MODERNISING LIGHT RAIL INFRASTRUCTURE TO MEET THE DEMANDS OF A GROWING CITY

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Summary

With Melbourne's tram network being the largest in the world but also with some infrastructure that has been around for over 100 years, there is an ongoing challenge to ensure it progresses with the needs and requirements of today's society. Regular maintenance and upgrades across the network are required to maintain its operational status however major improvements are required to upgrade and enhance the network to meet the demands of a growing city.

While network improvements from the point of view of operating environment and platform installation have been implemented across the network the extent of work remaining is significant.

The experience to date has demonstrated the difficulties and impediments in achieving the desired vision for converting Melbourne's tram network into a modern light rail service capable of providing the transport needs of a growing city.

Introduction

This paper will explore the recent experiences, desired outcomes and challenges associated with modernising light rail infrastructure to meet the demands of a growing city, including presenting specific examples on the Melbourne tram network drawn from the experiences and perspectives of both a designer (Mike Ford - Jacobs) and network operator (Les Kulesza – Yarra Trams).

Melbourne's tram network provides an essential service to its people. It is the main means of public transport for inner suburban residents and this use is being reinforced as higher-density housing is developed in the inner and middle suburbs. In addition, the tram network connects passengers from the heavy rail network to their destinations in the CBD and the growing Greater CBD areas of St Kilda Road and Docklands. It carries thousands of students every day to their studies at schools and universities.

The Melbourne tram network demonstrates the critical role that light rail contributes to a modern city's transport network and the importance of the ongoing process of modernising this system to keep pace with the city's growth.

Today, the Melbourne tram network supports a population of 4.5 million people and caters for annual patronage of over 190 million, creating pressure for capacity upgrades such as longer trams, larger depots and increased power supply. In addition, improvements to safety and accessibility including new low floor trams, level access platform stops and improved passenger facilities in line with DSAPT (Disability Standards for Accessible Public Transport) standards are being implemented to achieve compliance with the Disability Discrimination Act.

Notations

- SCATS – Sydney Coordinated Adaptive Traffic System
- DEDJTR - The Department of Economic Development, Jobs, Transport and Resources
- PTV – Public Transport Victoria
- DSAPT - Disability Standards for Accessible Public Transport
- CIP – Centre Island Platform
- COP – Central Offset Platform
- SP – Side Platform
- EAS – Easy Access Platform
- KAT – Kerbside Access Tram Stop

1. History

Trams have operated continuously in Melbourne since 1884 on a network which has progressively grown to become the world's largest.

In Australia, trams fell out of favour during the 20th century and most networks closed or were severely cut back due to the increasing rate of private car ownership and the perception that trams contributed to traffic congestion. This led to the progressive replacement of tram services with buses in all Australian cities by 1969 (Brisbane being the last to remove their tram system) with the exception of Melbourne and a single line in Adelaide.

By the 1970s Melbourne was the only Australian city with a major tram network. Melbourne was able to avoid following the trend of many other cities around the world at the time of removing its tram system in favour of buses for the following main reasons:

- Melbourne has wide city streets where the geometric street pattern made trams more practicable than in many other cities;
- The track infrastructure and trams were relatively new, having replaced Cable Tram equipment in only the 1920s–1940s. This removed the point used by many other cities, which was that renewal of the tram system would cost more than replacing it with buses.
- Strong resistance from the unions; and
- Melbourne had an independent tramways board with Sir Robert Risson as the Chairman of the MMTB. Risson, successfully argued that the cost of ripping up the concrete-embedded tram tracks would be prohibitive.

By the mid-1970s, as other cities suffered increasing traffic congestion and air pollution, Melbourne's decision to retain its tram network was vindicated, even though patronage had been declining since the 1950s in the face of increasing use of cars beyond the tram network's limits.

As cities around the world are growing, light rail is once again becoming a popular and financially viable method of mass public transport to move people efficiently. This is evident in Australia, with projects or plans in progress for the potential construction of new lines in Sydney, Canberra, Newcastle, Brisbane, Adelaide, Perth and Hobart. New light rail lines have the benefit of being built to the latest design standards for capacity, accessibility and safety. The use of advanced operational modelling and forecasting tools enables consideration of requirements for future development and expansion of the network. In contrast, systems such as Melbourne's that have grown and evolved over many years must continually modernise their existing assets and infrastructure if they are to meet the pressures of increased customer demand and community expectations in respect to transport needs. Upgrading infrastructure assets is driven by customer experience expectations as well as legislative requirements which have necessitated development of new standards and design solutions [1].

Melbourne's decision to retain its tram network is now paying off as to build a network on the scale of Melbourne's, built now, would take at least 20 years and cost $15-25 billion to build. There are however numerous challenges associated with maintaining and upgrading a tram network that was built over 100 years ago to ensure it is capable to meet the demands of a growing city.

1.1. Rollingstock (Trams)

Numerous models of trams have been built since trams first began in Melbourne including horse drawn and cable car trams. The first W-

Class trams were introduced on the Melbourne tram network in 1923 and different versions of the W-Class continued to be built right through to 1956 (33 year period) where an average of 23 trams per year were built (783 in total). Some of these W-Class trams are still in service today running on the free City Circle tram route.

No trams were built for 16 years from 1957 to 1972 at a time when public transport patronage was declining as affordability of motor vehicles improved and other cities around Australia were removing their tram networks in favour of buses.

As a result of a sustained period of no new trams being built and coupled with the fact that the average design life of trams is 30 years old, much of the W-Class fleet were fast approaching their life expiry. It wasn't until 1975 that the next generation of trams commenced construction with the introduction of 230 x Z Class trams which were built from 1973 – 1984 to retire the aging W-Class trams. A modified A-Class tram and a larger articulated B-Class tram were introduced from 1984 spanning through to 1994 with the larger B-Class trams put into service on the busier routes.

Following another period of no construction of new trams for the next 7 years, the first new low-floor trams were introduced after the tram network was privatised and operated by two separate operators (M-Tram and Yarra Trams) which saw the introduction of 95 new C & D Class trams.

Over the next 9 years, only 5 new larger C2 class trams were introduced to the network in 2008 before the introduction of the E-Class commenced in 2013 where approximately half of the current order of 70 have been delivered and introduced onto the network.

Melbourne's tram network currently has 460 trams in service operating on a daily basis. As a result of the extended periods of no trams being built, the average age of trams (excluding the W-Class trams running on the City Circle) is currently 24.2 years old (close to the life expectancy of 30 years). 147 (32%) of these trams in service are over 30 years old (Z3 Class trams) and a further 129 (28%) are between 25-30 years old (A & B Class trams)

If Melbourne has a need for 460 trams to operate on the network on any given day, with a 30 year design life, there is a need to replace the existing tram rollingstock with approximately 15 new trams every year, just to keep trams operating within their 30 year design life. This does not account for any future growth required (i.e. additional trams needed) or cover the periods of no growth where we now need to catch up to ensure we have a modern and reliable tram fleet.

It is therefore important that cities develop a long term procurement strategy of their rollingstock (particularly with the introduction of new light rail networks around the world) so the average age of the fleet is around 15 years or less to ensure modernising light rail infrastructure can meet the demands of a growing city.

2. Growth of Melbourne

2.1. Population

The population of Melbourne is growing faster than any other capital city in Australia in recent years with some 2,000 new residents each week. Melbourne is now expected to exceed previous population growth predictions and reach five million people during the mid to late 2020's, more than a decade earlier than previously forecast.

The Melbourne tram network demonstrates the critical role that light rail contributes to a modern city's transport network and the importance of the ongoing process of modernising the system to keep pace with the city's growth.

2.2. Road Space allocation

As the population increases and people move into the inner and middle suburbs, the liveability of these areas is compromised by associated similar levels of additional cars on the roads. Growing car numbers is leading to increased congestion which is also affecting the performance of the tram network which has a large proportion of the network operation in a shared environment with general traffic.

Measures to improve tram operational efficiency such as separating trams from general traffic, tram stop optimisation and upgrade to level access stops and traffic signal priority upgrades help to maximize the efficiency of the road network by ensuring our roads move more people rather than more vehicles.

To move towards a world class fast and efficient tram service the current operating environment requires improvement in respect to road space allocation and priority. With some 80% of the network currently sharing tram tracks with vehicle traffic, action is required in respect to how this space could be better utilised. For example, road based car parking along narrow tram streets needs to be reviewed and removed along critical sections which are causing traffic and tram delays and congestion.

On street parking causes bottlenecks and traffic congestion particularly at traffic lights. The importance of moving towards a separated tram operating environment has been recognised by the Victorian Government and included within Plan Melbourne.

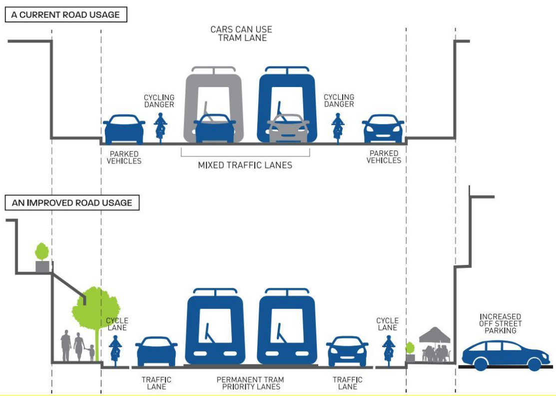


Figure 2.1 – Plan Melbourne cross section showing tram / vehicle segregation

The permanent separation of trams and traffic would improve journey times and reliability of travel for passengers. It is recognised however that achieving this outcome may require a step change approach starting with increased set back of parking on approach to intersections and increased clearway times to cover longer weekday peaks in addition to weekends.

2.3. Growth on Tram Corridors

With 80% of the tram network operating in mixed traffic conditions, it is therefore subject to the impact of increased traffic and congestion. Given the relatively slower speeds compared to train services, trams primarily tend to service short to medium journey lengths, typically averaging 3.6km.

The tram system carries more than 600,000 passengers on a typical weekday with two in three trips being for purposes other than work. Tram patronage has growth by some 32.5 % since 2015 with an 11.1% increase over the twelve month period to end of 2015.

More than 12% (420,000 people) of Melbourne's population live within 200m of a tram service where car ownership is also lower while 17% (600,000 people) live within 400m. In addition, more than a third of Melbourne's jobs are within 400m of a tram stop. There are some one hundred and forty activity centres located within these tram corridor catchment areas. The tram network therefore plays a significant role in making Melbourne a very liveable, successful and sustainable city.

Since 2010, one in four new homes approved to be built are within 5km of the Melbourne CBD and one in three within 10km, with one in ten being a high or medium rise apartment in Melbourne[2].

The growth in population is impacting the tram network, which is the dominant mode of mass transit servicing the inner 10km core of greater Melbourne. Increased population is also generating additional demand for work, educational, social and recreational trips.

