenger)	19%	19%	21%	23%	23%	25%
Public Transport	7%	6%	5%	5%	5%	6%
Cycle	3%	3%	2%	2%	1%	2%
Walk	17%	15%	14%	10%	16%	12%

(Sourced via email – Mercina Robinson Department for Planning and Infrastructure, 2005)

The following points of interest are noted: -

- Car as driver trips are lower in outer suburbs when compared to the middle ring suburbs in 1986 and 2000; and
- Car as driver trips are lower in the outer suburbs when compared to inner ring suburbs in 2000.

In Perth, the extension of the rail system to Joondalup has provided additional transportation options to outer-lying communities in the northern suburbs. Increased socio-economic prosperity in the inner and middle ring suburbs coupled with minimal traffic congestion has created an environment suitable for large increases in motor vehicle usage.

Train Trip Generation Split by Urban Location

This section provides a summary of train trip generation split by urban location, as collated in Table 26. The key hypothesis is to confirm that increased

journeys are undertaken on the basis of socio-economic status and / or urban location, (i.e. increased accessibility to transportation options).

Table 26 – Train Trip Generation, Total Trip Generation and Population by Urban Location (Sydney)

Urban Location	Percentage of Total Train Trips	Percentage of Total Trips	Percentage of Total Population
Inner City	15.0%	14.0%	7.0%
Outer Suburbs	10.0%	13.0%	10.0%

(City Rail, 2002)

Briefly this table shows: -

- Inner city residents generate greater total trip generation rates than residents in the outer suburbs (7% of the population with 14% of all trips compared to 10% of the population with 13% of all trips); and
- Inner city residents generate greater trip generation rates with train as mode than residents in the outer suburbs (7% of the population with 15% of all train trips compared to 10% of the population with 10% of all train trips).

These findings back-up the data collated thus far in Section 2.1. In addition, they are backed up by the key findings from the Train Users in Sydney Issues Paper 2000/01, including: -

- From 1991 to 1999 the number of train trips on weekdays by Sydney's residents increased at a faster rate than population growth. Strong increases in patronage were recorded until 2000/01;
- The growth in train travel by people living in the inner areas of Sydney increased at a rate double population growth; and
- Strong growth in train trips, total trips and residents by region between 1991 and 1999, however a strong drop in train usage from 2001.

(Department of Transport NSW, 2001)

2.3.4 Employment Catchments

Land use planning plays a vital role in the ability to provide alternative transportation modes. It is important to provide links between residential catchments and areas with employment generation capability such as commercial and industrial land zonings.

Where employment generating land is located in close proximity, (such as in the CBD) the provision of a workable mass-transit system is simpler. Where employment catchments are dispersed through the metropolitan region, it becomes more difficult to service these zones in an equitable manner. It is important to note that employment generating landholdings are dispersed widely across Sydney. The dispersion of employment, as compiled during Census 1996, is described in Table 27.

Table 27 - Employment Dispersion across the Sydney Metropolitan Region

Urban Location	Percentage of Total Employment
Not in Major Commercial Centres	69.0%
Sydney CBD	14.0%
North Sydney CBD	2.0%
Other Suburban Commercial Centres	15.0%

(Census, 1996.)

The total number of jobs in Sydney at Census date in 1996 was approximately 1.3 million, therefore Sydney still has a relatively strong CBD region compared with U.S. cities.

As noted above, disperse employment areas are difficult to service by public transport. In particular, the 69% of employment generating landholdings ranked

as not being in a recognised commercial centre will be difficult to service profitably. Services to the Sydney, North Sydney and Parramatta CBD's can be reasonably served by public transportation. As noted previously, approximately 75% of all trips to the Sydney CBD for commuting purposes are undertaken on alternative modes of transport. This is backed up by TPDC data which shows: -

- Most train trips on weekdays are by commuters with 42% of all train trips for travel to/from work; and
- Train trips tend to be concentrated in the morning and afternoon peaks.

2.3.5 Summary Comparative Analysis

In this section we will compare the data collated in Section 2 and provide a matrix style comparison of the performance of both cities.

Objective
To compare the performance of transportation modes in Sydney and Perth

Trip rates per person vary based on a number of factors. Table 28 provides a comparison of the average trip rates per person per day, for various transport modes and for the total average trip generation.

Table 28 - Trip Rates per Person per Day

City	Car	Walk / Cycle	Public Transport	Total
Sydney	2.49	0.76	0.38	3.63
Perth	2.86	0.36	0.22	3.44

(Australian Academy of Technological Sciences and Engineering, 1997.)

Total trip generation is greater in Sydney; however Perth generates greater car trips per person per day with lower rates for alternative modal choices.

The greater trip generation rates for alternative transport modes and total trips show there may be greater accessibility to all modes of transportation and lower average vehicle ownership rates in Sydney compared to Perth.

Key Performance Indicator's (KPI's) Performance Comparison, Sydney and Perth

This section provides a direct comparison of key data for each city and an assessment of performance as shown in Table 29. The objective of this section is to compare the performance of each transportation mode in Sydney and Perth.

Table 29 – KPI Performance Comparison, Sydney and Perth

Item	Sydney	Perth
Public Transport Patronage	**Bus**	
	Static patronage growth with a minor increase of **0.3% p.a. outpaced by** population growth of 1.2% p.a. but just short of motor vehicle kilometres travelled growth of 0.5% p.a. Short term **outlook** is **neutral to improving** with expansion of bus t-ways in the western suburbs, coupled with high levels of traffic congestion in peak periods and recent fuel price movements.	**Strong** average patronage growth of **4.5% p.a**. easily **outpacing** population growth of 1.5% p.a. but outpaced by motor vehicle kilometres travelled growth of 6.1% p.a. Short term **outlook** is **improving to good** due to potential increases in bus patronage and redeployment of resources south of Perth as a result of the Perth to Mandurah rail.
	Rail	

	Static patronage growth of **0.34% p.a. outpaced by** population growth of 1.2% p.a. and motor vehicle kilometres travelled growth of 0.5% p.a. to 2004, with a **substantial increase** in patronage growth to **0.61% p.a. outpacing** motor vehicle kilometres travelled growth. Patronage improvements expected to continue in 2006 / 2007. Short term **outlook** is **improving** to **good** due to Rail Clearways program and the commencement of the Epping to Chatswood rail in 2008 with potential for substantial patronage improvements with stronger investment.	**Good** patronage growth of **1.6% p.a. keeping pace** with population growth of 1.5% p.a. but **outpaced by** motor vehicle kilometres travelled growth of 6.1% p.a. Short term **outlook** is **strong** with commencement of the Perth to Mandurah rail in 2007 and increased capacity on the Perth to Joondalup line, plus other service improvements.
	Ferry	
	Strong Growth Rate of **1.6% p.a.** in ferry patronage **outpacing** population growth of 1.2% p.a. and motor vehicle kilometres travelled growth of 0.5% p.a.	**Declining** patronage of **-1.2% p.a. outpaced by** population growth of 1.5% p.a. and motor vehicle kilometres travelled growth of 6.1% p.a.

	Short term **outlook** is **neutral** to **improving**.	Travel negligible in Perth. Expected to stay **neutral** to **negative** in the short and long term.
	Light Rail	
	Declining patronage of **-2.9% p.a.** **Negligible** growth expected due to inappropriate service location and inaction on service expansion. Short term outlook is **poor** unless there is approval of a suitable light rail plan for inner Sydney.	**No Services.** Study currently being conducted into light rail in Perth with potential for an inner city route and replacement of sections of the Circle Route with a light rail service.
Rail, split by line and urban location	**Inner City**	
	Eastern suburbs patronage impacted by works at Bondi Junction and the construction of the Eastern Distributor. Re-opening of shopping district should provide a **positive** impact.	**Strong** growth in rail patronage at inner city stations. **Strong** recent growth at redeveloped stations such as Oats Street and development of Transit Oriented Demand (TOD) station at Subiaco.
	Middle and Outer Ring Suburbs	
	Negative growth in south-	**Negative** growth at most

	western suburbs lines due to opening of M5 East extension cutting vehicle travel times to the CBD, but patronage rebounding as M5 reaches capacity. Outlook is **improving.** Outlook for northern and north shore lines is **neutral** due to system operating close to capacity until 2008 when the Epping to Chatswood service provides additional capacity, however the opening of the Lane Cove Tunnel may provide improved conditions for motor vehicle traffic.	middle ring suburbs and **moderate** growth at outerlying suburbs, due to security and safety issues with Park and Ride facilities. Outlook for Armadale and Midland lines are **neutral** to **negative**. **Strong** growth in overall usage is expected due to the new stations at Thornlie and Clarkson and an **increase of around 20%** is expected in 2007 with the new service to Mandurah.
Case Studies	**Liverpool to Parramatta Transit-Way**	**Perth Circle Route**
	Strong patronage growth on LPT. Reached 50% of 10-year patronage target after 2.5 years. Roll-out commenced on North-West T-way. Outlook for growth is **strong**. Increased capacity may be required due to the initial	Perth Circle Route attracts **strong** patronage growth of **8.5% p.a**. Outlook for growth continues to be **positive** as the service is well marketed on Transperth buses and provides connectivity for employment, educational, social and shopping purposes.

	success of the LPT.	Current studies suggest some sections have potential to be upgraded to light rail.
Historical Modal Share	**Car As Driver and Car As Passenger**	
	Current Level **- 70%.** Short term outlook **– neutral.** Motor vehicle usage to hold around **70%.**	Current Level - **80%.** Short term outlook – **neutral to negative**. Motor vehicle usage to hold between **80% and 82.5%.**
	Public Transport – Bus, Light Rail and Rail as Mode	
	Current Level - **10%**. Short term outlook – **neutral**. Rail mode share to decrease in the short term before rail clearway programs begin to provide benefit. Epping to Chatswood service to provide first positive movement in patronage since 2000. Bus outlook is **neutral** with major growth coming from new bus t-way services in the western suburbs coupled with impact of higher fuel prices.	Current Level - **6.4%.** Short term outlook – **neutral**. New rail services to expand patronage. However expanding urban catchment and difficulty in servicing new outerlying areas means Perth is currently a city for motor vehicle drivers. The key external impact in Perth is rising fuel prices and the buoyant economic conditions driven by the resources boom.

	Alternative Modes – Walking and Cycling	
	Current Level - **20%.** Short term outlook – **neutral** to **positive.** Increased development densities in inner city providing impetus for local travel within walkable catchments.	Current Level - **13%.** Short term **outlook** – **neutral** to **positive**. Positive media campaigns providing impetus for behavioural change.
Population, Household Density and VKT Growth	**Population Growth**	
	Current Growth Rate - **1.2% p.a.** Short term outlook **– negative.** Population growth in Sydney is being impacted by congestion issues, perceptions regarding quality of life and land affordability forcing families and younger people out of the state. Recent population growth in the last 2 years has dropped to around 0.5% per annum.	Current Growth Rate – **1.5% p.a.** Short term outlook – **strong.** Growth outstripping national averages since 2004 to continue due to economic and employment demand in the resources sector underpinning strong growth in the housing market.

	Household Growth	
	Current Growth Rate – **1.5% p.a.** Short term outlook – **neutral.** Continued brownfield and inner city higher density development with some outerlying areas development	Short term outlook – **strong.** Continued buoyant land development market, with investors and interstate and overseas migrants purchasing.
	Weekday Vehicle Travel Growth	
	Current Growth Rate – **1.6% p.a.** Short term outlook – **neutral.** Peak period congestion, growth in fuel prices and economic conditions may provide a slowing environment for vehicle travel growth, if appropriate resources are put into public transport to maintain a behavioural change.	Current Growth Rate of all vehicle travel – **6.1% p.a**. Short term outlook – **strong**. Weekday vehicle travel expected to grow at greater than rate of population growth due to excess capacity available in peak suburban network and due to buoyant economic conditions.
	Weekend Day Vehicle Travel Growth	
	Weekend day vehicle travel growth – **1.7% p.a**. Short term outlook – **neutral.** Potential for trip blending or minimisation of trip generation due to economic	Current Growth Rate of all vehicle travel – **6.1% p.a**. Short term outlook – **strong**. Economic conditions providing environment for

	conditions and cost of fuel.	increased discretionary spending, therefore potential for increased social and recreational trip generation - this is typically difficult to service by public transport.

Longer Term Modal Share Assessments

Table 30 shows the forecast in the longer term for mode share based on two scenarios: -

- A continuation of current trends; and
- A target forecast based on provision of infrastructure and behavioural change.

Table 30 - Transport Usage Patterns & Modal Share (Trips Per Day)

	Sydney			Perth		
	1991	2021 pattern	2021 target	1991	2029 pattern	2029 target
Total avg weekday trips (,000)	13,774	17,794	17,000*	4,092	6,707	6,457
Car Driver	46%	55.0%*	45.0%*	63%	70.5%	46%
Car Passenger	21%	15.0%*	15.0%*	13%	9%	11.5%
Walk	20%	19.5%*	25.0%*	10%	5.8%	12.5%
Cycle	0.65%	0.5%*	1.0%*	5.7%	8.0%	11.5%
Public Transport	12%	10%*	15.0%*	6.4%	4.8%	12.5%

Other	0.35%	n.a.	n.a.	2%	1.8%	2%

(Sourced via email from Department of Planning and Infrastructure Officers', 2005 & 2006 - Note * 2021 targets are interpolated by the author.)

Summary and Analysis

The stated target of the New South Wales Government for 2021 is for 30% of all work related trips to be provided by public transport. Other stated goals and patterns have not been provided, which I believe is a failure to forward plan. As such the 2021 pattern may be a more likely occurrence in Sydney.

The Western Australian target and trend figures have been published by the Western Australian government as part of the Network Cities program. I believe this is positive, as a clear goal has been set and a number of projects have commenced to deliver improved patronage. The targets are extremely bullish however and I do not believe they will be met unless there is a significant road pricing scheme undertaken for vehicles entering the City of Perth. In addition motor vehicle trips as mode have already exceeded the nominated 2029 "pattern" figure of 79.5%. This statistic provides further proof of the need to increase public transport usage for a sustainable city.

3. TRANSPORTATION BEHAVIOURAL SCIENCE METHODOLOGY

This research proposes two key areas where public transportation mode share can be increased, namely behavioural science methodologies and engineering infrastructure methodologies. This section focuses on understanding how commuter behavioural science can enhance the growth of public transportation patronage and mode choice.

The key objectives in this section are to define Transportation Behavioural Science Theory in terms of the following objectives: -

Objectives
1. To discuss how human behaviour can impact transportation modal choice, in both the short term (reactionary behaviour) and the longer term (disposition behaviour). *2. To discuss the difference between individual behavioural choice and group or 'herd' driven behavioural choice.* *3. To define the term "Mode Choice Theory".* *4. To define "Travel Purpose Methodology", or why people travel.* *5. To define "Time Elasticity Theory" or comparative travel time analysis and its potential impact on mode choice.* *6. To define "Price Elasticity Theory".* *7. To discuss Maslow's Hierarchy of Needs and to adapt to transportation science as a descriptor of both short term reactionary behaviour and longer term disposition behaviour for modal choice.* *8. To review Elliot Wave Theory and to consider use of historical data as a potential predictive tool for both reactionary and disposition behaviour trends.*

9. To provide some examples where behavioural science-based programmes have resulted in an increase in public transportation patronage.

3.1 Human Behaviour Impacts Transportation Mode Choice

I propose that Transportation Behavioural Science Methodologies should be examined to understand two forms of human behaviour: -

- short term, or reactionary behaviour; and
- long term, or disposition behaviour.

These behavioural forms can occur in two ways, namely at an individual level or can be influenced at a group level, (i.e. herd behaviour).

A key understanding for this section is that the bulk of decisions regarding transportation mode choice are made at an individual level, based on a number of personal factors. However it is important to recognise that negative perception at an individual level can grow to a level where the influence begins to spread at group level.

Individual Decision Making Theories	Group Decision Making Theories
Mode Choice Theory	**Elliott Wave Theory**
Travel Purpose Theory	
Time Elasticity Theory	
Price Elasticity Theory	
Maslow's Hierarchy of Needs	
Behaviour Adaptation Theory	

3.2 Mode Choice Theory

There are a number of important factors to consider when assessing why people choose a transportation mode, (Mode Choice Theory): -

- What is the purpose of the trip;
- How accessible are the various transport options;
- Does the persons' urban location or socio-economic status provide a link to the number of journeys generated per day; and
- Does the person have a pre-disposition to a transportation mode?

While mode choice can be influenced by the provision of infrastructure, I believe that Mode Choice Theory is a behavioural science and arguably is the basis of transportation engineering. The objective for this section is: -

Objective
Define Mode Choice Theory

I define Mode Choice Theory as **"The user response to a variable number of internal and external factors that have the capacity to determine a users' travel behaviour."**

3.3 Travel Purpose Theory

To determine methods to re-assign trips generated to alternative transport modes, I believe it is important to develop an understanding of why trips are generated in the first place, namely "why do people travel?" or **Travel Purpose Theory**.

The following categories have been used in a number of studies to understand why trips are generated. For the purpose of this work, these are the key travel purposes: -

- Social;

- Shopping;
- Work;
- Personal business;
- Education;
- Serve passenger;
- Other work related; and
- Other.

Why People Travel in Sydney – Changes in Transport Need 1991 to 2003

Table 31 provides an understanding of why people travel in Sydney using all transport modes and importantly, how this has changed between 1991 and 2003. This data has been collated from the Transport Data Centre website.

Table 31 - Purpose Share (All Transport Modes, avg Weekday - Sydney)

Transport Need	1991	2000	2001	2002	2003
Social / Recreation	20.6%	21.7%	22.1%	23.3%	23.2%
Serve Passenger	15.8%	17.6%	17.4%	16.9%	17.4%
Shopping	17.7%	16.3%	16.1%	16.1%	15.7%
Commuting	15.1%	15.3%	14.9%	15.2%	15.0%
Other work related	10.6%	9.9%	10.3%	9.8%	9.5%
Education / childcare	8.6%	8.6%	8.4%	8.3%	7.8%
Personal business	8.2%	7.7%	7.9%	7.7%	8.2%
Other	3.4%	2.8%	2.9%	2.9%	3.0%

(New South Wales Transport Data Centre, 2003 & 2005)

Summary and Analysis

The trip segments exhibiting the greatest growth are the ‘social’ and ‘serve passenger’ trip segments, which arguably are the two most difficult to provide viable public transportation services for.

Commuting has remained relatively static at around 15.0% of all trips. Commuting and education offer greater opportunities for provision of public and alternative transportation modes as an end-point to the trip is clearly defined. If a suitable residential catchment can be serviced with a relatively direct route, the opportunity exists to create a viable public transportation system.

It will be interesting to see whether trip purpose generation splits will change over the period between 2002 and 2010 due to changes in population composition after the implementation of the “baby bonus” scheme. Recent Australian Bureau of Statistics Data show a slight increase in total fertility rates since the introduction of the scheme from 1.73 children in 2002 to 1.77 children per family in 2005. Further evidence from the Australian Bureau of Statistics shows that the birth rate in 2006 is approaching the highest level since 1991.

Why People Travel in Sydney (Rail as Mode, 2001)

Table 32 examines the same trip parameters, but assesses the split based on travel by train as mode for both weekdays and weekends.

Table 32 - Purpose Share (Train as Mode, avg Weekday and avg Weekend Day- Sydney)

Transport Need	Weekday	Weekend Day
Social	16%	47%
Serve Passenger	4%	5%
Shopping	10%	20%
Commuting	42%	12%
Other work related	5%	6%
Education / childcare	14%	3%

Personal business	8%	4%
Other	2%	2%

(New South Wales Department of Transport, Transport Data Centre, 2001.)

Summary and Analysis

This table shows a marked decrease for social and serve passenger trips, as these trips do not necessarily commence in residential catchments and end in commercial or employment generating land uses as discussed for Table 31.

One in two train travellers use the train for commuting and business related trips during the week, with education purposes attracting 14% of all travel. Weekend train patronage subsequently drops due to the drop in numbers of people generating these trips.

Future growth in train travel will be reliant upon maintaining and growing commuting and education trips during the week and promoting travel by public transport for entertainment and social purposes.

Why People Travel in Sydney (Bus as Mode, 2001)

Table 33 shows the same transport requirements however with bus as the mode of transport.

Table 33 - Purpose Share (Bus as Mode, avg Weekday and Weekend Day for State Transit - Sydney)

Transport Need	Weekday	Weekend Day
Social	18%	50%
Shopping	12%	28%
Commuting	34%	9%
Education	21%	2%
Other	15%	11%

(State Transit Authority, 2005)

Summary and Analysis

As per the results for the train network, commuting and education are dominant modes in bus travel. Commuting trips via bus are slightly lower percentage of the total than for the rail network; however a greater percentage of students use the bus. This partly explains the lower average wage of bus users.

Planning to incorporate social trips, such as sporting events is becoming important in the battle to increase public transport patronage.

Why People Travel in Sydney (Bicycle as Mode, 2001)

An interesting comparison to the reasons for trip generation shown in the above tables is to examine the reasons for trip generation when cycling is used as the transportation mode as presented in Table 34.

Table 34 - Purpose for Modal Choice - Bicycles (Sydney)

Reasons for Bicycle Use	Weekday	Weekend
Social / Recreation	45%	70%
Commuting	25%	4%
Education	12%	n.a.
Shopping	8%	12%

(NSW Roads and Traffic Authority, 2005)

Summary and Analysis

The dominant reason for travel by bicycle is for social and recreational purposes, however commuting, shopping and education form significant reasons for bicycle usage.

Bicycles are promoted in Perth as a sustainable method of transportation with associated health and lifestyle benefits. The Western Australian government is

providing a network of bicycle paths to promote the expanding use of bicycles in a safe and effective manner and this has provided the impetus for increased usage in the metropolitan area.

Trip Length and Transportation Need - Joondalup Western Australia

Table 35 provides a breakdown of trip length by transportation need in the City of Joondalup, which is an outerlying suburban region in Perth's northern suburbs with strong access to the Perth CBD by road and rail.

Table 35 - Trip Length and Transportation Need Matrix, Private Vehicle Trips per Annum - City of Joondalup

Transportation Need	Up to 1km	1.1 to 3km	3.1 to 5km	5.1 to 10km	Over 10 km	Total
Commuting	0.48%	1.52%	1.52%	3.71%	14.76%	22.0%
Education	0.10%	0.38%	0.38%	1.52%	1.62%	4.0%
Shopping	4.19%	7.52%	4.38%	6.48%	5.43%	28.0%
Leisure	2.19%	3.71%	3.43%	7.62%	9.05%	26.0%
Other	3.05%	4.76%	3.33%	4.76%	4.10%	20.0%
Total	10.0%	18.0%	13.0%	24.0%	35.0%	n.a.

(City of Joondalup, 2004)

Summary and Analysis

The following trips should be targeted for behaviour change: -

- Commuting or educational trips less than 1 km in length could be replaced by walking;
- Commuting or educational trips less than 5km in length could be replaced by cycling;

- Commuting or educational trips greater than 5km in length could be replaced by public transportation; and

- Shopping trips made on a more regular basis (reduced quantity of shopping therefore reduced weight) and less than 1 km in length could be replaced by walking.

It is important to note that trip length and transportation need forms the basis of Travel Smart programs across Australia.

3.4 Time Elasticity Theory

This section focuses on the potential impact of differing travel times by transportation mode for the same trip purpose, and whether improvements to public transportation travel times can improve the public transportation mode share relative to vehicular transportation mode share.

Comparison of travel times by mode is important as I believe that current travel times by mode can be used as a benchmark for modal choice.

Objective
To compare average travel times by transportation mode by trip purpose.

Theoretically, if improvements are made which create a positive effect on travel times for a particular transportation mode, then patronage for that travel mode should improve commensurate with the improvement in service, (barring other external factors influencing choice). To counter this, if travel time is extended for a particular mode, then consumers may seek an alternative route or mode.

Motor vehicles are the dominant mode of transportation as they are perceived to provide the greatest flexibility and the fastest way to get to a destination for most trips. State Rail studies have found that public transport is perceived as too slow and unreliable, doesn't meet specific requirements and that seats may not be available. (State Rail NSW, 2002)

Table 36 compares average travel times in minutes for all modes by trip purpose providing a base to assess variations and trends in modal share.

Table 36 - Average Travel Time in Minutes (By Mode, per Purpose - Sydney)

Transport Need	Vehicle Driver	Vehicle Passenger	Train	Bus
Social	21	22	69	41
Shopping	12	15	52	38
Commuting	27	23	62	41
Education / childcare	21	11	63	33
Personal business	17	18	71	39

(New South Wales Transport Data Centre, 1999.)

Summary and Analysis

As described earlier, this table may be considered as a base for re-allocating mode share. Therefore in theory if an infrastructure improvement is prescribed for a bus network along a certain route, resulting in improvements to bus travel time of x%, with other modes unchanged, it is reasonable to assume that the bus network should then attract an increase in patronage of y%. These percentages would change from situation to situation, but I believe this is a reasonable logic to apply when promoting infrastructure improvement projects.

Numerous TravelSmart studies have found that patrons are willing to travel for up to 60 minutes before they begin to consider the use of other transport modes, or indeed look at lifestyle choices such as house location or change of employment. In addition these studies have found that people are willing to wait up to 10 minutes for a journey to commence before they begin to question their choice of transportation mode. Train travel in Sydney's outerlying suburbs exceeds these values, however is seen as a viable peak hour alternative as the

relative difference in journey times between motor vehicle and rail journeys in is minimal. Where frequencies are low it will be difficult to generate reasonable patronage particularly while the balance of public / private infrastructure spending is tilted so heavily in favour of major road infrastructure.

Given that the use of a motor vehicle usually does not generate a perceived ‘dwell’ time, (except for the time taken to park in congested CBD areas) the growth in motor vehicle travel is understandable.

3.5 Price Elasticity Theory

This section discusses the impact of price elasticity theory on the consumers’ choice of transportation mode. The section is broken into price elasticity for public transport usage and price elasticity in petrol usage.

Objective
To quantify the effects of price movements on consumer behaviour.

3.5.1 Price Elasticity for Public Transport Usage

Price elasticity in Sydney for public transport usage is calculated at -0.4 for off-peak trips and -0.1 for peak travel due to differential pricing on the City Rail network. That is a rise of ten per cent in fares will result in a fall of one percent in patronage for peak travel and a fall of 4 percent for off peak travel.

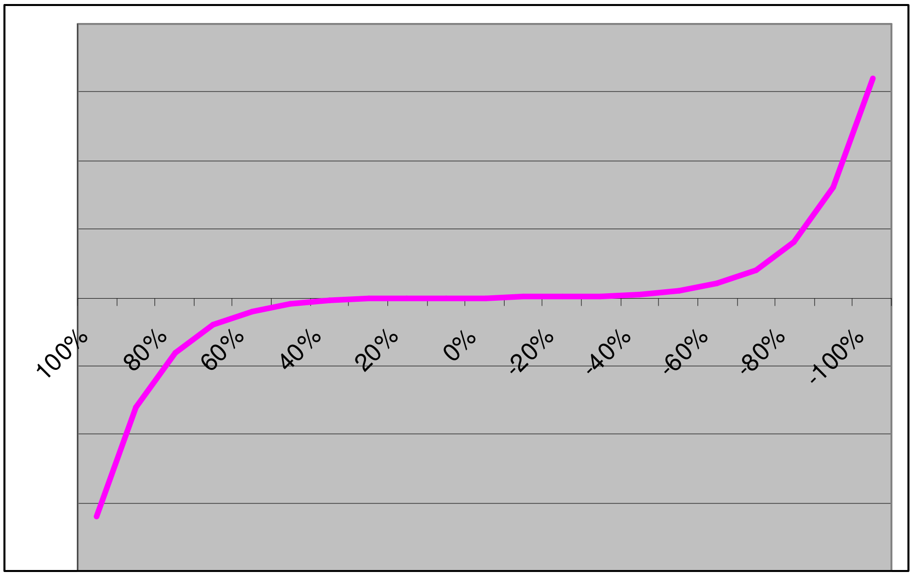
(University of Technology, Sydney 2001.)

I believe these models are simplistic as it suggests an infinite linear relationship. The model should be considered in a quadratic format. As the rise in fares increases, it is reasonable to expect a cumulative effect: -

- As price rises approach infinity, patronage loss approaches 100%; and
- As price reductions approach 100% (i.e. free public transportation), patronage gains approach and exceed system capacity.

Figure 7 shows a theoretical relationship between price and patronage, with price on the vertical and patronage on the horizontal axes.

Figure 7 - Theoretical Cumulative Relationship between Price and Patronage



A similar methodology has been used in Perth. The figure used is -0.3 for all public transport travel up to a 20% increase in fares. A higher rate of increase in fares however would clearly have a significantly greater impact on demand. For example, Socialdata showed that a 50% increase in fares would result in a 50% drop in patronage among standard fare passengers, while among concession passengers the impact on patronage would be only about 24%. The actual impact of a fare increase would depend largely on whether the user is a captive or discretionary traveller.

(Fernando, G. 2003)

3.5.2 Price Elasticity Case Study 1 – Airport Rail Link Sydney Fare Structure

The setting of appropriate fares should be examined for public transport infrastructure, whether the system is in public or private ownership. Recent private infrastructure projects such as the City to Airport rail link in Sydney highlight the acceleration of patronage loss due to inflated pricing.

Patronage on the Airport Link was approximately 20% of the budgeted break-even patronage and after a short running period the network has been managed in Receivership. I believe this is due to the expensive fare structure proposed for the Airport Link. Recent fares are approximately 3 times greater than for a comparative length City Rail journey. Many discretionary travellers have opted to use other forms of transportation. A key market for this rail service is air travellers. However given that it is arguably cheaper and more convenient for two travellers to share a taxi between the CBD and the airport, it is no surprise that patronage is low.

3.5.3 Price Elasticity Case Study 2 – Community Perception of Road Pricing

The recent Cross City and Lane Cove Tunnel projects have attracted negative reactions from the press and the public. The objective for this section is as follows: -

Objective
Is road pricing beginning to have an impact on consumer behaviour, or is perception of the deal structures the primary source of consumer dissatisfaction?

The Sydney Morning Herald ran an article in November 2005, which quoted the following statistics: -

- Financial planning for the tunnel showed a vehicle throughput of 90,000 vehicles a day for the first year;
- In the first few weeks, anecdotal evidence suggested the vehicle throughput was only 20,000-25,000, or approximately 25% of the expected volume.
- After significant public pressure, the New South Wales government and the toll road operator agreed to commence a four week free trial of the toll road. The New South Wales government agreed to provide further

road closures to filter traffic toward the tunnel. Tunnel traffic subsequently rose to around 35,000 in the first week of the free trial period.

(Sydney Morning Herald, 2005)

Continued public pressure and low patronage volumes have seen Cross City Tunnel offer a 50% discount for a 3 month period from the 6th of March 2006 on the full toll to promote further behavioural change. Further anecdotal evidence suggests that tunnel traffic is still around 30,000 vehicles per day.

