FINAL REPORT

Estimating the social marginal cost of public transport in Victoria

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Infrastructure Victoria

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Executive summary

Public transport in Victoria does not recover its costs from users. Public Transport Victoria indicates that fare revenue recovered 30 per cent of the costs in 2017/18.[1] The majority of costs for public transport services are funded through public subsidies.

There are three main reasons cited from an efficiency perspective for subsidising public transport fares:

1 Roads are not priced — in the absence of a subsidy on public transport there would be too much road use and congestion created from this road use.

2 Public transport has high fixed costs — this means the cost of servicing additional passengers (the marginal cost) can be below the average cost per passenger. An efficient price signal would therefore require a public transport subsidy.

3 Lower public transport fares lead to more demand which in turn leads to more services, lower waiting times and further increases in demand. Note that there is also a reverse case, where extra demand has to fit within existing services, leading to crowding.

From an equity perspective, there are also specific public transport subsidies, such as for concession holders.

Against the arguments for subsidies, public funding is not infinite. Raising money through taxes to pay for subsidies has costs of its own.

The purpose of this study is to consider how these different reasons compare in a quantitative sense, and what level and structure of fares these arguments would support.

To achieve this, The CIE and Jacobs have developed a model to analyse quantitatively the above factors to understand the trade-offs between these different impacts. This provides a guide for decisions on Victorian public transport fares. The model draws information on costs and behavioural change into a systematic view of the 'social marginal cost' of public transport use in Victoria. Social marginal cost combines the financial costs of additional public transport use and 'externalities' such as changes in road congestion and environmental impacts.

Key drivers of fare decisions

The key drivers of an efficiency driven public transport fare system are:

- the costs of accommodating additional passengers — higher costs support a higher level of fares

1 Public Transport Victoria 2018, Annual Report 2017/18, p. 13.

- the passenger response to public transport fare changes — if passengers are not responsive, then this supports a higher level of fares, because the impacts of these passengers using other forms of travel will be lower, and the loss of fare revenue from a higher fare will be smaller
- the level of road congestion avoided by public transport use — higher levels of avoided congestion support a justification for lower fares.

Costs of accommodating additional passengers

Where a public transport service is not at capacity, the cost of providing the service to more passengers is very low. This is typically the case for many bus services not focused on the CBD and for off-peak public transport services. However, when a service is at capacity, the costs to expand capacity can be very large. Mega projects such as Melbourne Metro 1 and Melbourne Metro 2 are, in part, about expanding the capacity of the rail system into the CBD. The estimated cost for Melbourne Metro, from its business case, was $10.8 billion (P90, nominal).[2]

Passenger response to public transport fares

The larger the passenger response to public transport fares, the smaller is the additional subsidy from reducing fares. For example, if a 10 per cent reduction in public transport fares led to 10 per cent more public transport users, then the amount of revenue collected is the same. However, if this led to only 2 per cent more users then then revenue collected is ~8 per cent lower.

The change in fare revenue is important because there is a cost of the Government obtaining funding to cover changes in fare revenue and costs. This is known as the excess burden of taxation.

Road decongestion impacts

Additional users of roads impose costs on others, because they congest the road network. Currently, there is no price signal for road users about these costs. Encouraging more public transport use through subsidies is an indirect way of addressing this issue. The direct solution is to charge road users directly.

The costs imposed by others from additional road use are substantial. Estimates from modelling conducted for this study are that each additional vehicle kilometre can impose costs of around $2 on other users in the AM peak in metro areas. Outside of peak times, impacts are substantially lower. Outside of metropolitan areas impacts are also lower per km travelled, however can result in larger decongestion benefits per trip as displaced road trips are significantly longer for trips beginning or ending in peri-urban and regional

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2 Victorian Government 2016, Melbourne Metro business case, February, https://metrotunnel.vic.gov.au/__data/assets/pdf_file/0006/40677/MM-Business-Case-Feb-2016-WEB.pdf.

areas. The pattern of these impacts suggests that **subsidies should be highest for metropolitan areas and times of peak road use.**

Results of this Project

Marginal financial costs

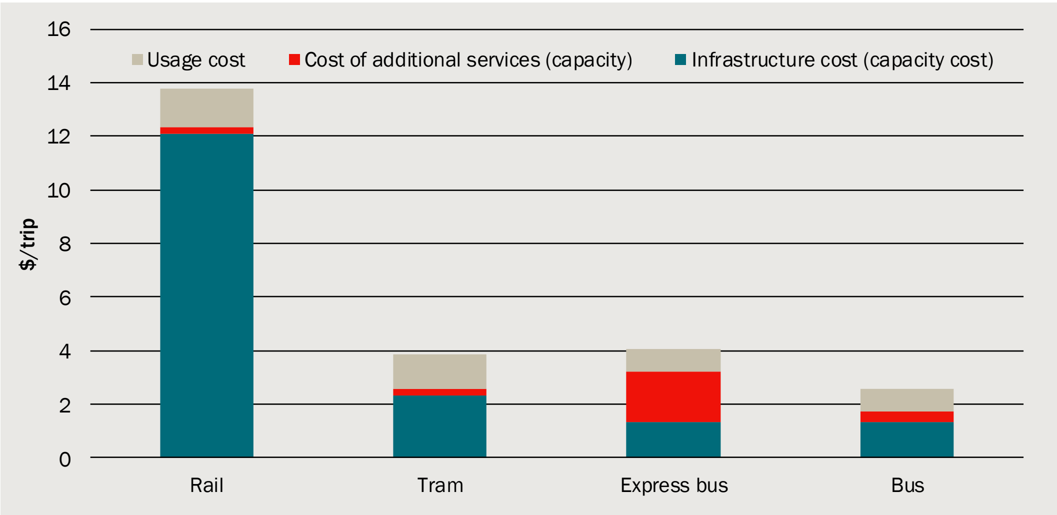
The marginal financial costs for metropolitan trips are shown in chart 1. Each rail trip during peak periods is expected to have a marginal cost of around $14. This is largely from additional infrastructure capacity costs. Trams tend to follow a similar pattern, however infrastructure capacity costs are significantly lower.

Buses have a lower cost, as many bus lines do not require additional services, even in peak periods. This reflects:

- the significantly lower cost of bus infrastructure compared to tram and, in particular, rail infrastructure as it consists primarily of new buses
- the significantly lower cost per bus service km compared to train (service costs are similar to tram)
- the low level of crowding on bus services, many bus services operate at very low levels of crowding so are able to increase patronage with small, or no, increase in services.

Express bus also has a very large cost of additional services; that is the cost associated with increased public transport trips to ensure crowding levels are the same under the base case and when there is marginal increase in demand. This cost is larger than the corresponding cost for normal bus trips, as increased demand for express buses tends to result in a need for more services on longer bus routes.