The modernisation of Melbourne's tram network has and will continue to take place at a different pace in different parts of Melbourne according to the different operating environment. Different parts of the network have the potential to achieve a higher overall standard more aligned with a light rail service. Theses routes include low floor accessible vehicles, upgraded tram platforms and highly effective separated tram tracks.

2.4. Land Use Redevelopment

One of the most critical aspects of any future development growth along tram corridors will be associated with additional traffic generated delays to tram services resulting from changes to land use.

An additional 600,000 homes will be required over the next 20 years. It has been envisaged that 53% or some 316,000 of theses will be located in Melbourne's established areas where trams are a primary source of public transport. The potential to house new residential developments close to tram routes requires careful planning for growth in population and public transport demands. A critical factor in assessing future developments located along existing tram corridors will be based on their impact on tram operating conditions as well as the capacity of the existing service to meet passenger growth demand.

The potential impact on tram delays due to new development proposals are related to the applicable road operating environment. Road environment where trams are operating in a fully segregated arrangement provide the most advantageous arrangement from the point of view of minimising delays and improving journey times. Establishment of high density developments along these corridors is therefore less likely to adversely impact on efficiency of tram services, assuming no additional formal or informal tramway crossing points are established. It is recognised that only some 20% of the tram network is currently segregated from general traffic therefore a great proportion of the majority of tram network unfortunately has potential for incurring additional development generated delays unless accompanied by supporting transport improvements and restrictions.

Arrangements for proposed development access and travel patterns for resulting generated traffic are also critical in consideration of development proposals. While left in/left out restrictions (i.e. the banning of vehicles turning right across the tram tracks) are often applied as a condition of planning permit approval, theses restrictions alone will not be sufficient to avoid additional delays to tram services.

While immediate direct impact at development access points may be avoided, additional generated traffic using alternative access means can still result in increasing overall delays and journey times for trams at adjoining intersections.

A key aspect of quantifying estimates of additional delays to tram services resulting from development proposals is associated with practice used in regard to traffic generated impact assessments. Tram delay assessments associated with development proposals along a tram corridor are always assessed in isolation as a standalone development compared to existing base case conditions. The resultant conclusions invariably predicted only relatively minor adverse impact on tram service delays resulting from development generated traffic movements. The standalone findings and conclusions make it very difficult for the responsible planning authority to reject a proposal, particularly given planning objectives to increase densification of the existing metropolitan area in order to maximize use of existing transport assets.

3. Existing Operating Environment

Melbourne has one of the largest tramway networks in the world comprising some 25 tram routes covering 250km. The tram network is viewed as an integral and essential component of Melbourne's transport network providing a key functional as well as characteristic element of the city.

Melbourne's tram network contributes strongly to the quality of life that Melburnians enjoy.

- In the morning peak on many Melbourne radial roads, trams make up around 1.5% of vehicles, but carry over 50% of the people travelling along them. Trams relieve road congestion, rather than create it.
- Melburnians and visitors make 195 million journeys by tram per year.
- Almost half a million people live within 200 metres of a tram route.
- Trams help to make the Melbourne CBD a better connected place to be with greater mobility than most city centres.
- Tram patronage has grown by over 65% since privatisation of the network in 1999.

Trams are a major success story for Melbourne. However, partly as a consequence of this success, the network is showing signs of strain which could affect its future:

- There is very little spare capacity in peak periods.
- The average speed of Melbourne's trams is 16km/h (which drops to 10km/h within the CBD), which is slow compared with other large tram networks worldwide, where average speeds range from 20km/hr to 30km/hr.

- New and larger trams have been ordered, but not enough of them to keep up with patronage growth and replace older trams reaching retirement age.
- Though better quality track is being relaid, the rate of track renewal has not kept up with the rate at which track is wearing out.

With approximately 80% (or approx. 200km) of the tram network operating on shared running track with road vehicles, Melbourne's tram network is scarcely referred to as a 'light rail' system like many other modern light rail systems being established around the globe where tram routes are fully segregated and high levels of tram priority provided at intersections providing passengers with a reliable and efficient journey.

3.1. Traffic Growth

Traffic volumes have increased largely in line with the population growth of Melbourne – with the population increasing by 2,000 people a week. The majority of this growth has taken place on the freeway system. During normal operations, this has a minimal impact on the tram network however when incidents on the freeway cause traffic to divert away or off the freeway they now have a greater impact on tram services because of the higher volumes. This results in an increase in variability on the network which cannot be timetabled for as it is impossible to predict when incidents will occur that diverts freeway traffic onto roads with trams.

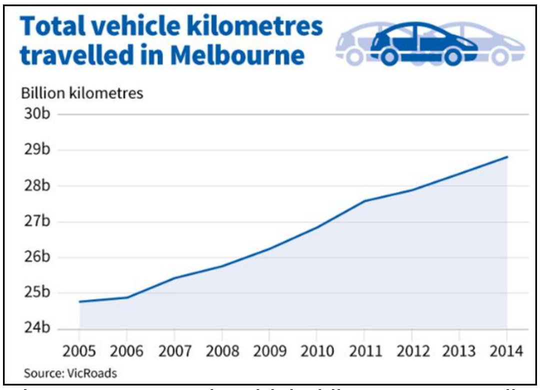


Figure 3.1 – Total Vehicle kilometres travelled in Melbourne

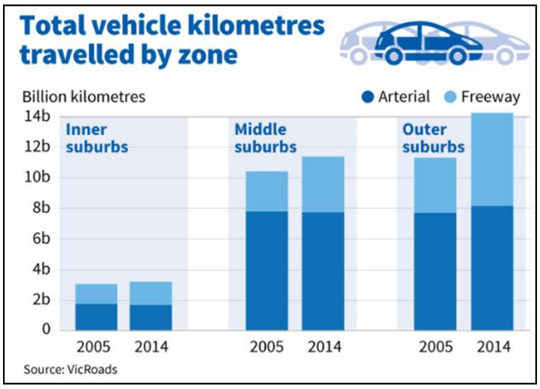


Figure 3.2 – Total Vehicle kilometres travelled by zone [3]

Average travel speeds have consistently decreased, as have average tram speeds. This is despite ongoing work to improve journey times and reduce delays, for instance through traffic signal reviews. The only exception to this is increases in travel speeds during the AM peak from 2009 to 2011 – driven potentially by clearway changes which have since been reversed.

Slower road and tram speeds, where they are consistent, can be addressed through journey time changes to timetabling (subject to rolling stock and staff availability impacts, operational costs, etc.).

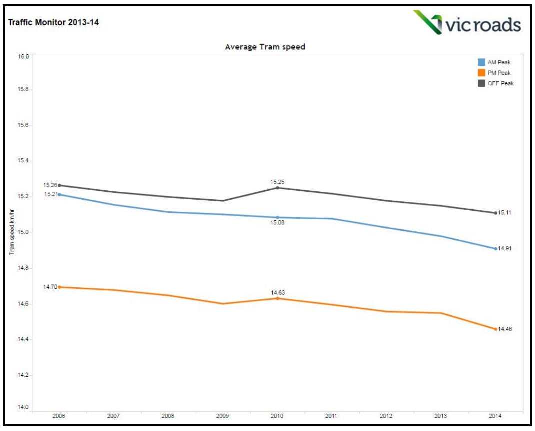


Figure 3.3 - Average Tram Speeds are decreasing

A further traffic growth trend that is adversely impacting on tram journey times and performance is the spread of the peak weekday period and high weekend traffic movement. VicRoads analysis of traffic levels by time of day reveals there is as much traffic on Melbourne's roads at 3pm as there is at

8am, when the morning peak is at its worst. Only the 5pm drive home from work is busier.

Midday Saturday is now also approaching morning and early evening peak traffic volumes, however unlike the weekday peak periods most kerbside parking restrictions do not operate on weekends, slowing traffic and in turn trams.

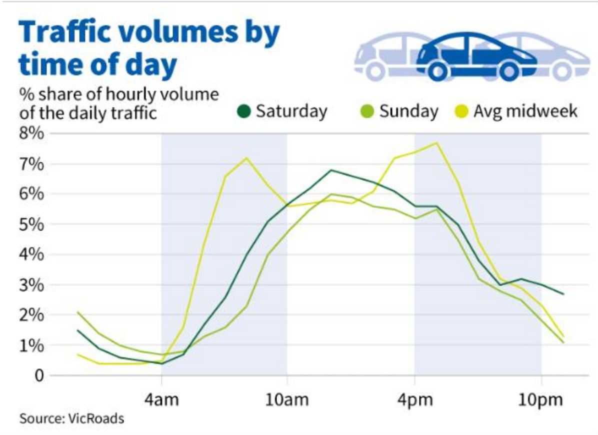


Figure 3.4 – Traffic volumes by time of day [4]

3.2. Traffic Signal Operation

Melbourne has a significant tram network by world standards. It includes some 690 signalised intersections and pedestrian crossings across the 250km of tram network. With the total number of signalised sites in Melbourne being in the order of 3000, trams operate through some 23% of traffic signal sites across greater Melbourne.

Traffic signal delays have been shown to contribute significantly to overall tram travel times. Previous assessments have shown that 17% of tram travel time in Melbourne is spent at traffic signals. This compares unfavourably with good overseas practice where traffic signals contribute only 1 to 4% of travel time.

Providing priority for trams has been recognised as an important way of moving people in Melbourne. The travel time and reliability of tram services can be improved by providing trams with road space clear of other vehicles and increasing traffic signal priority opportunities.

While all trams are fitted with transponders and have the ability to call tram activated priority phases across the entire tram network, the extent and level of tram priority currently provided is relatively limited and restricted.

Current practices for providing tram priority at traffic signals in Melbourne date back to the 1980's and 1990's. The current functions in SCATS at signalised intersections are based on monitoring and dynamically adjusting traffic signals to maximise traffic flow rather than people movement. There is potential to review current signal practices and application of signal priority for trams in context of the SmartRoads framework developed by VicRoads to guide decision making for all transport related projects.

SmartRoads sets out an approach for managing the many competing demands for allocating the limited available road space. It recognises the increasing role that trams, buses, trucks and bicycles play in moving people and goods around the network. The principle of moving people, rather than vehicles is a key SmartRoads objective.

Considering the movement of people rather than vehicles is an important strategic objective necessary in achieving improved operation at traffic signals for trams, In order to take a further strategic step and provide real people movement priority trams will need to be accorded with positive priority over general vehicle traffic.

3.3. Responsibility for delivering tram priority

The responsibility for delivering tram priority cannot be assigned to one organisation. A coordinated effort and commitment is necessary from a number of relevant stakeholders if a successful effective outcome is to be achieved. In addition Yarra Trams, VicRoads, DEDJTR and local councils all need to participate in ensuring improvements are progressed and implemented.

VicRoads' SmartRoads Network Operating Plans approach provides a systematic means by which desired transport function and priority for respective roads can be considered and assigned.

Trams are assigned the highest level of priority across the entire tram network with all routes nominated as being on the Principal Public

Transport Network (PPTN) apart from sections of route operating through high pedestrian activity strip shopping centre areas where pedestrian priority applies.