Negative sentiment towards projects' has been shown to have an impact on customer usage. It appears this is the case with the limited usage of the Cross City Tunnel. It is expected that as consumers forget, or become more accepting of the Cross City tunnel deal that patronage will approach the capacity of the network, however this project is another important lesson for governments in the setting of major infrastructure contracts.

It is important to note in the example of the Cross City Tunnel and the Airport Rail Link in Sydney that price elasticity assumptions and original project cash-flow estimates have been shown to be fundamentally flawed. I believe however the lower than expected patronage is due to both individual choice and the power of group mentality through a concerted media campaign. This theory is discussed in further detail in **Section 3.7 Elliott Wave Theory**.

3.5.4 Economic Accessibility to Transportation Theory

Currently, it is cheaper for three passengers to commute via taxi between Sydney and Brisbane CBD's to their respective airports than to use each cities Airport Link train services. This pricing system is out of kilter with the general public transport fare system in each city due to private ownership. It is also out of kilter with any sensible economic pricing system.

Given this, I believe a reasonable check for fare pricing is to have the fare equivalent to the following formula: -

- A public transportation fare should be 10% of an equivalent Taxi Fare over the same distance.

Therefore, if a taxi fare from the Sydney CBD to the Airport is approximately $25 one-way, then the maximum charge for a public transport fare should be $2.50 for the same start-finish trip.

It is proven through studies that the earning profile of public transportation users is lower than that of motor vehicle and taxi users. As such the fare pricing structures should not be comparable with these methods of travel, as discretionary users will prefer to use more direct, faster and personal modes of travel while captive users of public transportation are often captive due to economic reasons. The exception is during peak periods when congestion and parking price policies dissuade higher socio-economic users and promote alternative modes for journey to work purposes.

Therefore, the higher the public transportation fare when compared to other transportation forms the greater the drop in captive users, (higher fares equals lower affordability) and the greater the drop in discretionary users (lower price savings increase tendency toward personal preference in travel mode.)

3.5.5 Price Elasticity in Petrol Usage

A petrol price survey undertaken by the University of Melbourne Economics Department between 1999 and 2001 suggested a price elasticity of -0.04 for unleaded fuel usage, which translates as: -

- For every 10% rise in the price of unleaded fuel there will be a 0.4% drop in demand.

(Harding, D. 2001)

The recent increase in petrol prices is being shown to have a short term impact upon motor vehicle usage, with anecdotal evidence suggesting some short term behavioural changes. The following key points show the trend: -

- 30% increase in oil prices since early 2004;

- Caltex half year report 2005 / 2006 quotes 1% drop in petrol consumption in the second half of 2005, with a 9.6% drop in premium petrol usage.

(Caltex Australia Petroleum, 2007)

The drop in premium petroleum product sales shows an interesting reaction by consumers who have adjusted their purchasing habits to meet the rising cost of consumption.

The recent 30% increase in fuel costs is considered to be short term, therefore not all consumers have adjusted to the increase in prices and some have made behavioural changes to limit their increased spending, as noted below by The Age / AC Nielsen Research. Their research comprising 1435 households shows: -

- 84% were impacted by the rising cost of petrol;
- 61% were choosing to drive less;
- 57% were trip blending;
- 19% were using public transport more often; and
- 12% avoided peak hour travel.

Andra Jackson Fuel Prices Change Habits – The Age Newspaper 19 June 2006 http://www.theage.com.au/articles/2006/06/19/1150701484831.html

Anecdotal evidence suggests that the recent trend in Brisbane (including an allowance for introduction of an integrated ticketing system and improved services in mid 2004) shows: -

- Patronage on Brisbane Buses in 2004 / 2005 rose 10.5%; and
- Bus use in the year to Dec 2005 grew by 13.7%.

Anecdotal evidence in Sydney suggests that the patronage gains have not been as large, however there has been a positive impact: -

- Rail patronage has increased by approx 100,000 per week in the first months of 2006 representing an increase of approximately 2% on 2004 / 2005 figures; and (check latest figures)

- Strong recent growth on Sydney Buses (up to 5,000 additional patrons per day in 2006).

(Dodson, J. & Sipe, N. 2006)

It is important to note that the AC Nielsen study was conducted online as part of a global study of over 23,000 people. The increase in public transport usage was quoted as the fourth-lowest in the Asia Pacific region; however I believe it is difficult to compare countries within the region due to the variations in standard of living conditions, travel habits and a number of other factors.

The key is whether these short term changes to long term transportation mode choice can be sustained in the longer term. Some theories suggest that longer term behaviour trends may inevitably lead back to increasing motor vehicle usage, either through reduced trip making, purchase of smaller / more fuel efficient vehicles or similar as consumers become accustomed to the new pricing. As such, pricing alone should not be used as a mechanism to deter a particular mode of travel unless improvements to alternative service capacity, accessibility and frequency are made in conjunction. The potential exists however for long term behaviour changes toward public transport to develop, particularly if governments can provide additional stimuli such as new infrastructure, congestion pricing mechanisms and technological advancements in priority.

3.6 Maslow's Hierarchy of Needs

The objective of this section is as follows: -

Objective
To adapt Maslow's Hierarchy of Needs to transportation mode choice.

Maslow's Hierarchy of Needs is a theory of psychology that Abraham Maslow proposed in his 1943 paper "A Theory of Human Motivation." Maslow's Hierarchy is depicted as a pyramid consisting of five levels as shown in Figure 8: -

- The four lower levels are grouped together as **deficiency needs** (needs which must be met); and
- The top level is the **growth need** (a need which shapes our behaviour).

Figure 8 – Maslow's Hierarchy of Needs

To compare and adapt Maslow's Hierarchy of Needs to transportation modal choice, it is important to understand the levels within the pyramid as originally intended and why each level is placed in its nominated order. The pyramid is made up of the following requirements for human survival: -

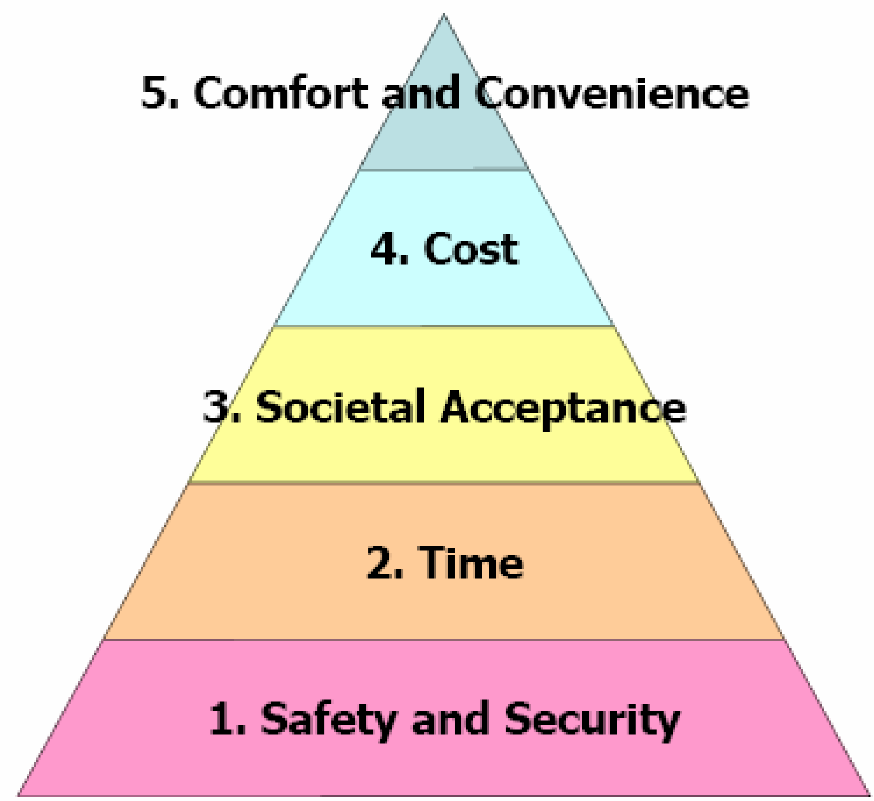
- Stage 1 – Physiological Needs. These are the basic human needs for survival, such as clean air, water and food, a sanitary disposal system and the ability to regulate temperature.
- Stage 2 – Safety Needs. This is the second element required for advancement of the human form. This includes provision of shelter and the base need to feel safe.
- Stage 3 – Love / Belonging Needs. This third element in human development is the family and society basis for human interaction.
- Stage 4 – Esteem. This fourth element is an extension of love and belonging and recognises human capability in the form of understanding that we have a worthwhile place in society (pride and self esteem).
- Stage 5 – Actualization. This final element is the human growth factor, where all of the base needs are met and behavioural instincts are formed, developed and honed through personal preferences.

The base philosophy is that 'needs' in the higher levels can only be met if the needs in the previous stages (below) are fully provided for.

3.6.1 Winters' and Tucker's Adaptation of Maslow's Hierarchy of Needs for Transportation

Winters and Tucker theorised that Maslow's Hierarchy of Needs could be adapted to show the needs of public transport users, refer Figure 9.

Figure 9 - Maslow's Hierarchy of Needs (Adaptation for Transport Mode Use by Winters' and Tucker)



(Winters P.L. & Tucker L.E. 2004)

The Winters' and Tucker Hierarchy places safety and security as the base need, with time of travel, societal acceptance, cost of transportation and comfort and convenience as the hierarchical order.

Table 37 provides a comparison of the basic descriptors of each need within Maslow's Hierarchy with the adapted hierarchy for transportation as theorised by Winters' and Tucker.

Table 37 - Comparison of Maslow's and Winters' & Tucker's Hierarchies of Needs

Maslow's Hierarchy Descriptors	Winters' & Tucker Hierarchy Descriptors
1. Basic need for survival	1. Safety and Security
2. Need to feel safe	2. Time
3. Need to feel loved	3. Societal Acceptance
4. Need to feel justified	4. Cost
5. Development of self preferences and potential for behaviour change.	5. Comfort and Convenience

I believe the theory of adapting Maslow's Hierarchy of Needs to a Transportation Hierarchy of Needs is an excellent one. It is important to understand why people travel and why people make mode choices. The development of a hierarchy is a succinct way to encapsulate the requirements for mode choice.

3.6.2 Kleyweg's Adaptation of Maslow's Hierarchy of Needs for Transportation

I believe the theory modified by Winters and Tucker has merit and is worthy of consideration. However, I believe this theory can be enhanced and improved.

As such, I propose the following amendments to the transportation mode choice hierarchy of needs: -

Table 38 – Maslow's Hierarchy of Descriptors and Development of Alternative Transport Mode Choice Hierarchy

Maslow's Hierarchy Descriptors	Kleyweg Descriptors
1. Basic need for survival	1. Basic need for transportation.
2. Need to feel safe	2. Need to feel safe
3. Need to feel loved	3. Need to feel comfortable
4. Need to feel justified	4. Need to feel justified
5. Development of self preferences and potential for behaviour change.	5. Development of self preferences and potential for behavioural change.

The purpose of the above table is to provide a match between the intent of Maslow's Hierarchy of Needs and an adapted Transportation Hierarchy of Needs. From this table, I propose the following hierarchy: -

- **Stage 1 - Accessibility**. For a transportation mode to be considered a reasonable choice it must exist and it must be accessible. Accessibility includes: -
    - Is the nearest stop within a walkable distance for me;
    - Is there sufficient car parking if it is a major park and ride stop;
    - Is there a suitable frequency of service;
    - Does the customers' socio-economic status dictate accessibility to transport options; and
    - Is a particular mode of transportation difficult to access if the customer has a pram/ is carrying shopping/ is elderly or disabled etc.

- **Stage 2 – Safety**. For exactly the same reasons as Maslow's Hierarchy, safety is a key reason for transport mode choice which has been nominated in a number of studies citing methods to improve transportation services. It is difficult to justify the use of a transportation mode on a longer term basis if you feel unsafe using it.

- **Stage 3 – Comfort.** Maslow's requirement for feeling loved cannot be fully met by using an inanimate object such as a transportation mode; however the feeling of comfort, once we realise that we are safe, is important. Over-crowding of services, service cancellation, not having a seat, travel too slow in comparison to other modes etc are prime reasons for mode change in 'discretionary' travel.

- **Stage 4 – Price Elasticity**. The justification for use is the comparison of the relative cost of transportation modes and consumer sensitivities to moderate price fluctuations. This is the final **deficiency need** in the Transportation Hierarchy of Needs. Movements in price are shown to have an impact on patronage rates of public transport, and have recently been shown to have an effect on motor vehicle usage. Major price fluctuations however may bring a consumer back to the Accessibility stage if they can no longer afford a transportation mode.

- **Stage 5 – Behavioural Change**. This is the transportation version of the **growth need**. Once all of the preceding needs have been met, the only method to encourage increased usage is to promote behavioural change. This stage sums up the potential within each consumer to accept change to their behaviour.

Figure 10 – Maslow's Hierarchy of Needs, Adapted for Transportation by Kleyweg

The purpose of the adapted Maslow's Hierarchy is to highlight the five most important basic elements which have the capacity to improve public transportation patronage. **Where projects can incorporate improvements in all five areas, the gains in patronage will arguably be the greatest.**

3.7 Elliott Wave Theory – Variations in Human Behaviour due to External Factors

It is reasonable to assume that the general trends shown in Section 2.1 show increasing motor vehicle usage and increasing motor vehicle mode share at the expense of alternative transportation modes. However, I believe this is a simplistic representation of the trend.

To develop methodologies to improve public transportation patronage it is important to translate historical data into graph form and to delineate past trends and cyclical fluctuations; and to assess whether these trends and

fluctuations were affected by external factors. This provides the opportunity to reverse the trend of declining public transportation mode share in the longer term through understanding which variables influence behaviour change.

In Section 3.5 I developed a Maslow's Hierarchy of Needs adapted for transportation modal share. In summary, the decision to use a form of transportation was described as a human decision influenced by: -

- Accessibility (in terms of number of transport options and proximity to / affordability of public transport);
- Safety and Security (whether we feel safe using a particular form of transportation, and which mode makes us feel "safer";
- Comfort (whether we have access to a seat when we want one, condition of the vehicles we are using etc);
- Price Elasticity (impact of external forces economic / market conditions, provision of infrastructure); and
- How open we are to behavioural change (Individual preferences).

I believe it is reasonable to suggest that the reasons for shifts in mode choice are not random or chaotic, but they are in fact **a response to changing conditions and how these changes impact upon each person's behaviour both individually and as part of a group**.

In terms of data collation I am interested in the following: -

- Are there repetitions or discernible patterns / trends in long-term patronage cycles;
- Are these repetitions, patterns or trends linked to certain repetitive external conditions; and

- Does history repeat itself and offer opportunities to understand why modal choice changes, and in particular, can we use graphical analysis as a predictor of upcoming behavioural changes?

One area of study in the financial sector is focussed on developing an understanding of past performance and linking repetitive cycles in financial markets to predict potential future performance. The common thread between understanding transportation modal choice and financial market behaviour is **the predictability or unpredictability of human behaviour**.

Objective
Can we use graphical analysis as a predictor of upcoming behavioural changes?

3.7.1 Elliott Wave Theory - Definition

Ralph Nelson Elliott developed the Elliott Wave Theory in the late 1920's. Its purpose was to examine potential cycles within data sets and uses past behaviour cycles to track future potential (identification of relationships that repeat infinitely).

The theory worked on the premise that stock markets did not behave in a chaotic manner as was previously thought - they traded in repetitive cycles, which he theorised was due to the emotions of investors as a cause of outside influences or the predominant psychology of the masses at the time. Elliott stated that the upward and downward swings of the mass psychology always showed up in the same repetitive patterns, which were then divided into patterns he termed "waves".

The interpretation of the Elliott Wave Theory is as follows: -

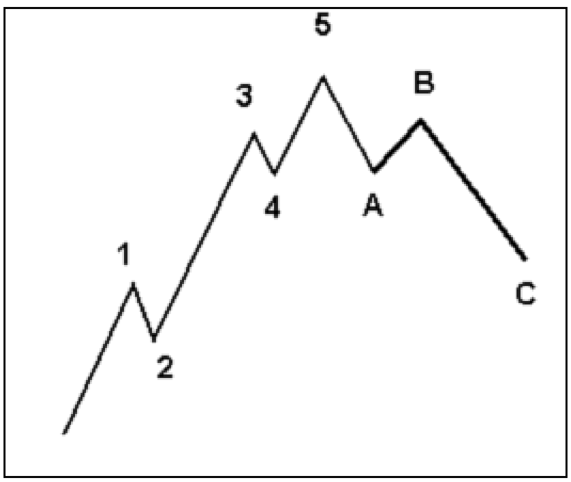
- Every action is followed by a reaction;
- There are five waves in the direction of the main trend followed by three corrective waves (a "5-3" move);

- A 5-3 move completes a cycle; and
- The underlying 5-3 pattern remains constant, though the time span of each may vary.

While a perfect 5-3 cycle does not occur in every graph, the premise that transportation patronage and stock market performance are products of human behaviour and human reaction to external events is one which, I believe has merit.

Figure 11 shows the theoretical Elliott Wave cycle in full.

Figure 11 - Elliott Wave Theory, Full Cycle



This figure shows the cycle in full from commencement of an accumulation trend, (points 1 to 5) to completion of the regression trend, (points A to C) signifying the completion of a full Elliott Wave cycle.

The following figures introduce the upper and lower bound trend lines.

Figure 12 - Elliott Wave Theory, Accumulation Phase

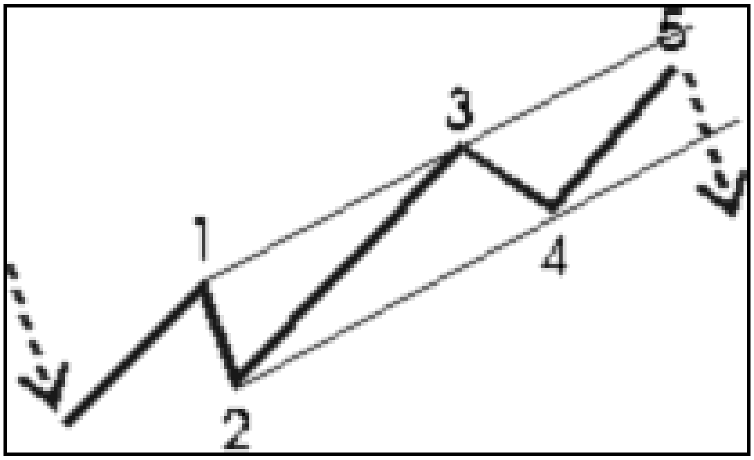
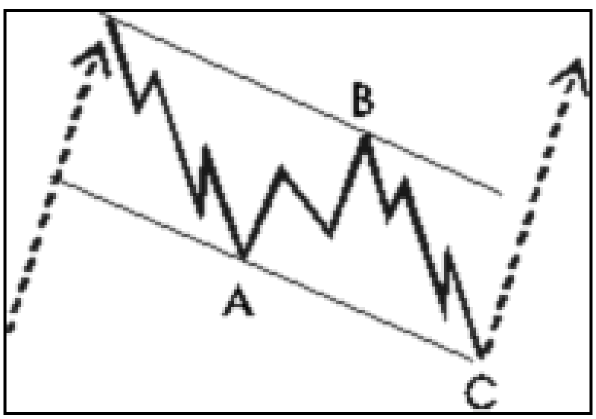


Figure 13 shows the first phase of the Elliott Wave Theory, the accumulation phase. In this phase, (points 1 to 5) a positive linear growth is maintained within the upper and lower bound trend lines.

Figure 13 - Elliott Wave Theory, Regression Phase



The second half of the Elliott Wave is the regression phase. The general trend is represented by the upper and lower bound trend lines between points A and C.

The following is an explanation of how the upper and lower bound trend lines are used in analysis of the graph: -

- Variations within the upper and lower bound trend lines are **short term behavioural responses** to external events which are predicted within the overall trend; and
- Variations which break the upper and lower bound trend lines are **long term behavioural responses** to external events and signify the commencement of a new trend.

I believe that these short term behavioural responses are normal shifts in sentiment due to individual choice or individual decision making.

3.7.2 Elliott Wave Theory and Transportation Statistics

Earlier in this Thesis, I collated research that showed recent changes in public transport patronage were due to behavioural changes to external events: -

- The sharp upturn in public transport in 2000 in Sydney was primarily due to expanding jobs growth in the Sydney CBD, urban consolidation and strong economic conditions through the late ‘90’s and the campaign by the NSW Government to promote the use of public transport during and around the Olympics, coupled with concern that there would be major traffic congestion;
- The marked decline in public transport usage since 2000 in Sydney due to high levels of customer dissatisfaction and poor performance of the City Rail network has led to continuing losses of rail patronage in real terms over the last 5 years; and
- The positive marketing and infrastructure improvements in Perth since 2000 are providing the impetus for strong patronage growth from a low base and limiting the rate of decline in modal share in both bus and rail.

Therefore, if we provide an infrastructure improvement which is accessible to consumers, there is an opportunity for positive behavioural changes. Countering this, if infrastructure is not maintained to support natural patronage

growth and service reliability drops, there is an opportunity for negative behavioural changes.

3.7.3 Examples of External Impacts upon Human Behaviour

The purpose of a graphical representation is to visualise patronage patterns and to associate external factors to those patterns which have influenced human behaviour. An example of a major external event is the electrification of the Perth rail network and the construction of the Perth to Currambine rail service in 1991 and 1993. Within 5 years, rail patronage in Perth moved from 8 million to 28 million boardings per annum.

Table 39 provides a list of potential influences upon consumer behaviour and mode choice.

Table 39 - Potential External Impacts upon Consumer Behaviour

Positive Impact for Public Transport	Negative Impact for Public Transport
New Public Transport Infrastructure (i.e. Rail, Light Rail, Bus Lanes)	New Road Infrastructure – induced demand may create more vehicle journeys.
Positive Advertising Campaign promoting public transport usage (i.e. Travel Smart)	Negative press due to safety, timeliness and general performance coupled with high customer dissatisfaction.
Maintenance of Public Transport fares at or below the rate of CPI	Increase in public transport fares at a rate greater than CPI
Significant increase in oil prices, taxation or road pricing.	Decrease in oil price, government subsidies to minimise impact of higher oil prices on end consumer.

The above are a representative sample of potential influences and are not intended to be an exhaustive list. It is important to note that these impacts work in two ways on human behaviour: -

- Influencing behaviour at the individual level; and
- Influencing behaviour at the mass-market or group level.

Factors which influence group level human behaviour obviously have a greater impact and these are usually shown as changes in trend behaviour. The reason for testing Elliott Wave Theory is to assess cyclical movements in patronage which may not be due to major external events.

The following case studies test patronage trends against Elliott Wave Theory.

3.7.4 Case Study No 1 – City Rail Patronage Figures (1980 to 2004)

Figure 14 shows long term City Rail trends for rail patronage growth between 1980 and 2005 tested against Elliott Wave Theory. The 5 point trend line is clearly evident in the patronage data.

Figure 14 - City Rail Patronage Trend (1980 / 1981 to 2004 / 2005)

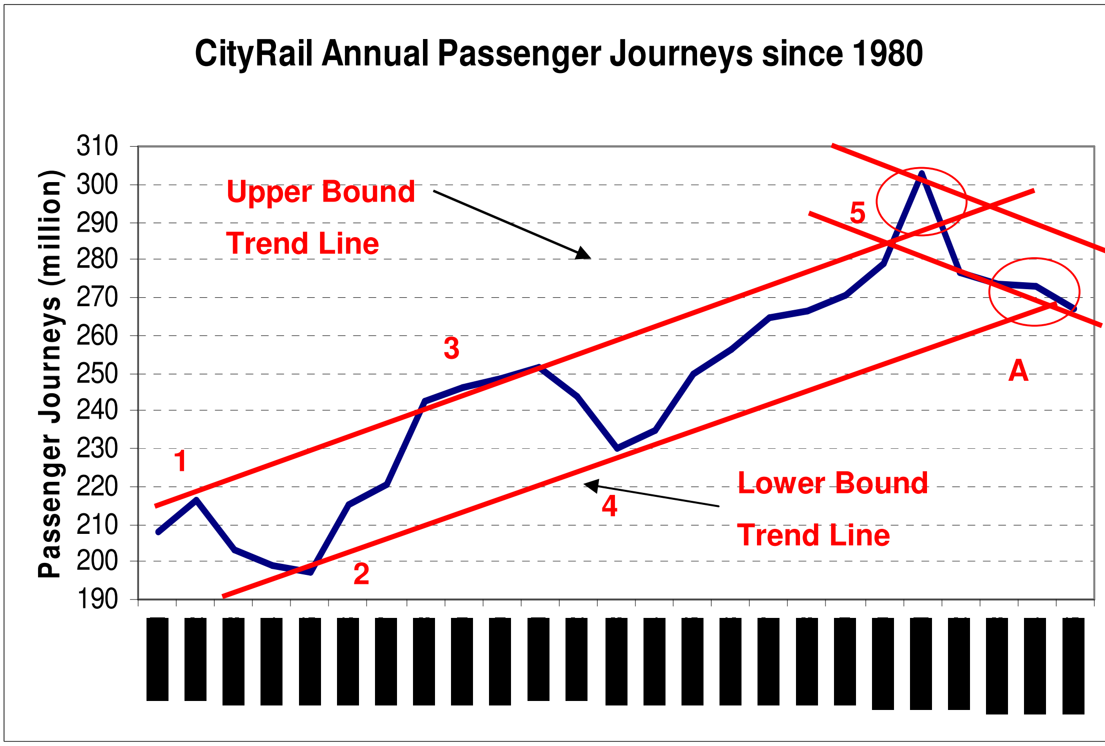


Figure 14 shows an almost perfect Elliott Wave from 1980 to 2005. Key points on the wave include: -

1. 1981 / 1982 patronage approaches the upper trend line at around 217 million passenger journeys;
2. 1984 /1985 patronage dips under 200 million creating the first lower bound point;
3. Sharp rises in patronage to 1987 / 1988 underpinned by strong economic conditions to approximately 242 million passenger journeys. This is the second point on the upper bound trend and provides a linear relationship between points 1 and 3;
4. Patronage retraces to 230 million in 1992 / 1993 creating the second point on the lower bound. The lower bound and upper bound linear trends are almost perfectly parallel;

5. The Sydney Olympics provides the impetus for a break slightly above the trend line in 2000 / 2001. Extension of the upper bound linear trend line shows a strong correlation; and

A. Record low customer satisfaction levels and lack of new infrastructure to meet growing residential catchments results in sharp drops in patronage.

The City Rail patronage graph shows a ‘perfect textbook’ accumulation phase, with the commencement of a regression phase in 2001 in response to major over-crowding and timetable issues. The following three points are the key outcomes from this graph and analysis: -

- The variations in the trend between points 1 and 2, 2 and 3 etc are short term behavioural responses to external conditions on an individual choice level. These responses are due to changes in accessibility, changes in travel needs, general changes in economic cycles etc;
- The break in the trend at point 5 is a positive major external impact (Olympic Games); and
- The commencement of the regression phase at point A is a negative major external impact (reduced on-time running and system approaching capacity).

New rail infrastructure has not been provided in growing regions to meet the pace of population growth; therefore rail patronage will not keep pace with population growth across the Greater Sydney Metropolitan region. To commence a new accumulation phase, new infrastructure is required which will meet the latent demand of the newly serviced population.

The assumption of latent demand for a transportation mode is a reasonable one. As populations grow, the use of each transportation mode increases, (albeit at varying rates). Due to variations in accessibility and mobility, there are captive users for all transportation modes. These users have an underlying preference to travel on a particular transportation mode, without consideration of short term impacts. This provides the latent demand when infrastructure is

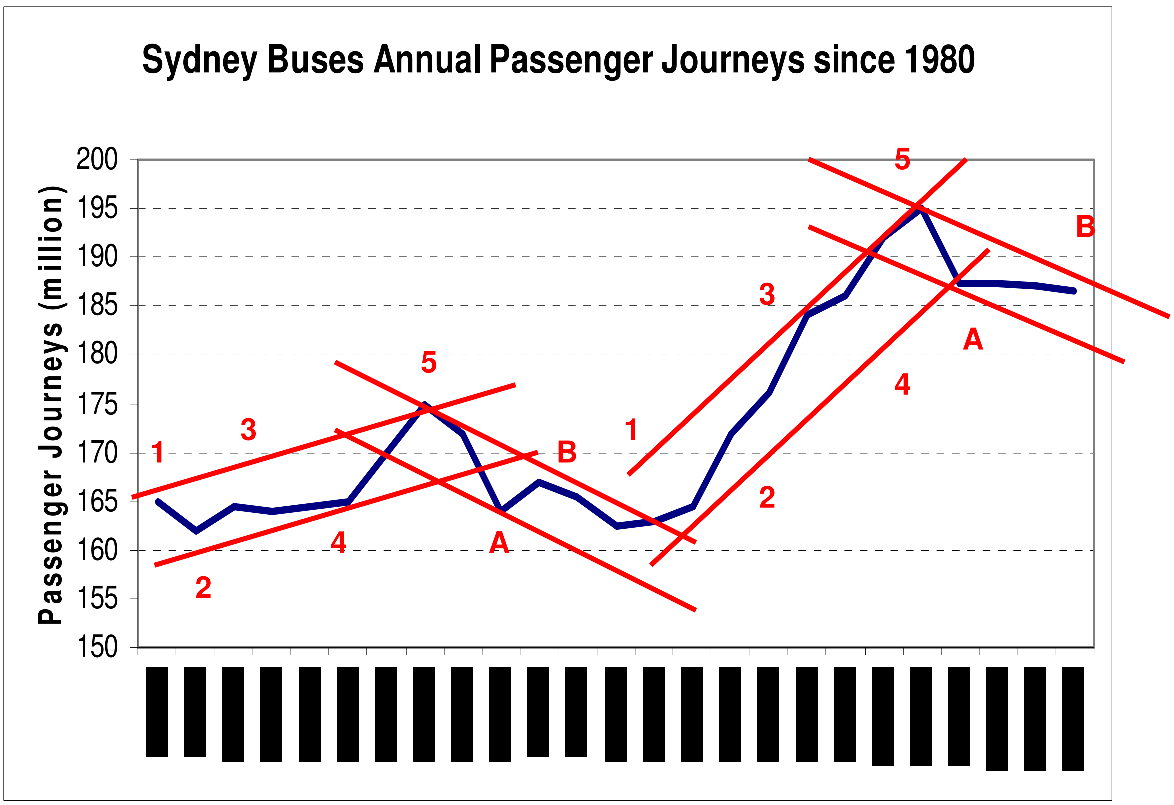
expanded into new regions. Discretionary users, (those with greater access to alternative transport modes) are more likely to be impacted by short term factors or improvements in travel times / services / comfort / safety etc.

In summary future patronage in Sydney will remain flat with yearly variations showing nominal positive and / or negative growth based on the market influences of the time, until a sustained effort is made to improve the provision of services and to improve the public perception of the services provided.