1 Marginal financial cost per trip — metropolitan peak

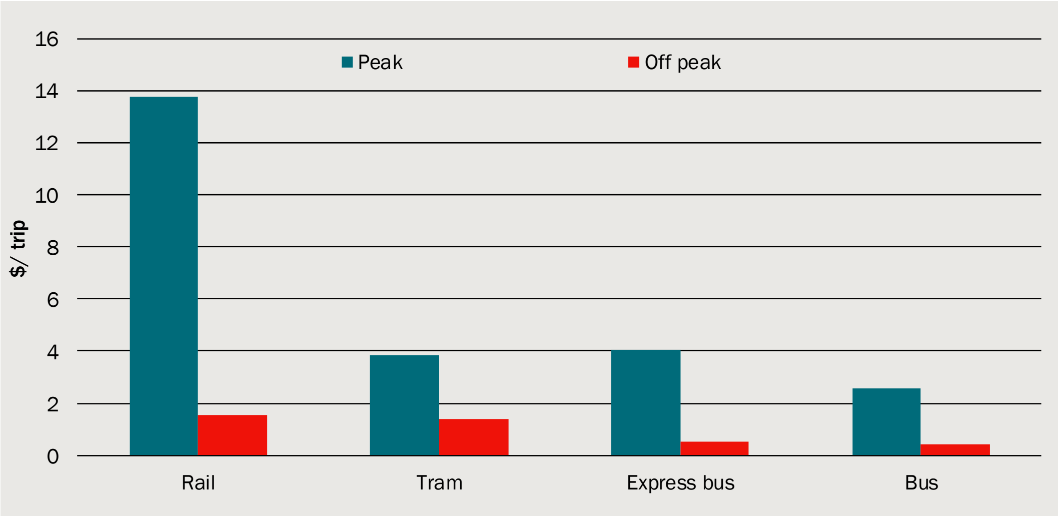


Data source: CIE and Jacobs.

During off-peak periods, marginal financial costs are low across all modes, as we assume that infrastructure capacity costs, are only incurred during peak periods (i.e. decisions around infrastructure capacity are driven by demand during peak periods, chart 2).

The pattern of financial costs indicates that, other factors equal, fares should be lower outside of peak periods and should be higher on a per trip basis for rail relative to other modes.

2 Marginal financial cost per trip — metropolitan peak and off-peak



Data source: CIE and Jacobs.

Marginal externalities

Marginal externalities are a mixture of positive and negative impacts from public transport use relative to alternatives.

Positive benefits are generally related to:

- reduced road decongestion
- reduced environmental externalities and reduced accidents from reduced private car use
- increase in the frequency of public transport
- reduced excess burden of taxation from the marginal public transport trip.

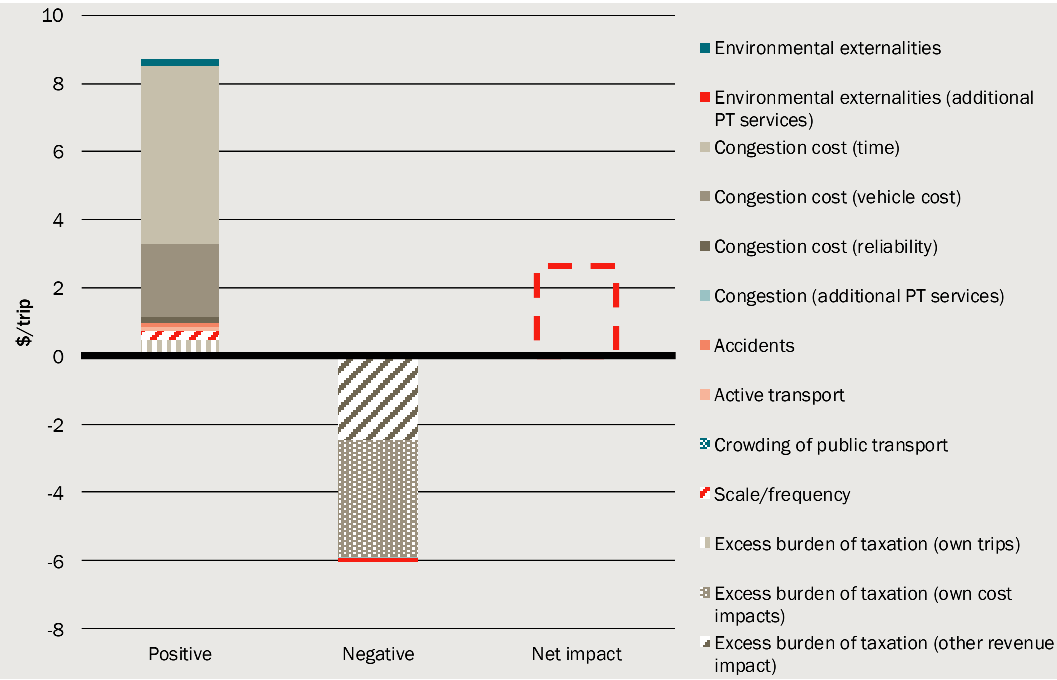
Negative benefits are generally related to:

- increased excess burden of taxation from the lower fare required to induce the marginal trip
- increased excess burden of taxation from higher infrastructure and operating costs
- increased environmental externalities and increased road congestion from additional public transport services.

Where externalities are positive, they tend to be dominated by road decongestion benefits (for instance for peak metropolitan rail trips). Where externalities are negative, they tend to be dominated by the marginal excess burden of taxation (for instance for peak peri-urban rail trips).

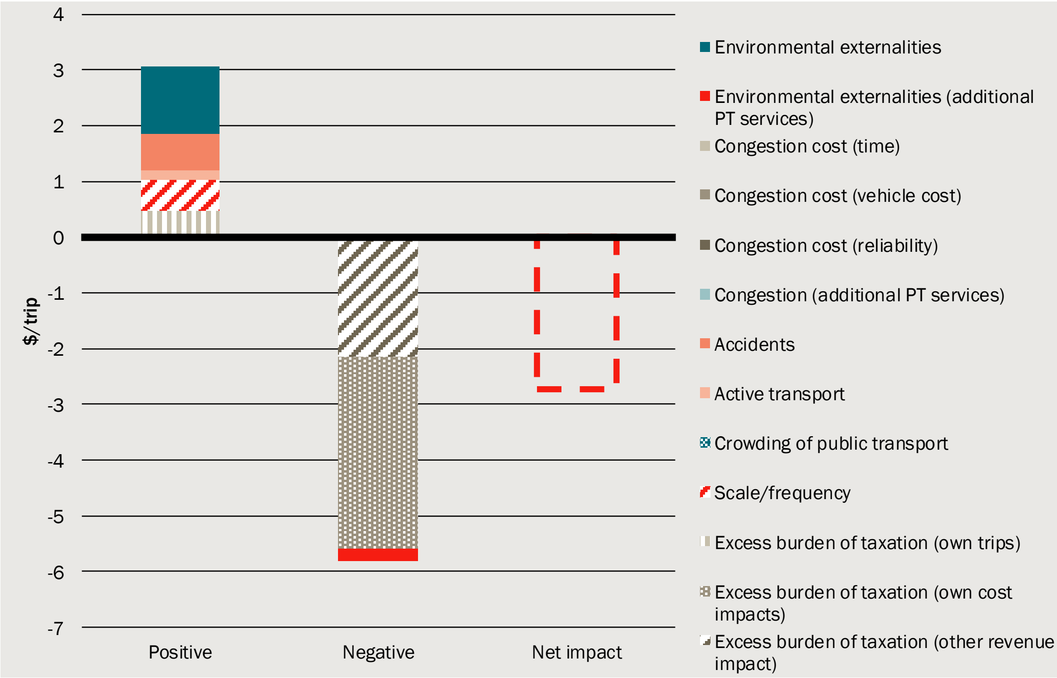
Each metropolitan peak rail trip travelled has a marginal external benefit of $2.7 (chart 3). However, a peak peri-urban trip has a negative externality of $2.7 per trip — because there are no road decongestion externalities, the positive impacts are estimated to be small and the financial costs result in a higher excess burden of taxation (chart 4).