Yarra Trams is responsible for the day to day operation of trams to Government performance standards as well as maintenance of tram fleet and infrastructure assets. These requirements and responsibilities are specified in detail in the Yarra Trams Franchise Agreement and Yarra Trams Infrastructure Lease.

VicRoads is exclusively responsible for the provision of traffic signal priority for trams. Local government plays a significant role in facilitating tram progression along roads primarily in regard to being responsible for the management of car parking on both local and arterial roads.

The local council is generally also the relevant statutory planning authority and ensures statutory requirements are met when considering tram improvement projects.

The PTV is also a referral authority for larger land use developments and is able to impose conditions on the issue of a planning permit in relation to ensuring tram impact issues are appropriately considered and accommodated as part of the development proposal.

There is no single, simple solution to managing traffic congestion and providing tram priority. Sustainable improvements will require an integrated approach involving consideration of land use planning, transport infrastructure improvements and community behavioural changes.

3.4. Tram Operation And Priority For Trams

Improving priority for trams is a key objective in order to provide a reliable, efficient and attractive light rail system. The majority of the tram network in Melbourne operates in a mixed operating road environment with tram tracks shared with traffic. These conditions result in imposed variable delays to tram services caused by traffic congestion, right turn vehicles on tram tracks and on street parking manoeuvres.

3.4.1. Reasons for Tram Priority

Benefit to Passengers

Research into passenger needs and preferences consistently identifies **reliability** and **journey time** as the two main factors which influence whether people who have a choice will use public transport or not.

The benefit of improved priority can be taken in different ways. Either it can yield improvement in service punctuality (because more trams can meet the scheduled run time) or a reduction in scheduled run time, or a combination of both effects.

Reliability

Reliability is the extent to which the service delivered matches the service promised. In an infrequent service, the issue is compliance with a published timetable. For a frequent service, where passengers do not use timetables, a service must appear within the advertised interval. In both cases, the journey time to the destination must match the promise.

Reliability can only be achieved where journey times are consistent from trip to trip in the short term. Over a longer period (such as the difference between peak and off-peak), timetables and frequencies can be adjusted to allow for predictable, systematic differences in journey time. The only way to stay punctual if a service suffers from short-term random variation is to provide excess time in schedules and have most trams waiting at timing points, which is wasteful and unpopular with passengers operators and roads authorities alike.

In Melbourne, journey times are very inconsistent from trip to trip. Each dot in the Figure 3.5 below represents one southbound trip over the northernmost section of Route 96, in East Brunswick. Because it is near a terminus, trams are not crowded with passengers in this section. It is typical of suburban Melbourne. The section is about 1.25km long and contains four sets of signals.

The effect of morning and evening peak road traffic is clear in the graph. It is more pronounced in the morning peak because the graph shows the southbound, or morning peak, direction. However, even during the off-peak period, and neglecting particularly long or short values, the journey time varies between 200 and 400 seconds – a factor of two. In the morning peak, trip-to-trip variation can be factor of three.

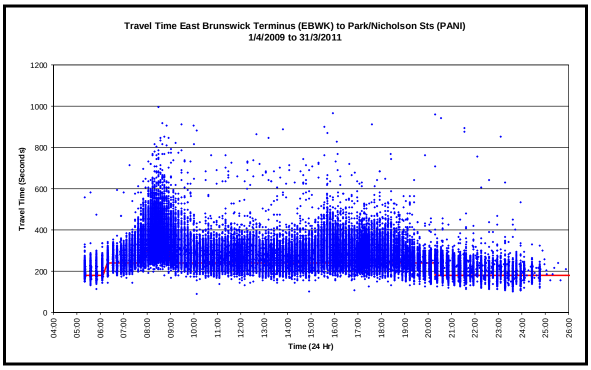


Figure 3.5 - Typical scatter diagram (Route 96, Blyth St – Park St Southbound)

Random delays cause the intervals between trams to vary. This has two detrimental effects:

§ Once a tram is delayed and an extended gap opens up between it and the tram in front, then it will spend more time at tram stops because there will be more passengers waiting. Similarly, a tram close to the tram in front picks up fewer passengers and spends less time waiting. Trams will tend to bunch together, so irregularity becomes worse.

§ A tram picking up fewer passengers also results in placing additional passenger loading strain on subsequent trams. During heavy peak periods this can result in overcrowded trams and inability to accommodate all waiting passengers, with some being delayed and having to wait for following services with room to board.

Signals make a major contribution to journey time inconsistency. It is now generally known that trams spend about 17% of the journey time waiting at signals. In the tests which produced this result, covering 19 journeys on a range of routes and at different times of day, the spread of results in the tests was from 2% of journey time stopped at signals to approx. 32%. Signal delays are essentially random.

The other major contributor to variation is request stopping, though this is not so random – broadly, trams stop at more stops in the peak direction at peak times.

A signalling system which gave consistent priority to trams would reduce short-term variability, which would discourage bunching and maximise the efficient use of available capacity to transport passengers.

Journey Time

As well as providing a more consistent journey time, an enhancement of tram priority should also provide a shorter average journey time.

If trams complete round-trip journeys in a shorter time, then either fewer trams can be used to operate the same service, or the same number of trams could be used to provide a more frequent service. At present, the second is more likely as many routes are operating at or near their capacity limits. The only thing preventing more services being run is that there are not enough trams to run them with.

In either case, the service which is provided will then be more attractive to passengers, because they will spend less time getting to their destinations. There are two sources of improvement. Firstly, the on-tram journey takes less long. Secondly, because the frequency is increased, the wait is shorter. There will be an increase in patronage because trams are more attractive compared with other modes. Because the competing mode for most tram journeys is the car, this will reduce road congestion. Typically, a 1% reduction in journey time would be expected to yield a 0.4% increase in patronage in the short term, and more in the long term as people adjust lifestyle choices (such as where they live and work) to exploit better services.

The service will also be more efficient to operate. The same number of trams and tram drivers can move more passengers in less time, with each tram running more kilometres in the day. The same level of service with the longer journey times would need more trams. Melbourne is currently buying trams at a cost of over $7M each, and needs to buy many more over the next few years. It is important that these expensive assets are used efficiently.

The efficiency improvement is coming from a reduction in the time the tram is standing still, not from it running faster between intersections, so there is no adverse effect on safety. This is why it is more appropriate to talk of reduced journey time rather than trams going faster. There are also specific safety benefits arising from improved priority.

3.4.2. Tram priority Measures

A range of tram priority measures have been introduced across Melbourne's tram network over the last 10 to 15 years under various improvement programs such as 'Think Tram' and other. The implementation of tram priority measures such as separation of traffic from tram tracks, traffic signal priority and construction of platforms can assist in reducing unnecessary delays to tram services. Although existing tram priority measures have had some success overall average tram journey times and reliability has remained relatively constant over the last 5 years. If tram priority measures are to make a significant improvement in travel time then clearer self enforcing traffic management measures are required to be progressed.

With around 80% of Melbourne's tram network operating in a shared road environment with general traffic separation and traffic signal priority are two significant improvement measures which have potential to have a real impact of realising tram travel time and reliability improvements.

3.4.3. Potential for Signal Improvements

Melbourne genuinely presents an exceptionally challenging environment, both technically and culturally for tram priority, it should however be nevertheless possible to substantially improve tram priority in Melbourne. Consideration and application of the following principles would assist in realising an improvement.

- Assign intersection time on the basis of people wishing to traverse the intersection, not vehicles.
- Introduce traffic metering strategies at key points in the network where traffic queueing can be accommodated upstream from congested shared tram route sections
- Investigate shorter signal cycle times at less busy times and places.
- Provide additional advance tram detectors, or transfer or demand arrangements, to provide earlier warning of tram approach.
- Tram stops should not be positioned on departure sides of intersections without providing effective priority on the approach side.
- Enforcement of right turn bans at intersections where right-turning road traffic regularly delays trams; consider introducing more hook turns.
- Provide physical self-enforcing separation wherever practicable – it provides the best situation for road traffic in signalling terms, because the tram window can be short because of the more predictable approach time, leaving more time for everyone else.

4. Opportunistic Renewals

Improving tram priority and fully separating trams from other traffic are considered to be critical elements in moving the tram system to a modern light rail service so that it becomes the best way to move around the inner suburbs of Melbourne.

Recognition and acknowledgement of the importance of taking opportunities for the reallocation of road space to prioritise public transport movement and access is particularly relevant to tram track renewal works.
A large and established tram network such as Melbourne's has an ongoing series of infrastructure renewal works taking place in order to maintain our assets to the latest standards necessary. These infrastructure renewal programs as well as other internal and external upgrade projects present potential opportunities to enhance and upgrade the operating environment to assist with its envisaged transformation.

Identifying opportunities for either undertaking network improvements as part of track renewal works or implementing changes to assist with achieving desired outcomes at a later date is a key opportunity that has been progressed where possible.

This future proof review and application not only provides immediate operational benefits but can also result in substantial longer term cost savings by making allowance for adjusting infrastructure at time of renewal. Relatively minor additional costs at time of renewal can present longer term savings in not having to rework and reposition costly track and overhead works whilst also saving on the high costs of occupations.

The primary opportunities associated with track renewal include consideration of improving tram right of way by achieving effective physical separation from vehicle traffic where road conditions allow. This could either be by raising the vertical level of tram tracks higher than adjacent roadway carrying traffic or by installation of other effective separation measures such as barrier kerbing or bollards.
Recent completed examples of this approach and application include Spencer Street and Fitzroy Street track works where tram tracks were raised by 120-150mm and established a significantly enhance tram right of way; separated from conflicts and delays caused by traffic which was previous able to encroach onto the tram tracks.

In addition raising tram tracks consideration is also given to opportunities to ensure track alignment and levels considers and future proofs the track works for desired platform construction either as part of the works or at a later date when funding is available. In some instances this may also take into account future plans for removal of existing tram stops.
Opportunities for immediate or future improvements are not just limited to simple straight track sections. Renewal of track junctions can also present greater cost/benefit returns by ensuring consideration is given to realignment opportunities which deliver enhanced upgrade outcomes.

5. Tram Network Accessibility

An accessible public transport network supports users at every stage of their lives. This includes parents with prams, people with temporary or permanent disabilities, customers with language barriers, senior citizens and people shifting from using cars to public transport. In 2009, Victoria had an estimated population of just over 5.4 million people, of which an estimated one million or 18 per cent lived with a disability. (Ref. Australian Bureau of Statistics 2011, Disability, ageing and carers, Australia: state tables for Victoria, cat. No. 4330.0, ABS, Canberra).

The proportion of older people is also trending upward with the current population aged 65 years and older expected to increase from current 13.6% to 23% by 2056. (Ref Population Projections, Australia 2006-2101, cat. No. 3222.0, Series B).

5.1. Accessibility & Legislation

In Victoria, one in five people has some form of disability. Under the Federal Legislation and Disability Standards for Accessible Public Transport, targets have been set for all public transport stops across the network to be upgraded to be DDA compliant by 2022 with preliminary targets of 55% and 90% for 2012 and 2017 respectively. These changes are designed to ensure safe and independent travel with dignity for people with a disability.