3.7.5 Case Study No 2 – Sydney Buses Patronage Figures (1980 to 2005)

Figure 15 shows long term Sydney Buses trends for bus patronage growth between 1980 and 2005 tested against Elliott Wave Theory.

Figure 15 - Sydney Buses Patronage Trend (1980 / 1981 to 2004 / 2005)



The above graph shows two full Elliott Wave cycles complete with accumulation and regression phases highlighting changes in behaviour over the 25 year study period. While the waves are not technically perfect when compared to the City Rail example, the general trends remain with both cycles showing a five point accumulation and three point regression trend.

I believe the graph highlights that bus patronage is more sensitive to negative consumer sentiment: -

- The negative user sentiment associated with the City Rail service has a flow-on effect to other public transport modes, due to loss of passengers using bus to train and due to loss of patronage on public transport in general; and

- Buses in Sydney have a higher ‘discretionary’ component than train as transportation mode.

This final statement is backed up by Transport Data Centre Research which shows that the average earning power of public transport users in Sydney is higher for train users.

Strong growth between 1993 and 2000 is due to provision of new, more comfortable buses, more direct routes and the commencement of a number of bus priority programs. The drop after 2000 is a combination of peak patronage due to the Olympics in 2000 and a short term reversal in investment into the bus system.

I believe the changes in patronage show classic reactionary decision making: -

- When trends are positive, governments focus on other problems as they believe the issues have been “fixed”; and

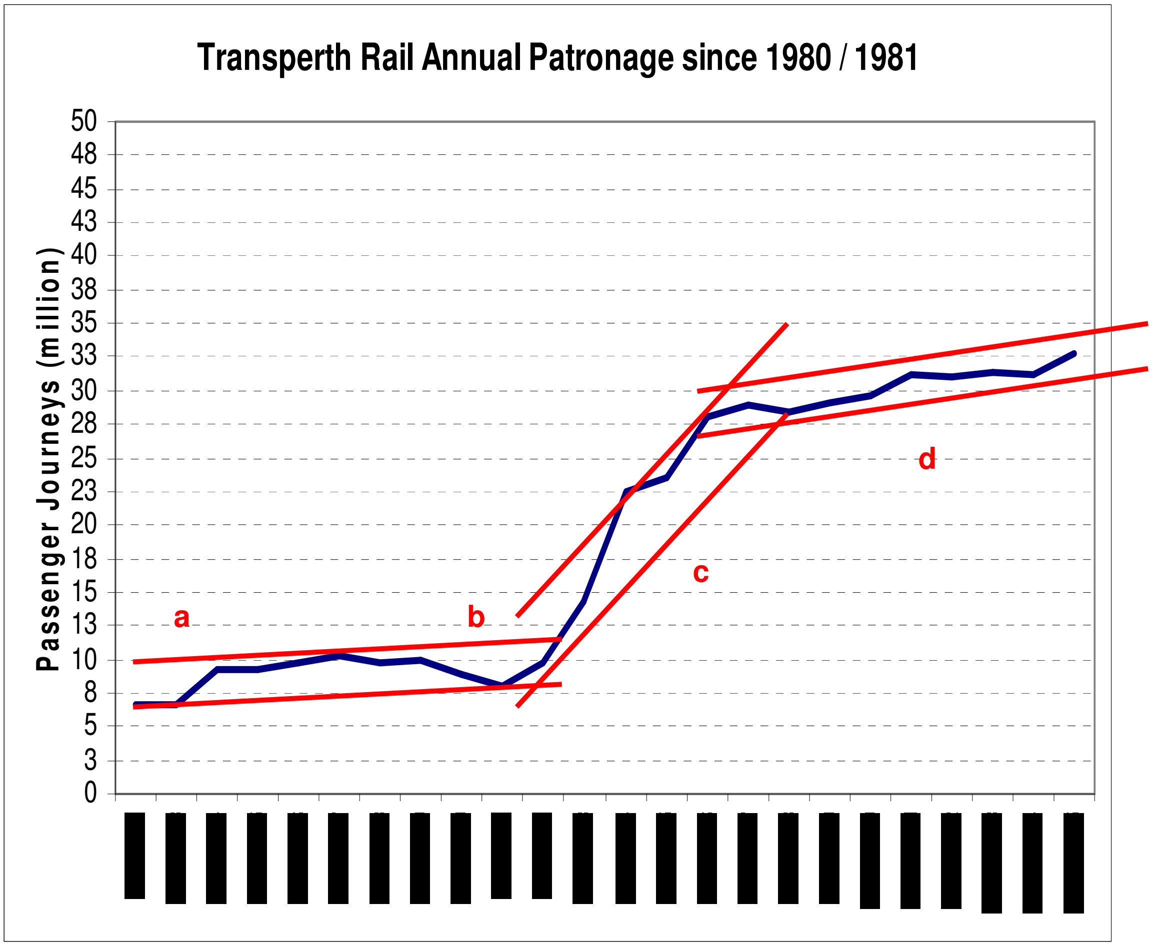
- When the trend is negative and the issue becomes a political necessity, the next round of infrastructure spending is committed.

Apart from this being a reactionary approach, I believe that there is an impact on latent demand due to the failure to maintain infrastructure services to meet population growth. I believe that each completed Elliott Wave cycle equates to a drop in latent demand for public transportation and an increase in latent demand for motor vehicle usage as consumers have a tendency toward motor vehicle travel.

3.7.6 Case Study No 3 – Perth Train Patronage, 1980 to 2004

Case Study 3 examines the trend of rail patronage in Perth over the same time period. Figure 16 shows the patronage trends on the Westrail system over the last 25 years. There is a lack of similarity between the Westrail and City Rail trends.

Figure 16 – Perth Westrail Patronage Trend, (1980 / 1981 to 2004 / 2005)



(Patronage data obtained via email from PTA staff)

There are strong correlations between the trends shown and the principles of Elliott Wave Theory.

There are two periods of nominal growth between 1981 / 1982 and 1990 / 1991 and between 1995 / 1996 and 2004 / 2005. The following historical events are depicted by the letters on the figure: -

a. Perth to Fremantle rail services resumed in 1993 resulting in an immediate improvement in capacity and therefore patronage;

b. Rail electrification program of existing services were completed in 1991 / 1992;

c. Perth to Joondalup rail services commenced in 1992 / 1993; and

d. In response to slowing growth, five car rail sets were introduced in 1998 / 1999 improving capacity.

Prior to 1981 the trend for rail patronage was poor, with a graphical trend similar to Sydney Rail's post 2000 trend. Patronage trends in Perth had shown a steady decline from 1974. The government of the time ceased operation of the Perth to Fremantle rail line in 1979 / 1980 as a response. A change of government saw a return of rail services in 1982 / 1983, however because the rail network had not been maintained to optimum levels over an extended period, patronage gains were limited until major programs were undertaken in the early 1990's to electrify the system, add capacity to the network through the additional northern suburbs route and the delivery of new, higher capacity rail car sets.

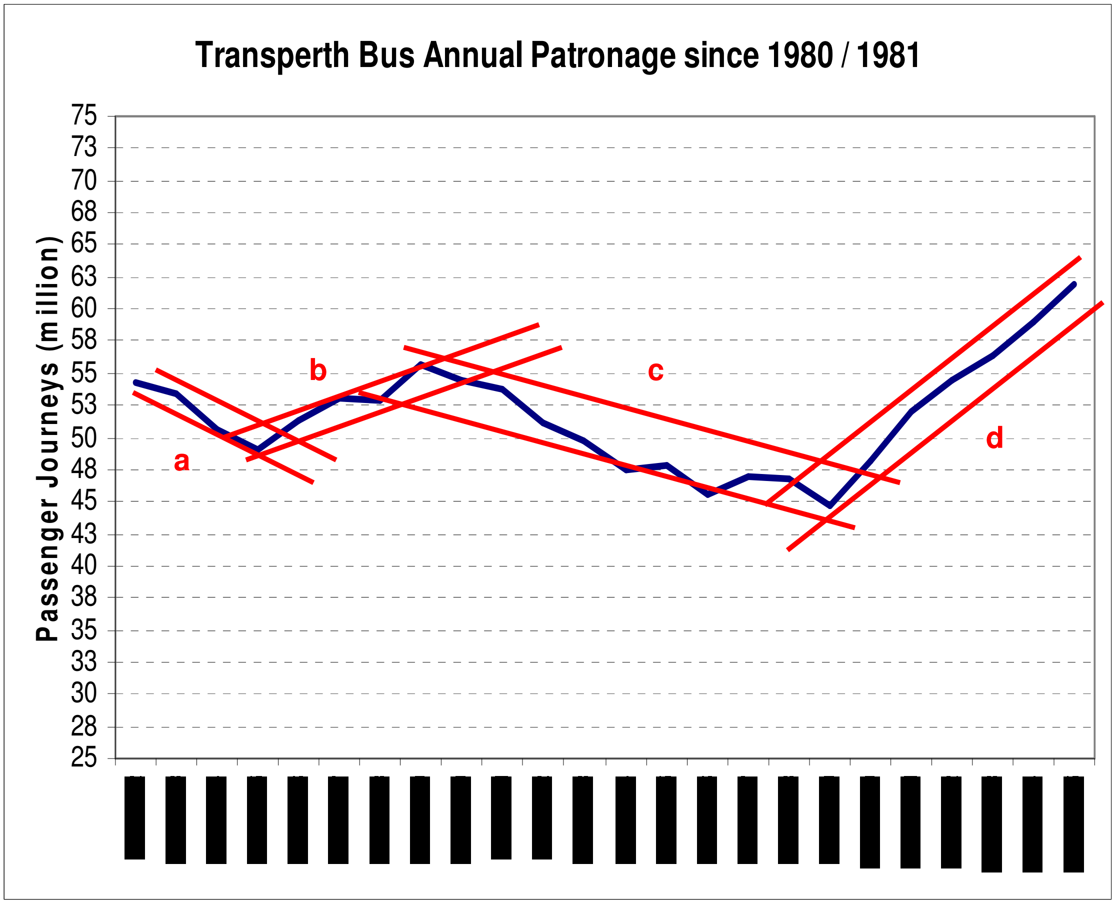
The strong growth between 1991 and 1996 is a result of new infrastructure providing the catalyst for behaviour change. A similar result can be expected when the Perth to Mandurah route is added to the network.

The continued growth between 1996 and 2005 shows an underlying trend for continued patronage growth. This comes from a positive consumer response to public transport service quality and meeting latent demand in new regions through the provision of infrastructure and service improvements on a regular basis. This has been the key difference between the City Rail and Westrail networks.

3.7.7 Case Study No 4 – Transperth Bus Patronage, (1980 / 1981 to 2004 / 2005)

Case study number 4 examines Transperth bus patronage between 1980 and 2005. Figure 17 shows the historical trend.

Figure 17 - Transperth Patronage Trend, (1980 / 1981 to 2004 / 2005)



The first point of interest is the similarity between the Transperth trend line and the Sydney Buses trend. There are two full Elliott Wave cycles in comparison to the one cycle for the rail network over the same time period. This provides further confirmation of the bus networks sensitivity to external factors.

The trend lines for the Transperth system make an interesting comparison to the Westrail network trend. The following notes pertain to the regression and accumulation phases as denoted by the letters on the graph: -

a. Linear regression between 1981 and 1983 coinciding with loss of Fremantle Rail – therefore negative public perception of rail impacts other public transport. (Similar behavioural change to 2001 to 2005 in Sydney);

b. Strong growth in bus travel between 1984 and 1989 coinciding with strong economic growth, America's Cup in 1986 in Fremantle and commencement of Free Transit Zone in 1989. Cycles a) and b) represent a full Elliott Wave;

c. 10 year regression between 1989 and 1999. Contracting of bus services announced in 1995, however not fully implemented until 1998 / 1999. Perth CAT service introduced in 1996 / 1997, funded by parking levies in the City of Perth. Some loss of bus patronage to increased rail usage from 1992 / 1993; and

d. Strong linear growth in bus patronage due to improved high frequency express services catering for am and pm peak commuter travel and replacement of older buses with newer stock. Cycles c) and d) represent the second full Elliott Wave.

Strong growth since 1999 has been delivered through the success of peak express services and multi-use services such as the Circle Route delivering strong growth. Future growth in patronage is expected when the Perth to Mandurah rail service commences in 2007 with increased patronage for bus to rail trips and redeployment of bus services to new regions.

Three case studies have been included from the United Kingdom to further examine the theory of using Elliott Wave as a tool to assess changes in patronage trends.

3.8 Behaviour Adaptation Theory

Accessibility to transportation options forms the basis of behavioural change methodologies. This theory underpins behavioural change programs such as Travel Smart, where respondents are asked to consider: -

- Combining or 'blending' trips. For example a journey home from work could be used to pick up the evening groceries. Trip blending may tend to be greater for customers with limited access to transportation.

Customers with greater accessibility to transportation therefore have increased flexibility to undertake trips at times of their choosing;

- Changing one vehicle journey per week or per day to alternative modes of transport such as bus, rail, cycling or walking; and
- Considering the health implications of a particular mode of travel, and considering mode changes to promote improved health and lifestyle benefits (i.e. increased walking and cycling).

Travel Smart programs effectively get respondents to consider their access to all forms of transport and to consider not being reliant upon their vehicles for all travel purposes, **i.e. it requests users to consider adaptation of other transportation modes by consideration**. This theory re-introduces two primary levels of transportation accessibility, namely ‘captive’ and ‘discretionary’ travel.

- Captive travel relates to essential travel for a person to undertake their daily, weekly or other periodical routines (needs); and
- Discretionary travel relates to non-essential travel (wants).

The theory of accessibility suggests that consumers from lower socio-economic sections of the community undertake less discretionary travel and may be more likely to generate a greater percentage of alternative modal use.

3.9 Public Transport Patronage Increases Through Transportation Behavioural Science Methodology

Public transport patronage has been shown to grow through the provision of a wide range of improvements. Greater improvements tend to occur where improvement mechanisms are combined and where measures are proactive and not reactionary– this is a holistic approach to transportation patronage improvement.

Objective
To provide examples where public transport patronage has increased through either infrastructure improvement, behaviour change or some external event.

Table 40 provides examples of infrastructure improvements which have led to growth in public transport patronage. The infrastructure improvement is compared to Maslow's Hierarchy of Needs as adopted for transportation in Section 2.3.4.

These examples have been quoted elsewhere throughout this research.

Table 40 - Examples of Public Transport Patronage Increases

Infrastructure Improvement	Maslow's Hierarchy (Adopted for Transportation) Need	Examples of Patronage Improvements
Improved route frequencies	Accessibility	Route 800 and 900 series buses in Perth replacing some 100 and 200 series Routes. Over **10% improvements** in patronage on some routes within 6 months.
Improved travel times through the provision of express or more direct routes	Accessibility	

New or dedicated public transport infrastructure	Accessibility and Comfort	Perth to Joondalup rail service – **100,000 patrons per day.**
	Comfort	Sydney Harbour Bridge Bus Lanes – carries more people in AM peak than all other lanes combined.
Improved safety and accessibility to services	Accessibility, Safety and Security and Comfort	Upgraded railway station infrastructure at Oats Street Interchange has resulted in **patronage gains of up to 20%** in the first year of use.
	Accessibility, Safety and Security and Comfort	Upgraded railway station infrastructure and integrating surrounding land uses at Subiaco interchange has resulted in **patronage gains of up to 80%** over the first year of use.
Improved comfort in journey	Comfort and Price Elasticity	Provision of new fleet of buses in London from around 2001 delivered **growth in patronage of up to 33%** (coupled with congestion pricing scheme)
Technologies promoting travel times improvements	Accessibility and Behaviour Change	Provision of integrated ticketing systems in Brisbane – forthcoming systems in Sydney and Perth should also deliver patronage benefits

Price elasticity movements	Price Elasticity	Recent significant rises in petrol prices (approximately 30%) have delivered anecdotal patronage increases.
Behaviour change programs	Behaviour Change	Targeted TravelSmart programs in the City of South Perth, Town of Cambridge and other areas have resulted in **increases in public transport usage of at least 20%** in the first year.

4. TRANSPORTATION INFRASTRUCTURE ENGINEERING METHODOLOGY

This research proposes two key areas where public transportation mode share can be increased, namely through the understanding of behavioural science methodologies and engineering infrastructure methodologies. This section focuses on understanding how the provision of engineering infrastructure can enhance the growth of public transportation patronage and mode choice.

The key objectives in this section are to define Transportation Infrastructure Engineering methodologies in terms of the following objectives: -

Objectives

1. To discuss how engineering infrastructure provision can impact transportation modal choice, in both the short term (reactionary behaviour) and the longer term (disposition behaviour) in terms of the adapted Maslow's Hierarchy of Needs for transportation.

2. To discuss infrastructure measures which improve accessibility to public transport.

3. To discuss infrastructure measures which improve travel time.

4. To discuss infrastructure measures which improve comfort, convenience and safety.

5. To discuss infrastructure measures which assist in the delivery of behaviour change.

6. To discuss active signal bus priority methodologies.

7. To discuss passive infrastructure bus priority methodologies.

8. To provide some examples where engineering infrastructure based programmes have resulted in an increase in public transportation

patronage.

4.1 Engineering Infrastructure Impacts Transportation Mode Choice

Similar to the behavioural change methodologies discussed in Section 3, engineering infrastructure methodologies should be examined in the context of their impacts upon two forms of human behaviour: -

- short term, or "reactionary" behaviour; and
- long term, or "disposition" behaviour.

The objective for this section is: -

Objective
To document the measures required to increase public transport use.

In Section 3.6 Maslow's Hierarchy of Needs was adapted to suit the transportation modal choice context. The five key elements of transportation modal choice were shown to include: -

- Accessibility;
- Travel time;
- Comfort, convenience and safety, (including provision of real time information and variable messages);
- Price elasticity; and
- Provision and dissemination of useful information to promote behaviour change.

These key elements impact our decisions regarding mode choice. Table 41 associates the above key factors for transportation mode choice behaviour in terms of whether they impact on individual level, group level, or both.

Table 41 - Engineering Infrastructure Methodologies and Their Impact on Individual and Group Decision Making

Individual Decision Making Theories	Group Decision Making Theories
Accessibility	**Accessibility**
Travel Time Improvement	**Comfort, Convenience and Safety**
Comfort, Convenience and Safety	**Infrastructure Pricing / Price Elasticity**
Infrastructure Pricing / Price Elasticity	
Information - Behaviour Adaptation Theory	

The key factor regarding infrastructure provision is the first item, accessibility. The lack of accessibility to transportation options in new suburban developments is shown to have a strong correlation to high motor vehicle usage. As such, accessibility (or lack thereof) can impact transportation mode choice at both individual level and at group or suburban level.

I believe the key opportunity for engineering and infrastructure provision is to **improve access to, and travel times** of public transport.

Assessing measures to increase public transport usage begins with understanding public transportation services and how they are delivered.

4.1.1 Road Capacity and Hierarchy

The development of liveable neighbourhoods requires inter-connecting urban communities, employment generating land, education precincts, shopping and other recreational land uses. A general understanding of road capacity and

hierarchy, to suit the expected traffic generated and to cater for alternative modes of transport assists this goal.

Road capacity is determined in the following terms: -

- Vehicles per day (vpd)

The vehicles' per day (or vpd) measurement is a manually collected measurement of the number of vehicles utilising a precise location within a roadway or intersection. These measurements are taken over a full 24 hour period, and are usually taken over a full week to enable a peak or maximum daily value to be found. The maximum daily value is then adopted as the vehicles per day for that given year. For the data to be meaningful it is important to choose a standard week to undertake the measurement. Special events or holiday periods should be avoided.

- Peak hour vehicle numbers

Peak hour calculations are widely accepted in the range of 8.5 to 10.0% of vpd travel in the PM peak, as shown: -

  - The "NSW RTA Guide to Traffic Generating Developments" quotes 9.44% of vpd travel for travel in the AM or PM peak for low density urban areas.
  - "Poisson Distribution" assumes peak hour vehicle counts to represent 10% of all daily travel.

The New South Wales Roads and Traffic Authority (RTA) have produced a document which assists in the planning of land-use developments by allowing and providing for traffic generation. This document is the 'Guide to Traffic Generating Developments'. Some of the key values for residential dwellings are shown below: -

- Daily vehicle trips generated = 9 per dwelling
- Weekday peak hour trips = 0.85 per dwelling

- 25% of trips are internal or local only

(New South Wales Roads and Traffic Authority, 2002.)

These values have been shown to be conservative, (over-estimated) and are geared toward development of infrastructure for the purpose of motor vehicle trip generation.

Referring to Table 17 – Population, Household and Travel Statistics, Sydney, the 2003 trip generation per household is 10.36 trips per household per day. Given an accepted historical modal split of 70% motor vehicle use, a more appropriate valuation for motor vehicle trip generation by household is 7.5 vehicle trips per household, based on current transportation mode choice patterns. Arguably, where greater accessibility to alternative modes is offered, road capacities could be designed for a lower number of vehicle trips per household per day.

Household trip generation rates provide a basic approximation for assessing traffic volumes and travel patterns in developing areas. They deliver opportunities to successfully plan for the travel needs of future residential catchments, however in many outer suburbs appropriate public transport has not been provided to service the growth.

Level of Service

The concept of level of service is an important one. It defines the potential speed and comfort level of the road either at a mid-block location or at an intersection. The level of service is often quoted as the basis for provision of infrastructure improvements, and is also used to determine the effectiveness of changes to the road cross-section for increased alternative mode uses.

The provision of **excess capacity** within a road reserve can have a large effect on **transport modal choice**, as improved travel times via motor vehicles may lure discretionary public transport users across to the faster mode of travel, or improved travel times provide greater accessibility to increased land uses (this is the theory of induced traffic). Conversely limiting traffic flows by providing bus

only lanes will improve public transport travel at the expense of motorists by constraining capacity and therefore may lure discretionary travellers back to public transport.

Road design to influence transportation mode choice should take into account a variety of these factors, including speed environment; adjacent development and land use; pedestrian and cyclist safety; noise; road function and hierarchy; public transport priority; commercial vehicle requirements; and gas emissions. An apparent single-minded focus of most road transportation engineers, and therefore of government policy has been to design the road network based on the maximum throughput of vehicles in the minimum timeframe, with little consideration of the number of passengers per vehicle. This highlights Australian cities growing dependence on the motor vehicle and declining public transport mode share. Recent NSW RTA policy however has been to maximise the number of passengers per vehicle within the existing road network – which should lead to improvements in public transportation mode share if implanted in a holistic manner.

These standardised road hierarchies are listed in Table 42 with the respective vehicles per day (vpd) and indicative speed environments highlighting the road's potential purposes.

Table 42 - Roadway Capacities in Vehicles per Day (vpd)

Road Configuration	Theoretical Capacity in Vehicles Per Day (vpd)	Speed Environment (kph) – Level of Service A
Primary Distributor **(Freeway / Highway 6 lane divided)**	50,000 +	70 – 100
Integrator Arterial A **(Main Road 4 lane**	< 35,000	60-80

divided)		
Integrator Arterial B **(2 lane divided sub-arterial)**	< 20,000	50-60
Neighbourhood Main Street	< 15,000	50
Neighbourhood Connector	< 7,000 to <10,000	40 – 50

(Reference: Western Australian Planning Commission 2000)

The road configurations noted above are suitable for the following vehicle compositions: -

- Primary Distributor and Integrator Arterial A roads are suitable for all vehicles up to (and in some cases including) B-Double trucks. Heavy vehicle composition can be quite high, up to 10% of all road traffic;
- Integrator Arterial B roads are used to inter-connect urban catchments and to provide connections to local employment and economic regions and higher order roads. Heavy vehicle composition is expected to be minimal, up to around 2.5% of all road traffic; and
- Neighbourhood main streets and connectors are predominantly used by motor vehicles and buses to connect smaller urban catchments to higher order roads and local land uses. Some regions are beginning to employ lower speed limits for shared road pavements. Typically these are around 20 to 30 kph.

4.1.2 Road User Characteristics

Each road has its own characteristic set of road users with special requirements. Each of these requirements has a direct impact upon the

capacity of the road. This section examines the following road users and how they impact road capacity: -

- Heavy vehicles;
- Buses;
- Pedestrians;
- Cyclists; and
- Parking vehicles.

Percentage of Heavy Vehicles

Due to their slower acceleration, particularly from a standing start, road capacity is affected by the volume of heavy vehicle traffic within the overall volume. This can be apparent on major freight routes such as through Botany and along Parramatta Road in Sydney, and along Leach Highway and South Street in Perth.

Where heavy vehicles are high in percentage, any roadway reconfigurations need to take into account specialised truck turning movements and offer design criteria to maintain safety and amenity for all road users.

Percentage of Buses

Similar to trucks, buses impact road capacity due to their size and their abilities to accelerate and decelerate from a standing start. These constraints are described as follows: -

- The space which the bus occupies (approximately 2 times the length of a standard vehicle for a standard bus and 3 times the length of a standard vehicle for an articulated bus);
- Slower acceleration and deceleration requirements due to passengers and vehicle sizing; and
- Position of bus stops.

Buses can create merging issues where a bus stop is located in a lay-by. If the bus stop is located in the kerbside lane, this will cause queuing during the dwell time and will cause a slow-down affect on adjacent lanes due to merging.

Pedestrians

Pedestrian crossings are a potential yield and delay in the road network, particularly at formal crossing points near schools and shopping centres. The time taken for pedestrians to cross the road is a direct delay as drivers may be forced to yield; however it can also be argued that the presence of a number of pedestrians within the road reserve may also lead to a reduced speed environment as the motorist takes into account the potential for pedestrians crossing.

Cyclists

Cyclists present a constrained road environment as the cyclist requires approximately 1.5 metres of the kerbside lane to navigate safely for on-road travel. The provision of cycle lanes alleviates this requirement to an extent, however similar to the pedestrian example above, the presence of a reasonable volume of cyclists may be enough to impact motorist behaviour and change the speed environment and therefore the overall road capacity.

Car Parking

The presence of on-road parking provides a similar kerbside impediment to those described above in cycling and pedestrian activity. However this is compounded by the requirement for vehicles to decelerate, park and merge back into traffic flow. In addition, in constrained environments the opening of car doors can also impact the general road environment and the behaviour of motorists.

Traffic congestion issues usually occur during peak periods. The following table provides a comparison of throughput for cars in a freeway lane; buses in a bus-only transit lane; light rail; and rail services. Each transportation mode is then compared against maximum rate of service flow (MSF); vehicle occupancy

rates and total capacities per hour. The table highlights the inefficiencies associated with increased motor vehicle usage in peak congested periods.

Table 43 - Theoretical Capacity per Hour (By Mode)

Transportation Mode	Maximum Rate of Service Flow	Vehicle Occupancy Rate	Theoretical Capacity per Hour (No of people per hour)
Car in Freeway (per lane)	2,000 vehicles per hour – Level of Service E	1.1	2,200
Buses in Bus Transit Lane (per lane)	60 buses per hour (average headway 60 seconds)	50 seats (standard length bus) to 80 seats (articulated bus)	3,000 to 4,800
Light Rail	30 trams per hour	2 to 3 carriages, 80 persons per carriage	4,800 to 7,200
Rail	20 rail trips per hour – quoted for North Shore rail	Up to 8 carriages, 104 people seated per carriage (Millennium Train)	16,000 to 20,000

Motor vehicles with an occupancy rate of around 1.1 persons per car carry around 30% to 67% of the total patronage volume of bus and light rail services. This decreases to approximately 12.5% of total train patronage.

The number of buses per hour is based on a dwell time at each bus stop of up to 60 seconds. It is important to note that bus frequencies of less than 10 minutes tend to force "platooning" of services. Platooning refers to the bunching

or grouping of buses through a full service run due to the combined effects of traffic conditions, signalised and unsignalised yields causing delays and dwell times at passenger pick-up points.

Light rail and rail services can also suffer from “platooning” affects; hence there is a limit to the number of rail cars which can run per hour, mainly due to patronage loading and unloading issues.

It is suggested that road hierarchies should also consider pedestrian, cyclist and universal access, (disabled and senior access) requirements. In Perth standard infrastructure provision for pedestrians and cyclists includes: -

- 1.2 metre wide footpaths in suburban areas where pedestrian traffic is expected to be limited constructed in in-situ concrete or concrete slabs;
- 2.0 metre wide footpaths in suburban areas along major arterial routes where pedestrian traffic is expected to be reasonable and providing connectivity to Dual Use Path systems, constructed in red pigmented asphalt;
- 1.5 metre wide cycle lanes located kerbside. In busy areas these can be painted green;
- 2.5 metre wide dual use path networks which provide direct connectivity between residential and commercial land uses. Pedestrian and cyclist traffic on dual use paths is expected to be high and the 2.5 metre width caters for users in two wheelchairs to comfortably pass in opposing directions; and
- All pedestrian road crossings to be provided with tactile ground surface indicators (TGSI) and directional indicators for visually impaired users.

4.1.3 Public Transportation Service Delivery

The delivery of public transportation services is based on: -

- Provision of service to minimum percentages of the community, defined by walkable catchment;
- Frequency of service in the peak and in off peak times;
- Hours of operation;
- Number of stops per journey;
- Travel time;
- Length of journey;
- Number of trip attractors (commercial, educational etc) along the route;
- Comparative ease of vehicle travel; and
- Socio-economic status of the area and the intended patrons.

This section discusses the issue of determining the most applicable form of on-road public transport systems based upon residential catchment (trip generation) and commercial catchment (trip attraction). On road shall include bus and light rail forms of public transport.

Some of the methods used to quantify the suitability of on-road public transport infrastructure include: -

- Route assessment;
- Positioning of stops and stations;
- Determination of walkable catchment;
- Consideration of access to station by other modes (i.e. vehicle, cycle etc);
- Existing vehicle traffic count and carriageway capacity (mid block analysis);
- Existing intersection configurations and theoretical capacities;
- Frequency of service;

- Topography and ease of access;
- Existing traffic volumes and determination of level of service and volume to capacity ratios;
- Measurement of delay to public transport services in minutes;
- Proposed carriageway amendments;
- Effect upon existing traffic volumes, level of service and volume to capacity ratios;
- Expected patronage increases due to improved running times;
- Net benefit cost ratio, including net construction cost and economic benefit/cost through reduced/increased congestion; and
- Improvements to air quality and minimisation of noise, particularly in residential and CBD areas. This should be a key objective in the CBD areas of Sydney and Perth.

There are a number of important terms in public transportation delivery which will be explained in the following pages.

4.1.4 Walkable Catchment

The provision of viable public transport is based on servicing a walkable catchment which is sufficient to support provision of a public transport service and connecting this catchment to an external location or 'attractor'.

Recent targets in Perth have looked at a maximum distance that pedestrians are generally willing to walk to commute via public transport within a suburban environment is 500 metres to a pick-up point or station. This distance provides a more equitable opportunity for elderly and disabled passengers to access services without being disadvantaged. A recent survey found that most people will walk a maximum of 5 minutes to a nearby bus stop and 10 minutes to a train station, or they would consider using another means of transportation. (Ker, James, Brog, 1998.)