3 Rail peak metropolitan externalities



Data source: CIE and Jacobs.

4 Rail peak peri-urban externalities



Data source: CIE and Jacobs.

Marginal external benefits for public transport use are substantially higher during peak periods than off-peak periods and higher for metropolitan trips compared to regional and peri-urban trips. This reflects the interpretation of the VITM modelling results:

- The change in travel time between the base case and the scenarios estimated in VITM was found to be within the VITM's convergence error for interpeak and evening periods. This has been interpreted as their being small or no road decongestion benefits during these periods and road decongestion benefits have been set to zero during the off-peak. This is likely to understate positive externalities, as there is likely to be some decongestion benefit, however VITM does not allow us to estimate this with any precision.
- Similarly, the change in travel times compared to the base case for regional and peri-urban runs was close to the convergence error of the model. We have chosen to also set the decongestion benefits for regional and peri-urban trips to zero. Again, there is likely to be some decongestion benefit, especially for trips which go into metropolitan areas, however VITM does not allow us to estimate this accurately.

Because of these modelling results, the externality result for off-peak, regional and peri-urban trips is primarily driven by the excess burden of taxation measure. The excess burden of taxation is important for each mode and time period and is sensitive to the chosen excess burden of taxation parameter.

Marginal social costs

The marginal social costs are presented in table 5. For example, the marginal social cost in the peak for metropolitan rail is $11 per trip; this suggests the efficient fare should $11 per trip.

Marginal social cost is significantly larger for rail, compared to the other modes. This is primarily due to longer marginal trips, and the significantly higher financial costs, in particular during peak periods.

5 Marginal social costs, allowing for service expansion per trip

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/trip	$/trip	$/trip	$/trip
Peak	Metropolitan	-11.1	-1.4	-0.7	2.3
Peak	Peri-urban	-16.5	na	na	-3.0
Peak	Regional	-20.9	na	na	na
Peak	Destination elsewhere than CBD	-11.7	-0.2	na	1.0
Peak	All trips	-10.0	na	na	1.0
Off peak	Metropolitan	-2.6	-2.4	-0.1	0.1
Off peak	Peri-urban	-1.8	na	na	0.9
Off peak	Regional	-9.1	na	na	na
Off peak	Destination elsewhere than CBD	-3.6	-2.5	na	0.2
Off peak	All trips	-2.5	na	na	0.3
All day	Metropolitan	-4.8	-1.4	0.4	2.1
All day	Peri-urban	-7.7	na	na	-0.4
All day	Regional	-10.9	na	na	na
All day	Destination elsewhere than CBD	-5.5	-1.1	na	1.2
All day	All trips	-4.2	na	na	1.4

Source: CIE and Jacobs.

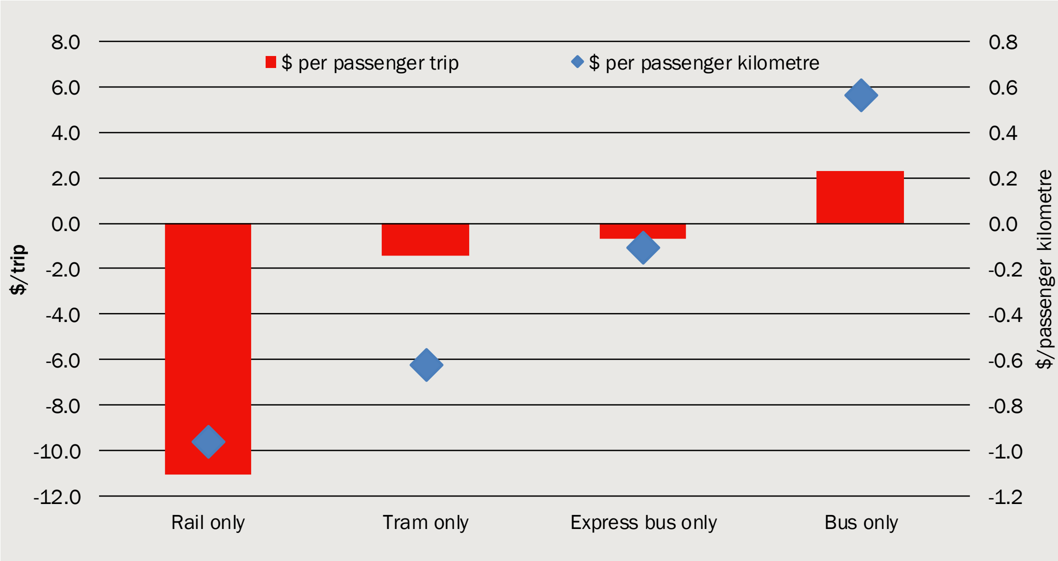
The key implication of these results are as follows (see charts 6, 7 and 8).

- The marginal social cost (MSC) varies considerably across modes, which supports the use of more specific mode pricing. It implies that fares for rail should generally be greater than tram fares on a per trip basis, which in turn should be greater than bus fares.
- For bus the MSC is consistently positive. This suggests there is enough bus capacity, such that the patronage could increase without incurring additional large infrastructure capacity costs. An alternative to increasing bus patronage on underutilised services, could be to rationalise existing services. The costs savings from reducing bus services could be larger than the social benefits of increasing demand.[3]
- For rail and express bus, MSC is higher during peak periods. This implies that peak fares should generally be greater than off-peak fares (chart 8).

3 The analysis assumes the public transport services as is and does not assess whether the current public transport services are optimal. A positive MSC may imply there would be benefits from rationalising services.

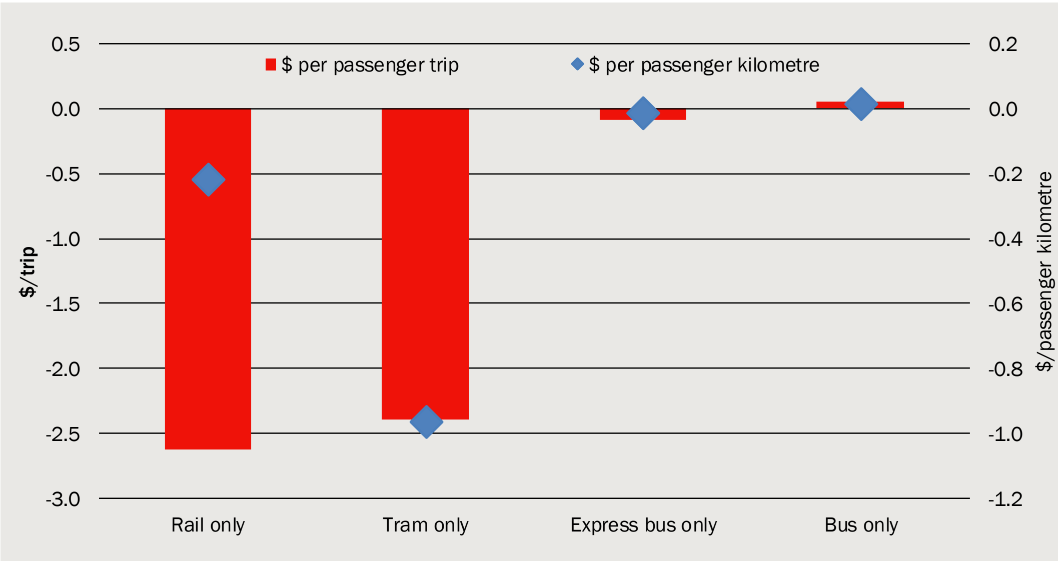
- For tram and bus only, MSC is lower during peak periods. On face value, this implies that prices should be lower during peak periods and higher during off-peak periods. However, these results do not consider the impacts of users switching their time of travel. We believe this result is due to the large decongestion benefits associated with tram and bus trips during peak periods. The model does not measure the negative externality of increased crowding, but instead assumes that services are increased to accommodate the increased demand. This may indicate that marginal financial costs are understated. We consider that this provides less support for peak and off-peak pricing than for rail and express bus services.