The purpose of the DDA Statutory and Legislative Requirements is to enable public transport operators and providers to improve accessibility of public transport services.

5.2. Legal Requirements

Victoria has an obligation to comply with the overarching Commonwealth **Disability Discrimination Act 1992 (DDA)** legislation to provide accessible public transport

The Commonwealth **Disability Discrimination Act, 1992 (DDA)** details the requirements for providing services and infrastructure that are accessible to people of all abilities. The **Disability Standards for Accessible Public Transport, 2002 (DSAPT)** were created under the DDA to cover requirements for access to public transport**.** The purpose of the Standards is to provide some guidance to public transport operators and providers to remove discrimination from public transport services.

Applicable Australian standards are also referenced by DSAPT, in particular **AS 1428** – Design for access and mobility.

In 2014 a Tram Platform Standard[5] was further created through the collaboration of members of the **Victorian Rail Industry Operators' Group (VRIOG)** for the purpose of establishing standards.

This standard covers the design requirements to deliver universally accessible tram stops on the Melbourne network. The document includes the functional requirements for platform design, passenger amenity, accessibility, tram operations, track design, construction standards, road design and traffic management that apply to the development of platform tram stops which designers and builders need to adhere to as part of the implementation of new rail infrastructure.

The **Accessible Public Transport in Victoria Action Plan (2013-17)** provides the actions and milestones to meet DDA compliance In accordance with the national Disability Standards for Accessible Public Transport, upgrading accessibility on highly patronised routes is prioritised.

Yarra Trams also have an **Accessibility Action Plan for 2015-2018** which supersedes their previous Accessibility Action Plan for 2012-2015. This outlines what they have achieved to date in improving accessibility to passengers and what they plan to do over the next 3 years. Yarra Trams are targeting 4 priority areas which include: customer service, consultation & community engagement, access to public transport services & access to facilities. Each of these priority areas are broken down with a number of objectives with associated actions to implement the object, timeframes to complete and an evaluation method to assess its success.

5.3. Compliance levels

The DSAPT includes target dates for transport operators and providers as well as technical standards. When the DSAPT was prepared in 2002, it was recognised that many significant changes would need to be made to Melbourne's public transport system. These would take time and involve significant expenditure so a staged compliance plan was developed. While the tram network is fully compliant with the DSAPT in some areas such as signs, symbols and information, it is unlikely to meet the 2017 targets in full, due to fleet and infrastructure constraints.

5.4. Trams

To date, there are currently 141 low floor trams in service on Melbourne's tram network. The government has placed an order for 70 E-Class trams, of which 41 have currently been delivered and are in service with the remaining 29 due to enter service over the next few years. Currently the total percentage of low floor trams operating on the network is 30.3%.

High Floor Trams:

Tram Class	Introduced	No. in Service	% Tram Fleet
W	1939-1956	10	2.1
Z3	1979-1984	114	24.5
A	1984-1986	69	14.8
B	1984-1994	132	28.3
Total High Floor Trams		**325**	**69.7**

Table 5.1 – High Floor Trams (as at 1 Sep 2016)

Low Floor Trams:

Tram Class	Introduced	No. in Service	% Tram Fleet
C	2001-2002	36	7.7
D1	2001-2002	38	8.2
D2	2003-2004	21	4.5
C2	2008	5	1.1
E	2013-2016	41	8.8
Total Low Floor Trams		**141**	**30.3**

Table 5.2 – Low Floor Trams (as at 1 Sep 2016)

* Average age of Melbourne's trams: 24.2 years old (excluding the W-Class trams).

5.4.1. DDA Compliance Progress – Low Floor Trams

The following graph shows the procurement and introduction of Low floor trams into service on the Melbourne tram network since 2001.

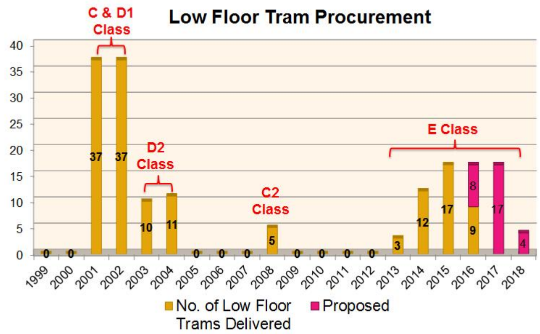


Figure 5.3 – Low Floor Tram Procurement

Currently, there are three routes which operate entirely with low-floor trams. In addition to

Routes 96 and 109, on which all trams have been low-floor for a number of years, Route 19 became a fully low-floor service in June 2015 as a result of cascading the D2 Class trams from Route 96 to Route 19 with the continual rollout of the E-Class trams. The E-Class trams are currently in operation on Route 96 and in the process of being rolled out on Route 11. Route 86 is proposed to introduce E-Class trams from November 2016.

5.5. Tram Stops

5.5.1. Tram Stop Upgrade

There are currently 1,739 tram stops on the Melbourne tram network. Of these, 411 are level access tram stops (23.6% total). There was an intense activity of level access tram stop construction where 175 tram stops were constructed during 2007 and 2008 when DDA funding was provided to upgrade existing safety zone tram stops.

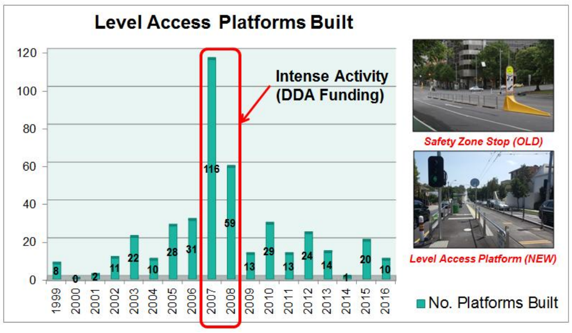


Figure 5.4 – Level Access Platforms Built

Since then however, over the following 7 years to 2015, an average of only 16 tram stops have been built per year. This can partly be attributed to the fact that a lot of the ‘easier' to construct platforms have now been upgraded where construction of the new platform stops had minimal impact to the community (through loss of parking or changes to the road environment).

Figure 5.5 shows the current DSAPT compliance progress and highlights the significant amount of work to be done to meet DSAPT compliance target dates for both platform infrastructure and procurement of low floor trams.

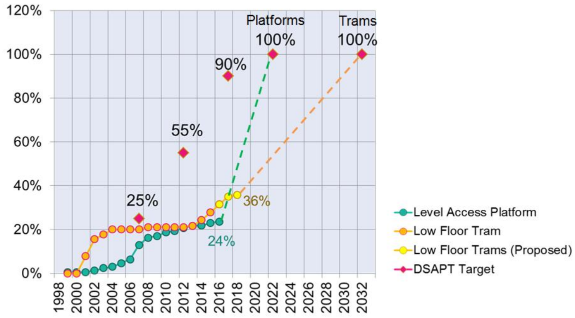


Figure 5.5 – DSAPT Compliance Progress

The introduction of DDA compliant accessible tram stops to date has provided numerous benefits whilst having a minimal impact to other road users. The benefits include:

a) Improved Accessibility

The rollout of DDA compliant accessible tram stops has improved accessibility for all users. It is estimated up to 20% of passengers have some form of mobility impairment that are significantly aided by accessible tram stops.

b) Improved Safety

Safety at platform stops has demonstrated to be significantly improved compared to safety zones and kerbside stops.

A recent study by Monash University in 2015 on *“Accident Analysis and Prevention”*[6] concluded that there has been up to an 86% improvement in the reduction in pedestrian involved injuries after platforms have been installed highlighting that platform stops have significant safety benefits for pedestrians as well as improving accessibility to the tram network.

c) Improved Tram Operation

Accessible tram stops improve boarding and alighting times. Independent studies show that passengers take up to 40% less time to board and alight trams at platform stops compared to safety zones. This has resulted in tram travel time savings and improved tram reliability.

d) Improved Passenger Facilities

Platform stops offer passengers improved amenity by providing shelters and seating, improved lighting and real time tram arrival displays. The significant growth in tram stop usage particularly within the CBD area in the last decade reinforces the need for platform stops that can cater for an increased number of passengers.

Compliance with DDA requirements improves accessibility for passengers of all abilities, while contributing to the State's compliance with the Disability Discrimination Act 1992. It also provides opportunities to improve the existing tram network including consideration of stop optimisation and changes to traffic conditions leading to improved capacity and efficiency of the new and current tram fleet. The costs associated with the introduction of these changes are significant given the size of the network and extent of tram stops remaining to be upgraded to achieve DDA compliance. Careful planning, coordination and consultation will be required in order to successfully achieve the outcomes sought.

5.5.2. Tram Stop Optimisation

The current stop spacing in Melbourne is low compared with international standards. The average distance between stops is approximately 260m compared to other light rail systems which are typically 400m. 160 stops are less than 150m apart, 370 are 200m or less apart and 860 are 250m or less apart.

Along with traffic signals, stopping at tram stops is a major cause of delay to tram services. While convenient tram stop arrangements are important to service and attract passengers, the balance between access and stop spacing and efficiency for all passengers requires review and correction.

The benefits of increasing stop spacing include:

- Shorter journey times for tram passengers;
- Improved reliability of journey times;
- Improved opportunity to improve stop facility and safety with fewer upgraded stops;
- Reduce costs for DDA compliance;
- Reduced delays for general traffic at fewer kerb side stops; and,
- Reduced impact on streetscape and parking.

When reviewing tram stop optimisation, it is important that a reasonable section of a tram route is reviewed and tram stops are not looked at in isolation. While optimisation may in a few cases involve the removal of an existing tram stop, it is often coupled with the Tram Stop Upgrade Strategy in reviewing and locating tram stops in the most appropriate locations if they are not already in these positions.

Tram stop placement and optimisation considerations include the following factors to ensure that they are appropriately located for passenger convenience and connectivity;

Land Use and Activity

- Importance to ensure tram stops are appropriately positioned at major landmarks or key activity nodes
- Passenger generators such as universities, sporting venues, major shopping centres.
- Places of interests (education, health and aged care facilities, community's facilities,
- City hall, library, museums, schools, mall, cinemas).
- Places for people with specific needs (e.g. hospitals, blind association).
- Site constraints (traffic requirements, parking, property access).
- Tourist hot spots / public destination / major sporting venues.

Connectivity

- Importance to ensure stops are provided to enable quick and convenient transfer between other Public Transport modes (bus, train and tram).

Distance

- Tram stop spacing in the order of 400m. Spacing less than 400m may also be appropriate when considering connectivity and land use objectives.

Patronage

- Stops with high patronage should not be removed.

Safety

- Optimisation or change of design at high loadings stops

Operations

- Operational needs (short run, drivers' relief point, location of toilets).
- Special events.