In addition, park and ride facilities are becoming more common for access to major rail, light rail and bus infrastructure.

4.1.5 Radial and Orbital Routes

Radial routes are a traditional method of allocating public transport services and where the route is reasonably direct and the travel time is in an acceptable bracket (usually under 60 minutes) this method is suited to long haul or specific use journeys such as commuting trips. Earlier planning in the 70's and 80's was to provide radial routes which attempted to service larger community catchments, however this meant that routes were indirect and therefore not attractive due to the timeframe to travel. The largest falls in public transport travel, particularly bus travel was in the 70's and 80's.

With the growth in leisure and shopping trips generated, transport routes are being designed to accommodate multiple catchments (trip generators) and multiple nodes (trip attractors). In Perth the Circle Route is a good example of a successful orbital bus route which caters for a number of residential catchments and a number of trip attractors. The Liverpool to Parramatta Transit-way and Route 400, Bondi Junction to Burwood via Sydney Airport are examples of successful orbital routes in Sydney.

4.2 Measures to Improve Access to Public Transport

Improving access to public transport is a key driver to improving the take-up of public transportation services. Accessibility is determined by a combination of: -

- Proximity of the household to a public transport service of reasonable frequency in both the peak and off-peak; and
- The affordability of the service relative to the customers earning power.

When considering the accessibility of public transport, it is important to consider all of the methods which a person may use to access the service. These include: -

- Walking;
- Cycling;
- Motor vehicle as driver;
- Motor vehicle as passenger; and
- Other public transport.

Walking to Public Transport

When considering walking as a form of connectivity to public transport travel, it is important to understand the concept of a walkable catchment. Walkable catchments are defined by a mapping process known as a ‘Ped-Shed’. Where the location of a bus stop or light rail station and its surrounding urban environment including road layout, lot boundaries and land usage is known, the walkable catchment can be quantified. The first step is to show the bus stop or light rail station as a node and draw a catchment circle around the node, (400 metres for bus and 800 metres for light rail). The next step is to draw lines running from the bus stop or light rail station (this is known as the node) along the centreline of roads and pedestrian access ways (PAW’s). Even though a house may be located within a 400 metre radius of a node ‘as the crow flies’, this may not necessarily translate on the ground due to the urban form and the road and pedestrian access layout. Therefore the distances from the node along the centrelines are measured and any houses outside the 400 or 800 metre length are ignored with regard to the walkable catchment.

The NSW Transport Data Centre recently found that 78% of inner city bus patrons and 84% of outer suburbs bus patrons walked to connect to their bus journey. (Transport Data Centre, 2002)

Determining patronage for walking is based on a number of important factors: -

- The number of households within the walkable catchment;

- The relative topography within the walkable catchment, (steeper catchments tend to generate lower volumes, particularly for older and disabled pedestrians);
- The socio-economic profile of the suburb;
- The number of people per household;
- The household age groups, (younger people tend to utilise public transport more often); and
- The number of vehicles per household, (households with more vehicles will tend to walk to public transport less).

Cycling to Public Transport

It is accepted that people of reasonable fitness will cycle up to 5km to reach a destination. Whilst bicycle trips to catch a bus are rare, there is greater potential for bicycle to light rail and rail trips due to the increased patronage space on light rail and rail. Recently, Brisbane City Council's bus service trialled buses fitted with bicycle racks to cater for this modal choice, however the results of this trial and the number of buses fitted out are unknown. In Perth, a number of bus and rail stations have provided lockable, enclosed bicycle shelters.

The NSW Transport Data Centre recently found that less than 1% of bus patrons cycled to connect to their bus journey. (Transport Data Centre, 2002)

Motor Vehicle Connections to Public Transport

Access via motor vehicle is split into two groups, vehicle driver and vehicle passenger. However for the purpose of estimating patronage at a particular node or station, we examine the potential patronage in terms of 'Park and Ride' and 'Kiss and Ride'.

Motor Vehicle (As Driver)

The advent of park and ride facilities at bus stations, particularly in Perth and recently along the Liverpool to Parramatta Transitway has provided the opportunity for increased modal share for vehicle trips to connect to bus services. As discussed earlier in this thesis, this model is highly successful for commuting trips, particularly into CBD areas.

The NSW Transport Data Centre recently found that less than 1% of bus patrons drove a vehicle to connect to their bus journey, mainly due to the lack of car parking infrastructure at suburban rail stations in Sydney. Park and Ride however in Perth is an important catchment generator, particularly for stations along the Perth to Joondalup line, the new Thornlie station and the future Perth to Mandurah line.

(Transport Data Centre, 2002)

Motor Vehicle (As Passenger)

The advent of park and ride facilities has also provided opportunities for patrons to be dropped off and / or picked up adjacent to the point of departure / arrival. This has been called a 'Kiss and Ride' facility at various stages of marketing in NSW and WA.

The NSW Transport Data Centre recently found that 3% of inner city bus patrons and 8% of outer suburb bus patrons were vehicle passengers prior to connecting to their bus journey. (Transport Data Centre, 2002)

Potential Improvements to Increase Accessibility to Public Transport Infrastructure

Potential improvements to public transport infrastructure to increase accessibility include the provision of: -

- Car parking within a suitable distance of the station or node;
- Kiss and ride facilities adjacent to the station or node;
- Bicycle lockers and / or racks;

- Providing bicycle storage facilities on the front or rear of buses;
- Providing footpaths or dual use paths to increase connectivity within the walkable catchment; and
- Road layouts designed to increase walkable catchment within a residential zone.

4.3 Measures to Improve Travel Time

Improving the travel time of public transport services, particularly in comparison with the time taken for motor vehicle travel is a key to promoting increased public transportation usage. Methods to increase and improve on-time running include: -

- Limiting stops, (Express services);
- Decreasing dwell time at stops, (contactless smartcard payment systems); and
- Improving average journey speed, (active signal priority, bus lanes).

Provision of express services is generally used in peak periods to improve travel time performance relative to motor vehicle use, however transport service planners are tending to implement more direct routes which are improving bus patronage.

Dwell time can be reduced at stops through infrastructure improvements, such as providing bus only transit lanes. I believe another measure to improve dwell time is to remove bus bays at stops, as buses are forced to wait to re-enter traffic in busy periods. Bus bays were brought in during the 70's and 80's to limit vehicle queuing behind dwelling buses, however this infrastructure improvement is aimed at minimising delay to general vehicle traffic without consideration for negative impacts on bus travel times.

Provision of bus transit lanes also provides advantages in reduced travel times by improving the travel speed of buses relative to other traffic in congested conditions.

Within existing road reserves there are a number of potential engineering solutions which can assist in developing improved travel time and potentially improve patronage. This section will be broken into the various transport modes and will offer potential solutions and provide examples of where these have

been used, both in Sydney and in Perth. The solutions examined will be limited to within existing road reservations.

Bus Infrastructure

The author has recently been involved in a number of bus improvement projects of varying nature. As a general rule, improvements to travel time should be examined on a case by case and site by site basis. Major infrastructure improvements can be delivered for marquee routes with high frequencies and high patronage, pending a benefit cost ratio analysis to all road users. Minor infrastructure improvements can be looked at for all routes, particularly where financial outlays and time to construct / implement are minimal. In all cases, opportunities for partnership with local and state government agencies should be examined.

Travel time improvements on public transportation systems can be delivered through the following infrastructure improvements: -

- Bus transit-ways – new roads built or existing roads designated for bus and emergency services uses only. The Liverpool to Parramatta Transit-way is a successful example of implementation of major infrastructure as described in Section 2.

- Bus lanes – these are lanes designated for bus use on a full-time basis. The most successful bus lane in Australia is arguably the Sydney Harbour Bridge bus lanes which carry eight (8) times the number of people per peak hour into the city than any other lane. Bus lanes on the Causeway and Kwinana Freeway in Perth have proven successful. The Kwinana Freeway bus lane is currently being replaced by the Perth to Mandurah rail.

- Peak operation bus lanes – These bus lanes commence operation at peak times only to alleviate delays experienced during periods of high congestion. The bus lanes then revert to normal operation outside of hours. This is useful where on-street parking is allowed outside of peak

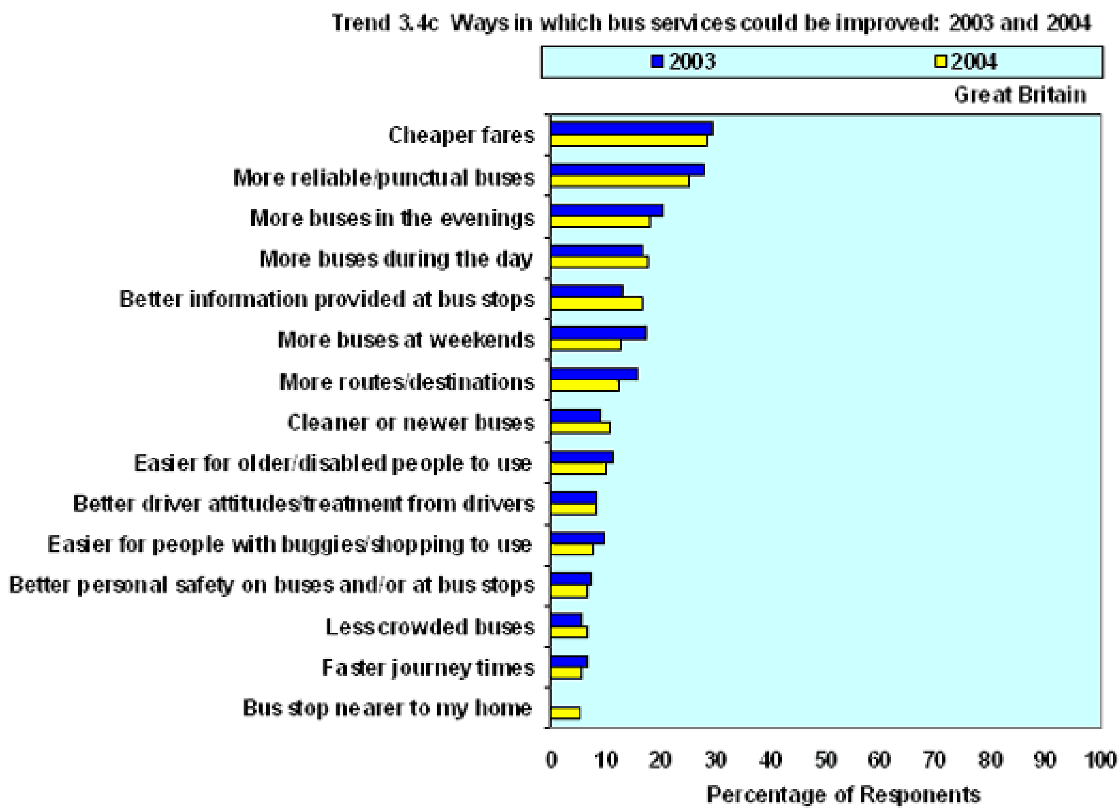
periods, as motorists are used to a constrained operating environment and buses achieve a big benefit in the peak. Peak operation bus lanes are favoured in Sydney as a method for improving peak travel and to persuade vehicle users to alternative forms of transport. Examples of successful peak operation bus lanes include Broadway / Parramatta Road from Central to Leichhardt and Warringah Road. A short section of peak operation bus lane has been deployed in Perth in Beaufort Street, Inglewood with future stages to be confirmed.

- Intersection queue jumps – These facilities can either be placed within bus only lanes (Parramatta Road / Glebe Point Road citybound) or can be placed at busy intersection where peak queue lengths mean that multiple phases can be extinguished prior to the bus clearing the intersection. An example recently occurred in our study on the Perth Circle Route with significant delays for peak Fremantle bound buses at the intersection of Centenary Avenue and Leach Highway. This project is described in further detail in Section 4.6.

4.4 Measures to Improve Comfort / Convenience / Safety and Security

Whilst the highest ranking potential improvements to public transport services focus on pricing and reliability of service, improving the comfort, convenience, safety and general security are key drivers to customer satisfaction. Figure 21 below shows recent customer feedback in Great Britain ranking the ways in which bus services could be improved.

Figure 18 - Customer Ranking of Potential Improvements to Bus Services (Great Britain)



(Department for Transport UK, 2006)

In this survey, respondents could make up to three suggestions about how bus services could be improved. In the 2004 survey, the two most common suggestions of how to improve the bus service were cheaper fares (28 per cent) and more reliable/punctual buses (25 per cent). The next most common suggestions were about accessibility to the bus service, in terms of more buses at various times of day and more routes/destinations.

10 per cent of respondents thought the bus service could be easier for the elderly and disabled to use and 8 per cent thought it could be easier for those with buggies or shopping. Only 5 per cent of the respondents thought bus services could be improved by having a bus stop nearer to their home.

Cheaper fares are the dominant improvement. This is due to the average lower “buying” power of public transport consumers compared to motor vehicle users and shows a heavy link between patronage and price elasticity. Pricing is an underestimated form of attracting patrons and should be used by government to make systems more attractive. Competitive pricing should be used as a stimulus for behaviour change. The remaining service improvements have been grouped as follows, and showcase the adapted Maslow’s’ Hierarchy of Needs as developed in Section 2.2.4.

Table 44 - Survey Responses

Comfort	Convenience	Safety and Security
Cleaner or newer buses	Bus stop nearer to my home	Better personal safety on buses / at stops
Less crowded buses	More buses, greater frequency	Personal safety after dark between home / destination and bus stop
Easier for people with buggies / shopping	More bus routes and destinations	
Easier for the elderly	More buses at various times of the day / weekend	

4.5 Measures to Improve Information Through Infrastructure Delivering Behaviour Change

The importance of improving information is also highlighted in the study of UK bus patrons, with the category "Better Information Provided at Bus Stops" ranked 5th in terms of importance. Interestingly there was a marked increase in the percentage of patrons who felt this would improve the service between 2003 and 2004. As provision of variable message signs (VMS) at bus stops is an emerging technology, it is reasonable to assume that this information will be sought by more and more users as the technology is made available to a wider market.

Historically, information at bus stops has been provided in timetable format, however this has had two main detractions: -

- Potential for vandalism; and
- Reduction in accuracy of arrival times due to traffic conditions.

A variable message system would provide the user with an accurate estimate of when the bus will arrive due to automatic vehicle location technology providing an accurate location of the bus. This information is relayed to a server which calculates the expected time to travel from the buses location to the bus stop, with a far greater potential for accuracy than a static timetable.

Provision of accurate information limits the potential for customers to be disappointed. One of the biggest drawbacks for public transport is the dwell time at the bus stop. This is where customers tend to feel the greatest levels of frustration with the service, (as evidenced in the UK survey where 5 of the top 7 responses requested greater service levels). Repeated instances of late bus arrival is shown to result in patronage loss. Provision of accurate arrival time information can have a “calming” effect on waiting customers as they know when the bus will arrive. The potential negatives of the dwell time are therefore removed, providing the opportunity for behaviour change.

4.6 Bus Priority Schemes

In this section, bus priority schemes are described in terms of their objectives, the types of priority available and an examination of recent bus priority trials and their results.

Objective
To document and describe passive and active bus priority schemes.

Included in this section is an analysis of the Circle Route trial in Perth which I am providing systems research and design and specification skills to the Public Transport Authority.

Traffic Congestion and the Impacts on Bus Services

Traffic congestion impacts bus services by reducing reliability, increasing running times and increasing operating costs. Providing bus lanes can be expensive and space within the road reserve may be limited. While

advantageous for public transport, installing passive priority systems such as B-Signals can reduce green time for other movements at signalised intersections, which may reduce intersection performance in a congested network. Electronic bus priority alleviates these problems by opening communication between the bus and the traffic signals. Priority can be given to selected buses such as those that are running behind schedule. The use of congestion resolution techniques enables the intersection to return to its previous state of equilibrium within a reasonable timeframe. It is also important that the bus does not run early as some passengers may not arrive on-time. The key objective of the bus priority system is to improve the reliability and on-time running of buses.

Queues can be formed in the road environment due to traffic changes associated with congestion, incidents, transit priority over-rides and random fluctuations. The most common locations for queues are at intersections, either signalised or unsignalised. This is due to the requirement to yield prior to entry and navigation through the intersection.

A signalised intersection generally provides a set timeframe for the yield and is usually associated with greater vehicle volumes. Signalised intersections can either be: -

- Adaptive, i.e. the total cycle times and times for each phase ‘adapt’ to suit the current on-site congestion conditions (SCATS or SCOOT);
- Pre-programmed to a set cycle time (Signals controlled by a local controller, such as Pelican Crossings); or
- Pre-programmed to meet congestion requirements found during a traffic study or similar (TRANSYT).

Unsignalised intersections generally provide a variable delay and are usually associated with lower vehicle volumes. Unsignalised intersections include ‘stop’ or ‘give way’ yields.

Overcoming Barriers to Implementation

Barriers to implementation of bus priority schemes exist from a number of sources. These include financial and political constraints, as well as winning the confidence of key stakeholders, such as road authorities. Planning should be undertaken with a reasonable knowledge of the engineering constraints, the projected benefit to public transport, the cost of implementation and the potential impacts upon all road users. Examples of barriers to implementation include: -

- Congested road networks and intersections, (potential lobbying for motorists and non acceptance of alternative measures);
- Low bus frequencies equating to low economic benefits (benefit cost ratio not suitable); and
- Local government policies and gaining acceptance from other key stakeholders.

To alleviate these constraints, it is important that the design of a trial or design and implementation of a system considers the stakeholders and addresses the points above. This can be done through: -

- Marketing and promotion of the scheme, to gain acceptance from the wider community;
- Adherence to budget and limiting budget over-runs to maintain positive review and coverage of the project;
- Appropriate staffing to implement and manage the process; and
- Appropriate enforcement and maintenance to ensure continued premium operation.

4.6.1 Objectives of Bus Priority

The objectives of bus priority systems are to improve the patronage and comparative timeliness of public transport systems to motor vehicle travel over the same distance. Other objectives include: -

- Improved reliability (on-time running) and reduced wait times;
- Integration with real time information through provision of variable message signs (VMS); and
- Improved operational efficiency and capacity.

The summary goals are to obtain **reduced travel times**, **increased reliability of on-time running** and **maintenance of headway between buses**.

Bus Priority is divided into active and passive priority techniques. Active priority techniques are those which are able to adapt to traffic conditions in real-time without influence from a particular road-user. Passive priority techniques are those which require input from the road user. Priority techniques include: -

- Active signal priority (Section 4.2); and
- Passive signal priority (Section 4.3).

4.6.2 Active Signal Bus Priority

Active signal priority describes systems which have the ability to track bus location and request priority at signalised intersections based upon qualification within a series of predetermined parameters, which can change in real time to suit intersection traffic conditions.

There are many ways to provide active priority for buses at signalised intersections. The most appropriate method depends on many factors and the form of priority may be required to change in real-time to suit a particular buses operational needs, including whether the bus is early or late, has passengers or is empty running and the likely impact on other buses and other road users.

Active signal priority is effectively a request for intervention within a signal phase to allow a complying or green phase to be activated or extended. This allows a bus to clear an intersection with reduced delays. Some methods used to request a complying phase include: -

- Green extension – an ‘x’ (usually 10) second extension to the length of time allocated for a green or complying phase;
- Green early start – an ‘x’ (usually 10) second early intervention on the length of time allocated to a non-complying phase immediately prior to the commencement of a green or complying phase;
- Special phase – an additional green or complying phase which is slotted between non complying phases;
- Phase suppression – the removal or skipping of non-complying phases;
- Priority phase sequences – the addition or re-running of complying phases;
- Phase compensation – running complying phases to maximum run times and non-complying phases to minimum run times; and
- Variable priority based on individual bus operating requirements.

Active signal priority systems are already in use within the Perth traffic signal system at all signalised intersections adjacent to railway crossings where the detection of a train approaching the railway crossing changes the traffic signal operation to ensure motor vehicles are not inadvertently stopped across the rail crossing. Also, the traffic signals in the vicinity of the Perth number one Fire Station in Hay Street are controlled to assist fire appliances leaving the station in the case of an emergency.

This information has been summarised from the WorleyParsons report “Design and Specification of an Active Signal Priority Trial”.

Active Signal Priority – The State of the Market

Active signal priority is an emerging technology. There are a small number of systems that have been developed and trialled in the field. All existing known systems are undergoing research and development to alleviate communications issues and all systems require integration with a number of location-specific factors, including: -

- Integrated ticketing systems;
- Bus scheduling software;
- Adaptive traffic control systems (SCATS);
- Automatic vehicle location systems; and
- Communications systems.

Active signal priority systems have typically been developed by the developers of traffic control systems (i.e. research teams within government road authorities). These include: -

- NSW RTA – SCATS / PTIPS;
- Brisbane City Council / Technisyst – BLISS / RAPID; and
- Transport Research Board UK – SCOOT / SCOOT Bus Priority.

Other systems have been developed in trial situations by University Research teams, a number of which are in the United States, with results usually simulated in a laboratory.

Bus priority has also been deployed in a number of locations in a "passive" or infrastructure based manner using physical infrastructure (such as in-road loops or vehicle sensors) to detect the presence of a bus. Once the bus is detected a message is sent to the local controller, either requesting priority or sending an over-ride signal. Physical systems however have delivered mixed

results as other vehicles can impact the reliability of the system if they are queuing over the loop or if a parked vehicle causes a bus to overtake and miss the loop altogether.

This section provides details on the following proprietary systems: -

- SCATS Bus Priority – PTIPS (Section 4.7.3);
- BLISS Bus Priority – RAPID (Section 4.7.4); and
- SCOOT Bus Priority (Section 4.7.5).

4.6.3 SCATS Bus Priority - PTIPS

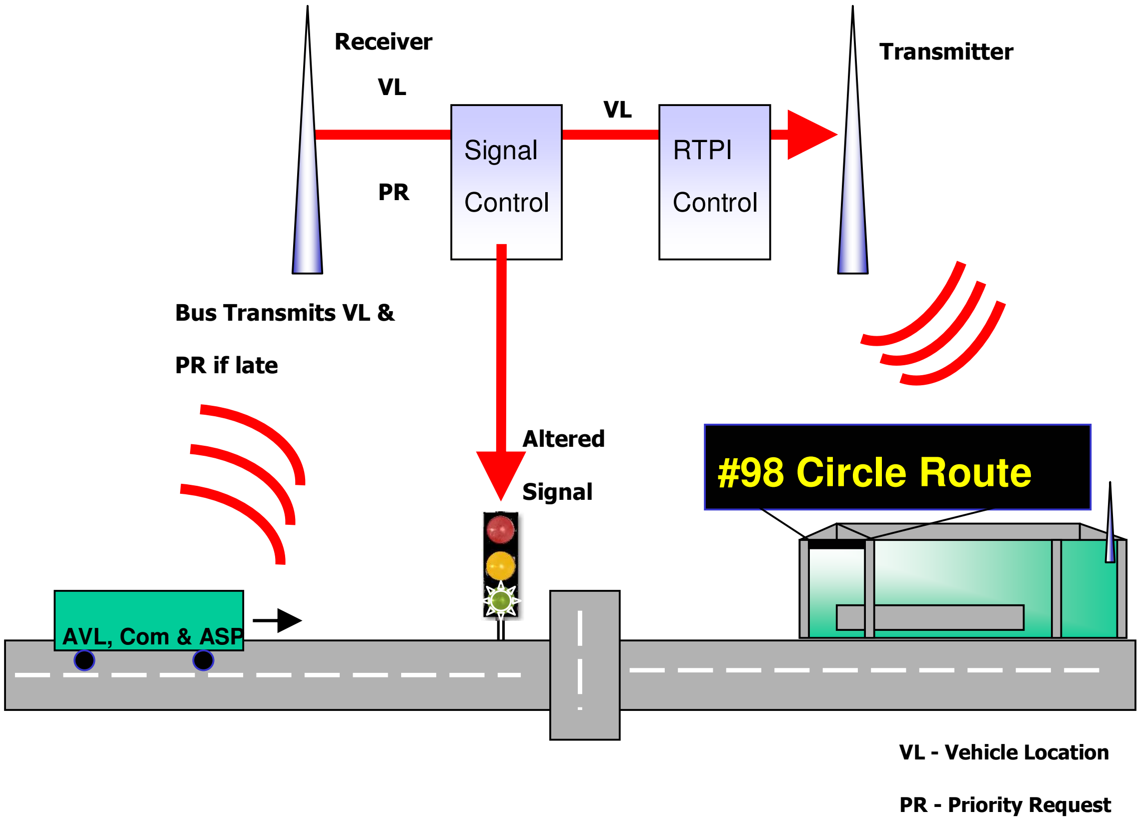
PTIPS (Public Transport Information Priority System) has been developed by the NSW RTA and trialled on the Route 400 bus service between Burwood and Bondi, running from Sydney's inner west to the eastern suburbs. PTIPS is designed as an interface to the SCATS system. SCATS regulates performance of the intersections across a metropolitan network. SCATS is used in all Australian capital cities except Brisbane and extensively overseas, particularly throughout Asia. The NSW RTA develops SCATS and therefore the PTIPS software integrates with SCATS in a logical manner.

PTIPS needs to work concurrently with the following technologies: -

- Timetable (including double banked buses);
- Patronage and ticketing information;
- Congestion monitoring; and
- OBU (on board unit) comprising AVL, ETM and digital radio system.

Figure 19 shows the communication flow path between the bus and the signalised intersection, and also shows the option of providing VMS or variable message signs at the bus stop.

Figure 19 – Flow Diagram of Active Signal Priority System



(Diagram used with permission of Michael Somerville Brown, Public Transport Authority of Western Australia).

This information has been summarised from the WorleyParsons report "Design and Specification of an Active Signal Priority Trial".

Active Signal Priority Interface with SCATS (Adaptive Traffic Co-ordinating System)

In Sydney and Perth, the active signal priority system shall interface with SCATS. Traffic flow and volumes are measured at each intersection by sensors embedded in the road. Regional computers analyse this data and calculate the best possible traffic signal timings, based on queue lengths and delays at each

approach to the intersection. SCATS is currently installed in 80 cities worldwide.

Figures 20 and 21 show the typical SCATS Architecture and the communication flow path.

Figure 20 - Typical SCATS Architecture

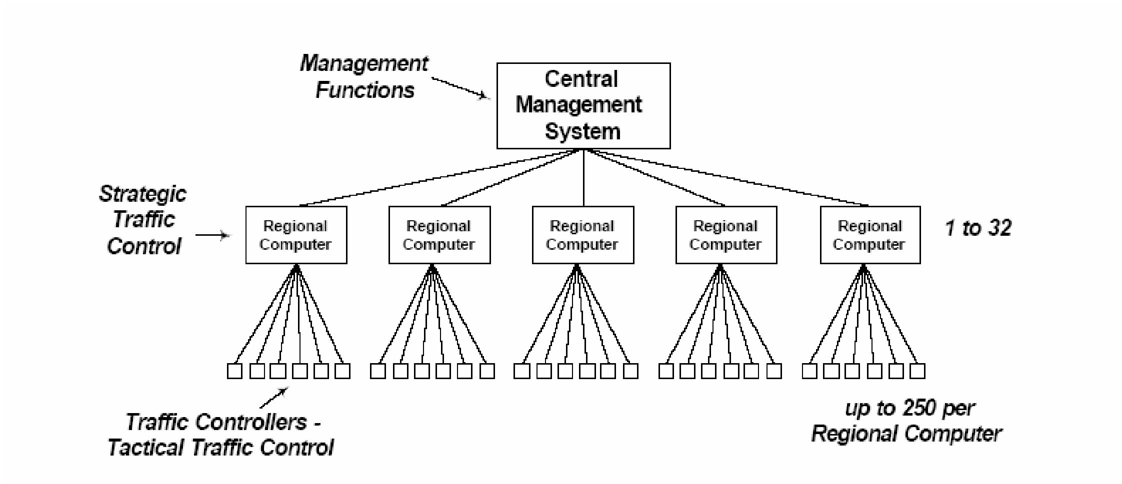
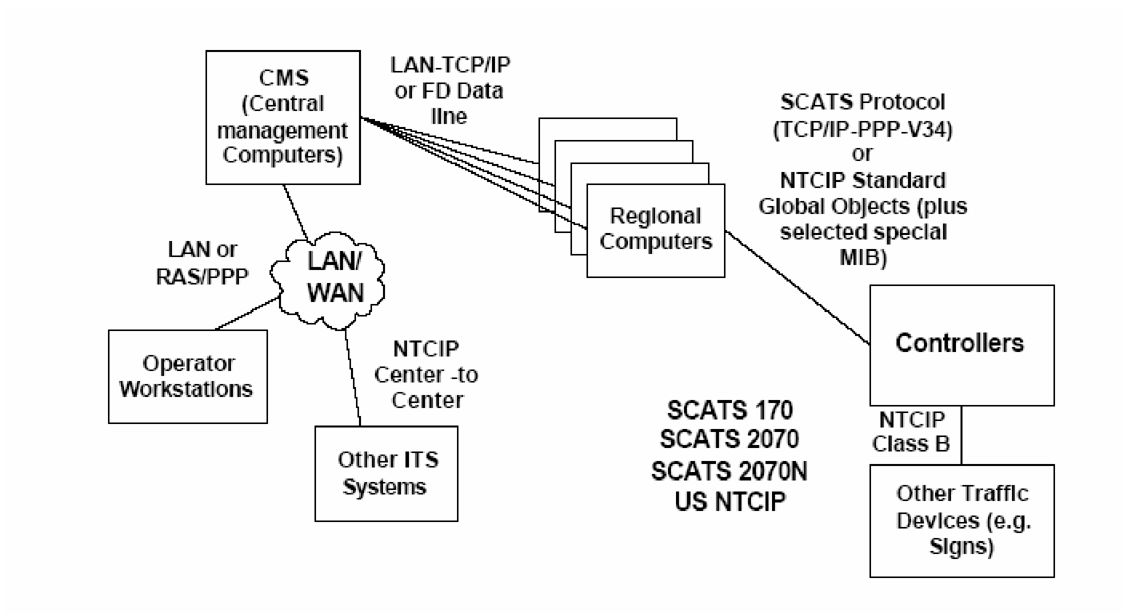


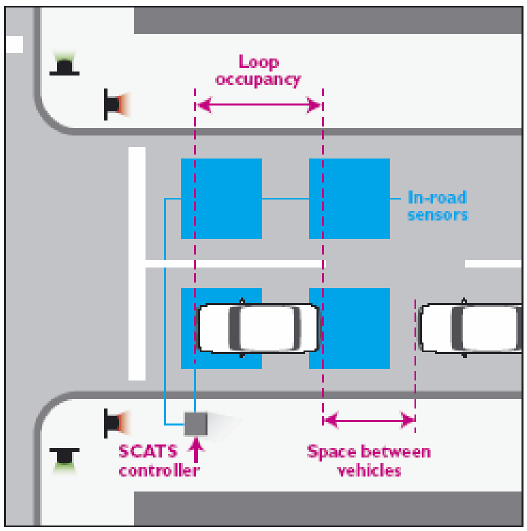
Figure 21 - SCATS Simplified Communication Flow Path



SCATS – from Traffic Controller to Regional Computer Levels

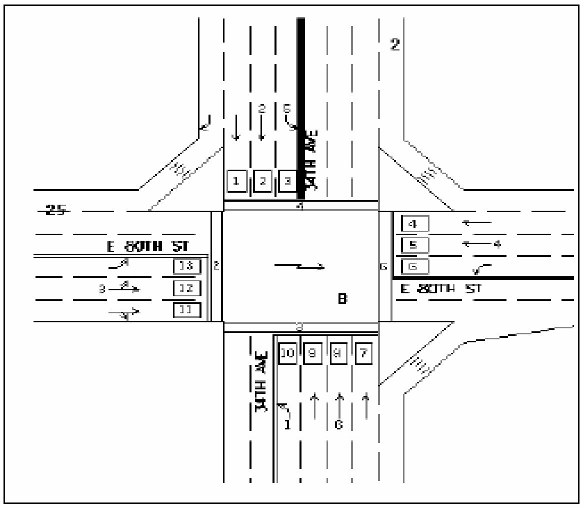
Figure 22 below shows the typical location of embedded road sensors based on standard vehicle sizes. This information is sent to an on-site controller which is linked to a regional computer as shown in Figure 19 to provide connectivity in traffic and data flow through to adjoining intersections.