6 Social marginal cost — metropolitan peak



Data source: CIE and Jacobs.

7 Social marginal cost — metropolitan off-peak



Data source: CIE and Jacobs.

8 Peak and off-peak social marginal cost

Data source: CIE and Jacobs.

Policy implications

Is mode-based pricing justified?

The marginal social cost varies considerably across modes, which supports the use of more specific mode-based pricing. It implies that fares for rail should generally be greater than tram fares, which in turn should be greater than bus fares during peak periods (chart 6). During off-peak periods, the difference between rail and tram costs per trip is significantly lower, as tram has a much larger social cost per passenger kilometre (chart 7).

On a per passenger km basis many of the externality values are similar across mode, however the large differences in trip distances translate to differences in MSC across modes.

Is peak/off-peak pricing justified?

There is a case for peak/off peak pricing. This is somewhat presupposed by our (reasonable) assumption that marginal infrastructure capacity costs are only incurred during peak periods, in particular for rail for which these costs are large (chart 8).

- For rail and express bus, MSC is higher during peak periods, which implies that peak fares should be generally be greater than off-peak fares. For these modes this is primarily due to changes in marginal financial costs between peak and off-peak periods.
- For tram MSC is lower during peak periods. We believe this is due to the characteristics of the tram network and the VITM model.
  - During peak periods, we expect a large proportion of tram use to be in the CBD free tram zone, such that changes in prices will not result in a change in behaviour.

  - During peak periods, there is also little substitution from car to tram trips, with a reduction in tram fares (one additional tram trip reduces car trips by 0.28 in the peak and 0.38 in the off-peak). Externalities are driven by public transport reducing car use, such that if peak tram use reduces car use by less than off-peak tram use, we would expect peak tram trips to have lower externalities, all else equal.
- For bus MSC is positive in both the peak and off-peak, and is higher during the peak period. This appears to be due to a large road decongestion benefit, which is larger than the increase in financial costs between the peak and off-peak.
- Where we take a weighted average of the metropolitan results for individual modes, MSC is higher during the peak periods. This suggests that even without mode specific pricing, peak and off-peak pricing would be supported.

Note that the modelling does not consider the impact of people switching their time of travel. This would further strengthen the case for higher peak prices.

Is distance-based pricing justified?

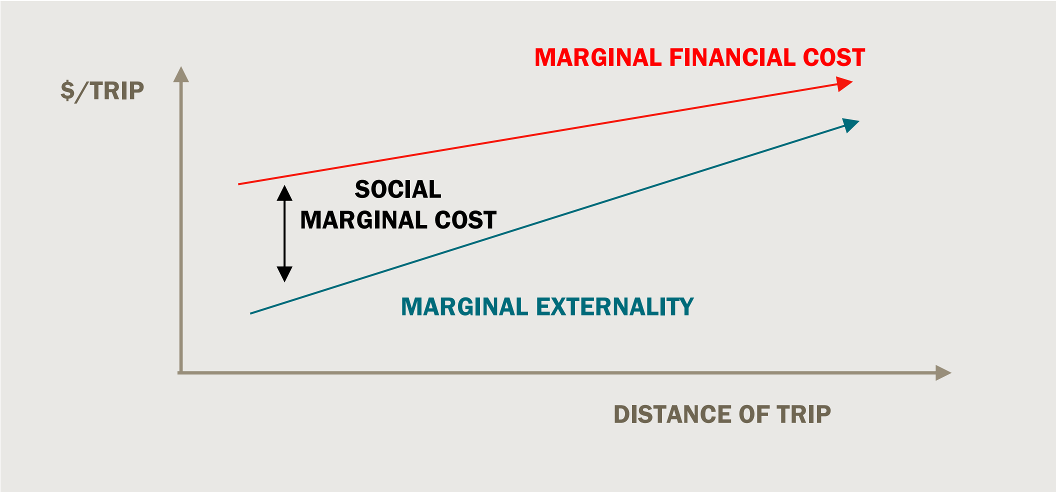
The case for distance-based pricing is not very strong. The externalities from public transport use tend to increase more steeply than the costs of providing services (chart 9).

- Marginal financial costs increase gradually for longer trips. However, a substantial part of these costs is for capacity issues in the centre of the network, which are the same regardless of the distance of the trip, as long as it starts or ends in the CBD
- Marginal externalities increase more for longer trips than the marginal financial cost. This is because congestion impacts are more widespread for the road network than for the public transport network, and not just focused on the CBD.

The outcome is that the marginal social cost may well be lower for longer trips. In this case there is no reason to support higher prices for longer trips.

These outcomes reflect that existing infrastructure is considered sunk, and we focus on the incremental costs required to address capacity. That is, we focus on the existing rail network. The costs of new infrastructure unrelated to capacity, such as the suburban rail loop, will tend to be much more costly per passenger trip for longer trips and locations more distant from the CBD.

9 Financial costs and externalities by trip distance



Data source: CIE.

The modelling result is consistent with this conclusion (table 10):

- For rail, short trip distances have a higher MSC than for all distance metropolitan trips, which on average are longer as they include both long and short dist.
- For bus and tram, MSC is broadly the same for short and metropolitan trips. This implies that financial costs increase broadly in line with externalities such that the MSC of different length trips is broadly the same.

10 Social marginal cost – metropolitan distance-based runs

Time period	Trip type	Rail only	Tram only	Bus only
		$/trip	$/trip	$/trip
Peak	All distance (short and long)	-9.0	-1.7	1.2
Peak	Short distance	-15.5	-1.8	1.6
Off-peak	All distance (short and long)	-2.8	-2.4	-1.2
Off-peak	Short distance	-3.9	-2.2	-1.4
All day	All distance (short and long)	-3.8	-1.6	0.9
All day	Short distance	-8.0	-1.6	1.2

Note: Externalities for all distance trips are measured using the same distance-based fare structure used to estimate the externalities for short distance trips.

Source: CIE and Jacobs.

Limitations of modelling and future work

VITM

The results of this study are limited by the convergence error of VITM. In VITM the difference between the last road iterations is roughly 500 hours and 5 000 km; which is the convergence error of the model. Where the incremental change relative to the base case is within this range, the modelled results cannot be interpreted. Where the model run for longer, to allow a smaller convergence error, we would expect the impact of this issue on our interpretation of results would be reduced.