Infrastructure

- Stops close to any cross over should not be removed as they can be used as a temporary terminus

6. Platforms

Some tram routes that share the running with cars on roads in Melbourne such as St Kilda Road have a very large road reserve and sacrificing one lane of traffic to provide a platform stop doesn't have a significant impact, however the challenge arises on smaller width streets such as Toorak Road where there are only two lanes in each direction, one of which is shared with the trams (approx. 14m from kerb to kerb). As soon as a platform is built, it forces vehicles onto the tram tracks thereby causing shared running with trams which is not in line with the goal of segregating the tram tracks from the road traffic to improve the efficiency of the tram network and reduce the number of daily collisions that occur between trams and vehicles. The following details the different types of tram stops that can and have been implemented on Melbourne's tram network to suit the functional needs of the tram stop location.

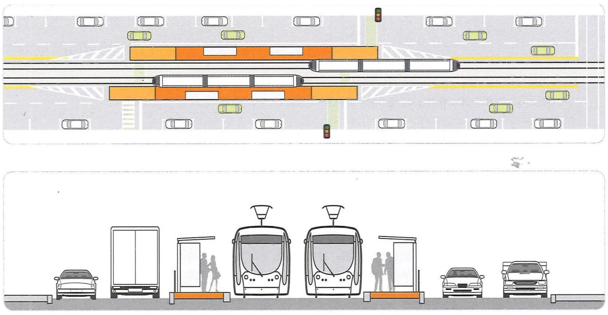
6.1. Types of Platform

While traditional platform stops are generally considered to provide the most desirable platform arrangement from passenger loading and safety point of view site specific physical constraints often prevent installation of this type of tram platform. A number of alternative tram platform designs have therefore been developed and applied across the network depending on the operating environment and constraints along specific route sections. Figure 6.1 below provides an overall summary and comparison of the main types of platforms stops on the Melbourne tram network.

		Comfort & Safety	Road Impact	Urban Form	Cost
Trafficable Easy Access Stop (TEAS)		✓	Retains Conditions	✓✓	Low to Med
Kerb Extension		✓✓✓	Reduces to One Through Lane	✓✓	Med
Platform Stop		✓✓✓	Reduces Road Width	✓	High
Centre Island Platform		✓✓	Reduces Lane Width	✓	V High

Figure 6.1 – Tram stop type comparison

6.1.1. Side Platform Stops



Level Access Platform Stops (33m)

Figure 6.2 – Side Platforms

Single faced platform stops either in roadways or medians have been the primary platform types constructed to date. These platforms have been and continue to be the preferred stop arrangement in Melbourne where sufficient space is available for introduction.

Tram passengers board and alight the platforms separated from vehicle traffic. Pedestrian access between platforms and adjacent footpaths is made safe and convenient by provision of controlled crossings. The platforms also assist in reducing overall travel times for tram services by providing more efficient passenger loading, especially when combined with low floor tram services. The 290mm high raised platform also separates vehicle traffic from trams at the stop providing a safe conflict free environment for passengers

Minimum platform widths are specified at 3100mm (with 2785mm possible under special conditions if space constraints are demonstrated). Platform widths however should be determined based on patronage levels.

Platform lengths also need to take into account number of tram routes and tram services frequency operating at the specific location.

Single faced median platforms have been constructed at a significant number of locations across the network to date where space provision has enabled ease of installation.

Platforms have been the main type of platform constructed in the CBD where road width has enable installation.

6.1.2.Kerb Access Tram Stops (KATS)

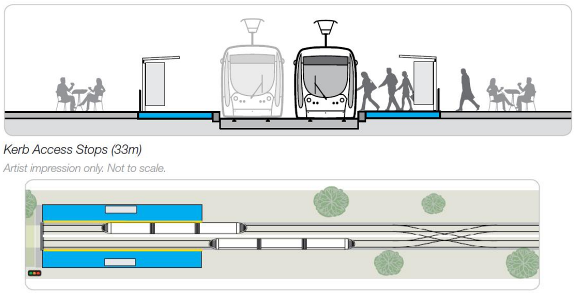


Figure 6.3 – Kerb Access Tram Stops

Kerb extension stops are ideal for designated pedestrian areas such as Bourke Street Mall and can also be constructed along roadways by building the footpath out to meet tram tracks. They provide a safe passenger boarding arrangement by narrowing road to a shared single traffic lane on tram tracks preventing any traffic movement from passing during loading. While passenger safety and loading times are improved in the same way as platform stops, this stop arrangement has potential to cause delays to tram journey times as a consequence of all traffic movement being placed onto tram tracks. This eliminates the potential for establishing tram separation in the vicinity of the platform

The application of this platform stop arrangement should therefore be restricted to areas which are either pedestrianised or at midblock locations where traffic volumes are low and free flowing.

In the case of shared roadway this platform arrangement requires the reconstruction of tram tracks to increase tram track centres in order to provide safer width between raised platform and oncoming traffic.

Some kerb access tram stops include a shared path for pedestrians and cyclists either across the front of the platform or behind it.

6.1.3.Centre Island Platforms (CIP)

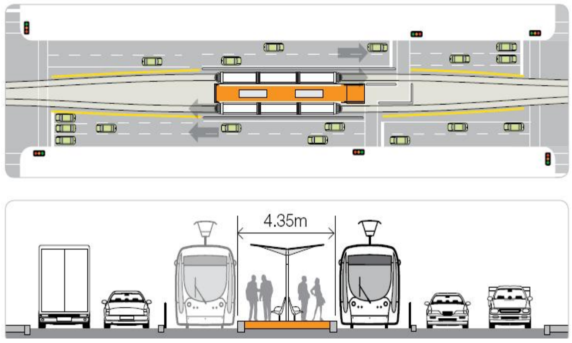


Figure 6.4 – Centre Island Platform

CIPS are positioned in the centre of the road between separated tram tracks providing a common platform for trams to load passengers travelling in both directions. Passengers board and alight from the right hand side of the tram and therefore a physical barrier is included on the left hand side of tram tracks between trams and traffic in order to provide protection in case of loading confusion.

6.1.4.Centre Offset Platforms (COP)

A platform variation of CIP has also been installed which provides staggered central single side loading at opposite ends of the central platform often referred to as a Central Offset Platform.

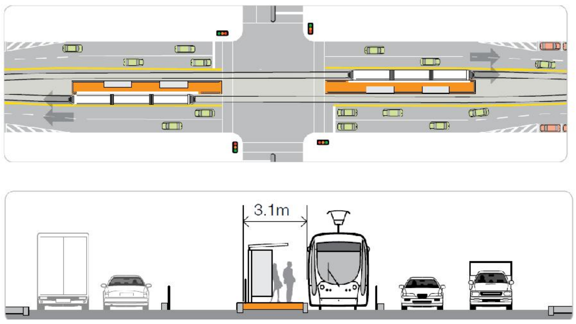


Figure 6.5 – Central Offset Platform

This arrangement requires less road width than a single double sided central platform. Passenger waiting / loading areas are spread and enables installation of a pedestrian fence at the rear of the platform as well as passenger shelters at the respective loading ends. Platform length is doubled to at least 66m as trams are only able to use half of the platform for passengers to alight with fencing along the back of the platform preventing trams from the other track to alight passengers. This is due to circulation space requirements.

6.1.5. Easy Access Stops (EAS)

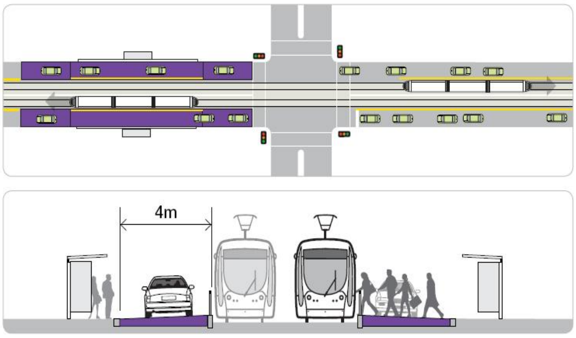


Figure 6.6 – Easy Access Tram Stop

Due to road width constraints over a large part of the tram network typical platform designs cannot be installed in most of the remaining locations without adverse impacts on road users (including tram services) and adjacent land occupiers.

Easy Access Stops (EAS) have therefore been developed and installed at a number of locations in Melbourne as a design solution for space constrained road environments.

EAS involve raising and extending the kerbside traffic lanes to tram platform height to provide 290mm level access loading for passengers. Vehicular traffic is able to travel along the tram tracks or over the raised section of roadway in a similar way to a long elongated road hump. The tram tracks remain at road level. Fifteen (15) of these platforms have been constructed to date have proved to function safely and effectively.

Given the high number of kerbside sides stops (approximately 1150) remaining across the network on relatively narrow constrained roads, the EAS platform design has the potential to the applied across a large proportion of remaining stops across the network.

Investigation undertaken by VicRoads has recommended that EAS platforms could be installed along road sections where widths are greater than 13.6m. On this basis EAS platforms could potential be introduced across 76% of the network currently covered by kerb side stops.

Preserving the potential opportunity for establishing EAS across the network in the future will be considered in all upcoming tram track renewal works by investigating the practicality of increasing tram track centres from standard 3.353m to 3.800m at time of track works. This could be carried out along entire lengths of renewal works thereby preserving flexibility for future tram platform placement as well as maintaining straight track alignment for passenger comfort as well as minimising track asset wear.

6.2. Challenges of Meeting Compliance Targets

While every effort is made to provide fully DDA compliant tram stops on the network, it is not always possible due to the urban environment in which tram stops are located. As such, there are a number of challenges associated with meeting specific DSAPT requirements and targets which include:

- The DSAPT standards set a 100% compliance target by 2022 for tram infrastructure.
- PTV and Yarra Trams have produced Action Plans which cover targets over the next 3 years however no long term program / plan has been established that sets out what needs to be completed each year.
- State funding will need to be provided for rollingstock and each infrastructure project.
- Authority Approvals - currently the process of installing new tram infrastructure is lead by the tram infrastructure projects upgrading trams stops to be DDA compliant. Competing stakeholder interests associated with upgrading some tram stops results in authority approvals becoming a real challenge to implementing DDA compliant infrastructure across the tram network. Particularly sensitive areas on most projects involve parking removal, heritage listed bluestone gutters and restrictions to local traffic movements (left in-left out). Projects can then be forced through planning permit submissions and approvals processes which are both time consuming, costly and also no guarantee a platform stop will be able to be built at the end of it.

- Unique engineering solutions are required due to spatial constraints such as different road reserve widths, side streets, bike lane requirements and access to local properties
- Meeting all DSAPT standards can be a challenge and when dispensation is required, significant effort is required to demonstrate that all other options have been explored and to justify the proposed design. Packaging tram stops along routes could allow for efficiencies in this process.

6.3. Potential Way Forward

If the government has provided a target for Melbourne's tram network to be DDA compliant by 2032, an overall program needs to be established which can feed into PTV and Yarra Trams shorter term Action Plans released each 3 years with specific targets of which platforms are to be upgraded each year. To achieve efficiencies in design and construction, a review of the delivery method for the implementation of DDA accessible tram stops, including packaging tram stops by routes instead of on an individual stop by stop basis, should be considered. The creation of a new government agency which incorporates representatives from PTV and VicRoads in Victoria called Transport for Victoria (TfV) provides an opportunity for clarifying the future approach for upgrading the network.