Figure 22 - Plan of Typical SCATS Installation



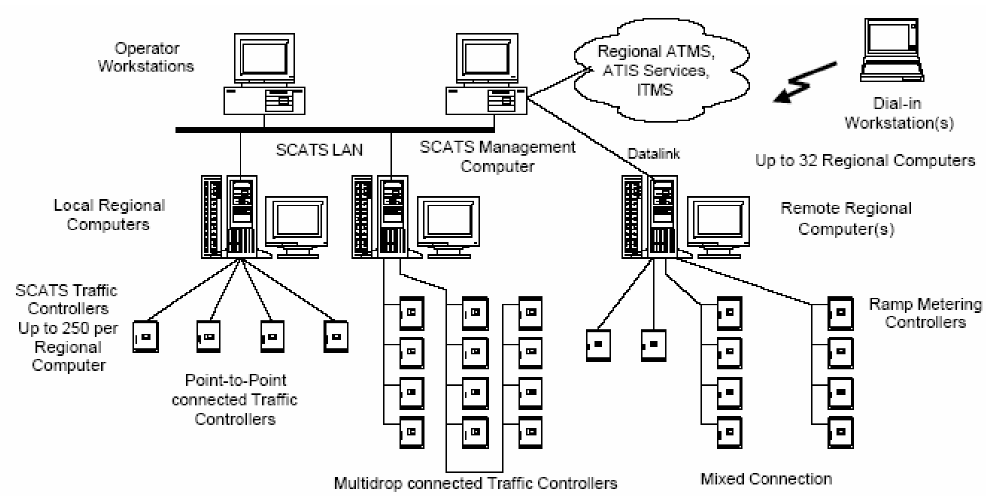
SCATS is able to calculate congestion on a per lane basis from the sensors and SCATS controller in accordance with Figure 23 below.

Figure 23 - SCATS Intersection Output Showing Embedded Sensors per Lane



Figures 21 to 23 are highlighted in further detail by examining the typical connection and flow-path for data between the on-site infrastructure and the regional computer.

Figure 24 - SCATS System Architecture (Traffic Controller to Regional Computer Hierarchy)

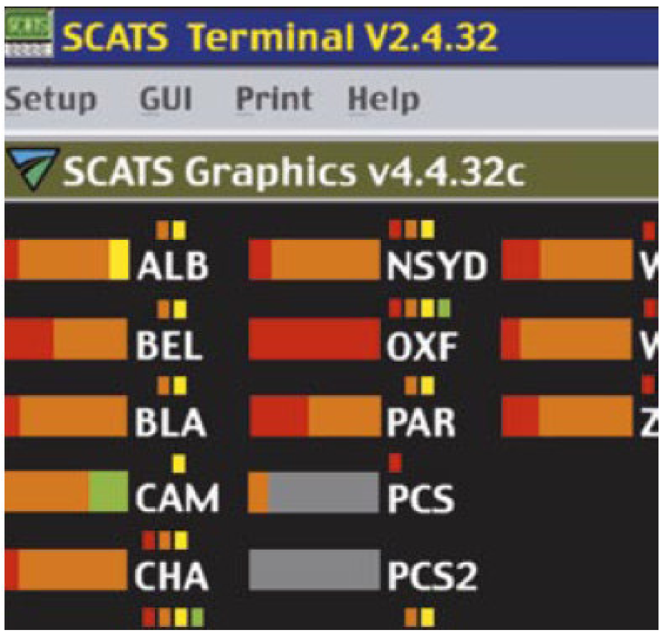


SCATS – Central Management System

The regional computer provides information on intersection capacity to the Central Management System. In Sydney this is located at Australian Technology Park in Redfern. This information provides a summary of intersection performance by regional sub-set. An example of this is shown in Figure 25.

The colour coded bars shown in Figure 25 refer to congestion levels across the various regional controllers. This information is monitored constantly at the NSW RTA's headquarters.

Figure 25 - SCATS Screen Print, Congestion Analysis by Region



SCATS General Hardware Requirements

The SCATS Management Computer and Database systems are a series of networked personal computers or pc's. The regional computers, or strategic control systems are a network of personal computers on a Windows NT platform with a Digi Serial Interface system.

Examining the SCATS system in this level of detail provides a basic understanding for how active signal priority may interact with the existing signal network.

Active Signal Priority Interaction with SCATS (Business Rules and Congestion Rules Resolution)

An active signal priority system needs to interact with SCATS and provide the SCATS system with potential reasons to vary its phasing cycles to suit an approaching bus. The algorithm to complete this task simply and effectively is the Business Rules and the resolution of Congestion Rules within SCATS.

The business rules for the use of bus priority software on the Perth Circle Route are being developed through extensive consultation with key stakeholders, and include: -

- The proximity and location of bus stops with respect to the signalised intersection (i.e. whether the bus stop is on the approach or departure side of the intersection). If the bus stop is on the approach side, whether it is too close to the intersection to allow a reasonable opportunity to call for priority based on the time / distance rule and the acceleration / distance rule for bus stops in close proximity on the approach side;
- The level of congestion at the signalised intersection, (i.e. allow bus priority to be called unless the degree of saturation greater than or equal to ‘x’ %;
- The ability to null a request for priority at an intersection if one or two downstream intersections have degrees of saturation equal to or less than ‘x’ %;
- To resolve any congestion caused by the deployment of active signal priority, a moratorium on calls at an intersection is set for a minimum period of ‘x’ minutes;

- The minimum number of passengers on the bus (when the system is connected to the ticketing system in the project implementation phase);
- The relative importance of one bus route as opposed to another (to resolve conflicting requests); and
- Buses start trips no later than ‘x’ minutes late or ‘y’ % of the trip time late.

This information has been summarised from the WorleyParsons report “Design and Specification of an Active Signal Priority Trial”.

4.6.4 BLISS Bus Priority – RAPID 2

RAPID was initially developed by the Brisbane City Council as a bus priority system complimenting the BLISS adaptive traffic signal network which controls all signalised intersections in Brisbane. To expand the commercial opportunities associated with RAPID, the Brisbane City Council obtained a development partner in Saab. Recently the rights to RAPID have been purchased by Technisyst, who have further refined the RAPID system and managed the delivery of a system in Auckland on the SCATS network. Technisyst are currently developing a system for trial in Melbourne, (with SCATS controlling all intersections) as part of the Smart Bus Project.

RAPID needs to work concurrently with the same technologies as noted for PTIPS.

The following documentation was obtained in a telephone interview conducted with David Panter of Technisyst.

Telephone Interview - Technisyst

It is important to define an entry and exit radius at each intersection for the location of waypoints. Entry radii at intersections are typically 150 to 200 metres in advance and exit radii are typically 20 to 30 metres from the

intersection. The size of the entry and exit radii are based on a number of parameters including: -

- Location of bus stops;
- The type and overall configuration of the intersection; and
- The level of congestion of the intersection.

Buses are usually only given priority when they are running late. The request for priority can be accepted at any agreed measure of lateness. Industry discussions appear to suggest anywhere within a range from 1 minute to 5 minutes. It appears to be accepted that once a bus begins to run more than 5 minutes late, it will continue to run later through the journey as the bus is beginning to accept patronage arriving at bus stops intended for the next bus. This causes buses to bunch or double bank, as the next timetabled bus then begins to run faster through the route as it is not picking up as many passengers. Bunching or double banking of buses is frustrating for commuters.

An important future part of the priority system is the ability to integrate with the ticketing machine and allocate priority on the basis of number of passengers. This is an important point as many current ticketing machines only calculate the number of boarding's and do not calculate passengers disembarking. Future systems to be installed in the eastern states and in Perth will allow accurate calculation of the number of passengers at any point in the trip as the new ticketing systems will count boarding's and departures.

Priority systems look at each intersections phasing and group the phasings into one of the following categories: -

- Complying phase; and
- Non complying phase.

A complying phase is one which enables access through the intersection under green signal for the bus in the direction of travel. A non complying phase is one which causes the bus to yield to other turning movements.

During the signal phasing there is a short period prior to the commencement of the next phase known as the **commit period**. The call for priority from the bus will not be registered whenever the intersection signals are in a commit period to the next phase. The request for priority usually lasts for 10 seconds. This means that the most common forms of priority allocation include: -

- Early call – i.e. interrupt previous phase and call for an early start to the satisfying phase;
- Green extension – i.e. extend the satisfying phase by an additional 10 seconds to enable the bus to clear the intersection; and
- Supplementary phase – if phases A and B are defined as satisfying phases and phases C through to F are non satisfying, the bus can call for a supplementary phase if it crosses the way point, say during the C phase. In this instance there are two methods of supplementary phasing: -
    - Phase Re-start – When the phase sequence is interrupted at the completion of Phase C and returns to Phase A to recommence the phasing in its entirety
    - Additional Satisfying Phase – After the completion of Phase C, the bus priority request asks for a satisfying phase, (say Phase A) and upon completion reverts back to the previous phase at Phase D

The following items should be included in the database to enable the priority system to work to full capability: -

- Full timetable, (including double banked buses etc);

- Recent historical trip data – enables the operator to view trends;
- Requirements for banking (such as patronage, delay etc);
- Potential for stops to be skipped in the route where buses are behind timetable – this will affect the data which is received via AVL system; and
- Patronage data.

It is important to note that the priority system will only work to capability where it is monitored by the bus operator and information is passed onto the drivers, particularly regarding delays, patronage concerns or potential to bunch or double bank.

This information has been summarised from the WorleyParsons report "Design and Specification of an Active Signal Priority Trial".

4.6.5 SCOOT Bus Priority

SCOOT is an adaptive traffic control system similar to SCATS. SCOOT was originally developed by the Transportation Research Board of the UK, however is now developed in conjunction with commercial partners. In 1995 the Transportation Research Board developed a bus priority addition in 1995.

SCOOT Bus Priority has been developed using bus loops and bus-borne transponders, but recently has moved to automatic vehicle location techniques.

Bus stops

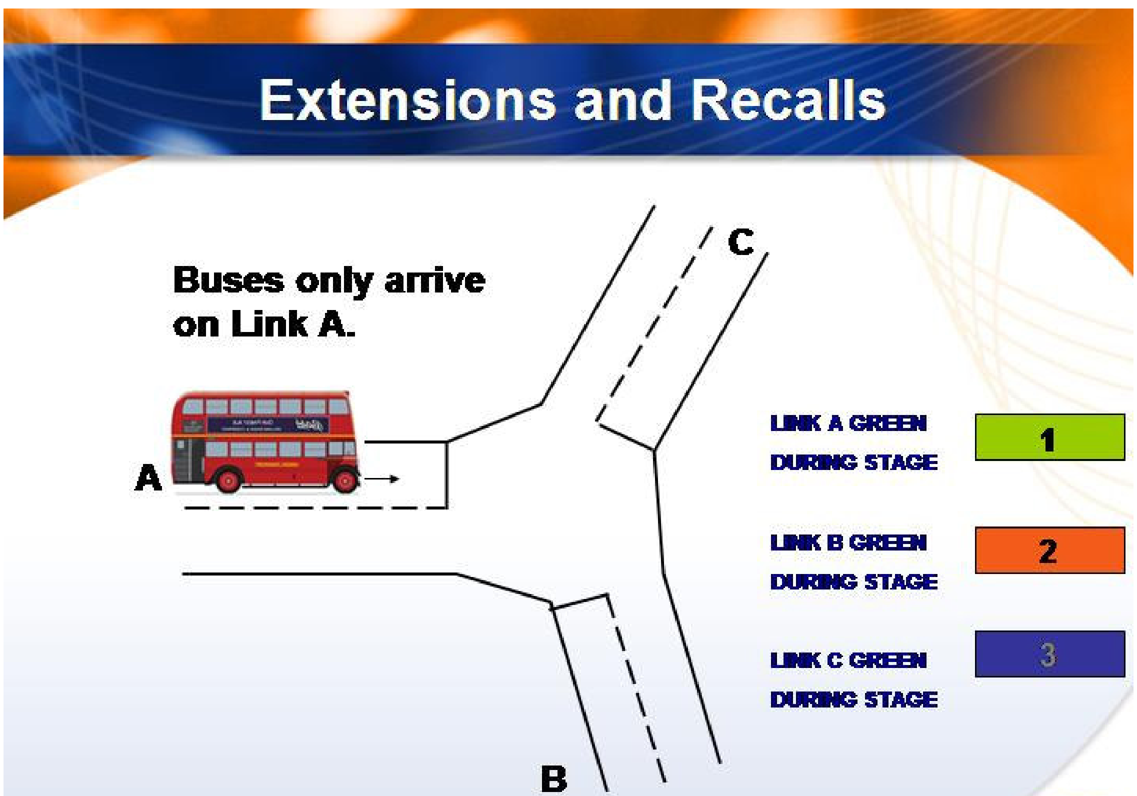
SCOOT methodology suggests that buses need to be detected after any bus stop on the link as SCOOT does not attempt to model the time spent at a bus stop. Accuracy of bus position can be critical in this area, and it may be best to configure SCOOT to ignore AVL detection which is near a bus stop. In this case, bus loops or AVL systems where bus detection points can be specified have an advantage as they can be set in the optimum position which is often

just after a bus stop. I believe that recent technology provides the ability to only send a signal when the bus leaves a way point zone.

Optimisation

The signal timings are optimised to benefit the buses by either extending a current green signal (an extension) or causing succeeding stages to occur early (a recall). Extensions can be awarded centrally, or the signal controller can be programmed to implement extensions locally on street (a local extension). SCOOT can be configured by node to allow or disallow each of these methods of priority. In principle recalls could also be awarded locally, but the timing is less critical and the extra programming of the controllers is not considered cost effective.

Figure 26 – SCOOT Priority Explained in Diagram



(SCOOT-UTC, 2006)

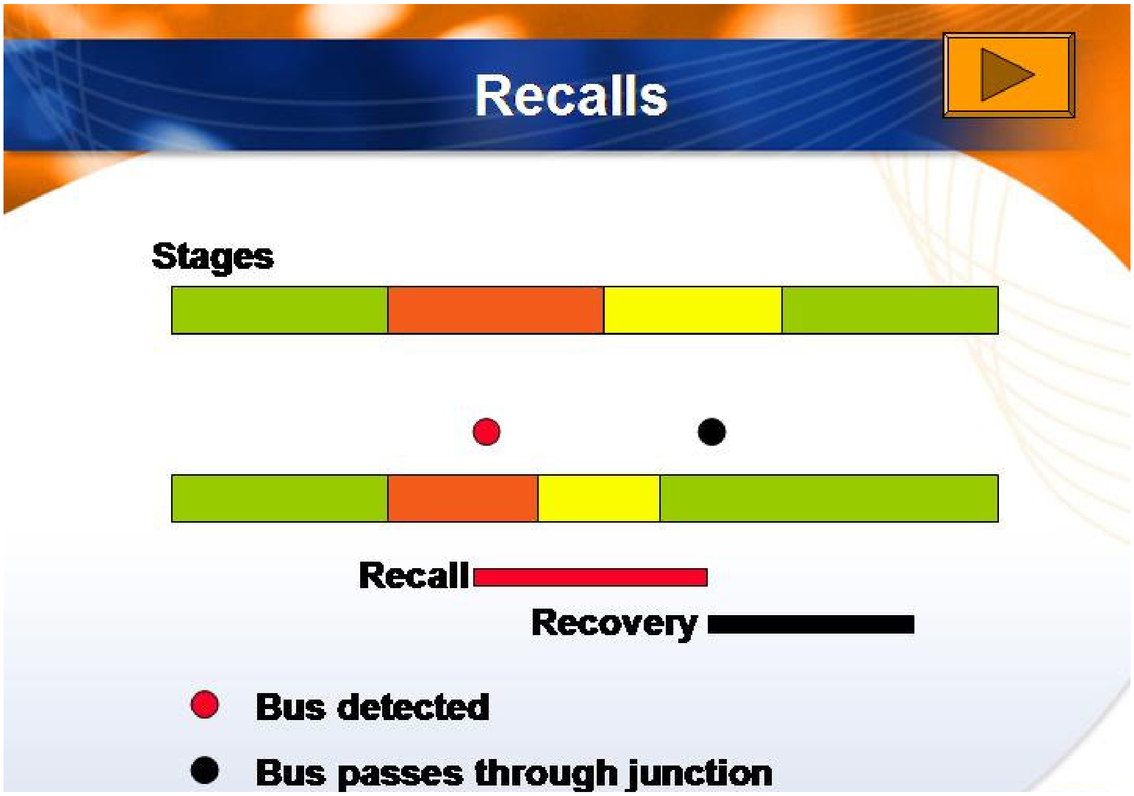
In this example a bus arrives on Link "A" at a junction. The SCOOT Bus Priority interface requests priority through the local controller for all movements along Link A. The local controller is notified when the bus has successfully negotiated the intersection.

Figure 27 - SCOOT Bus Priority, Request for Phase Extension

(SCOOT-UTC, 2006)

This slide produced by SCOOT-UTC shows two “bars”. The upper bar represents in graphical format the timeframe for each phase cycle at a signalised intersection. The lower bar shows the phase cycles as influenced by SCOOT Bus Priority request. The red circle denotes the time within the first green phase where a bus was detected in the system. The black circle is recognition that the bus has successfully negotiated the intersection. A second message is sent to the SCOOT controller and the phase is changed.

Figure 28 - SCOOT Bus Priority, Phase Recall and Recovery



(SCOOT-UTC, 2006)

This slide produced by SCOOT-UTC again shows two “bars”. The upper bar represents in graphical format the timeframe for each phase cycle at a signalised intersection. The lower bar shows the phase cycles as influenced by SCOOT Bus Priority request when the request is made during a red or non complying phase. In this instance the signal controller “speeds up” the non-complying phases and commences the next green phase early (known as an “early start”).

The black circle is recognition that the bus has successfully negotiated the intersection. A second message is sent to the SCOOT controller and the phase is changed.

Local extension

Extensions awarded in the controller can be advantageous as they eliminate 3 to 4 seconds transmission delay from street to computer and back to street, and so allow the system to grant extensions to buses which arrive in the last few seconds of green. This is especially important in London where link lengths are short; with bus stops often further restricting the effective length. SCOOT is still in control as it sends a bit each second to permit local extensions only when the saturation of the junction is sufficiently low, (similar to the congestion resolution techniques developed for SCATS). Techniques for programming the signal controller have been developed and implemented in London to suit local traffic conditions and constant congestion levels.

Recovery

Once the bus has passed through the signals, a period of recovery occurs to bring the timings back into line with the normal SCOOT optimisation, termed equilibrium when discussing the SCATS network. Four methods of recovery are provided for operation after extensions and recalls, of which two methods (one for extensions and one for recalls) are recommended for normal use and operate by default.

Restrictions on priority

The amount of priority given to buses can be restricted depending on the saturation of the junction as modelled by SCOOT, (termed business rules and congestion resolution rules in PTIPS). This is controlled by target degrees of saturation for extensions and recalls. These are the degrees of saturation to which the non-priority stages can be run in the case of a priority extension or recall respectively. Normally the target saturations should be set so that the junction is not allowed to become oversaturated, although some degree of oversaturation may be allowed to service an extension. This means that bus priority will be most effective at junctions which have spare capacity.

Congestion Management and Gating

SCOOT Bus Priority applications aim to extend green phases or reduce "phase delays" (due to buses arriving at a junction on red). However, these methods do not cater for overly congested networks. To alleviate this, SCOOT-UTC has developed a “gating” facility.

Gating (also known as traffic metering) is a traffic management technique which allows traffic to be relocated away from one or more congested link within a network, onto one or more upstream links where it is more feasible to protect buses by physical bus priority, such as a bus lane. Typically, gating is used to hold traffic outside of a town centre to maintain free movement of vehicles in the central area. It is hoped that, in keeping internal, critical, links relatively free of congestion, the network becomes more stable with the following positive effects on public transport: -

- Bus journey times become more reliable;
- Buses will be able to enter links more easily;
- Buses will be able to pull out from bus stops more easily; and
- Delay is reduced for buses.

4.7 Passive Bus Priority

Passive forms of priority are infrastructure improvements which are permanent and do not update or change according to traffic conditions. The infrastructure is either provided for the use of buses full-time, available on a peak only basis or is deployed when a bus is detected through loops or sensors placed in the lane. This section describes some common passive bus priority infrastructure improvements including: -

- Mid-block infrastructure (Section 4.8.1);
- At-node or intersections (Section 4.8.2); and
- Enforcement of Passive Priority Measures (Section 4.8.3).

4.7.1 Mid Block Infrastructure Improvements

Bus only lanes are a mid-block solution to moving buses quicker in general traffic due to peak congestion conditions. Bus lanes provide faster access for buses after picking up or setting down passengers at bus stops located in embayments. Figure 29 shows a bus only lane in Shepperton Road.

Figure 29 - Bus Only Lane Example

When addressing the merit of a mid-block improvement project, it is important to analyse the following points: -

Table 45 - Mid Block Infrastructure Assessment Criteria

Item	Decision	Quantification
Is there a significant delay to buses and other forms of traffic?	Yes / No	Point to point travel time (seconds)
What are the adjacent natural and man-made conditions, and are these conditions sympathetic to road widening (if required)?	Yes / No	Order of magnitude cost estimates for removal and provision of infrastructure
Opportunity to re-allocate existing road resources to buses only without creating an overly congested network?	Yes / No	Check vehicles per hour per lane and then re-assign to new format and check capacity
What is the frequency of bus operations along the route?	n.a.	Increased frequency of buses provides greater economic benefit
Will there be a disproportionate impact on other forms of traffic?	Yes / No	Check impacts on other transport forms
Is the project cost viable?	Yes / No	Compare project costs to budget and provide cost / benefit analysis
Can the infrastructure upgrade be augmented by other forms of priority, i.e. active or passive signal technologies to provide even greater time saving benefits?	Yes / No	Examine isolated improvement in terms of "whole of network" or holistic approach.

Bus Transit-ways

Bus transit-ways are road infrastructure built to highway standards but for use by buses and emergency vehicles only. It involves the complete segregation of buses from other vehicles and provides a high speed environment for buses to operate in. Examples in Australia include the Liverpool to Parramatta Transit-way and the Kwinana Freeway bus lanes.

Shared Use Lanes

Shared-use, or high occupancy vehicle (HOV) lanes can be useful for promoting both public transport and car-pooling. In Sydney T2 and T3 lanes are used in various locations around the city, including along the M4. High occupancy vehicle lanes are not used in Perth.

Bus stop within trafficable lane

Bus stops located within the kerbside travel lane enable buses to rejoin traffic after picking up passengers without having to merge back into traffic, as can be the case with bus embayments. Theory appears to be split however on whether bus stops should have embayments, as some road network planners argue that queue length congestion caused by dwelling buses adversely impacts other traffic and therefore general intersection performance.

4.7.2 At-node or Intersection Improvements

B-signals or bus queue jumps are an at-node or intersection improvement allowing buses to be the first in the queue at a signalised junction, or by providing priority through an intersection with the addition of a bus-only phase in the signal cycle, usually with minimal impacts on intersection capacity.

Figure 30 below shows additional phases in the signal cycle for buses only at two intersections.

Figure 30 - Passive Priority - Additional Bus Only Phases in Cycle

When addressing the merit of an at-node or intersection improvement project, it is important to analyse the following points: -

Table 46 - At-Node or Intersection Infrastructure Assessment Criteria

Item	Decision	Quantification
Is there a significant delay to buses and other forms of traffic?	Yes / No	Point to point travel time (seconds)
What are the adjacent natural and man-made conditions, and are these conditions sympathetic to road widening (if required)?	Yes / No	Order of magnitude cost estimates for removal and provision of infrastructure
What are the average queue lengths during the day and what is the length of the average queue in peak conditions?	Traffic Survey	Check peak volumes, quantify intersection capacity and measure queue lengths on-site
Is there a platooning or bunching problem in peak periods due to the impact of adjacent intersections?	Yes / No	Check vehicle volumes at adjacent intersections, mid block volumes and speeds
What is the frequency of bus operations along the route?	Number of buses per hr	Increased frequency of buses provides greater economic benefit

Will there be a disproportionate impact on other forms of traffic?	Yes / No	Check impacts on other transport forms
Is the project cost viable?	Yes / No	Compare project costs to budget and provide cost / benefit analysis
Can the infrastructure upgrade be augmented by other forms of priority to provide even greater time saving benefits?	Yes / No	Examine isolated improvement in terms of "whole of network" or holistic approach.

4.7.3 Enforcement of Passive Priority

Priority lanes can only work if they are respected by other road users. A parked vehicle in a priority bus lane forces buses to enter general traffic lanes, and therefore potential benefits may be lost.

Non-priority vehicles travelling in a priority lane may increase queue lengths at junctions, delaying priority vehicles and reducing benefits. Manual enforcement is costly, though some innovations, including traffic wardens travelling on buses to catch offenders, have improved efficiency.

Automated systems are now in use, which increase the level of offence detection, and therefore afford stronger deterrence. These include: -

- Bus mounted cameras;
- Roadside CCTV; and
- Roadside fixed cameras.

Such systems require initial purchase of equipment, the setting up of an operations centre and signage.

Self-enforcement design features can make bus priority easier to enforce, and reduce the need for active enforcement. Features include:

- Physical entry treatments to deter vehicles from accidentally entering a bus priority lane, e.g. chicanes, islands and bollards, (the Kwinana Freeway bus lane is an example where the bus lane is separated from other traffic by both bollards and concrete islands);

- Conspicuous lane markings and signing to help deter the unauthorised use of priority features, (most bus lanes in Australia are now conventionally painted red with yellow line marking to signify buses only. These include peak lanes along Broadway and Parramatta Road in Sydney and along the Causeway in Perth;

- Entry to a bus lane direct from a bus stop embayment;

- Exit from a bus lane controlled by features such as bus activated signals or rising bollards. B signals are used commonly in Australia to enable buses to gain a “jump” on other vehicle traffic. Two examples include the intersection of Parramatta Road and Glebe Point Road citybound and the intersection of Shepperton Road / Great Eastern Highway on the eastern end of the Causeway in Perth).

It is important to consider the marketing of services and to show the average user that bus services are a timely way to travel. The use of real time information at bus stops provides patrons with accurate waiting times for their next service.

4.8 Public Transport Patronage Increases through Transportation Engineering Infrastructure Provision

This section provides examples and case studies showing potential infrastructure improvement solutions and provides an assessment of their potential net gain for improving public transport travel time.

4.8.1 Infrastructure Upgrades

Changes to road networks and infrastructure improvements have been shown earlier in this report to have a potential impact upon modal choice. In 2001 the M5 East opened and the impact upon patronage on the East Hills line was immediately negative. Improved road networks develop 'induced traffic flow' for this very reason as improved travel times usually equate to increased volume. The bulk of the infrastructure work in metropolitan Sydney has been focused on the road network. This provides a tangible explanation for the loss of train patronage to additional vehicles on the road network. The improvements to the road system appear to have been less of a dis-benefit to the bus network as bus patronage has been maintained over the recent period. This is due motorway and rail function catering for longer haul trips than trips generated by bus.

Current major infrastructure projects in Sydney and Perth are notated in Table 47 below.

Table 47 - Current Major Infrastructure Projects

Mode	Sydney	Perth
Road	Cross City Tunnel	Perth to Bunbury Highway (Peel Deviation)
	M7 Westlink	Kwinana Freeway Extension to Peel Deviation

	Lane Cove Tunnel	Mitchell Freeway Extension (north of Joondalup City Centre – Hodges Drive to Burns Beach Road)
Rail	Rail Clearways Project	Northern Rail Extension – Currambine to Clarkson (expected patronage 2,850 weekday boardings in late 2005)
	Epping to Chatswood Rail (expected patronage 10,000 weekday boardings in 2008)	Perth to Thornlie rail line (expected patronage 3,500 weekday boardings in late 2005)
	South-West Rail Link (patronage gain not quantified)	Perth to Mandurah rail line (expected patronage 24,950 weekday boardings in late 2007).
	North-West Rail Link (expected patronage 20,750 weekday boardings in 2017)	
	CBD Rail Link (additional capacity to North Shore lines)	
Bus	North-West Transitway	Perth Circle Route Active Signal Priority Trial
Light Rail	City centre and inner suburbs routes being assessed but limited political will for deployment.	Several routes currently being assessed. Currently politically palatable.

The political climate may be amenable to change in NSW regarding the domination of road infrastructure investment with the early failure of the Cross City Tunnel to attract anywhere near the projected traffic volumes. Continual road improvements in Sydney's suburban network, without corresponding improvements to supply and capacity across the network to public transport services are a large reason why alternative modal share continues to drop.

Public Transport Infrastructure Improvement Case Study - Centenary Avenue Bus Lanes

As part of the assessment of the Perth Circle Route for the active signal priority trial, all intersections were examined for level of service and queue length under various conditions. The intersection of Centenary Avenue and Leach Highway was found to be one of the most congested and as such produces significant delays in the AM and PM peaks for both general traffic and public transport. As such it was considered that the deployment of active signal priority alone would provide no net tangible benefit and that additional engineering solutions would be required to improve intersection performance and travel time through the intersection.

The diagrams below show one of the options for the construction of a full bus lane from Manning Road to Leach Highway.

Figure 31 – Centenary Avenue Bus Lane Proposal, Northern Section (Intersection of Manning Road)

Figure 32 - Centenary Avenue Bus Lane Proposal, Southern Section (Intersection of Leach Highway)

Recently, as part of the Active Signal Priority Design and Specification of a Trial for the Perth Circle Route project, I provided a Benefit Cost Ratio with other tangible benefits, including an assessment of the potential reduction in greenhouse gases due to proposed road improvements to improve travel times for both public transport and other road users.