Because of the convergence error we have not been able to measure externality parameters for a number of runs and has resulted in some uncertainty around the marginal trip distances used in the MSC model. In particular:

- The change in travel time between the base case and the scenarios estimated in VITM was found to be within the VITM's convergence error for interpeak and evening periods. This has been interpreted as their being no road decongestion benefits during these periods and road decongestion benefits have been set to zero during the off-peak. This is a conservative approach, as there is likely to be some small decongestion benefit, however VITM does not allow us to estimate this.
- The change in travel times compared to the base case for regional and peri-urban runs was close to the convergence error of the model. This resulted in large decongestion benefits for these runs, which is not consistent with expectations. We have chosen to also set the decongestion benefits for regional and peri-urban trips to zero. Again, there is likely to be some decongestion benefit, especially for trips which go into metropolitan areas, however VITM does not allow us to estimate this.
- The marginal distance of lost car trips for some of the runs appear to be unrealistic. For instance, the regional rail modelling implied for each additional kilometre travelled by train, the number of car VKTs fell by 1.5 km. This is surprising as we would generally expect that the VKTs displaced by public transport to be less than 1:1, because vehicle occupancy is greater than 1, and we would generally expect car trips to be more direct than public transport trips (i.e. a car trip between the same origin and destination will generally be shorter than an equivalent pubic transport trips between the same points). Other runs had very small VKTs for each additional public transport trip (e.g. express bus am run). Given marginal trip distances are key determinants of benefits, there is some uncertainty in interpreting these results.

The VITM model and economic module more generally pose a number of issues. Through this project a number of issues were identified with the VITM economic module. Although we understand the key issues identified have been resolved, we have not been able to undertake a detailed sense check of the results. Insofar as there are remaining issues with VITM, they may impact on the results of this analysis.

Issues around measuring crowding

The estimates of crowding from VITM are lower than the estimates of the cost of increasing services. This suggests that trains should be allowed to become more crowded rather than incurring the costs of new services, as the marginal costs of crowding are estimated to be smaller than the marginal costs of crowding. However, there may be other ways crowding impacts that have higher costs:

- the above estimate focuses on the person losing their seat. However, others may also face impacts because their standing space is smaller/more crushed
- high levels of crowding may have negative impacts on station/stop amenity, as well as the crowding impacts on the vehicle itself
- high levels of crowding may disrupt the reliability of the service, because vehicles have higher dwell times as people try to exit and enter vehicles
- high levels of crowding may lead to people being displaced to the next service altogether.

Offsetting this is that many services will not have any crowding penalty. Only services in a small part of the AM and PM peaks going to the CBD will tend to be crowded.

Given the limitations in the VITM modelling of crowding, our view is that the social marginal cost estimates should focus on the scenario where services are increased to offset increases in crowding, as this may provide a more accurate estimate of the cost of crowding compared to the crowding measure from VITM, which we believe is likely to understate costs.

Methodological limitations

The results are highly sensitivity to the methodology chosen to measure MSC. For instance:

- the level of MSC would differ somewhat if we used an alternative approach to measure marginal financial costs (we use the perturbation method, but other studies have used the average incremental cost or simply average costs)[4]
- the level of MSC changes somewhat depending on the choice of excess burden of taxation parameter, which vary depending on the data source, methodology and the taxes deemed to be marginal
- estimates of MSC are sensitive to assumptions around whether future capital costs are related to capacity or not, which are based on judgement. Only capital costs related to capacity and used to measure marginal financial costs
- MSC may vary over different time periods – short, medium and long rung costs were not considered separated due to data limitations
- analysis on capacity is undertaken at the network level and not for individual lines due to data limitations. MSC is likely to vary for different trips across the network, depending on available capacity for specific sections of the public transport network.

4 These methods are used to approximate as we use these techniques to approximate marginal infrastructure capacity costs which are not observed.

While one approach may be preferred to another, there is ultimately no right or wrong answer to these questions. Therefore, caution must be used in directly mapping MSC cost estimates directly to fares, as these issues cast some uncertainty on the level of MSC.

1 Introduction to fare setting

Public transport in Victoria

Victoria operates public transport services comprising rail, bus and tram services. Tram services are restricted to metropolitan Melbourne, while rail and bus services operate across Victoria. Rail is the largest public transport service, with 241 million metropolitan passengers, and also costs the most in terms of payments to operators (VLine and Metro Trains) (table 1.1). Rail trips are also substantially longer than other modes, so on a passenger kilometre basis it is undertaking a much larger task.

1.1 Summary of Victorian public transport

	Rail [a]	Bus	Tram
Passenger trips – metropolitan 2017/18 (million)	240.9	117.8	206.3
Passenger trips – regional 2017/18 (million)	20.8	12.5	na
Payments to operators 2017/18 ($ million)	1 427	799	369

[a] Rail includes VLine rail and coaches.

Source: Public Transport Victoria 2018, Annual Report 2017/18; Victorian Budget 2019/20, Service Delivery 2019/20, Budget Paper No. 3.

Services are mainly provided under franchise arrangements by private providers.

- Metropolitan rail services are provided by Metro Trains Melbourne (Metro Trains), under a franchise agreement with the Victorian Government
- Regional rail services (and coach services) are provided by VLine, which is a Government owned corporation
- Tram services are provided by Keolis Downer (Yarra Trams), under a franchise agreement with the Victorian Government
- Bus services are provided by a number of private operators, under contracts with the Victorian Government.

For the year ended 30 June 2018, PTV report that the total metropolitan and regional farebox revenue and non-farebox receipts was $948 million.[5] This is much lower than the payments to franchisees/operators, and covers an even smaller amount of costs if capital costs for public transport services are considered.

5 Public Transport Victoria 2018, Annual Report 2017/18.

Fare structure

The majority of Victorian public transport fares are fully integrated:[6]

- the price of the independent of the mode of transport used to complete the journey, with the exception of the Free Tram Zone
- fares are calculated based on the zones where the journey originates and finishes, as well as a time cap.
- within Melbourne a flat fare is charged for trips between zones 1 and 2, regardless of distance, while travel in zone 2 is discounted
- regional fares are broadly distance-based

Fares also do not vary by time of day for users travelling in the metropolitan area, with the exception of early bird train travel which provides free travel if you touch on and off before 7.15am on a weekday.

Considerations for fare setting

The economic justification for public transport fare subsidies largely revolves around:

- unpriced road use, and particularly the unpriced congestion externalities that result from road use
- positive externalities for public transport users from increased public transport demand (arising from the increased frequency of services to meet demand and also known as the Mohring effect)
- and economies of scale in the production of public transport services, meaning that the marginal cost is below the average cost.[7]

The sorts of circumstances where a lower fare will be more economically efficient are shown in chart 1.2. These reasons lead to different arguments for peak and off-peak subsidies. For example, in the off-peak, there will be lower costs for accommodating extra demand, but also lower benefits from reducing road congestion. Introducing a cost of a Government subsidy — through an excess burden of taxation — also means that a lower fare will be more efficient when demand is more responsive to fares or the costs of taxation are low.