There remains 1328 tram stops to be upgraded. Assuming there will be a 20% reduction in the number of tram stops on the network as a result of sighting and optimisation, this number could be reduced to approx. 1063 tram stops. At approx. $3m per pair of tram stops, approx. $1.6b is required to upgrade the tram stops to level access tram stops.

Low Floor E-Class trams cost approx. $7m each and assuming a like-for-like replacement of the 325 remaining high-floor trams with new E-Class trams, that's $2.1b to upgrade the trams. i.e. at least $3.7b is required to provide a fully compliant DDA tram network in Melbourne and this is just for the rolling stock and platform infrastructure. This doesn't allow for additional works required such as increased stabling yard capacity, power supply upgrades to the traction power network, increasing lengths of existing termini etc.

A budget or funding model should be provided to deliver this important accessibility upgrade.

A number of options exist for expediting delivery including:

- Streamlining the planning process (State involvement)

- Improved community consultation to explain benefits

- Review of DSAPT standards/ prescriptive requirements (e.g. 2.5% gradient limit for platform stops).

Tram stop designs are continually evolving. The first level access tram stop was constructed in 2001 at Collins Street as a side platform and since then, we have had CIP's, Easy Access Tram Stops, COP's and Kerbside tram stops. Are there other styles of platform stops which could be more efficient that haven't been explored yet such as Kerbside running of trams instead of central running? While consistency of tram stop design is important, tram stops will continue to evolve to meet local constraints along routes and the changing demands of a growing city taking into consideration not just the cars, but bicycles, pedestrian access, car parking, access for local residents, turning movements and sighting lines from side streets.

Design of these stops therefore requires skill and experience to develop stop upgrades that suit the community.

7. Case Studies

7.1. Toorak Terminus

7.1.1.Background

Toorak Terminus was first proposed to be upgraded 30 years ago. The terminus was considered unsafe and was the last unprotected terminus on Melbourne's tram network. The terminus was located on a 6.7% gradient, no protected access for pedestrians to get onto the tram and having to cross 2 lanes of traffic in the shadow of a red light at Glenferrie Road. Terminating trams would need to cross into oncoming traffic to switch tracks to travel back to the city and the terminus was located near the top of a hill so westbound cars travelling over Glenferrie Road would often find themselves with a tram blocking their lane, forcing cars to merge lanes while travelling across the intersection.

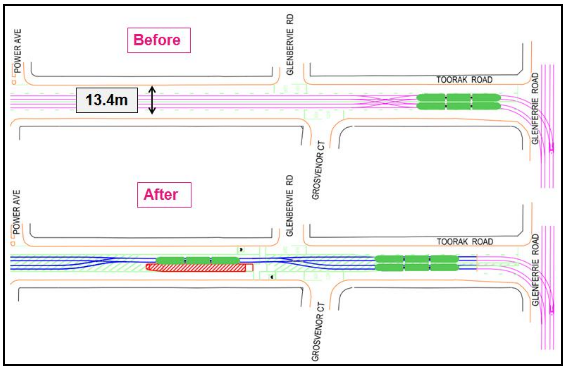


Figure 7.1 – Toorak Terminus Before & After Layout

7.1.2.Investigation Options

Many options were investigated for a suitable location for the terminus to minimise the overall impacts to stakeholders including moving the terminus into Glenferrie Road or extending the tracks further to the east or to Kooyong Station. Glenferrie Road is not wide enough to terminate a tram on a separate track given there is already the Route 16 tram service that runs up and down Glenferrie Road. East of Glenferrie has too greater impact to traffic. A traffic analysis indicated a stop could be located 210m east of Glenferrie, which located the stop on a steep hill and so far from Glenferrie Road ,there would need to be another stop on Toorak Road anyhow to the west of Glenferrie Road where the current terminus is located. Kooyong station (to the north) was not feasible unless the station is grade separated as a result of traffic congestion on Glenferrie Road. This left moving the terminus further west on Toorak Road approx. 100m away from Glenferrie Road.

Toorak Road also has a tight road reserve which required a single track side platform which was feasible for Toorak Road given it didn't have any other through running tram routes (unlike Glenferrie Road). Kerb Side / EAS stops are not suitable for termini where trams are stopped for long periods of time as trams block road traffic and cars don't know when they can proceed as per road rules associated with passing stopped trams.

7.1.3.Challenges

The main issue with the proposed location was the gradient of Toorak Road being on a 6.7% grade where platforms are required to be 2.5%. All options were investigated, including what would be required to implement a 2.5% gradient platform. Keeping the eastern end at road surface level so pedestrians could access the platform resulted in the western end of the platform being 2.3m above road surface level. As the maximum design grade for track is theoretically 6.67% and the topography of Toorak Road gets steeper at 6.85% as it goes downhill, the 2.3m concrete retaining wall with trams on top running down the centre of Toorak Road would continue for approx. 200m to the bottom of the hill creating a visual eyesore, numerous safety issues and practical restrictions and challenges from splitting Toorak Road and restricting turning movements. Even providing a 5% gradient platform required the tracks to be raised almost 700mm above road surface level for approx. 200m down Toorak Road.

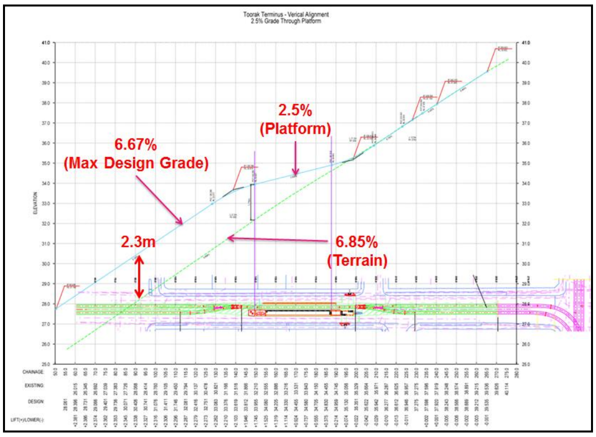


Figure 7.2 – Vertical Alignment with 2.5% gradient platform

For Toorak Terminus, the gradient was the main issue both on the platform and access to the platform however all other aspects are able to achieve DDA compliance. Trial Tests were also organised and conducted with mobility impaired volunteers at two Melbourne CBD tram stops, one of which was the Collins Street tram stop D15 outside PTV's office which is on a 6.3% gradient. Users in the trial indicated that despite the steep grade, they were still able to negotiate the platform and board the tram without much difficulty so long as the gap between tram and platform is suitable and there is enough manoeuvring space on the platform.

Further design considerations had to minimise any impact on the local community with the location of the platform. Two driveways were restricted to left-in, left-out as a result of the new platform located outside their driveways. The platform layout was also modified to allow unrestricted access to a third property without the need for any kerb works to their driveway crossover over the median.

Consultation with VicRoads and Yarra Trams occurred to seek collaboration around the signalling of the traffic lights, the location and frequency of the trams stabled to the east of the platform, merging traffic lanes and visible sight lines for turning vehicles.

With trams stabled to the east of the terminus, the location had added complexity due to trams returning to or entering service from Malvern depot via Glenferrie Road. Traffic signals at Glenferrie Road needed to be modified based on tram movements from the terminus to avoid trams approaching on-coming traffic.

Merge lane lengths meant it was preferable to stable trams as far west as possible away from the intersection however sight line requirements for right turning vehicles out of Glenbervie Road meant it was preferable for trams to be stabled as far east as possible. Reducing the speed limit to 40km/h was discussed with VicRoads and eventually approved which assisted the sighting distance requirement as well as the lane merging requirements.

7.1.4.Platform Design

In addition to the standard platform infrastructure required to be installed for DDA compliant tram stops such tactiles, audio bollards, PIDs, mirrors etc., being such a steep gradient also provided challenges for the ramp and seating associated with the platform design.

As ramps can have a maximum gradient of 1:14 with 1.2m length landings (at a max 1:40 grade) every 6m, this equates to a maximum gradient of 6.37% (over 7.2m) that can be achieved. As Toorak Road was on a 6.85% gradient, a ramp compliant with the DSAPT 2.5% grade requirement could not be positioned at the downhill end as the natural terrain was falling away quicker than the gradient of the ramp, Fortunately for Toorak Terminus, the preference was for the passenger entry point to the station to be located nearer Glenferrie Road which was at the uphill end.

Image 7.3 – Completed Toorak Terminus

Due to sighting line constraints from constructing a new platform, the original two 8m shelters had to be reduced to a single 8m shelter. A normal 8m long Adshel shelter however was not suitable as the seat height would not have been compliant (greater than 520mm above ground level) so this had to be split into two separate 4m shelters next to each other. These were located centrally on the platform as on most low floor rolling stock, the allocated spaces for mobility aids is near the centre of the trams (as opposed to trains which is near the front of the train).

7.2. Elgin Street

The level access tram stop in Elgin Street was constructed in 2015 after first being approved to proceed in 2012. The Elgin Street platform upgrade provided the opportunity to optimise two pairs of tram stops at either end of Elgin Street at Swanston Street and Lygon Street into a single Central Offset Platform (COP) between Lygon Street and Cardigan Street at the eastern end of Elgin Street.

The road reserve in Elgin Street is somewhat narrow and contains bluestone cobblestone adjacent the kerbside lane which is only useful for parking and not considered trafficable for through running vehicles. City of Melbourne Council also insisted that a bike lane be provided in each direction which immediately restricted available options for types of platforms to be used as Side Platforms and a Centre Island Platform (CIP) took up too much road reserve width.

Image 7.4 – Elgin Street with parking, bicycle and a through traffic lane adjacent the COP.

A COP was considered to give the best result however the platform was required to be reduced in width by 100mm to 3.0m (instead of 3.1m). 2735mm is the absolute minimum to meet circulation space requirements. The COP which is required to be a minimum of 66m to allow one tram in either direction to utilise each side of the platform offset from the other tram. At this location, it formed a practical solution to extend the platform to 73m to allow access to the platform from both Lygon Street (to the east) and Cardigan Street (to the west) without introducing an additional pedestrian crossing.

Image 7.5 – Midpoint of the Elgin Street COP showing loading areas on either side

As a result of the requirement to include parking lanes, bike lanes and a through traffic lane, the space remaining for a platform stop meant the horizontal alignment of the track and platform was pretty fixed by the surrounding environment. A sewer manhole was located beneath the proposed location of the offside fencing to separate the trams from the road traffic. City West Water required access to the manhole without being obstructed by the fencing over the top. As such, we needed to modify the sewer manhole and reconstruct the top to shift the entrance 250mm to the south which was possible due to the concentric design of the manhole shaft. With some slight modification of the kerbing in the area, we were able to come up with a design that was suitable for City West Water and with Yarra Trams.