The project involved increasing road capacity and providing a 300 metre length of bus lane along Centenary Avenue in Waterford, an area which causes considerable delay to Circle Route buses operating from Oats Street to Fremantle in the pm peak. The total area of congestion is currently approximately 1.2 kilometres.

The following fuel efficiencies of a standard 6 cylinder vehicle (which we used as a representative of all motor vehicle traffic) were quoted: -

- 1996 3.0L Magna in drive with air-con on 45mL / min (idling); and
- 1996 3.0L Magna in drive with air-con on 135mL / min (at 60kph).

(Australian Academy of Technological Sciences and Engineering, 1997)

The following fuel efficiencies were then quoted in discussion with Transperth representatives for a representative bus: -

- Mercedes Automatic bus in drive with air-con on 133mL / min (idling); and
- Mercedes Automatic bus in drive with air-con on 400mL / min (at 60kph).

This is a conservative estimate based on a series of readings undertaken on various Sydney buses in the State Transit Authority of NSW fleet in 1998.

(King and Hensher, 1998)

Table 48 below examines the following information: -

- Total vehicles per day in the direction of travel;

- An assessment of the number of peak hour vehicles based on Poisson Distribution (10% of the total daily traffic arrives in the PM peak hour flow);
- Standard motor vehicle fuel usage per car in congested conditions;
- Number of hours where maximum benefit is deemed to be gained (evening peak hour between 4:00pm and 6:00pm on week nights);
- Total fuel usage based on cumulative traffic volumes; and
- Average fuel usage based on a vehicle occupation rate of 1.2 persons per vehicle, broken down into a resource usage per person.

The purpose of the tables is to compare the resources used per person by the various modes of traffic.

Table 48 – Fuel Usage for Motor Vehicles in Congested Conditions

Item	Calculations
Motor vehicle fuel usage (3.0L Magna in idle)	450 mL (in 10 minutes)
Average Vehicle Occupancy	1.2
Fuel usage per person	**0.375 L per person**

The average fuel usage per person on this 1.2 km section of road in evening peak hours is deemed to be 0.375 L per person in congested conditions.

Table 49 examines the same section of road under the same traffic conditions and quantifies the fuel usage per person given average patronage during timetabled school periods. This information includes: -

- Total number of buses per day in the PM peak in the direction of travel;
- Standard fuel usage per bus in congested conditions;
- Number of hours where maximum benefit is deemed to be gained (evening peak hour between 4:00pm and 6:00pm on week nights);
- Total fuel usage based on cumulative bus volumes; and
- Average fuel usage based on a patronage of 50 persons per bus, gained anecdotally from bus operator.

Table 49 - Fuel Usage for Buses in Congested Conditions

Item	Calculations
Total No of Buses in PM Peak	14
Motor vehicle fuel usage (Mercedes bus in idle)	1,330 mL (in 10 minutes)
Fuel usage	18.6 L
Average Vehicle Occupancy	50
Fuel usage per person	**0.027 L per person**

The average fuel usage per person on this 1.2 km section of road in evening peak hours is deemed to be 0.027 L per person in congested conditions. This is approximately 7% of the fuel usage of motor vehicle users and represents a major saving on greenhouse gas emissions.

Interestingly form these tables a minimum patronage level on the buses should also be examined. If the patronage on the buses falls below a certain level then the provision of bus infrastructure which excludes and impacts general traffic may actually be counter-productive with regard to preservation of resources. It is important that all infrastructure improvements are supported by a marketing campaign to improve patronage to deliver increased benefits to society from the changes. It is important that infrastructure improvements are looked at in this ideology so that government funds can be spent in the most appropriate manner.

Given the current road situation can be improved by the provision of an additional lane in the southbound direction with minimal construction required, (the road pavement is currently approximately 10 metres wide and the roadway is single lane in each direction), improvements in greenhouse gas emissions can be provided for both motor vehicle and bus users through improved travel times along this 1.2 km stretch of road. The key item change in the following tables is an assessment of the future delay to navigate this section of road.

Where existing delays have been measured at up to 600 seconds in the pm peak, standard times to successfully clear this section of road at other times of the day are closer to 120 seconds. The calculations in this example assume the full benefit is passed on to all road users.

Tables 50 and 51 examine fuel usage for both motor vehicles and buses in free flow conditions. These tables represent the improved road condition, post implementation of the suggested infrastructure improvement.

Table 50 - Fuel Usage for Motor Vehicles in Free Flow Conditions

Item	Calculations
Total vehicles per day (southbound)	7,849
Vehicles per hour (10% of total)	785
Total vehicles in 2 hr peak period	1,570
Motor vehicle fuel usage (3.0L Magna in idle)	90 mL (in 2 minutes)
Motor vehicle fuel usage (3.0L Magna in Free Flow)	270 mL (in 2 minutes)
Fuel usage	565.2 L
Average Vehicle Occupancy	1.2
Fuel usage per person	**0.30 L per person**

Therefore by removing congestion this represents a 25% improvement in fuel economy and therefore a 25% reduction in greenhouse gas emissions.

Table 51 - Fuel Usage for Buses in Free Flow Conditions

Item	Calculations
Total No of Buses in Peak	14
Bus fuel usage (in idle)	266 mL (in 2 minutes)
Bus fuel usage (in free flow condition)	800 mL (in 2 minutes)
Fuel usage	14.9 L
Average Vehicle Occupancy	50
Fuel usage per person	**0.021 L per person**

Improvements in travel time for buses equate to an improvement in greenhouse gas emissions of approximately 18%.

Patronage elasticity is deemed to be 0.3. i.e. a 3% increase in patronage for every 10% gain in transit time. Industry figures suggest between 1% and 5% increases in patronage for a 10% improvement in travel time. It has been assumed that the increase in patronage will be offset by induced traffic due to improved road conditions, however this is an example of improving the road network for all users with a net benefit to society as the outcome.

Public Transport Infrastructure Improvement Case Study - Intersection of South Street and Karel Avenue

Some infrastructure improvements can be as simple as lengthening a turning and deceleration lane to meet intersection queue length requirements. During the intersection assessment portion of the Perth Circle Route project, we found there were significant delays for buses at this intersection. The ability to turn left into Karel Avenue from South Street is compromised by queue lengths in the kerbside lane during pm peaks and intermittently at all times during work hours and the am peak. During work hours the main issue appears to be the number of trucks in the kerbside lane. During pm peak the percentage of cars is greater and the queue lengths appear to be a result of volume.

After visiting site and watching traffic throughput there appear to be two solutions worth further consideration: -

Option 1 – Infrastructure Upgrade Option

Extend bus bay into left hand slip lane. This work will require the following: -

- Site mobilisation, earthworks and subgrade preparation;
- Provision of new semi-mountable kerbing;
- Removal of existing kerbing;
- Provisional sum to remove and relocate irrigation and traffic management during works; and
- Provision of new pavement (hand lay sections) and linemarking.

Option 2 – Behavioural Change Option

Provide signage and painted lanemarking requesting trucks to use central lane only. Similar signage has been used on Leach Highway (eastbound) just past the intersection of Bull Creek Drive. By requesting trucks to use both the kerbside and central lanes appears to minimise queue lengths in the kerbside lane in evening peaks at the intersection of Webb Street opposite the

Rossmoyne High School and therefore allows traffic to enter the left turn slip lane during periods of red for through traffic on Leach Highway. In addition the requirement that trucks and larger vehicles use the kerbside and central lanes allows the two right turn deceleration lanes into Karel Avenue to fill in most situations prior to queue lengths in the median-side lane preventing access. This option is worth discussing with Main Roads to see if there is potential to deploy in this location on South Street. The change may improve vehicular access for both cars and buses.

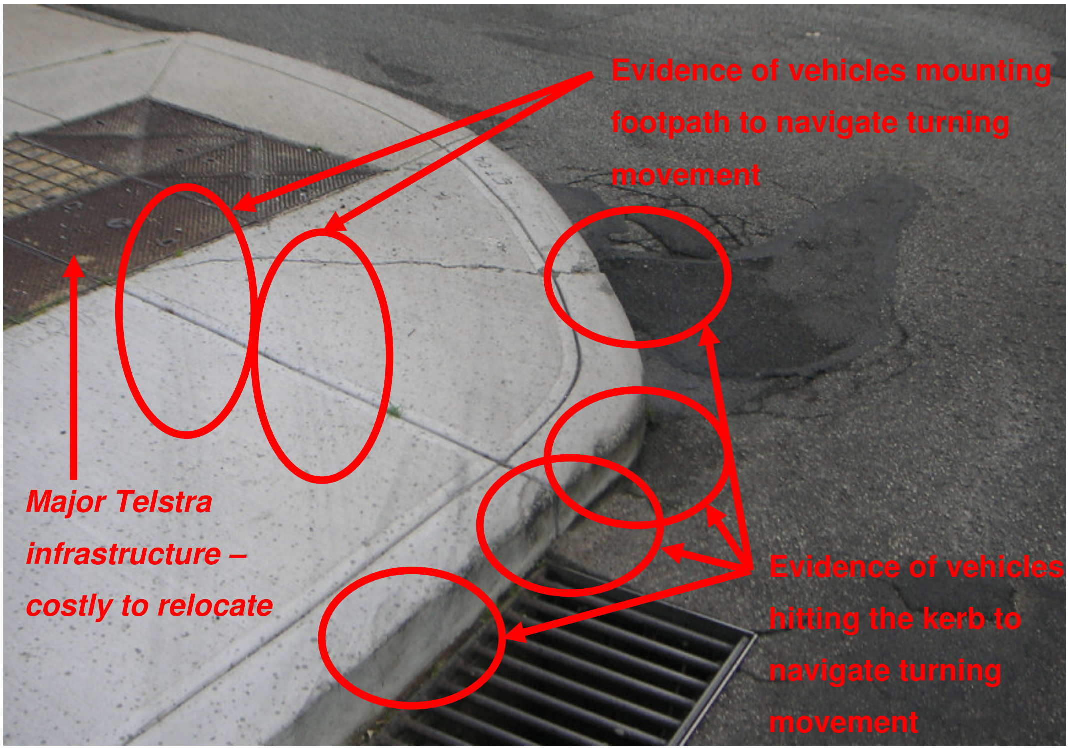
Figure 33 - Intersection of South Street and Karel Avenue

Public Transport Infrastructure Improvement Case Study - Intersection of South Street and South Terrace

Delays at this intersection are minimal due to lower traffic volumes, however it is worth noting that the intersection is difficult to navigate for larger vehicles (including buses) due to tight intersection geometry and kerb radii as shown and depicted in Figures 34 and 35.

Figure 34 - Intersection of South Terrace and South Street

Figure 35 - Close-up Photo of Kerb Radii South Terrace into South Street



The proximity of the Telstra infrastructure appears to be the major obstacle in re-designing suitable kerb radii; however minimal additional works to smooth the kerb radii could bring minor improvements. The current set-up will require maintenance in the foreseeable future as significant cracking has occurred due to the loads on both the kerbing and the footpath.

Whilst this is worthwhile to point out in the context of bus delays and wear and tear on bus tyres, it is arguably a maintenance issue for the applicable local government (City of Fremantle) to resolve.

Public Transport Infrastructure Improvement Case Study - Intersection of South Terrace / Parry Avenue / Norfolk Street

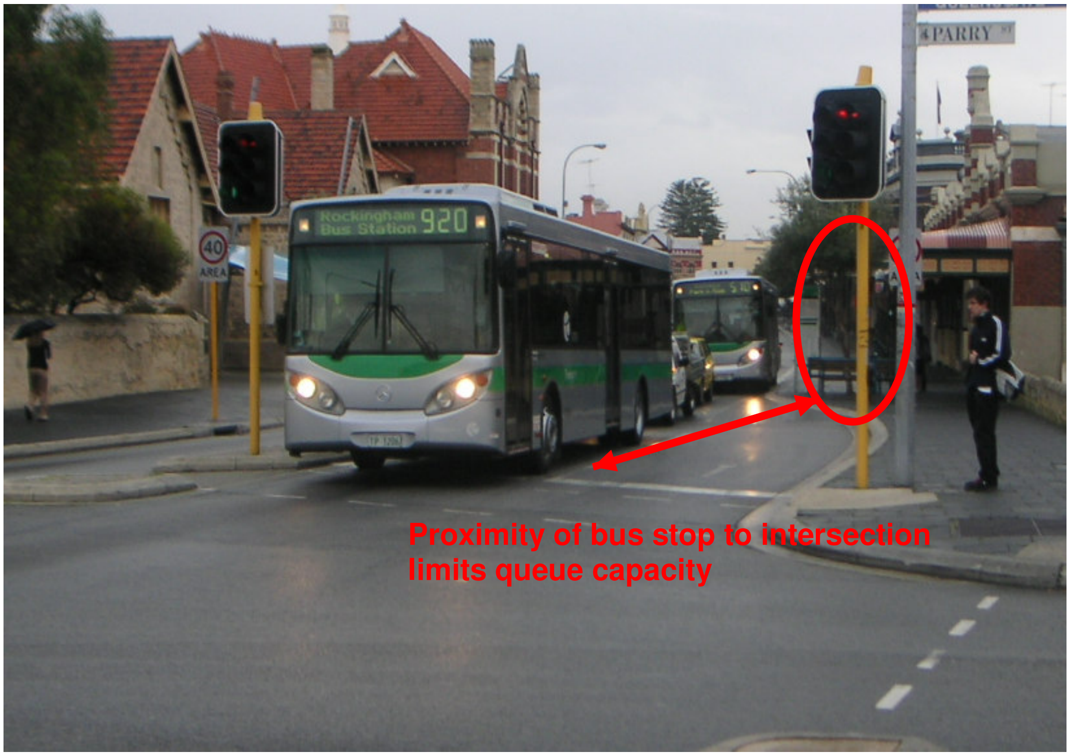
This intersection provides an example of providing a bus stop within the intersection approach capacity; therefore buses are forced to queue before setting down for passengers. This is a situation which occurs regularly during peak periods and on busy weekends and evenings.

The photo below shows the location of the bus stop on the approach side of the intersection and limited queue capacity between the bus stop and the yield at the intersection. As such buses can be delayed in reaching the bus stop and then cause delays whilst dwelling to allow passengers to board and disembark.

Options available to discuss with appropriate stakeholders include: -

- Relocating the bus stop further away from the intersection to allow reasonable queue lengths at the intersection. Based on preliminary observations, a reasonable distance would be a further 50 metres from the intersection;
- Amending the status of South Terrace between Parry Avenue / Norfolk Street and Market Street / High Street from road to bus-only transitway with access allowed for emergency service vehicles, taxis, cyclists and pedestrians only.

Figure 36 - South Terrace / Parry Avenue / Norfolk Street Intersection



This section details a number of case studies undertaken globally, in Sydney and in Perth as managed by the author. The purpose of the section is to identify: -

- The various systems used;
- The benefits presented to travel time improvements for buses; and
- The potential disbenefits to other road users.

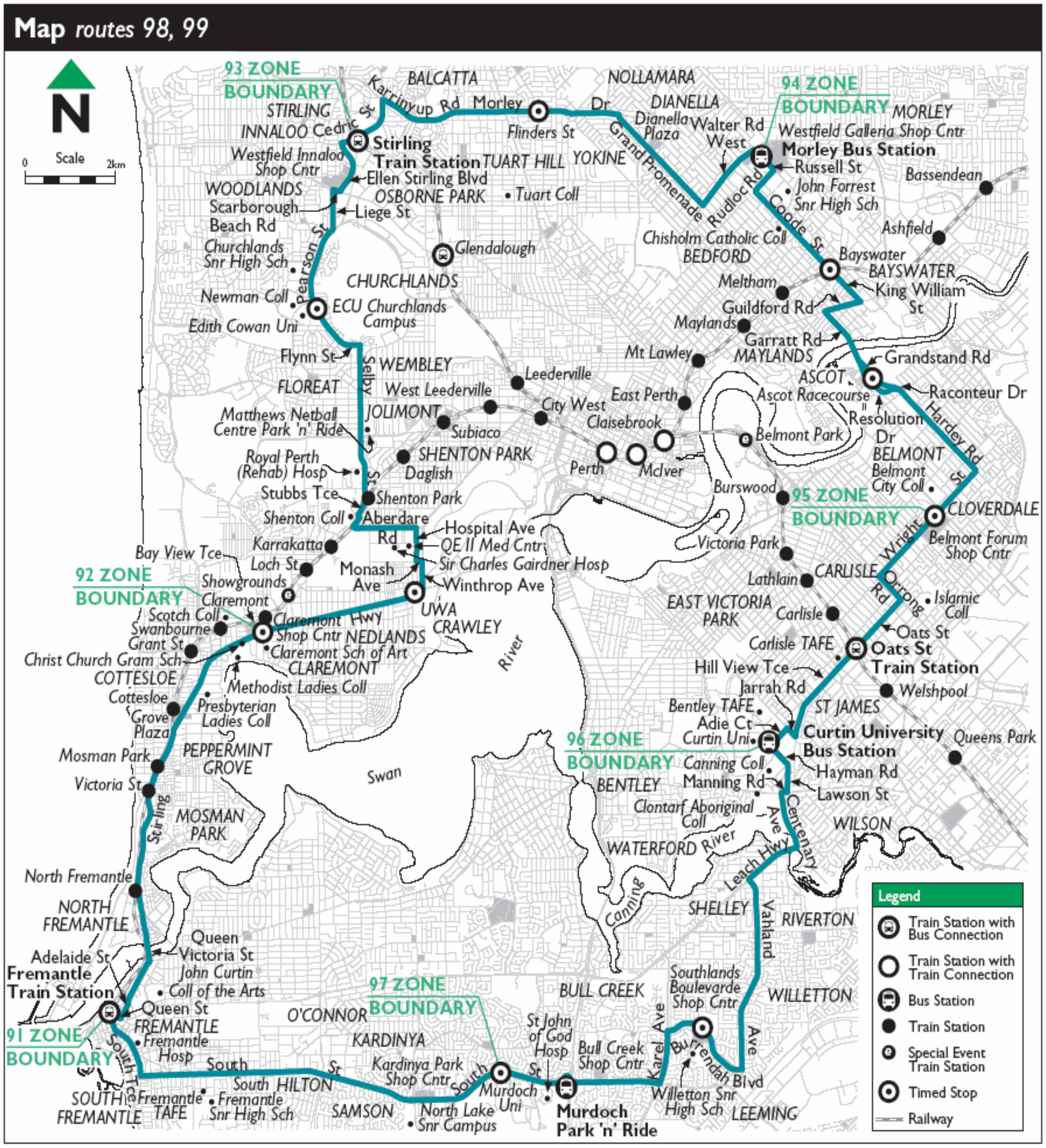
4.8.2 Perth Circle Route

The Perth Circle Route is one of Transperth's premier patronage generators, with average weekly patronage around the level of that experienced on the Midland to Perth rail service. During peak periods the Circle Route captures approximately 113,000 customers per week. Patronage gains are strong on a

per annum basis (running at just under 10% for the 12 months to 31 March 2005), making the Circle Route one of the most important and successful public transport routes in the Perth network. Noting the importance of on-time arrival for commuters, the Public Transport Authority (PTA) recently commissioned the design and specification of an active, signalised bus priority system trial for the Perth Circle Route.

The Perth Circle Route is shown below in Figure 37.

Figure 37 - Map of Perth Circle Route



(Transperth Circle Route Map, Transperth 2005)

After extensive research it was found that there are two active signal priority systems which have been deployed either in trials or in live projects in Australia and New Zealand. These systems are PTIPS (developed by the NSW RTA) and RAPID (marketed by Technisyst after initial development and marketing by

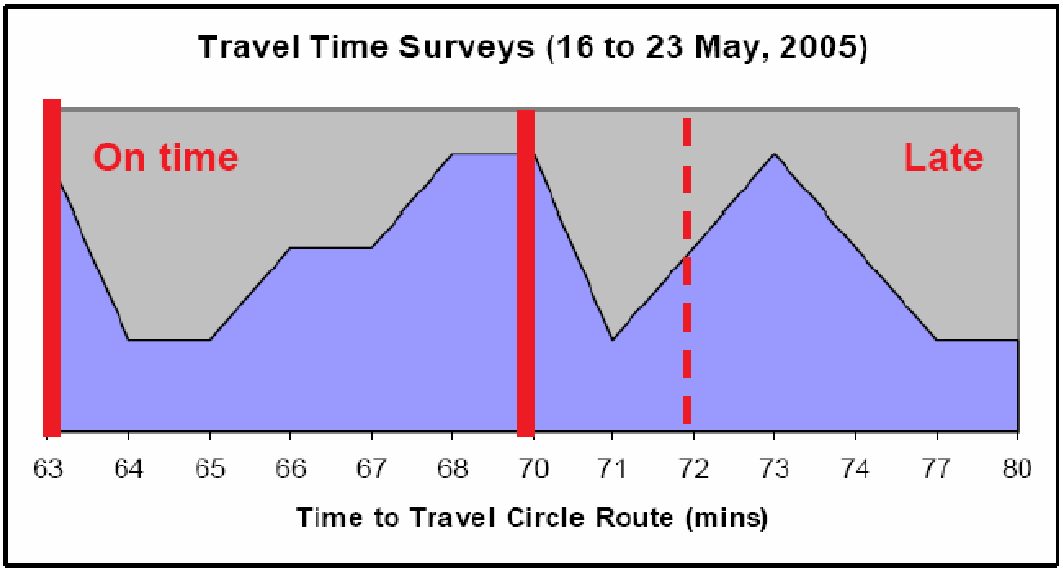
the Brisbane City Council). This report describes how these active signal priority systems' work and the system architecture required for successful deployment. During consultation it was found that Main Roads WA's preference for a trial of active signal priority software is for additions to the SCATS system to be developed by an entity highly familiar and conversant with SCATS.

There are a series of lessons to be learnt from a number of similar trials in Australia and recently in Auckland, including a brief examination of the loop and transponder system as trialled on the Liverpool to Parramatta Transitway in Western Sydney, and why this technology is not suitable for use in the upcoming trial on the Perth Circle Route.

The performance of existing intersections along the Circle Route was collated using data obtained from both state and local government sources. It was found that most intersections between Karel Avenue and Oats Street would be suitable for active signal priority and that substantial time savings could be generated.

In general it was found that most buses currently run on time, (anecdotally approximately 80%), however when a bus runs over 5 minutes late it is then very difficult to catch up lost time and in some instances the bus can be over 15 minutes late. This is caused by increased patronage on the late running bus, (the bus is starting to pick up some of the next buses passengers). In these instances buses tend to bunch and run out of timetable causing flow-on problems throughout the day. The provision of active signal priority will assist in maintaining reasonable scheduled headways between buses. Travel time and bus driver surveys confirmed that most buses run on time with approximately 10 to 20% of buses running late, depending on the time of day, time of week, passenger loadings and traffic conditions. Figure 38 shows the number of late running vehicles as surveyed in May 2005.

Figure 38 - Travel Time Surveys , Perth Circle Route May 2005



Description of the Circle Route

The Circle Route is currently one of Transperth's highest patronage services and differs from the majority of Transperth's bus routes. Traditionally, services operate in a radial fashion, transferring passengers from the suburbs to CBD areas. This system offers a reasonable alternative during peak service periods for commuting or education trips, however because these systems tend to operate direct between residential zones (trip generation zones) and CBD areas (trip attraction zones), there is very little requirement to utilise the service other than for commuting or education trips.

The Perth Circle Route however operates in an orbital system, connecting residential areas to local business districts, shops, places of education and recreation and the Perth rail system. As such, these routes tend to generate a more even patronage across the day as opposed to the traditional AM and PM peaks experienced with radial routes.

The purpose of the orbital or circle route is to essentially amalgamate a number of inter-suburb bus routes into one service. The system operates through inner and middle suburban areas including Stirling Train Station, University of WA,

Claremont CBD, Fremantle CBD, Murdoch University, Willetton (Southlands Shopping Centre), Curtin University, Oats Street Train Station, and Belmont Forum Shopping Centre. As such, this service interconnects a number of trip generating zones with trip attracting zones.

The key objective of this project is to deliver productivity and patronage benefits to Transperth and the PTA whilst minimising negative impacts on other forms of traffic in accordance with Main Roads WA requirements. Time savings benefits can be delivered to the customer through: -

- Utilising travel time savings as additional resources to allow increased bus frequency on either the Circle Route or on other Transperth routes;
- Improved frequency of bus services to assist Transperth in their goal of increasing overall patronage. Many studies have shown that services with higher frequencies (up to 10 minutes) tend to develop higher patronage levels due to customers not needing to timetable their arrival;
- More consistent headway between buses and more reliable buses. Bunching or double banking of buses can be frustrating for customers who miss their bus and are then forced to wait an extended time for the next bus to arrive. This is a strong source of current complaints.

The summary goals are to obtain reduced travel times, increased reliability and increased frequency of service.

Site Inspections to Determine Applicability of Active Signal Technology

Site inspections at the intersections along the southern half of the Circle Route offered the following observations: -

- It may be difficult to obtain priority along intersections on South Street in peak congested periods (with the exception of Gilbertson Road and Benningfield Road);

- Centenary Avenue is highly congested in evening peak periods, particularly for the Route 98 bus from Oats Street to Fremantle, and the provision of active signal priority will probably not provide tangible benefits in this location;

- Priority at intersections such as Oats Street / Shepperton Road, South Street / Carrington Street, Hill View Terrace / Berwick Street, South Terrace / Parry Avenue and Market Street / High Street may be difficult due to the proximity of the bus stop on the approach side of the intersection;

- Traffic congestion along South Terrace near Parry Street should be examined as a separate issue, however improvements could have a positive impact on bus travel times;

- Route 99 buses turning into South Street from South Terrace have difficulty due to tight intersection horizontal geometry and are forced to turn from the centre lane to avoid collision with kerbs and / or islands in South Street;

- Major traffic congestion can be encountered at South Street / Kwinana Freeway linked intersections during morning and evening peak periods. Considerable delays can occur on the entry and exit of the Murdoch Park and Ride facility, (except when entry and exit are provided under give way yield);

- Pedestrians crossing mid block on South Street between Benningfield Road and Calley Drive may present safety issues when buses are arriving / departing.

Priority could be successfully obtained at most other intersections where the required ‘business rules’ are met. These business rules will be discussed in later sections.

Proximity of Bus Stop to Approach Side of Intersection

To develop the most effective active signal priority system, the location of the bus stop with respect to the intersection is important. The following table shows the location of bus stops with respect to the intersection. Of particular importance is the location of bus stops on the approach side of the intersection. Bus stops in this location may hinder the ability of a bus to successfully request priority with minimal delay due to the time / distance rule regarding appropriate setbacks from intersections for the location of way points.

From anecdotal information provided, it takes approximately 3 seconds from the time the bus priority software requests priority to compute through an active signal priority system and SCATS and for the answer to be sent to the intersection control box. However anecdotal evidence suggests it is important to note that the provision of priority at an intersection is difficult to obtain where the travel time from a way point or bus stop to the stop line at the intersection is less than 20 seconds, (depending on the complexity of the intersection, 20 seconds is considered a reasonable ballpark figure to start from). I have calculated a time / distance specific rule based on the average speed of buses between Oats Street Station and Fremantle Station and found that active signal priority should be able to deliver benefits where a bus stop is at least 130 metres away from the approach to an intersection.

Time / Distance and Acceleration / Distance Relationships

There are a number of issues regarding intersection and road improvements and the location of way points within the southern half of the Circle Route. It is important to note that our design philosophy is not to shift the location of bus stops as these have been located to suit attaining the highest walkable catchment numbers. It is also important to note however that the ability to request priority is diminished at an intersection where the travel time from the bus stop or an appropriately set way point is less than 20 seconds to the intersection. The following speed limits have been converted to distances

travelled per second, and these numbers make up the **Time** / **Distance Rule** which is used to equate the distance of way points from an intersection: -

Table 52 – Distance / Time Relationship (Way Point Location Theory)

Vehicle Speed (km/h)	Distance Travelled Per Second (m/sec)	Distance Travelled Per 20 Seconds (m)
60	16.7	334
50	13.9	278
40	11.1	222
30	8.3	166
20	5.6	112

Therefore given an average approach speed of 30kph, a typical setback for a way point from an intersection would be approximately 166 metres, depending on other constraints such as whether on road parking is an issues, or the location of a bus stop on the approach side of an intersection.

There has been a school of thought that the ability to call for and receive priority is diminished if the bus stop is within 200 metres of the intersection and the ability is diminished markedly where the bus stop is within 100 metres of the intersection.

This simplistic rule is useful for determining the location of way points prior to intersections where there are no bus stops, however does not take into account that if the bus has stopped at a bus stop to allow passengers to board and / or alight, the bus speed will be 0kph and the rate of acceleration becomes an important criteria. After reviewing a number of sources for standard acceleration rates of buses, it was agreed that 2.0m/sec/sec would be used.

Table 53 - Acceleration / Time Relationship (Way Point Location Theory)

Time Elapsed (seconds)	Speed (acceleration = 2 m/sec/sec)	Speed Reached	Distance Travelled (m)
1	2 m/sec		2
2	4 m/sec		6
3	6 m/sec	20 kph	12
4	8 m/sec	30 kph	20
5	10 m/sec		30
6	12 m/sec	40 kph	42
7	14 m/sec	50 kph	56
8	16 m/sec		72
9	18 m/sec	60 kph	90

Therefore given: -

- an average speed of approximately 30kph for bus travel on the Circle Route;
- an elapsed time of 4 seconds and a distance travelled of 20 metres to reach 30kph from a standing start;
- remaining time of 16 seconds to attain maximum opportunity to request priority and not experience delay; and
- 16 seconds * 8.3 m/sec = 133 metres travelled at 30 kph.

A bus stop within 150 metres of the approach side of an intersection with an approach speed of 30 kph may not have enough time to request priority; however this should be reviewed on a case by case basis.

Given these calculations, I have developed layouts showing minimum way point distances based on a typical four-way intersection layout (Figure 39) and based on a bus stop on the approach side of the intersection (Figure 40).