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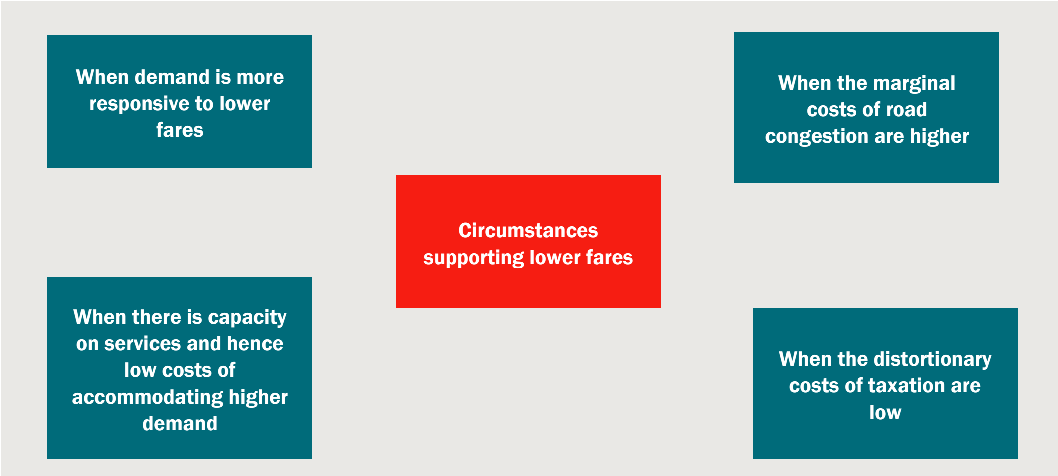
6 Transport for Victoria 2018, Public Transport Fares Review, p. 15-16.

7 Parry, IWH and KA Small 2009, Should urban transit subsidies be reduced? American Economic Review, 99(3): 700–742; Allison, N., D. Lupton and I. Wallis 2013, Development of a public transport investment model, NZ Transport Agency Research Report 524, May; Glaister, S. 1987, Allocation of urban public transport subsidy, pp. 27–39 in Transport subsidy. S Glaister (Ed). Berkshire: Policy Journals.

1.2 When will a lower fare be economically efficient?



Data source: CIE.

Additional considerations are discussed below.

Second-best outcomes

In the context of efficient transport, the first best outcome would users paying the marginal social cost associated with their travel. For road users, this would mean road pricing equal to the marginal costs of car trips, including road congestion and environmental externalities. In the absence of the first best outcome, allocative efficiency can be maximised by setting public transport fares to account for the external costs of road transport, which are not reflected in prices.

Government subsidies of public transport can result in a second-best solution, but a setting the subsidy to reflect the externalities of car travel, as well as the externalities and costs associated with additional public transport trips.

Cost recovery

In broad terms, service provided by the government can be funded through either general taxation revenue or through some form of cost recovery arrangement, such as public transport fares. Increasing fares may result in:

- reducing the call on general taxation revenue — all taxes have efficiency costs. Funding transport through efficient fares reduces the burden on general taxpayers and minimises the associated efficiency losses
- improved equity — an efficient fare can ensure that the users or beneficiaries of the public transport network pay for it, rather than general taxpayers (after accounting for externalities) who may not use or directly benefit from public transport use.

As discussed above, a well-designed fare structure can reduce efficiency losses from taxation and increase equity, by only charging users who benefit from using public transport (after controlling for externalities).

Equity and social inclusion

Equity of public transport fares is an important consideration for fare setting. There are two types of equity to consider:[8]

- vertical equity, which refers to ability-to-pay considerations. This relates to the consideration that individuals on lower incomes should pay less than those on higher incomes, and to some extent can be resolved through concession fares
- Horizontal equity, which refers to treating people in similar situations in similar ways. This is consistent with equity consideration related to cost recover, such that users undertaking similar trips, should pay similar amounts.

Equity is not accounted for in a fare setting model based on marginal social cost. This approach focuses on maximising economic efficiency and does not consider equity impacts. Equity considerations should be accounted for separately from this analysis.

Determining economically efficient fares

From an economic perspective, the most efficient public transport fares are those where the fare is set equal to the **marginal social cost** of providing the service. The marginal social cost incorporates:

- the financial cost of providing services to additional passengers. This includes the additional capital costs (costs for long-lived assets) and the additional operating costs
- any externalities — costs or benefits to others — from providing services to additional passengers. The main externality from additional public transport use is that there is less use of the roads, which reduces costs of congestion. The other main externality is that subsidies for public transport require funding from other sources of government revenue, and this has costs of its own.

Note that the externalities from using roads could be addressed directly through placing a price on the use of the road. In this case, there would be no need to subsidise public transport to achieve an economically efficient balance between road and public transport use. Directly pricing of roads would be substantially more effective than using public transport pricing, because many trips encouraged onto public transport as a result of fare changes are not road users — this may include people not making trips at all or moving from walking or cycling to taking public transport.

8 Transport for Victoria 2018, Public Transport Fares Review, p. 24.

2 Methodological framework to estimate marginal social cost

There are two main pathways for measuring the social costs of public transport use with very different patterns of costs, and which reflect the trade-offs between costs and benefits for planners faced with an increase in demand (chart 2.1).

1. Pathway 1 — services respond to demand. Lower fares lead to higher demand for public transport services. In response, additional public transport services are put in place. In this case there is a financial cost, no crowding impacts and frequency benefits for existing users
2. Pathway 2 — services remain the same. Lower fares lead to higher demand for public transport services. In response, no additional public transport services are put in place. In this case there is no financial cost, but there are costs for existing users from crowding of vehicles and stations and worsening reliability.[9]

If service levels are optimal then the marginal cost of dealing with an extra passenger by expanding services is equal to the marginal cost of doing so by increasing crowding.[10]

It is critically important that the overall cost is measured in a way consistent with a well specified pathway for how the system changes. It is incorrect to add a financial cost of providing more services without accounting for benefits of frequency changes. It is incorrect to add a financial cost of providing more services and a cost of crowding for existing public transport users.

Our approach is to model both of these pathways and presenting results alongside each other. The theoretically correct approach for informing fares is to use the lower of the two estimates, as this represents the most efficient way to respond to higher demand. In practice this is difficult to implement due to:

- uncertainties around the precise investment required to alleviate capacity constraints
- limitations in transport modelling being able to fully measure congestion.

Because of these limits we chosen to model these two pathways and present results. This allows users to consider the results under different scenarios and limiting the reliance of results on imperfect measures.