Planning permits and heritage approvals also needed to be taken into consideration at Elgin Street due to the overlays in the area. As the kerbing needed to be modified to provide suitable access for turning vehicles into adjacent streets and the tracks were to be raised, this triggered the need for a planning permit which required additional time to be allowed for the planning process.

The drainage along Elgin Street also needed to be taken into consideration. At the Elgin / Lygon Street intersection, there was already an existing drainage problem that required improvement. A hydraulic assessment was undertaken and confirmed that the raised track along Elgin Street would not cause any issues for overland flow however additional drainage pits and a reconfiguration of the drainage network around the Elgin / Lygon Street intersection was required to improve the drainage.

Image 7.6 – Relocated sewer manhole on Elgin Street with modified kerbing to maintain access

The project ended up being constructed within the occupation program over 7 days of 24 hour construction providing a level access tram stop in Elgin Street which all passengers could use and access trams.

7.3. Easy Access Stop (EAS) – Bridge Road

7.3.1. Background

With a large part of the tram network operating in a constrained road space environment a need to explore and develop alternative platform designs was required in order to achieve the objective of providing level access loading to trams while also being conscious of not adversely impacting on traffic and tram performance.
A trafficable raised shared platform design was subsequently developed referred to as Easy Access Stop (EAS).

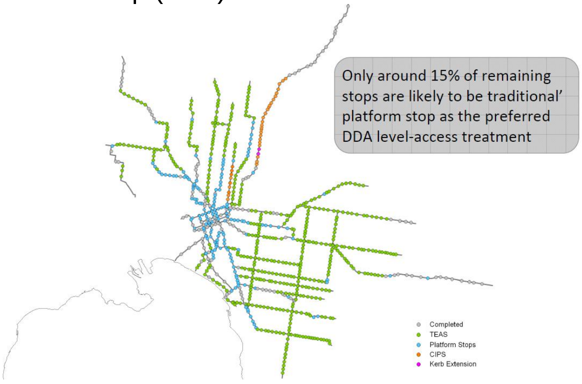


Figure 7.7 – Map showing likely tram stop types proposed on remaining tram stops

The first Easy Access platforms were installed in 2004 in Dank Street, South Melbourne by City of Port Phillip in conjunction with Yarra Trams. Additional platforms followed in Albert Park as well as Docklands. While the stops proved to work well on low speed, low traffic roads application on busy arterials where traffic volumes necessitated two lanes of traffic required testing.
A series of off road tests were carried out in 2010 to assess performance of various ramp lengths at a range of speeds for a variety of vehicle types. The outcome of the testing was that ramps of 1 in 40 gradient was appropriate to adopt for 60km/h speed environments.
A Design Reference Group was subsequently established involving representatives from VicRoads, the Department of Transport, Yarra Trams and Cities of Melbourne and Yarra to further develop a design standard for application of EAS in a mixed traffic road environment. One of the design factors that were established through the process was the requirement to maintain minimum traffic lane widths of 3.3m passed the 290mm raised EAS platforms. Given the requirement for 700mm offset of platform to tram tracks 3.3m width traffic lanes necessitated spreading the tram tracks by some 400mm in order to provide the 3.3m wide lanes.

7.3.2. Bridge Road EAS Construction

Previous EAS stops all involved traffic travelling in kerbside lane only. The application of establishing in a situation where traffic travelled in kerbside lane as well as central shared tram track lane had yet to be tested. The planned renewal of tram tracks along Bridge Road provided the opportunity to reconstruct the tram tracks with increased tram track centres and install and test the EAS design arrangement on a busy four lane arterial road.

Following considerable design development including extensive risk assessment consideration and pre installation survey and data gathering by Jacobs/SKM construction progressed in early 2013. The majority of construction activity was undertaken under live operating conditions with only minimal full road and tram service occupation being necessitated. Two pairs of EAS platforms where completed and open for operation on 25 March 2013.

7.3.3. Using Easy Access Stops

Easy access stops required a process of informing and educating both passengers and motorists on required use.

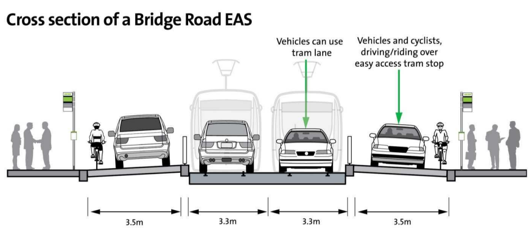


Figure 7.8 – Cross section of a Bridge Road EAS

Passengers

- Tram passengers use an easy access stop in the same way as a kerbside tram stop

- Passengers wait on the footpath behind the yellow line and hail the tram
- Passengers then cross the kerbside traffic lane to the tram when the tram has arrived and stopped at the tram stop

Drivers

- Drivers must obey road rules in the same way as applicable at kerbside tram stops
- Drivers must stop at the rear of the stopped tram for boarding and alighting passengers
- Where applicable in clearway times general traffic can use both the kerbside and centre shared traffic lanes.
- Parking is not permitted on the ramps or over the tram stop at any time.

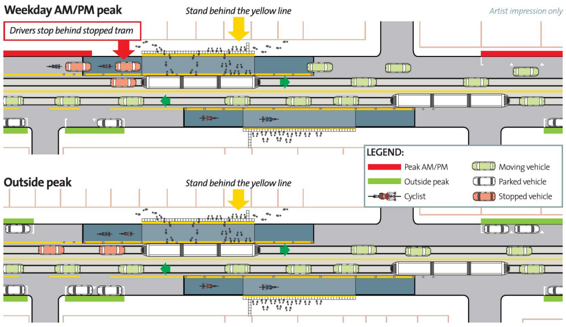


Figure 7.9 – Plan View of a Bridge Road EAS

7.3.4.Before and After Assessment

Jacobs was engaged to monitor Bridge Road before and after the installation of the Easy Access Stops (EAS)[7]

- Before Assessment Sept 2012
- After Assessment May 2013
- Further enhancements to the stops made in October 2013 (Stage 3)[8].
- Further monitoring was completed to test the enhancements.

Following the initial After Assessments, further enhancements were also provided which included:

- Pavement Arrows
- Stop for Trams pavement markings
- Zig zag pavement markings
- Wider "Stand Behind This Line"
- "Watch For Traffic" linemarking

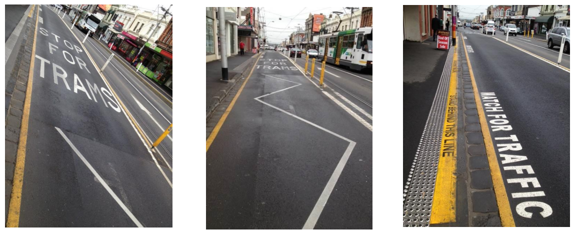


Image 7.10 – Typical line marking on an EAS

7.3.5.Assessment Methodology

Purpose:

To evaluate impacts of EAS, in particular:
- Car driver, pedestrian and tram passenger behaviours
- Tram travel time and stop time at tram stops
- Safety

1. Video monitoring before and after installation of EAS
2. Interviews with tram passengers and drivers
3. Site visit with representatives with visual and mobility disabilities
4. Further monitoring after additional enhancements to stops

- Two cameras recorded movements at each stop
- Vehicle speeds and tram times
- Numbers and locations of parked vehicles
- Time periods:
  - AM Peak: 7:00am - 9:00am
  - PM Peak: 4:30pm - 6:30pm
  - Inter-peak: 12:00pm - 2:00pm
  - Night:12:00am - 1:00am, 5:00am - 6:00am

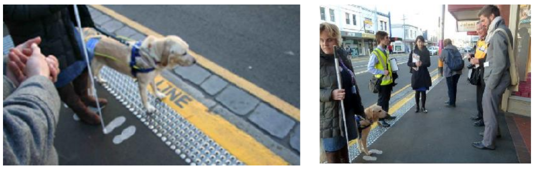
Image 7.11 – Vehicles using EAS' during peak and non-peak times

7.3.6. Disability Access Audit

- Site visit to all stops on Bridge Road (and Macarthur Street) with representatives of groups with visual and mobility disabilities

Purpose:

- Test DDA usability of the new stops
- Gather feedback from users with disabilities
- Identify areas for improvement



Images 7.12 – Participants of the Disability Access Audit

Positive outcomes

- Users with a disability found the new stops were a great improvement over traditional kerbside stops:
- Tactile tiling was well placed
- Tram stops were easy to understand and negotiate

Learnings for future projects:

- Placement of tactile tiles should take poles into account
- Tactile tiling contrast is very important
- Trams sometimes stop with bollards in their doorways
- Stops located mid-block are not as easy to find

7.3.7. Perceptions of users

Findings

- Both drivers and tram passengers had a good understanding of the tram stops
- Most users identified safety or disability access as reasons the stops have been installed
- Responses were generally positive to the new tram stops, with passengers indicating that they improved the route. Car drivers tended to be indifferent.

7.3.8. Passengers getting on and off

Questions:

- Has the total number of passengers getting on and off the trams changed with the installation of EAS?
- How do passengers redistribute between stops when the number of stops is reduced?

Findings

- Stops have not affected patronage
- Stop 15 used more than stop 17 in "after" case
- Main movements are Melbourne CBD-based trips

7.3.9. Tram Travel Times

Questions:

- Do tram travel times increase or decrease after the installation of easy access stops?
- Do trams stop for the same amount of time at the easy access stops?

Findings

- The overall travel time has decreased
- Tram priority enhancements and fewer stops are main contributors
- Tram stopping time per stop remains relatively constant

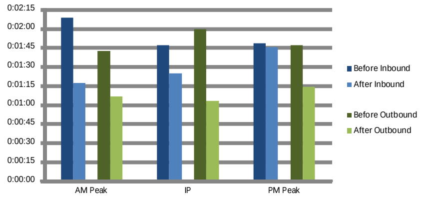


Figure 7.13 – Overall reduction in tram travel times

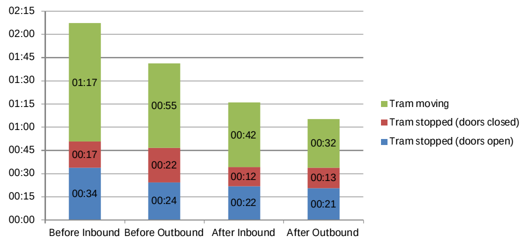


Figure 7.14 – Breakdown of tram travel times

7.3.10. Passenger Behaviour

Questions:

- Do passengers most wait on the kerb or step onto the roadway before the tram arrives?
- What were the interim findings and what was done to improve compliance?