Figure 39 – Waypoint Layout at Typical Intersection

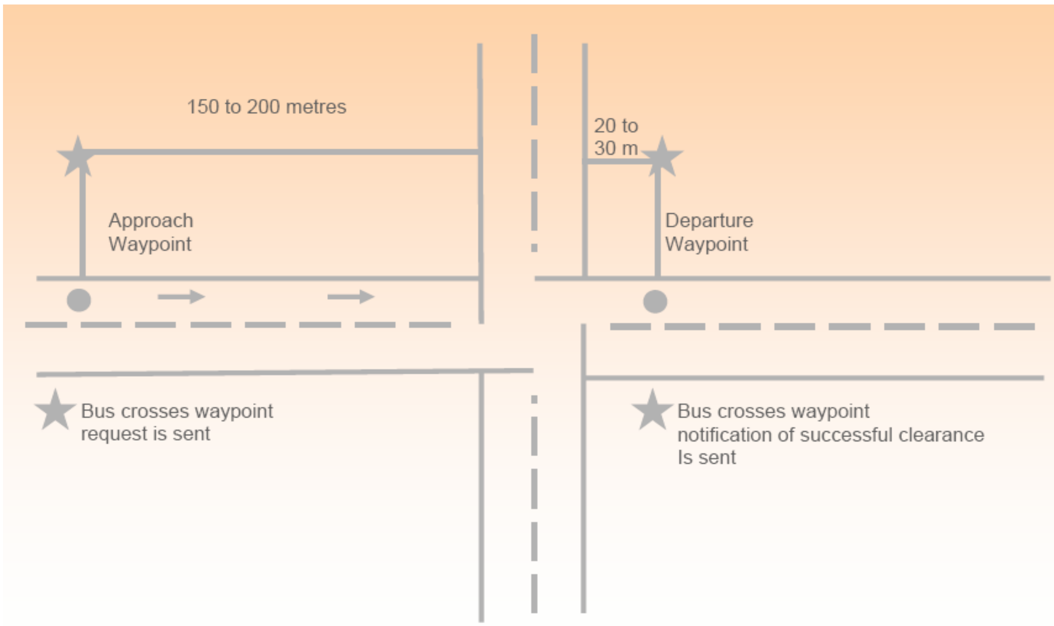
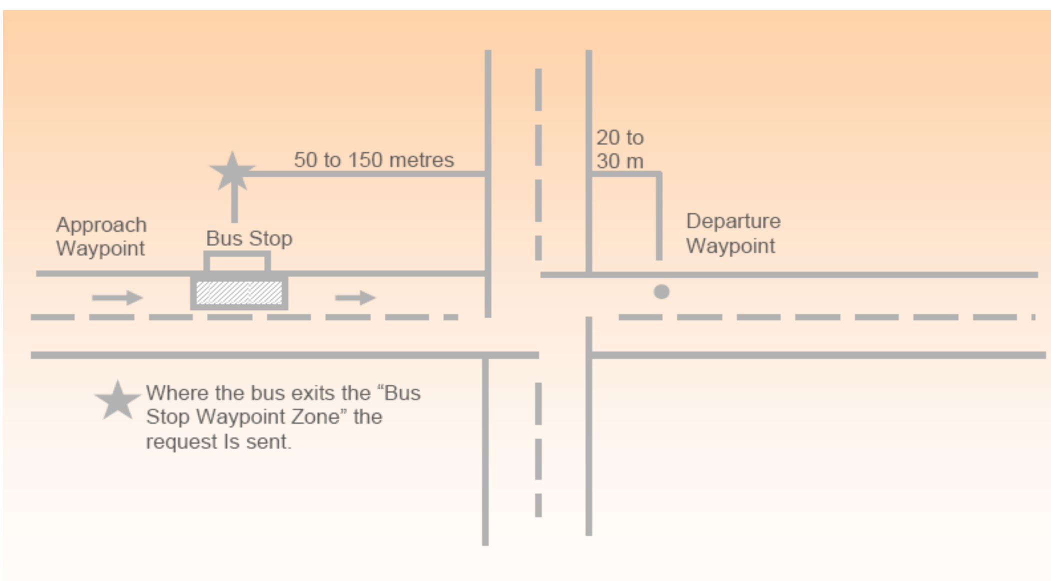


Figure 40 – Waypoint Layout with Bus Stop on Approach Side of Intersection



Actual Bus Stop Locations and Identification of Potential Issues

Given the Distance / Time and Acceleration / Time formulae and relationships developed above, I have provided a selection of bus stop locations which were identified in the report. Locations highlighted in red signify where the bus stop is located less than 100 metres on the approach side of the intersection. Table 54 below shows one of the intersections with a bus stop noted as within the 100 metre calculation zone as a risk to be monitored during the trial.

Table 54 - Bus Stop Locations and Identification of Potential Issues Regarding Acceptable Timeframes Between Request and Intersection Entry

Intersection	Fremantle to Oats Route 99	Oats to Fremantle Route 98
Oats Street / Shepperton Road	**Approach side - 80m**	Departure side – 80m

As part of the study, I assessed the following intersections as having potential issues during peak operation times regarding queue lengths and bus clearance during a signal phase: -

- South Terrace / Parry Street (Route 99) due to location of bus stop and significant queue length in afternoon and evening peaks;
- South Street / Carrington Road (Route 98) due to location of bus stop and significant queue lengths for left turning and straight through vehicles;
- South Street / Stock Road (both directions) due to phasing requirements for trucks turning from Stock Road into South Street;
- South Street / Murdoch Drive (particularly Route 99) due to current roadworks associated with the Perth to Mandurah railway;

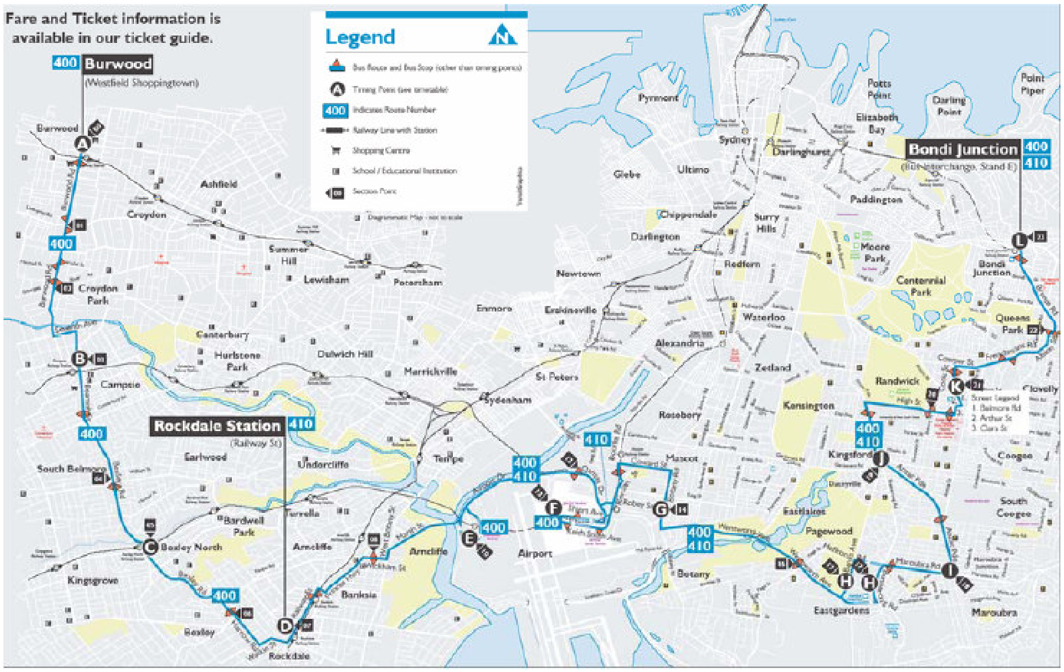
- South Street / Kwinana Freeway (both directions) due to phasing requirements;
- South Street / Calley Drive (both directions) due to close proximity of bus stops and traffic exiting Calley Drive Medical Centres and residential catchments and Bull Creek Shopping Centre;
- South Street / Karel Avenue (Route 99) due to queue lengths in the peak along South Street eastbound toward Canning Vale – occasionally queue lengths do not allow bus to access deceleration lane into Karel Avenue; and
- Centenary Avenue / Leach Hwy (Route 98) due to significant queue lengths along Centenary Avenue – Circle Route has been trialled along alternative route to Bungaree Avenue, then left into Manning Road and back onto Lawson Street. A decision is expected in the next couple of weeks.

This information has been summarised from the WorleyParsons report “Design and Specification of an Active Signal Priority Trial”.

4.8.3 Route 400, Burwood to Bondi Junction Sydney

In Sydney, the NSW RTA has developed an active priority system known as PTIPS (Public Transport Information and Priority System). PTIPS runs on SCATS Version 6.3 or later. This system has been trialled on Route 400 between Bondi Junction in Sydney’s eastern suburbs and Burwood in Sydney’s inner west. The route is semi-circular in nature and similar to the Perth circle route in that it is an orbital service. The route covers 40 km and runs through 81 sets of signals in some of Sydney’s most congested networks. The average trip time is timetabled between 60 and 70 minutes, however it has been noted that some trips are taking over 95 minutes to complete.

Figure 41 - Sydney Buses Route 400 Route Map



The trial was performed on a total of 800 bus trips with equipment on 15 buses and priority given at 60 signalised intersections. Twenty intersections were deemed too congested. Initially during the trial PTIPS fed data to SCATS. This PTIPS data took precedence over the SCATS software. To enable PTIPS to be used on all signalised intersections the NSW RTA developed a ‘Congestion Rules Resolver’. Essentially the Congestion Rules Resolver operates when a pre-determined level of congestion is detected in real time. i.e. when detectors are running at a certain degree of saturation. Therefore if there is too much congestion, PTIPS will not request priority from SCATS.

Other rules for provision of priority include the amount of green time available on various phases and location of bus stops. Where bus stops were located immediately prior to intersections no priority would be given at the intersection. As such, the NSW RTA now suggests that bus stops are placed on the departure side of the intersection, however no bus stops were moved for the trial – in general the NSW RTA accepts the location of a bus stop. In addition the NSW RTA may consider priority to ‘hold’ green where stops are located prior to the intersection.

To ensure the test represented a broad cross-section of time periods throughout the day, the test was run over 24 different time periods. Most combinations showed slight to strong improvement, with two combinations returning slightly higher running times. In addition adherence to timetable was measured at 8 major bus stops. With priority on, no buses were late. Indeed after travel times were plotted in each direction, PTIPS was shown to **improve on time running by 37%.** Importantly with PTIPS active, **82% of trips were started on time,** which equates to a **15.5% improvement**. Some off peak services have been timed completing the route in 85 minutes, providing the opportunity to improve frequency in off peak services from one bus every 20 minutes to one bus every 10 to 15 minutes. Anecdotal evidence suggests that stress and strain on bus drivers was improved.

Due to the small number of vehicles fitted during the trial, it was difficult to assess any adverse impacts on the network due to the implementation of bus priority; however anecdotal evidence from the NSW RTA suggests any impacts were negligible.

Table 55 – NSW Route 400 Trial Comparisons

Time	Route Description	Without PTIPS Activated	With PTIPS Activated
7:00 to 9:00	Bondi to Eastgardens	33 mins	**23 mins**
11:00 to 13:00	Burwood to Bondi	93 mins	**87 mins**
	Bondi to Burwood	90 mins	**87 mins**
13:00 to 15:00	Burwood to Bondi	95 mins	**85 mins**
17:00 to 19:00	Bondi to Burwood	90 mins	**80 mins**
	Burwood to Bondi	95 mins	**90 mins**

Major improvements were noted on the morning trips between Bondi to Eastgardens, however it should be noted that the NSW RTA are sceptical of this result.

Some minor intersections were not connected to SCATS, however this has been shown not to have had an impact upon the results.

Feedback through the NSW RTA suggests that the bus operator has been happy with the performance of the trial. The NSW Treasury have had a limited involvement. The Ministry of Transport are enthusiastic regarding bus performance, as penalty regimes apply for operators where on time performance drops below 80%. The NSW RTA operations section has been positive as PTIPS doesn't request priority where congestion levels breach a pre-determined level.

The conclusion to the trial includes full fit out of buses on the route with PTIPS OBU. The NSW RTA believe they can improve travel time by a further 5 minutes, allowing either additional services to be run or buses to be redeployed through the network.

It is important to note that the allocation of active signal priority has not removed the instances of double banking of buses, however there has been minimisation. This issue will be addressed separately.

This information has been summarised from the WorleyParsons report "Design and Specification of an Active Signal Priority Trial".

Rapid 2 Case Studies - Brisbane City Council Interview

The RAPID system was initially developed by the Brisbane City Council (BCC) as a loop / transponder system (similar to the LPT in western Sydney). The system has been developed for the 900 series buses operating on a number of inner city busways, transit lanes and in shared traffic.

There are two key components to the RAPID system: -

- Real Time Passenger Information provided at stops and stations throughout the city.

- Signal priority for buses which are running late.

When a bus is running late the signals can be adjusted (early green or extended green) to help get the bus through with reduced delay. The bus could trigger this assuming it met a number of conditions relating to passenger loadings, congestion at the intersection and how late it was running.

Because the system relies on transponders and loops there were large "holes" where the exact location of the bus was not known, a similar complaint to that on the LPT. The coordination between adjusting the signals and buses can therefore be poor.

Brisbane has a large number of intersections where relatively equal volumes of traffic approach the intersection from each leg. This is also believed to influence the success of the system.

Because priority was linked to both passenger numbers and whether the service was on time only a relatively small number of buses actually triggered the system to provide priority. This coupled with the 'holes' in information about service location mean that very few services received a tangible benefit. The system is only capable of adjusting the signals once because it only knows when a bus is approaching. There are no loops on the departure side of signals so the system does not know when the bus has cleared the signals. Adjustments to phases were therefore only made once and assumed that the bus would clear the intersection as a result.

The system is now used to provide real time passenger information and can be used to let bus drivers know if they are on time or not.

This information has been summarised from the WorleyParsons report "Design and Specification of an Active Signal Priority Trial".

Melbourne SMART Bus Trials

The purpose of the Melbourne Smart Bus Project is to improve the travel times for both buses and trams. The system currently uses an inductive loop to activate the signal phase, however this is seen as redundant technology. The Melbourne Smart Bus network will utilise the RAPID 2 system which is similar to PTIPS. VicRoads is currently conducting further trialling of inductive loops on the tram network.

Importantly, in Melbourne the team is considering asking for priority at intersections where a bus stop is on the approach side of the signals. In this instance the bus can cross a waypoint in advance of the bus stop and request a 'red light' phase. This will be requested on the basis of average passenger time loadings matching the length of the red light phase requested. Therefore when the bus exits the bus stop, the signal phasing should match.

The system operates through 'data validation' parameters to ensure that SCATS is not 'spammed' by continuous data requesting priority.

Linked intersections are incrementally advanced.

There has not been a physical trial of the system in Melbourne yet, but the system is currently in design review.

The goals of the Melbourne project include: -

- Timetable optimisation;
- 15 minute headways to be maintained;
- Improvement in overall travel time;
- Incorporation of passenger patronage information;
- Collation of recent historical travel times, to cater for changing traffic conditions (i.e. school holidays, extended periods of roadworks etc);

- Calculation of off-peak and peak travel times to ensure timetables and headways can be set according to time of departure;
- Feedback to drivers regarding on time performance;
- Feedback to bus operator regarding maintenance and running performance; and
- Increased profile of public transport services.

The initial trials of Smart Bus (using loop / transponder system with VMS) delivered a patronage increase of approximately 25% to 30% however these increases may also have been influenced by increased service frequency and other events. The trial ran over 6 months.

This information has been summarised from the WorleyParsons report “Design and Specification of an Active Signal Priority Trial”.

Rapid 2 Trial and Deployment, Auckland NZ

The Rapid 2 system in Auckland runs on real time information provided via a GPS system with communications delivered through GPRS. There are two signal pre-emption methods where Rapid 2 requests priority: -

- 10 second head start
- Hold the signal for an additional 10 seconds.

Rapid 2 can also request a supplementary phase or request re-ordering of the phases however both are rare on the Auckland system as congestion was deemed to be an issue in inner suburban and CBD areas, thus the opportunities for intervention are limited.

Communications between the on-board software and the Rapid 2 server are event based, not constant. An event is classified as the moment the software crosses a waypoint and is located in the system.

Waypoints are located at each bus stop and at each intersection both on the arrival and departure sides. Entry is usually 80-90 metres prior to and 15-20 metres after an intersection, or 30 metres prior to and 15 metres after a bus stop, depending upon local conditions. These distances are computed separately at each intersection depending upon local factors such as congestion, road layout, whether the bus stop is embayed or in the kerbside lane, proximity of the bus stop to the intersection etc.

To obtain reasonable positioning data, GPS is usually reliant on data being fed to at least 3 satellites to deliver the required minimum accuracy in bus location. Where data is retrieved and interpreted by less than 3 satellites the location can be effected by ‘noise’. In these instances Rapid 2 will request further positioning data via odometer readings. Accuracy is provided to within 6 metres.

The Auckland link bus service is approximately a 60 minute circuit. Some buses run the full loop, however there are 17 different short routes run within the link.

The system also utilises predictions based on historical travel time data. The data is collated and a running 5 week average is used to check whether buses are running on time, ahead or behind schedule. There are 50 VMS signs deployed on the route all displaying information which is updated as buses cross way points in the system. A maximum of 24 buses are used on the route with between 12 and 18 deployed at any one time. The buses are run on 10 minute frequencies, which essentially means that a timetable for passenger usage is not required. One operator runs the route.

The system runs at its peak efficiency when the server output is constantly monitored by the bus operator, (i.e. under human intervention). This enables the operator to inform bus drivers via radio whether bunching is an issue. Patronage data can be used to let upcoming customers know that an upcoming bus is full via the VMS.

One important point to note is the system can fall down where bus drivers do not input data correctly into the ticketing machine, i.e. run codes, driver numbers, route start times etc.

Auckland Stages 2 and 3 are about to be deployed. This will include an additional 150 intersections, 150 VMS signs and 150 more buses to be fitted out at an approximate cost of NZ$7,000,000. The on bus equipment is approximately NZ$7,500 each including fitting.

The servers can handle up to 1,000 signs and intersections connected into the one system without further software upgrade.

The current travel time improvement on the 60 minute journey is approximately 8 minutes.

The system includes a series of databases which includes the journey planner and average starting times across the network for any particular bus on any day of the week. Priority can be given to the late bus or the bus with the most passengers on board.

Communication cost for each bus trip is approximately NZ$0.20. Given 8,000 bus trips per day this equates to a cost of NZ$1,600 per day for communications.

The Rapid box is usually located behind the drivers' seat and is approximately 400mm wide, 300mm deep and 100mm thick. The VMS signs are approximately NZ$15,000 each. 5 servers are required to operate the Auckland Link system.

This information has been summarised from the WorleyParsons report "Design and Specification of an Active Signal Priority Trial".

4.8.4 Eindhoven, Netherlands

Furth and Muller conducted a study into the impact of active signal priority on delays experienced by buses and private vehicle traffic at one intersection in Eindhoven, the Netherlands.

In their study, three signal priority conditions were tested, for one AM and one PM period each, during the 3-day data collection period: -

- No priority – providing no signal priority for transit buses approaching the intersection;
- Absolute priority – providing a green phase to each bus regardless of whether or not it was running ahead of schedule; and
- Conditional priority – providing priority to a bus only when it was behind schedule.

Importantly, to assess the impact of priority on all vehicular traffic, the study measured the average total vehicular delay. This delay is defined as the difference between the actual time it took a vehicle to traverse the intersection and the time it took a typical unimpeded vehicle to do the same. Data recorded by in-vehicle computers, used to determine the schedule deviation status of the buses for the priority system, enabled the determination of the delay experienced by transit buses.

The study found that average total vehicular delay experienced during the three busiest hours at the intersection increased by 40 seconds per vehicle under absolute priority. There was no significant change in delay with the buses operating under conditional priority. This pattern held true for all of the surveyed hours, with absolute priority causing large delays to other traffic, while conditional priority causes little, if any additional delay. Buses experienced an average of 27 seconds of delay without priority. This figure dropped to 3 seconds per bus with absolute priority. During conditional priority, the bus delay fell in between these values. 90% of all buses received zero-delay service

under absolute priority. Only 74% of the late buses experienced zero-delay service under conditional priority. The authors state that this indicates a need to improve the schedule deviation tracking system, the traffic signal controllers, or the communication between the two, in order to ensure priority treatment for late buses.

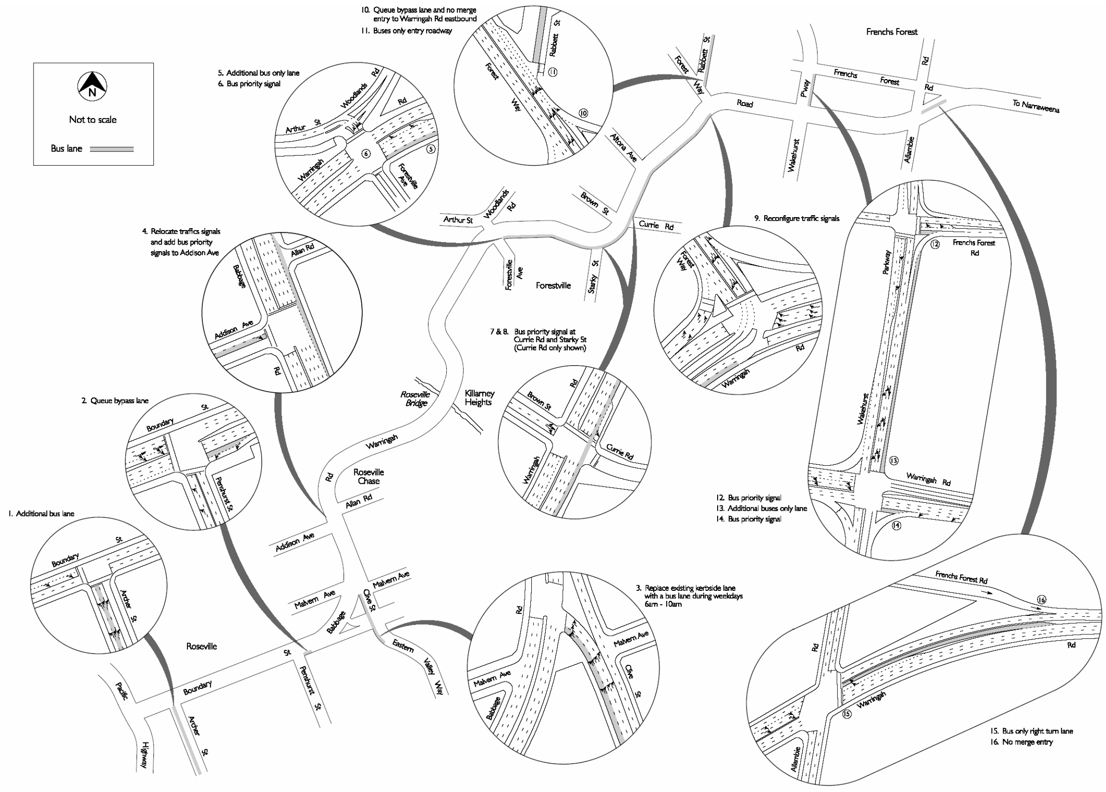
Table 56 – Delays to Buses and General Traffic During 3-Day Trial, Eindhoven The Netherlands

Time	Delay for Buses (sec)	Delay for General Traffic (sec)
No Priority	27	0
Conditional Priority	15	Negligible
Absolute Priority	3	40

The authors' conducted a simulated study which predicts use of automated decision support tools can decrease travel times by up to 29%. This translates to a marked improvement in public transport travel times, which importantly may lead to increased patronage and may impact upon commuter modal choices across the network.

Figure 42 below shows the extent of the Eindhoven Trial Area and highlights the intersection configuration and location of priority intervention at signals.

Figure 42 - Eindhoven Priority Trial Area



(Furth, P. & Muller, T. 2000)

4.8.5 Helsinki Finland Trial

The general traffic planning policy of the City of Helsinki is to promote public transport. The very first trial project with tram priority was started in 1978. Now more than a hundred signalised junctions in Helsinki are equipped with tram priority equipment.

Initially priority for buses was based on signal timing co-ordination on major routes, timed coincide with the timetabled arrival of buses. This was known as “green wave”. No detectors were used in this system, but the benefit to buses was based on on-time commencement of journey and no unforeseen delays along the way.

The “green wave” however was shown to have many drawbacks however, with delays to other road users the major problem. Priority was also delivered only to buses which arrived on-time. Therefore late running buses, which feasibly need priority, would be further delayed due to the intersections returning to their previous state of equilibrium.

The failure of these systems necessitated the development of detection systems. The City also required that the system would have understanding of which bus was crossing the detector and therefore, whether or not the bus was late or running on-time. Importantly, the City also sought to develop a system which understood how many people were on the bus, and therefore to develop business rules which would allow the deployment of bus priority based on measures of “lateness” and “patronage”.

This type of system could not run using passive detection techniques such as road loops. The system required the ability to interact on a real time basis, via an on-board transmitter and a receiver at each traffic signal junction controller box.

Fixed Location Detectors

Fixed location detection systems utilise fixed cabling and receiver components including loops, beacons and infrared readers at fixed locations along the route.

These systems have a high construction cost as the infrastructure required is physical and occupies a rigid space within the road reserve. This type of system has been used on the Liverpool to Parramatta Transitway with mixed results due to parked vehicles over loops and queue lengths in congested peak periods causing buses to not trigger loops.

Infrared Bus Detectors

Infrared bus detectors are another physical installation within the roadway similar to loops, however are based on an infrared receiver mounted on overhead cabling. As the bus travels underneath the receiver, a roof mounted infrared transmitter on the bus sends a signal to the receiver. The system

delivered similar problems to fixed, in-road loop infrastructure. Where buses were travelling in other traffic lanes, no communication would be registered between the transmitter and receiver.

Microwave Bus Detectors

Microwave detection is based on microwave communication between the bus and roadside equipment. The equipment included a transponder unit mounted on the right hand side (kerbside) of the bus, with beacons located on traffic signal poles at the intersection. The microwave communication range was set a 24GHz.

The trial exhibited greater success for the City of Helsinki, however once again the cost of locating physical infrastructure and cabling at each intersection became prohibitive to roll the system out across the network. System performance was greater than that of previous “hard infrastructure” systems, however the system could still be affected by parked vehicles and the receiver could only pick up data within certain bus speed parameters. The project did however successfully integrate other functions for priority such as “lateness” and “patronage”. Reliability at intersections varied between 50% and 99%.

The microwave bus detector system was also trialled using separate tags for each bus, (developed by a Swedish company called Combitech). The system utilised two 45 GHz microwave frequencies to improve reliability. The reliability of the system indeed proved to be excellent with results exceeding 99%, however the cost of the system precluded widespread deployment.

Inductive Loop Detector with Bus Transmitter

This bus system, developed by Swedish company Trafikdata is once again based on an in-situ road based loop wit antenna transmitter located under the bus. Communication is based in the 40 to 50 kHz range. This system was developed to utilise existing loops placed within trafficked lanes for detection at signalised intersections, thereby minimising additional costs to deploy the

system. The system also enabled dissemination of other data such as “late running” however this was by driver input.

It was found that the reliability of the detection was around 98%, however the system did not deliver tangible benefits in congested areas as the bus was not able to trigger the loop until the intersection gave a complying phase, thereby eliminating the purpose of the request. They system worked well however on sections of road built primarily for bus travel and on intersections exhibiting low traffic volumes or during non-pea periods of the day. The detector was used for a number of years in 80 buses and deployed across 15 to 20 junctions in eastern Helsinki.

The following issues summarise the problems found in Helsinki using physical, on road infrastructure for the detection of buses and the deployment of signal priority schemes: -

- Functional Issues – varying levels of success due to traffic conditions, illegally parked vehicles and other on-site constraints preventing bus detection;
- Requirement for additional cabling – All detector equipment had to be directly connected to each signal controller. The preferable location for detection was between 200 and 300 metres from the intersection, therefore cabling would be required to traverse this distance.
- Inability to relocate infrastructure – Due to the physical nature of infrastructure, once the infrastructure is positioned it is difficult and expensive to relocate infrastructure on a location by location basis.
- Volume of equipment required – To improve reliability, increasing the number of detection points per intersection was initially considered, however due to the cost per unit of transmission / receiver equipment this was quickly found to be prohibitive.
- Optimum location for detection equipment may not be physically possible – Where infrastructure such as cabling or mounting on street

poles is required, the location of the receiver is dictated by the location of street furniture within the road reserve. The location of cut-in loops and cabling may be dictated by parking requirements or the location of existing underground services.

Low Power Radio Detection (Non-fixed Infrastructure)

The City of Helsinki is currently developing an active signal priority system which will detect the location of vehicles in real time using non-physical infrastructure in the roadway. This system utilises a GPS system to track the location of the bus in real time. The system also includes: -

- A positioning odometer – used to notify the system of arrival at a bus stop;
- A pre-call or early detection located between 200 and 300 metres from the intersection;
- A call detection located between 150 and 200 metres from the intersection; and
- An exit detection located between 0 and 10 metres from the intersection to notify the system of successful departure of the intersection.

This system is very similar in specification to the system developed by the NSW RTA for the Route 400 trial and similar to the system specification developed by myself and others for the Public Transport Authority for the upcoming Circle Route trial.

4.8.6 Texas Transport Institute

In 2000, Balke, Dudek and Urbanik completed a study into the provision of an ‘intelligent’ bus priority system in Texas. The basis of the study was to grant priority to buses based on two key criteria: -

- Whether the bus was late running, the authors determined that 5 minutes was considered “late running”; and

- How best to intervene and provide a complying phase at an upcoming intersection based on the expected time of arrival of the bus and the expected phase the intersection will be operating in at the time of arrival.

The system operates via a satellite tracking system which enables the study team to monitor the progress of a bus along the route. On-time running can be determined by setting expected arrival times at each location ad comparing the actual recorded data to the base-line data.

Importantly, the study sought to compare performance of the system at the following volume to capacity (v-c) ratios at each intersection: -

- 0.5;
- 0.8; and
- 0.95.

It was found that major improvements in bus running times were delivered in all conditions, however other motorists began to experience increased congestion during deployment of the system in levels of volume to capacity greater than 0.9.

Potential issues with this system could arise in periods of unexpected traffic congestion, high patronage or delays due to vehicle accident. In these instances the bus would not reach the intersection at the expected time, however the intersection would provide priority at the expected time of arrival.

The following table shows the improvements in travel time for buses during the trial based on v-c ratio and compares the disbenefits for other vehicles both on the perpendicular route to the bus route and on the same route as the bus.

Table 57 - Travel Time Variation for Buses and Other Motorists at 0.5, 0.8 and 0.95 Volume / Congestion Ratio - Texas Trial

V - C Level and Direction of Travel	Travel Time (no priority)	Travel Time (with priority)	% Improvement in Travel Time
Bus Travel Times			
0.5	345.5	259.6	25%
0.8	382.6	280.4	27%
0.95	421.3	309.4	27%
Other Motorist Travel Times			
0.5 – same route	239.9	235.1	2%
0.5 – opposite route	230.8	226.5	2%
0.8 – same route	283.1	275.2	3%
0.8 – opposite route	274.9	267.8	3%
0.95 – same route	315.1	300.7	5%
0.95 – opposite route	301.8	293.0	3%

Note: Travel times are noted in seconds.