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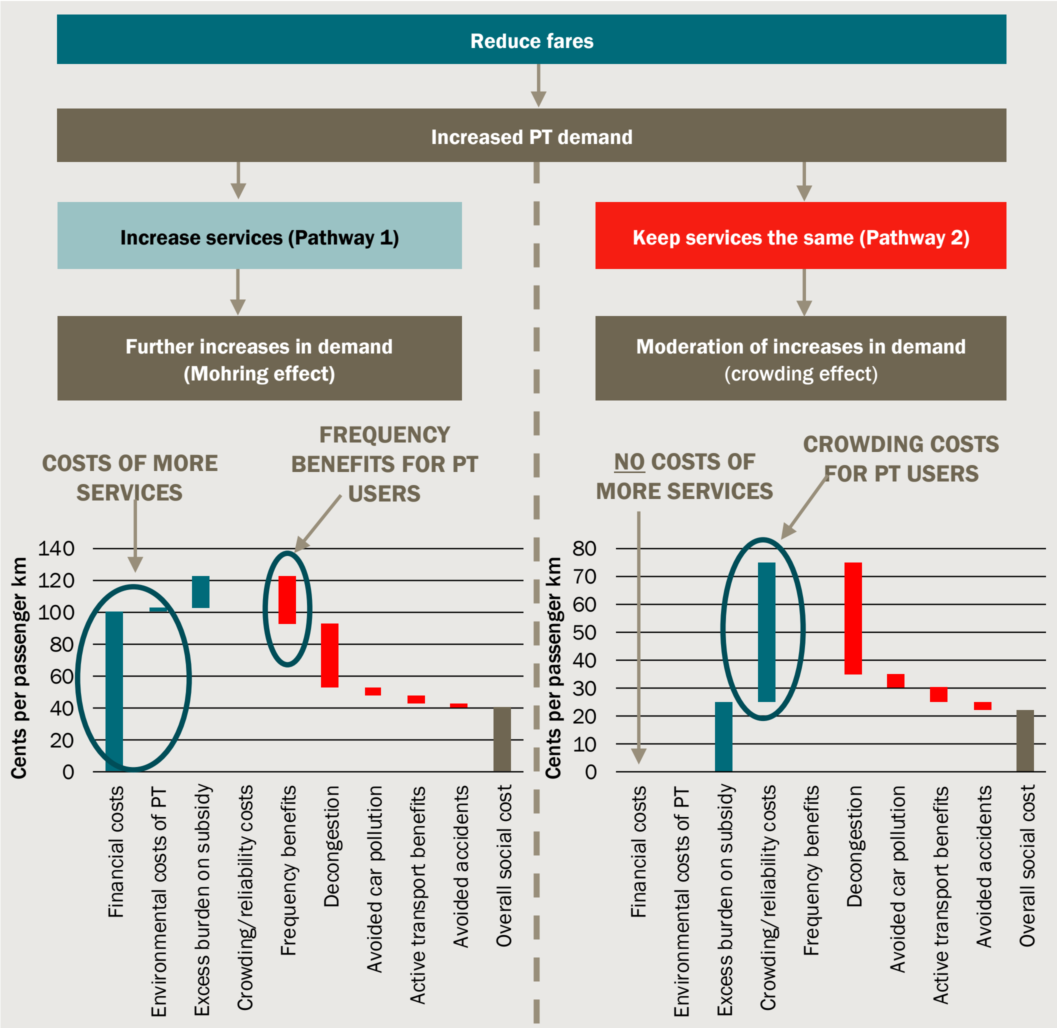
9 In addition to these two main pathways, there will be intermediate responses where services respond only partially to demand. This will result in a combination of financial costs for new services, frequency benefits and increased crowding, as the increase in services will not be large enough to fully offset increased congestion.

10 Nash, C. 2018, Benefits and costs of public transport - Final Report, review of Sapere work prepared for Transport for Victoria.

2.1 Different pathways for estimating the social costs of public transport use



Note: Estimates are illustrative only.

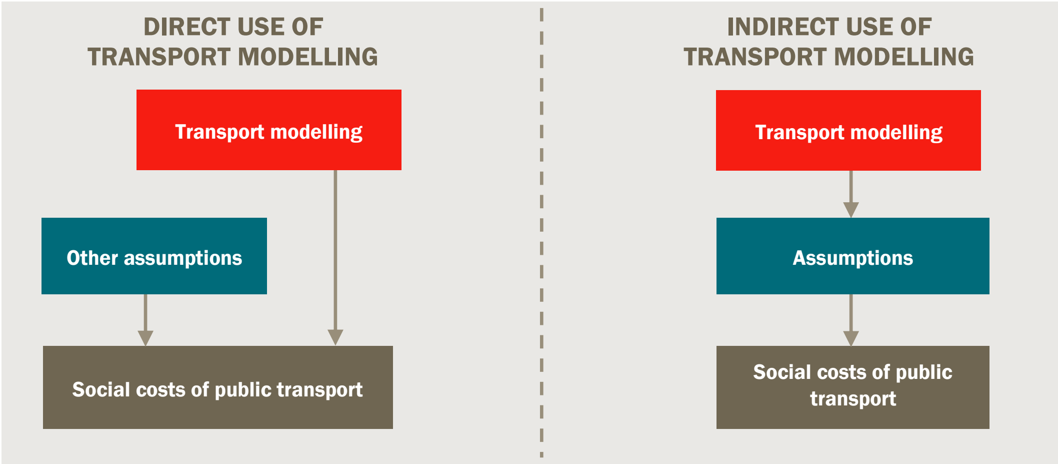
Data source: CIE.

Conceptual approach to measure incremental externalities

Externality and behavioural parameters are estimated from VITM transport modelling runs. This gives us a range of assumptions which are informed by modelling runs conducted specifically for Victoria and this project (chart 2.2). We then calculate specific externality values by combining externality parameters, elasticities and modal substation rates. This approach breaks the direct link between the transport modelling and estimated of externalities; in the model parameter values, elasticities and substitution behaviour can be set to values other than those implied from the VITM modelling run.

We have chosen to use the transport modelling results indirectly as this allows greater flexibility in undertaking future updates to the model, but also enables choosing alternative estimates where we believe the VITM model may be providing erroneous results. This allows for additional information outside of the transport model to be incorporated into the analysis, such as other information of fare elasticities, and provides greater transparency about key assumptions from the transport model. This also has advantage of allowing for a wider, more realistic, set of behavioural changes all occurring at the same time. For example, a higher peak rail fare could lead to lower peak road use but could also lead to spreading of rail trips outside of the peak period – using the indirect approach to modelling allows for these changes to be implemented.

2.2 Mechanisms for using transport modelling



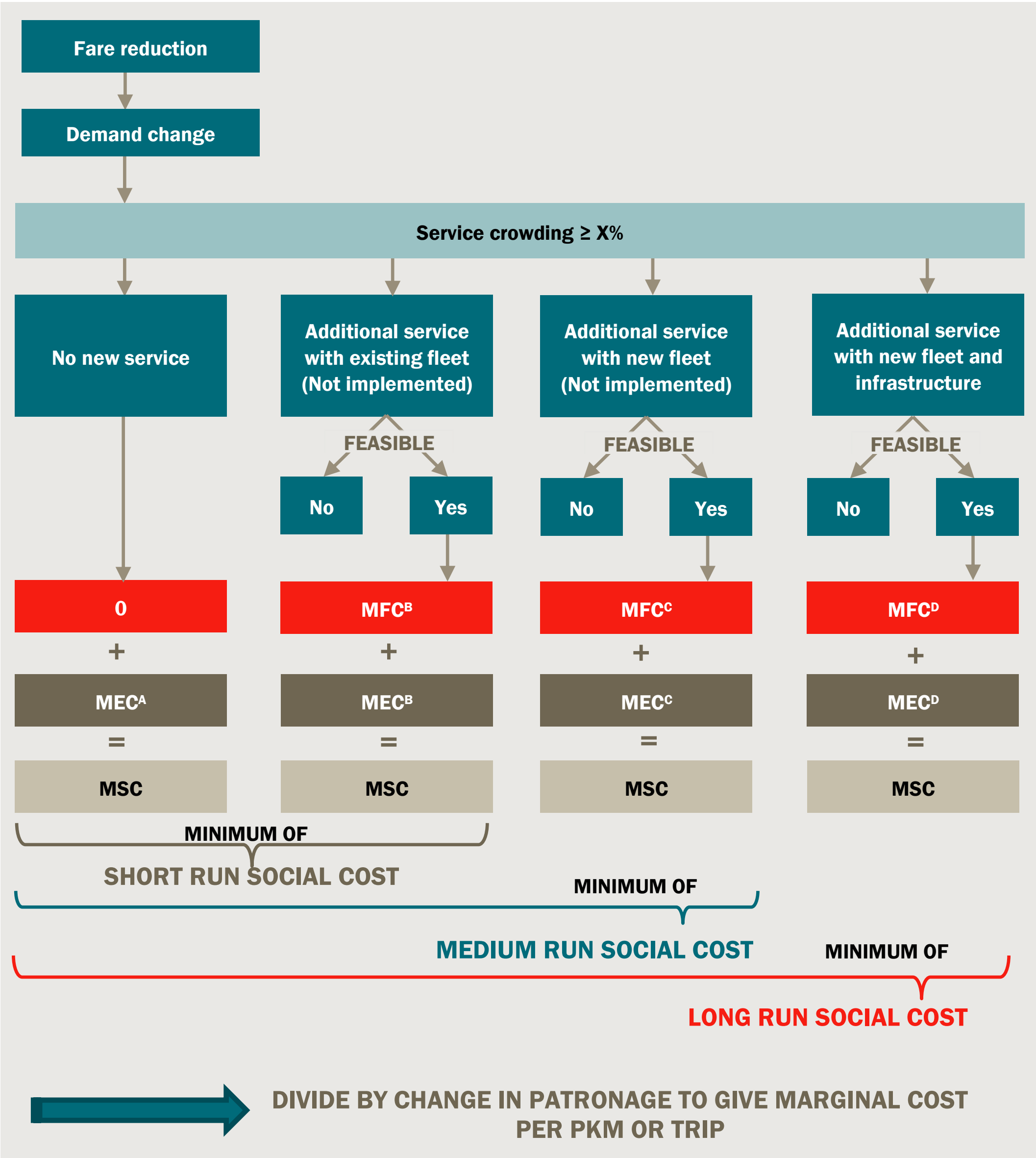
Data source: CIE.