Findings

- New stops have not increased the risk-taking by pedestrians stepping onto the road early
- Extra signage added to increase safety awareness

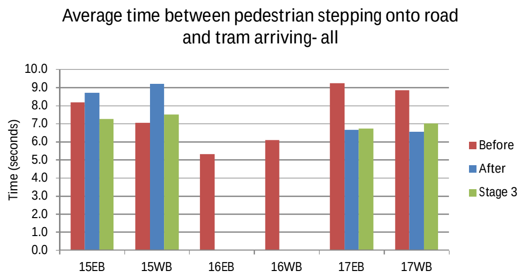


Figure 7.15 – Average time between pedestrian stepping onto road and tram arriving - all

7.3.11. Time Passengers Take to Disembark

Question:

- Has there been a change to the time passengers take to disembark?

Findings

- The relationship between how long it takes for passengers to get off the tram and the number of passengers remains constant
- With more passengers at each stop, total disembarking time increases
- Times vary between stops

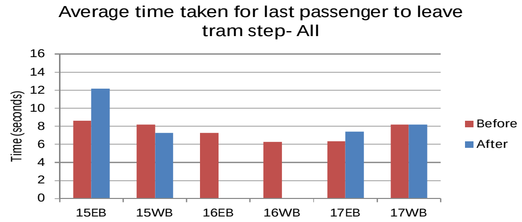


Figure 7.16 – Average time taken for last passenger to leave tram stop - All

7.3.12. Pedestrian behaviour

Question:

- Are the walking routes of disembarking passengers different with the installation of easy access stops?

Findings

- Positively for passenger safety, the number of passengers getting off the tram and crossing straight to the nearest footpath has increased from 93.7% to 97.2% with the installation of the easy access stops.

Question:

- Is there a greater incidence of pedestrians straying onto the roadway when walking past the tram stops on the footpath?

Findings

- More than 99% of pedestrians are compliant and stick to the footpath

Tram Stop		Pedestrian Movement			
		In Direction of Traffic		Against Direction of Traffic	
		Walking entirely on footpath	Staying in kerbside lane	Walking entirely on footpath	Staying in kerbside lane
Before	15 EB	481	1	425	0
	15 WB	544	1	511	0
	16 EB	546	1	506	3
	16 WB	627	0	587	1
	17 EB	503	7	449	13
	17 WB	490	0	491	0
After	15 EB	672	5	621	4
	15 WB	629	2	455	4
	17 EB	519	4	399	3
	17 WB	506	4	481	3

Table 7.17 – Pedestrian compliant movements

7.3.13. Pedestrians Crossing at the Tram Stop

Question:

- Are more pedestrians crossing the road at tram stops?

Findings

- Small reduction in number of pedestrians crossing at tram stops
- A greater proportion of pedestrians choose to return to the kerb, rather than complete the crossing

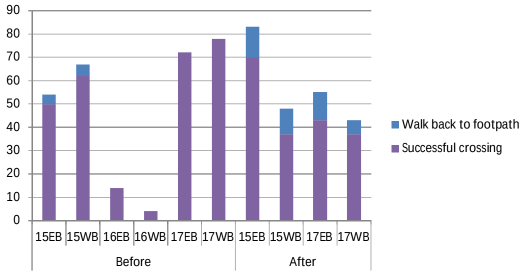


Figure 7.18 – Pedestrians crossing at tram stops (AM, Interpeak, PM Peak time periods)

7.3.14. Motor Vehicle Compliance at the Tram Stop

Questions:

- Do motorists comply with rules to stop for trams at tram stops?
- Was there any change in compliance after the easy access stops were installed?

Findings

- Motorist compliance has improved with the installation of EAS.

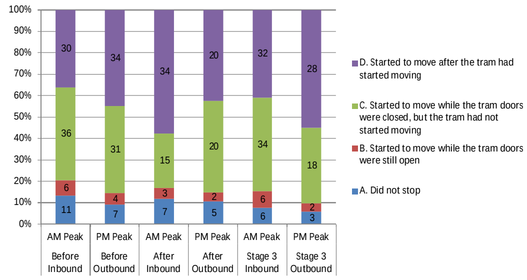


Figure 7.19 – Motorist compliance at EAS's

7.3.15. Motor vehicle lane usage

Questions:

- Which lanes do cars and trucks prefer?
- Does this change after the installation of the easy access stops?
- Is this change different in the peak direction (when clearways are in place) compared to off peak (when no clearways are in place)?

Findings

- Lane choice varies by stop location
- In the peak, when clearways are operational, both lanes are equally favoured
- The tram stops have not discouraged drivers from using both lanes, which is an important outcome for road use efficiency

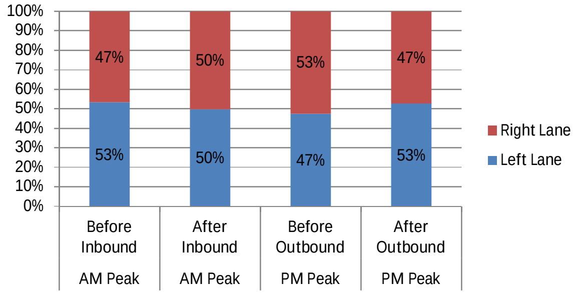


Figure 7.20 – Lane choice – with clearways operational

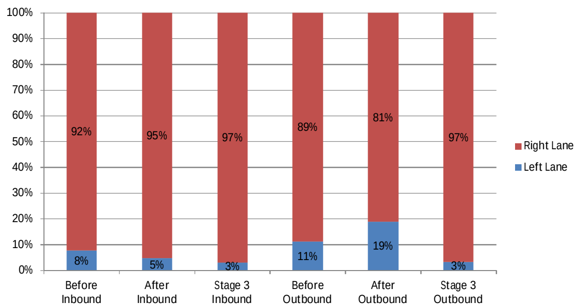


Figure 7.21 – Lane choice – clearways not in operation

7.3.16. Car Speeds

Question:

- How have vehicle speeds changed after the installation of the easy access stops?

Finding

- Speeds have reduced at every location in every time period since the installation of the easy access stops

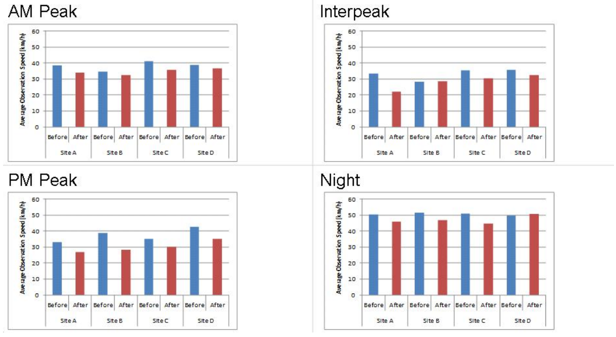


Figure 7.22 – Speeds at EAS's in AM Peak, PM Peak, Interpeak and Night

7.3.17. Summary

- Drivers and passengers understood how the tram stops worked, nominating safety and disability access as main benefits of new stops
- Users with a disability found the new stops a great improvement over traditional kerbside stops
- Some further improvements (e.g. placement of tiles) could be made to improve disability access further
- Tram passengers were mostly positive towards the new stops. Car drivers were mostly indifferent.
- Vehicle speeds reduced
- Tram travel times decreased (noting that there are fewer stops)
- Evidence of safer pedestrian behaviour:
- More tram passengers moved straight to kerb
- Fewer pedestrians attempted road crossings at tram stops
- Motorist compliance has improved with the installation of EAS

These case studies provide an appreciation of the numerous challenges encountered as part of implementing DDA compliant tram infrastructure on Melbourne's tram network. Designs are required to be adapted to the surrounding environment due to the complexities at each site which provides safer and improved accessibility to trams for all passengers.

8. Conclusion

With Melbourne's tram network being the largest in the world but also with some infrastructure that has been around for over 100 years, there is an ongoing challenge to ensure it progresses with the needs and requirements of today's society. Regular maintenance and upgrades across the network are required to maintain its operational status however major improvements are required to upgrade and enhance the network to meet the demands of a growing city.

While network improvements from the point of view of operating environment and platform installation have been implemented across the network the extent of work remaining is significant.

The experience to date has demonstrated the difficulties and impediments in achieving the desire to convert Melbourne's tram network into a modern light rail service capable of providing the transport needs of a growing city.

The following issues have arisen and require consideration when upgrading tram stops:

- Impact on parking;
- Restrictions to property and vehicle access;
- Restrictions to road traffic capacity;
- Removal and relocation of tram stops; and
- Impact on local community and corresponding local acceptance and support for tram improvements.

Lessons learnt from progressing the implementation of tram improvement measures to date include the following:

- Achieving significant improvements in tram travel time has proven difficult;
- Road space allocation is limited, with almost 80% of the tram network operating in mixed traffic conditions, which impacts efficient tram performance;
- Traffic growth continues to adversely impact on tram journey times and performance across a larger part of weekdays and weekends.
- Physical self-enforcing traffic separation treatments are more effective and sustainable than administrative controls
- Traffic signal and road based priority improvement measures have demonstrated benefits to tram travel times and reliability and provide significant opportunity for further improvement.;
- Restricted road space makes establishment of level access tram platforms difficult, particularly if also needing to cater for traffic movements.
- Competing stakeholder interests can be difficult to resolve and require skilled stakeholder management;
- There is a need to improve 'selling' the benefits of tram related improvements to the community;
- Smart solutions are required to remove impediments causing tram delays in order to achieve sustainable long term benefits;
- Improvements along an entire route have greater potential to realise tram time and performance improvements.

A partnership approach involving State and local government, road authority, rail operator and community provides the best approach to achieving network improvements.

8.1. What does the Vision for a Modern Light Rail Service Look Like?

The vision for a modern light rail service in Melbourne would ideally provide the following:

- 100% accessible tram system (all rollingstock to be low floor trams and all level access tram stops and infrastructure).
- Maximise tram separation from other traffic where feasible.
- Faster and, more reliable than existing with tram priority at traffic signals.
- A frequent and regular "turn up and go" service not requiring reliance on timetables
- Excellent interchange and connectivity with other Public Transport modes.
- Safe and comfortable journeys with enhanced customer information.
- A system that encourages urban growth and development along tram corridors
- Quiet infrastructure that does not adversely impact on communities

8.2. How Will This Be Achieved?

- Continued ongoing program of new high capacity, low floor tram procurement.
- Tram stop upgrades and optimisation of stops
- Introduction of effective tram separation to reduce / eliminate the conflict between trams and vehicles that contribute to delays and some 1000 tram / vehicles accidents each year on Melbourne's tram network
- Tram priority at traffic signals
- Regular, 10 minute turn up and go services
- Opportunistic infrastructure renewals that upgrade the assets as well as including provision for enhanced operating environment and passenger experience.

8.3. Summary

Melbourne's tram network has a long way to go to achieve the desired goal of establishing a light rail network that meets the demands of a growing city. Recent developments however of level access tram stops and the commitment by the government to procure more modern low floor trams for the network outlines the progress being made toward this outcome. Taking advantage of opportunistic renewals and reviewing tram corridors as a whole in relation to tram stop optimisation also assists in achieving these goals around providing platforms and improvements in the operating environment through enhanced separation from road vehicles.

As these developments will continue into the future, the tram network will transition towards a modern light rail system that will be better placed to meet the demands of a continually growing city.

9. References

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