This table appears to provide misleading data in that it suggests there are benefits to all motorists after the provision of bus priority. Later Balke, Dudek and Urbanik show that delays for other vehicles increased as follows: -

- At 0.5 v-c on all routes the average travel time remained constant and there was no adverse impact to other road users;
- At 0.8 v-c on all routes the average travel time increased by 0.7 seconds per vehicle or 2.0% and should be considered negligible; and
- At 0.95 v-c on all routes the average travel time increased by 5.3 seconds per vehicle or 11%.

The authors considered the change in travel times were significant above 0.90 v-c, however I would counter that given the benefit to bus travel and the fact that most motorists will not notice an increased delay of 5 seconds that this result may be considered negligible.

(Balke, Dudek & Urbanik, 2000.)

4.8.7 SCOOT Bus Priority Examples

The SCOOT-UTC web site provides details of a number of trials and test-runs of bus priority across the United Kingdom. The following points relate to trials of SCOOT Bus Priority in conjunction with gating techniques and provision of bus lanes in Twickenham and Edgeware Road Camden Town: -

- The Twickenham trial demonstrated the benefits of using gating in conjunction with bus priority.
- The trial at Edgware Road was less successful in that the gating strategy increased the overall delays.
- Network characteristics: gating is most beneficial to general traffic where there is a substantial amount of cross-movement traffic flow, e.g. where north-south traffic conflicts with east-west traffic.
- Conversely, gating is less effective on arterial roads where the large majority of traffic is travelling in the same direction.
- Bus lanes: public transport gains most when the gated link(s) has/have a bus lane, allowing buses to bypass queues.
- Benefits will be maximised by restricting priority to late/long headway buses.

The following tables show SCOOT Bus Priority results as trialled in Camden Town and Edgware Road London and in Southampton. The Camden Town trial involved a network of 11 nodes (signalised intersections) with 28 links (approaches to intersection). The Edgware Road section included 8 nodes and 2 pelican crossings.

Table 58 - SCOOT Bus Priority, (London, Camden Town 1996)

Strategy	Delay for Buses (sec) Travel Time Improvement (%)	Gain in Vehicle Delay (sec)
Centrally Processed Extensions Only	0.2 (1%)	1.7
Centrally Processed Extensions + Recall	3.7 (17%)	5.3
Local Controller Extensions	4.2 (19%)	0.4
Local Controller Extensions + Recall	4.8 (22%)	5.0

The same trial was run through Camden Town with the intersection operating at 50% saturation levels only (i.e. Level of Service A).

Table 59 - Camden Town (Operating at 50% Saturation Levels Only)

Strategy	Delay for Buses (sec) Travel Time Improvement (%)	Gain in Vehicle Delay (sec)
Centrally Processed Extensions Only	4.8 (44%)	-0.1 sec
Centrally Processed Extensions + Recall	7.5 (68%)	-1.6 sec
Local Controller Extensions	7.5 (68%)	-1.2 sec
Local Controller Extensions + Recall	7.8 (71%)	-0.6 sec

The negative gain in vehicle delay is therefore a net reduction in travel time for other vehicles.

The Edgware Road trial also delivered gains for buses and reduction in travel time for other vehicles.

Table 60 - Edgware Road Trial

Strategy	Delay for Buses (sec)	Gain in Vehicle Delay (sec)
Local Controller Extensions	2.8 (33%)	-0.1sec
Local Controller Extensions + Recall	3.1 (35%)	-4.0 sec

Table 61 - Southampton (Lances Hill and Maybray King Way) 1994 / 1995

Time Period	% Reduction in Journey Time
Morning Peak	60.7
Off Peak	3.6
Evening Peak	36.8
All Times	41.7

It is important to note that the strong results were delivered due to the combination of active signal priority technology with the introduction of dedicated bus lane approaches to intersections.

4.8.8 Trial Summaries and Comparisons

The trials contained in Section 4.8 have shown a consistent improvement in travel times for buses under both conditional and absolute priority. It is important to note that under conditional priority, the impact upon general traffic has been considered negligible where studied, however there have been greater delays caused when priority settings were changed to absolute priority under all conditions. In Australia it is noted that the Route 400 trial was conducted using conditional priority requests. The proposed Circle Route trial in Perth will also use conditional priority requests to limit the impact upon other motorists. Given the impacts associated with greenhouse gas generation as shown in the Centenary Avenue Bus Lanes calculations in Section 4, it is important to consider both the net improvement to bus services and also the net negative impact upon vehicular traffic when assessing the positive impact of commencing conditional or absolute priority. As a general rule, it appears that the use of conditional priority provides the greatest net benefit to the environment, whilst improving the travel time performance of bus services.

As shown in the trials, travel time improvements through intersections of approximately 25% and over the journey of approximately 7.5% are reasonable targets for the deployment of a new active signal priority system.

5. CONCLUSIONS

Key Hypothesis

Present and discuss the key conclusions to increase public transport modal share in Sydney and Perth using statistical analysis, transportation behavioural science and transportation engineering infrastructure methodologies.

This section of the dissertation provides overall conclusions as a result of the 5 years of study, research and details the main findings, as outlined in the Executive Summary. The section is completed with potential directions for further research to be conducted.

The research shows that while the use of public transport is greater in Sydney, patronage growth is currently greater in Perth due to a greater un-used capacity in the public transportation system and provision of major new rail infrastructure promoting public transportation usage. It can be argued that the Sydney transportation system operated at close to capacity in 2000 / 2001 which led to an increasing level of dissatisfaction with the service in the early part of this decade. This was a key reason for exploring behavioural sciences in transportation mode choice, as external factors influence customer decision making processes in both the short term and the longer term. The key conclusion here is that short term consumer reaction can change to meet day to day events, however once decision making becomes dispositionary, or longer term, it is far more difficult to engineer behaviour change solutions. Recent improvements in service reliability and capacity have delivered increasing patronage toward 2000 levels, however due to the amendments in longer term behaviour by many Sydney residents since 2000/2001 this improvement has taken over 5 years.

The key to this work is its evolution as an iterative learning process driven by the compilation and understanding of transportation usage data. This research

has delivered a clear understanding of the **historical context of transportation modal share over 25 years in Sydney and Perth**.

Once the statistics were collated, the next phase in the research was to understand what influences those historical mode choices. This context is highlighted in Section 2. Upon summary of the statistics, it became clear there are four main influences on travel mode choice. These conclusions are summarised below: -

- Accessibility to the CBD and trip generation

In general, proximity to the CBD in Sydney and Perth correlates to greater access to multiple transportation modes; greater levels of peak and off-peak road congestion; pricing or availability constraints regarding personal vehicular parking and other road pricing considerations (particularly in Sydney).

1. Alternative mode share is generally higher based on proximity to the CBD.

- Accessibility to transportation options (socio-economic status, including age and financial capacity) and its impact on public transport usage;

Socio-economic access, including age or financial capacity to transportation options has a strong correlation to transportation mode choice. The ability to use personal forms of transportation is dictated both by age and financial capacity.

2. Alternative mode share is generally influenced by age and financial capacity.

- Whether the purpose of the trip had an impact on the mode chosen.

Trip purpose is highly important when it comes to transportation mode choice. Commuting and education trips offered the highest mode shares for alternative transportation modes, whilst social and personal trips offered the lowest mode shares for alternative transportation modes. In general it can be argued the

greater discretionary travel is undertaken by those with greater financial capacity, and therefore with greater access to personalised transportation. This correlates to a higher trip generation rate, usually for higher percentages of personalised, non-essential (or discretionary) travel.

3. Trip purposes strongly influence our choice of transportation mode.

- Whether household composition and dwelling densities had an impact on motor vehicle usage.

The concept of dwelling densities is important from the consideration of walkable catchment to public transportation options. In general the greater number of dwellings / persons within a walkable catchment, the greater the potential for a higher alternative transportation mode share. Household composition for smaller households tends to show a lower number of persons per dwelling. I believe however the household composition (number of persons per dwelling) is largely irrelevant in determining transportation mode choice, with other factors having greater influence and importance.

4. Higher dwelling densities within walkable catchments strongly correlate to greater alternative transportation mode choice.

A key conclusion to the statistical analysis is that growth in traffic congestion is linked to a number of factors. These include increased percentage and number of single occupant vehicles as the primary mode of transport; population growth in outer-lying urban areas with a reduction in persons per dwelling; growth in car ownership outstripping population growth and increased urban sprawl contributing to greater travel distances.

5.1 Conclusions – Transportation Statistical Analysis

As explained in the Executive Summary, a project goal was to create a concise, single source of information which delivered an in-depth understanding of patronage trends. The goal of this was to then formulate behavioural science theories on how societies' attitudes were evolving over time to trip generation.

The following Figures highlight the patronage performance for both rail and bus networks in Sydney and Perth over the last 10 years.

The key points from the following graphs are to understand the differences between Sydney and Perth public transportation patronage growth. There are a number of factors involved, including: -

- Greater recent investment in major new infrastructure over the survey time period in Perth.
- Growth from a much lower base with a concerted effort to push behavioural change.
- Much higher rate of population growth in Perth than Sydney.

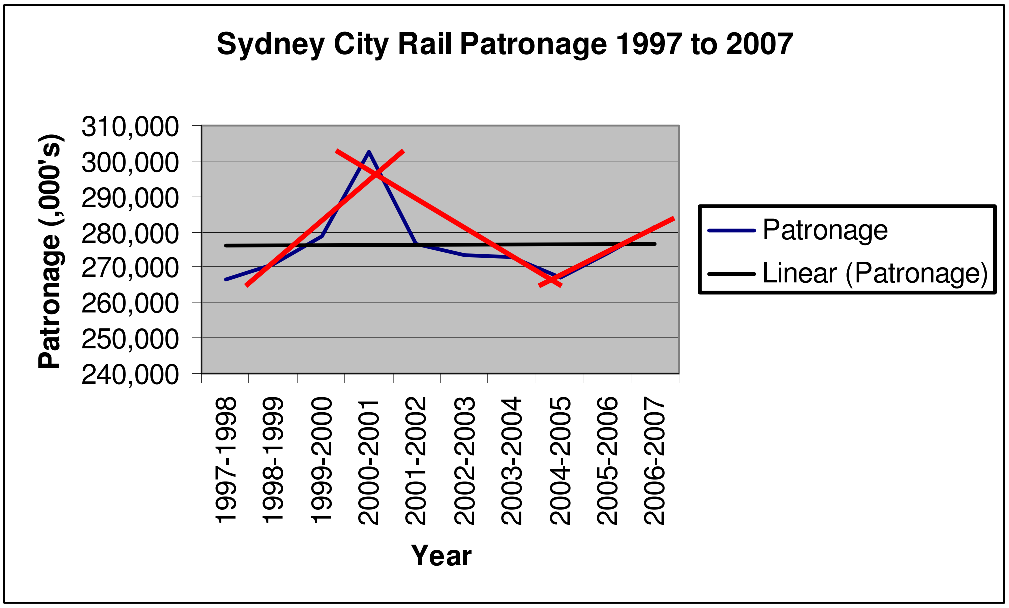
Interestingly, the growth of motor vehicle travel is outstripping the pace of growth of public transportation patronage, meaning that the improvements in Perth public transportation patronage will not correlate to an improved mode share. In Sydney, due to lower population growth and slower economic conditions over the last 5 years, private vehicle traffic has grown at a similar pace to public transportation patronage growth. Therefore mode share percentages are holding over the last 5 years.

It can be argued that Sydney is likely to have more favourable conditions for improving public transport mode share if significant investment can improve capacities in the City Rail network and is accompanied by a behavioural change program to utilise the additional capacity created quickly.

It is expected that the recent public transportation patronage growth in both cities will accelerate due to the increasing cost of fuel minimising discretionary trip making and in some cases forcing behaviour change due to accessibility and financial capacity. Again, it is likely these pressures will be felt more in Sydney than in Perth due to the differing economic conditions in the two cities.

Additional growth in Sydney rail and bus patronage can be expected with the addition of new infrastructure over the next 12 to 24 months. I would expect rail and bus patronage in Sydney to accelerate, while patronage growth in Perth would be expected to dip slightly from the recent acceleration. The information presented below leads into the reasons why Elliott Wave theory has been considered as a predictor of human behaviour.

Figure 43- City Rail Patronage 1997 to 2007

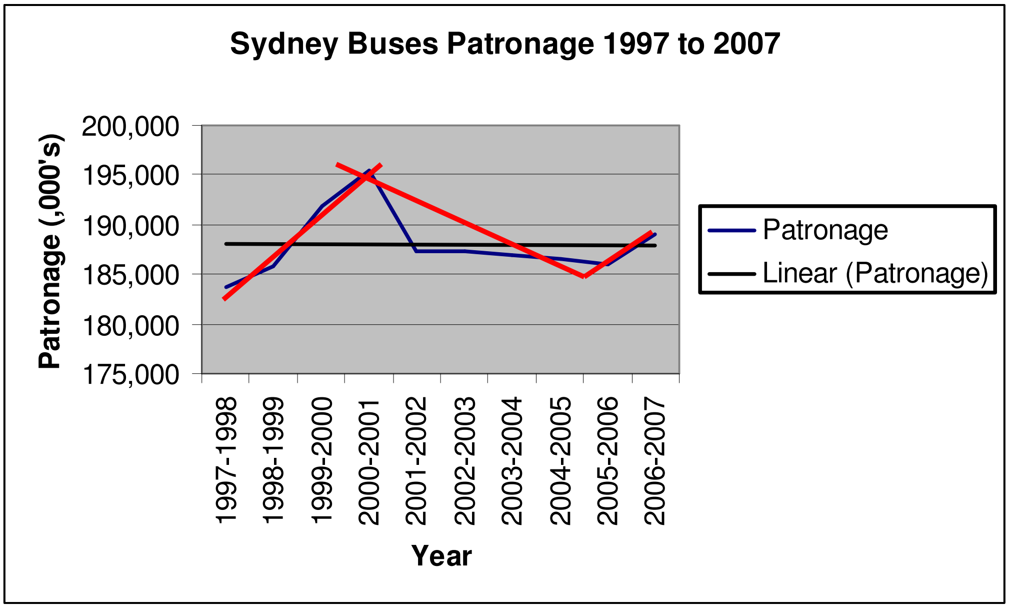


The above figure shows the patronage trend (in blue) for City Rail over the last decade. Strong growth in patronage in the late 90's culminating in the peak around September 2000, coinciding with the Olympics. At this stage Sydney had a public transport mode share almost double most other Australian mainland capital cities. A combination of capacity issues, safety issues and a concerted negative press campaign saw a 5 year regression in patronage growth.

I have shown two linear trends, the black line shows the trend over the 10 year period. This linear trend represents flat growth over the 10 year period due to minimal additional infrastructure added to the network. The 3 red trend lines however provide much greater detail – sharp up trend to network capacity,

sharp downtrend removing many discretionary customers from the system followed by sharp uptrend again due to increased potential captive customers due to increasing fuel prices and increased congestion on Sydney road networks.

Figure 44 - Sydney Buses Patronage 1997 to 2007

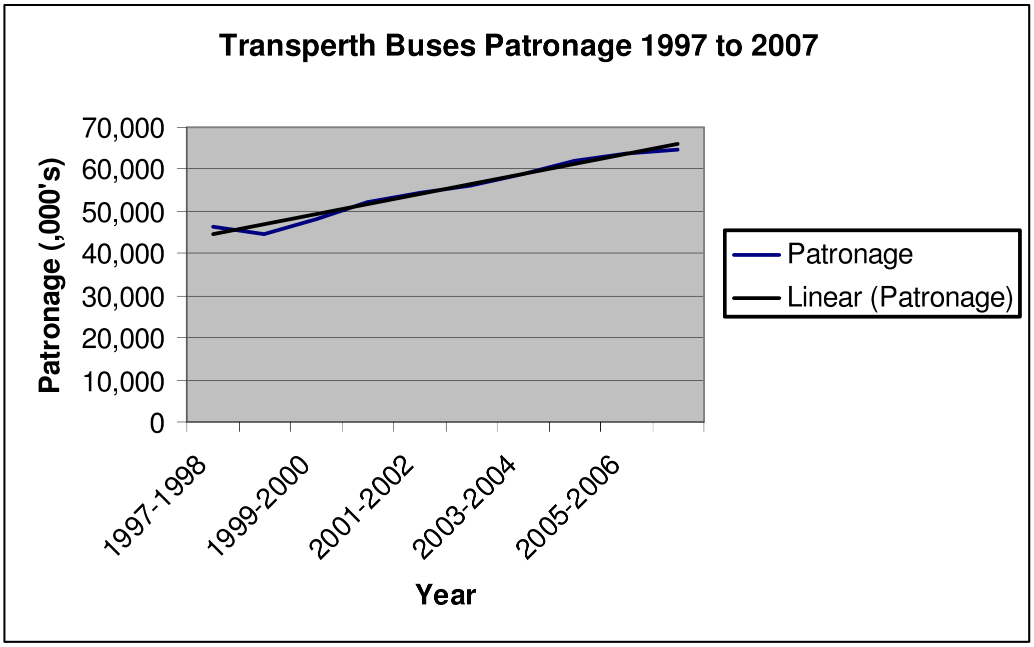


The above figure shows the patronage trend (in blue) for Sydney Buses over the last decade. Like the City Rail graph, strong growth in patronage in the late 90's culminating in the peak around September 2000. Again a combination of capacity issues and a concerted negative press campaign saw a 6 year regression in patronage growth. New capacity in Western Sydney is beginning to deliver upward growth.

Same as for City Rail, I have shown two linear trends, the black line shows the trend over the 10 year period. This linear trend represents flat growth over the 10 year period due to minimal additional infrastructure added to the network. The 3 red trend lines however provide much greater detail – sharp up trend to network capacity, sharp downtrend removing many discretionary customers from the system followed by sharp uptrend again due to increased potential

captive customers due to increasing fuel prices and increased congestion on Sydney road networks.

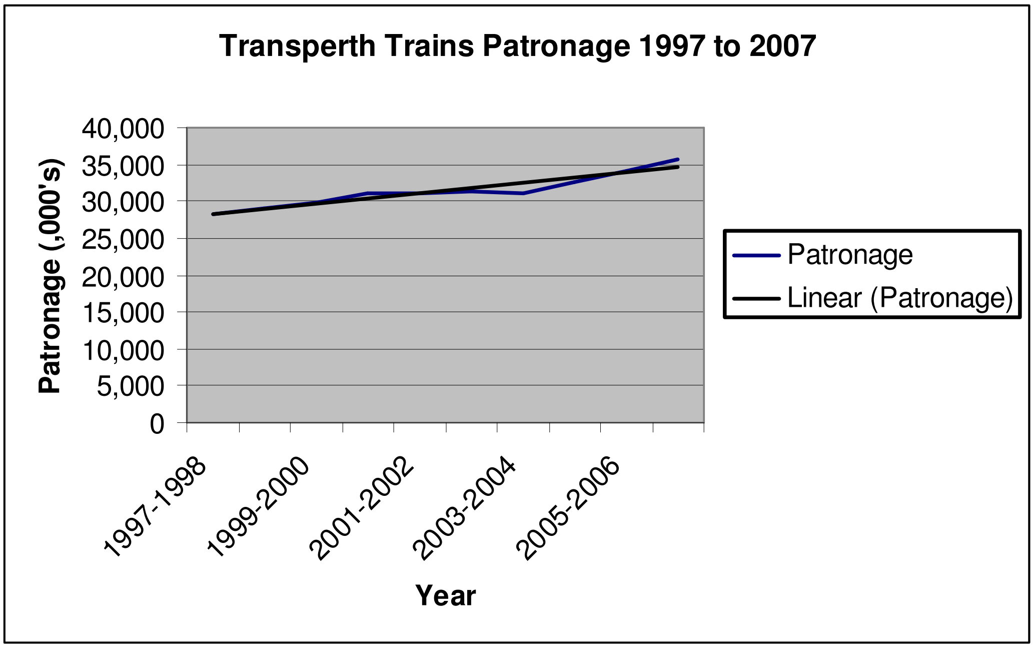
Figure 45 - Transperth Buses Patronage 1997 to 2007



The above figure shows the patronage trend (in blue) for Transperth Buses over the last decade. The patronage growth is almost identical to the linear growth for the last decade. In graphical form this data is an interesting comparison to Sydney as the external factors impacting choice in each city are almost diametrically opposed. The value in this comparison lies in the differing external factors and their impacts on the trends. This is where a tool such as Elliott Wave Theory could be useful as a predictor of timing to reach capacity. Therefore infrastructure / behavioural change commissioning decisions can be made in advance to meet expected growth and to limit the potential for group decision making, for example to stop a negative growth phase such as that which occurred in Sydney between 2001 and 2006 due to capacity issues then impacting consumer behaviour. This is summarised further in Section 5.2.

The Transperth rail patronage data shown in Figure 46 is similar, with a strong linear upward movement in patronage. It is expected this will kick further with the introduction of the Perth to Mandurah rail line.

Figure 46 - Transperth Rail Patronage 1997 to 2007



5.2 Conclusions – Behavioural Change Methodology

The key objective was to understand **why people generate trips and why a particular mode is chosen for those purposes**. In the section on Maslow's Hierarchy of Needs, it was argued that transportation choice is arguably a personalised commodity, once certain needs are met (i.e. accessibility to transportation options and financial capacity). Vehicle manufacturers consider their target markets carefully and purchasers associate themselves with the various stereotypes shown. Public transportation and other alternative modes are also associated with stereotyping. This has been quantified in data collated by the Transport Data Centre and quoted in this work. Further, I theorised that transportation mode choice is impacted by two forms of behaviour, short term or 'reactionary' behaviour and longer term or 'disposition' behaviour trends: -

- Short term (or ‘reactionary’ behaviour) is behaviour which is an immediate reaction to certain external events and results in an immediate but temporary behavioural change; and
- Long term (or ‘disposition’ behaviour) is behaviour which is an accumulated reaction to external events and results in a complete behavioural change.

The work on Maslow’s Hierarchy of Needs has been applied to transportation to show that short term variations in patronage growth and / or decline are influenced by external forces including accessibility to transportation options; variations in fuel prices and fares (price elasticity theory); and timeliness, cleanliness, frequency and degree of crowding on public transportation.

The work on Elliott Wave Theory highlights an opportunity to be predictive about future directions for patronage growth. The purpose of this theory is not that it be misused as a tool to predict opportunities to cut transportation funding at various cycles. The purpose of the theory is to show potential trigger points for greater levels of investment in infrastructure and / or behavioural science programs.

The question of behavioural science is examined in detail by providing research on why people use various modes of travel, how this is changing over time and whether the reason for travel predicates an inclination to use one form of transport over another. An example of this is the general increase in trips generated for social and other purposes and the relative decline in trips generated for commuting purposes. Social, shopping and other trips tend to be discretionary in nature and as such users are biased towards using a motor vehicle for those trips. Commuting, (particularly to the CBD’s in Sydney, North Sydney, Parramatta and Perth) however offers strong opportunities for mass-transit transportation modes. Information provided by various public transportation agencies shows that lower socio-economic denominations tend to utilise public and alternative transport modes for a higher percentage of their

daily trips than those with a greater earning capacity. In essence, this explains the theory behind ‘captive’ and ‘discretionary’ users and points to continued latent growth in motor vehicle usage as economic conditions and availability and pricing of new motor vehicles increases accessibility to greater numbers of consumers. This is further exacerbated by an imbalance in relative travel times between public transport and private motor vehicle usage.

5.3 Conclusions – Engineering Infrastructure

The availability of, and accessibility to engineering infrastructure has been shown to have a major bearing on transportation mode choice. The work in this section focussed on **understanding the impact of transportation engineering infrastructure on mode choice**.

Engineering and infrastructure case studies such as the Centenary Avenue Bus Lane project show the potential for engineering infrastructure improvements such as variation of road capacity to provide a net tangible benefit to the environment by promoting public transportation, whilst minimising excessive delays on other forms of traffic. It is important to note that the promotion of public transportation should not be at the expense of a net gain to the environment. The suggested infrastructure improvement shows a net travel gain to all forms of traffic.

Project expenditure is an important component, and this has been considered in the research through the delivery of active, signalised bus priority systems which utilise technology as opposed to infrastructure to provide time travel benefits to buses. Research in five locations shows the potential for tangible improvements in adherence to timetable for buses operating in a priority environment. The delivery of an active signal bus priority system can be achieved with minimal upgrade to existing infrastructure and has been shown to provide at least 10% improvements in on-time running. Where coupled with bus-only infrastructure such as bus transit lanes, the productivity gains have been shown to be even greater, as evidenced on the Liverpool to Parramatta Transit-Way.

The future of bus / transit priority and improving public transport patronage is to integrate infrastructure improvement measures and land usages with technological advances, economic stimuli and behavioural change methodologies.

Australian cities have evolved to suit the motor car as the dominant form of transportation, and while this will continue to be the case moving forward, it is important that infrastructure is provided which promotes alternative transportation modes and seeks to re-address the balance. It has been shown however that provision of infrastructure alone is not enough, as our current natural tendency as a society inclines us toward motor vehicle usage as the dominant transportation form. It is a behavioural trait that we believe the motor vehicle is m ore convenient and allows us greater access and mobility.

This section provides theories and examples of the potential future for improving transit priority through the deployment of other, additional methodologies, including: -

- Technology (Section 5.3.1); and
- Integration with other measures (Section 5.3.2).

The above sections will include commentary on strategies to adopt in specific cases.

5.3.1 Technology

This section discusses potential technological advances which may improve alternative transportation mode share.

Fuel Efficiencies and Hybrid Fuel Technologies

Technological advances in motor vehicles, particularly in fuel efficiencies and cleaner fuels has an important role to play in the future, however technological advances in motor vehicles tend to be more focused on 'discretionary' items and while this may increase the marketability of the vehicle, it does little to

promote sustainability. Technological advances in fuel efficiencies and hybrid fuels for buses and mass transit have been trialled and deployed in Sydney and Perth. A 2-year trial of three hydrogen cell buses is due for completion in the final quarter of 2006 in Perth. The hydrogen cell powered bus processes liquefied hydrogen and produces a pure steam exhaust. These buses are very expensive to purchase per unit and the success of the measure is unknown at this stage, however the buses have been highly visible on flagship routes during the trial.

Smart Cards / Cashless Vehicle Entry

Smart card systems are currently being trialled in Perth and Sydney, with the aim to reduce the number of customers paying cash fares and therefore decrease the dwell time at each stop. This reduction in dwell time at each stop will provide opportunities to improve on-time running performance and may potentially improve service frequencies as gains across the day may be translated into additional services.

Smart cards also enable public transport planners to gain a better understanding of how their services are used by passengers as unlike cash fares, they record the location where a passenger disembarks the service (destination). This is important as public transport planners can then improve service performance around popular sections of the route and can gain a better understanding of the potential origins and destinations within a service area and how best to service them.

Active Signal Priority

As discussed in Section 4 of this work, active signalised priority is a key opportunity for technology to improve public transport as a viable transportation alternative through improved on-time running and potentially increased frequencies.

5.3.2 Integration with Other Measures

This section discusses potential measures which should be integrated with technological advances to improve alternative transportation mode share.

Transit Oriented Development (TOD)

A key finding in this research is the importance of land-use planning and developing urban and commercial centres which promotes the integration and usage of alternative transportation options, (such as Transit Oriented Development). Transit Oriented Development should promote walking and cycling as key modes in residential areas, with houses located within a 1km catchment of neighbourhood commercial centres. This provides the opportunity to perform some local shopping trips by pedestrian or bicycle modes and also provides local employment opportunities which may remove the necessity to commute to distant workplaces by vehicle. Design of larger commercial regions should focus on mass-haul transit options and provide major, visible alternative transportation hubs at the heart of the destination node and to reduce the visibility of deterrence's such as car parks. To improve alternative transportation mode share, a mixture of residential and commercial within the same node provides public transport planners with the opportunity to develop an origin / destination node, increasing the potential usage of alternative transit modes by improving the reasons why people use that transportation mode.

Transit Oriented Development principles can be provided in the following situations: -

- Retro-fitting to existing residential and commercial centres by improving public transport access and providing improved bicycle and pedestrian connectivity;
- Amending zonings around existing infrastructure and increasing development densities within walkable catchments and / or increasing land usages such as mixing commercial, retail and residential uses; and
- Designing greenfield suburban nodes to best principles.

Positive Promotion

Positive promotion of public and alternative transportation modes is vitally important to instituting behavioural change. Use of advertising space on buses and trains reminds patrons of the potential health benefits of increased walking and mobility and the economic benefits of using public transport over vehicle and car-parking fees. In addition, public transport travel allows the passenger time to relax without having to concentrate on driving in peak traffic. These are important points that remind potential customers of the benefits for them and the greater community in sharing infrastructure.

5.4 Summary of Main Conclusion

After five years of research I believe that engineering and infrastructure improvements can have an impact upon mode choices, but the underlying trend away from public transport is behavioural. Understanding and implementing schemes which target both aspects will deliver improved opportunities for success. Reduction in traffic congestion, vehicle travel times and ultimately greenhouse gas emissions are the ultimate goals for a mode share shift from private motor vehicles to public transportation systems.

The issue of transportation modal choice is a complex issue with a large number of variables. The initial goal of this research was to focus on engineering methodologies which would promote increased public transport usage. However after completing this body of work I believe that engineering solutions have been used as a reactive tool only and have not addressed the real reasons behind the declining public transport mode share through the 70's, 80's, 90's and the early years of the 21st century. The key issues regarding transportation modal choice are: -

- Behavioural; and
- Economic.

The issue of transportation modal choice should also be considered by state and federal government in its full context, namely the environmental, health, social and economic contexts: -

- There is a quantifiable environmental cost associated with increased motor vehicle usage and congestion;
- There is a quantifiable health cost due to decreased mobility and increased inactivity impacting upon the general health and wellbeing of the population;
- There is a quantifiable social cost due to the segregation / connection of communities due to major transportation infrastructure. The rising fuel price further impacts the social divide between the “rich” and the “poor”; and
- There is a quantifiable economic cost of congestion in terms of productivity lost.

The planning and development of infrastructure should therefore be tailored to meet these criteria, as the infrastructure we provide assists in the shaping of user behaviour. The question of how our cities grow and how our lives are impacted really is a question which needs broader input than the domain of planners and engineers.

In summary, this research has presented a concise understanding of the background dynamics involved in transportation engineering. For material gains to be made in alternative modal share there needs to be a consistent effort made at State and Federal Government level to promote the use of public transportation, while decreasing the access to sole occupancy motor vehicles in peak times on congested networks.

5.5 Directions for Further Research

I believe this research has shown that transportation mode choice is decided by three major external impacts on people within urban regions: -

- Accessibility to infrastructure and modal choice;
- Behavioural tendencies; and
- Economic factors.

This research has uncovered some interesting areas in the fields of the behavioural sciences and economics which could be expanded upon for further studies, including: -

- Are certain people pre-determined to use a particular mode of transportation;
- Could a person who has a preference for motor vehicle travel become conditioned to accept public transport travel and what would be the main drivers to this acceptance;
- Would congestion pricing limit vehicle access into the CBD;
- Would tax breaks on public transport usage increase patronage;
- Could our cities function more effectively with a doubling of public transport patronages?

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