For each of the runs we measure externality parameters from the observed changes, which are expressed in term of avoided vehicle km (externalities related to mode shifting from car to public transport) and additional public transport passenger km travelled (for externalities related to public transport).

Conceptual approach to estimate incremental costs

Our conceptual approach to estimating incremental costs is shown in chart 2.3.

2.3 Fully integrated social cost estimation process



Note: MFC is marginal financial cost, MEC is marginal external cost (including benefits). Capacity would be seated and standing capacity.

Data source: CIE.

This approach relates a fare reduction to change in demand, which then flows through to four potential demand response pathways, which describe the range of actions available to policy makers across different periods given a change in demand:

- no new services – in this case there is no MFC and the cost of additional patronage is borne by existing users via higher levels of crowding
- additional services with the existing fleet (this was not modelled)

- additional services with new fleet (this was not modelled)
- additional services with new fleet and infrastructure – in this case service levels can increase to a level where there is no increase in crowding, but there is a marginal financial cost and an external benefit from higher service frequency.

We have only measured the extremes of these fare response, as there is limited information to inform the capacity of the network to implement additional services with the existing fleet, or how existing services could be expanded with new fleet. Determining available capacity at the network level is particularly complicated for tram and rail services, given the dependencies across the networks. For instance, introducing a new service on one train line in the city loop will in turn affect the level of capacity available to other rail services into the CBD. Similarly, this is also complicated by different constraints at differ parts of the network – without a detailed study of network constrains and feasible timetables, the intermediate scenarios cannot be meaningfully implemented.

The two approaches for measuring MSC are illustrated in box 2.4 with a worked example.

2.4 Measure MSC for the two demand response pathway

Assume that a 30 per cent reduction in fares results in some increase in demand. The hypothetical marginal costs are outlined in table 2.5.

MSC is calculated for each of the different demand response pathways, which gives two estimates of MSC. Road congestion and other benefits are constant across the pathways due to mode switching, while, the remaining externalities reflect the specific characteristics of the demand response pathways. In general, there is a trade-off between positive and negative externalities depending on the financial costs – higher financial costs generally result in larger positive externalities and lower negative externalities.

2.5 Option 2, MSC worked example

	No new services (A)	Additional services with new fleet and infra (B)
	$ per pkm	$ per pkm
Marginal financial cost	**0.00**	**0.15**
Road congestion costs	-0.38	-0.38
PT crowding costs	0.07	0.00
PT scale /frequency	0.00	-0.14
Marginal excess burden of taxation	0.00	0.03
Other benefits	-0.04	-0.04
Total marginal external costs	**-0.36**	**-0.54**
Social Marginal Cost	**-0.36**	**-0.39**

Note: A negative number is a positive externality, km is passenger km travelled.

Source: CIE.

From this we can infer the MSC over different economic horizons:

- Short run MSC is -$0.36 (A)
- Long run MSC is -$0.39 (minimum of A and B).

The MSC at a given time period is selected assuming that the policy maker, who selects timetables, fleet size and infrastructure investments, chooses the demand pathway approach with the lowest MSC at each time horizon. For instance, if the short run MSC is the lowest cost, then:

$$Short\ run\ MSC = Long\ run\ MSC$$

3 Marginal financial costs

Methodology to measure marginal financial costs

There are two methodologies which are commonly used to measure the financial cost or long run marginal cost (LRMC):

- the perturbation method, or Turvey approach, which specifies the increment as the demand from the expected profile to a different expected profile
- the average incremental cost approach (AIC), which specifies the increment as the future change in demand from current demand

There are several variations to these approaches which have been used in previous studies. In its 2016 review, IPART essentially estimated average operating and maintenance costs, plus vehicle costs, for its medium run cost estimates. The increment was moving from current demand to no demand. This involved allocating current costs to peak or off-peak and to distance or per trip and dividing costs by current passenger numbers to give costs per trip or per passenger kilometre for peak and off-peak trips.

For its long-run approach IPART took the cost of two major projects (one for light rail and one for rail) and allocated these to the capacity of the projects. This is effectively the AIC approach.

These approaches follow similar steps diverging only in the definition of the hypothetical demand increment which is used to measure the cost increment. The demand increment chosen is important as it changes what we are conceptually measuring with LRMC. The interpretation of LRMC depends on how this increment is defined.

- Under the perturbation method, LRMC can be interpreted as the cost of bringing forward or delaying (in the case of a demand decrement) capital and operating costs. This approach assumes that future growth cannot be avoided but can be delayed or brought forward.[11] This conceives marginal cost as a time related dynamic concept.
- Under the AIC approach (and IPART long run approach), marginal cost can be interpreted as the cost of forecast growth, from current demand levels, occurring. This interpretation is appealing, where future demand can be defrayed or substituted (i.e. public transport demand does not necessarily have to increase). Here marginal cost is avoidable.

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11 Turvey discusses 'central system costs', which are not avoidable, hence in determining marginal cost, it is not a question of whether these costs are incurred or not, but rather their timing. For example, in the case of water infrastructure, Turvey argues that economy in water use may enable the next investment to be delayed, but would unlikely result in in it to be altogether dropped. Turvey, R. 1976, Analysing the Marginal Cost of Water Supply, Land Economics, 52(2), p. 158-168

- Under IPART's medium run marginal cost approach, marginal cost is the average cost of meeting current levels of demand. The increment assumes that total demand can be defrayed, effectively assuming that the total cost is avoidable and in the case of transport can be reassigned to alternative transport modes.

Perturbation method (Turvey approach)

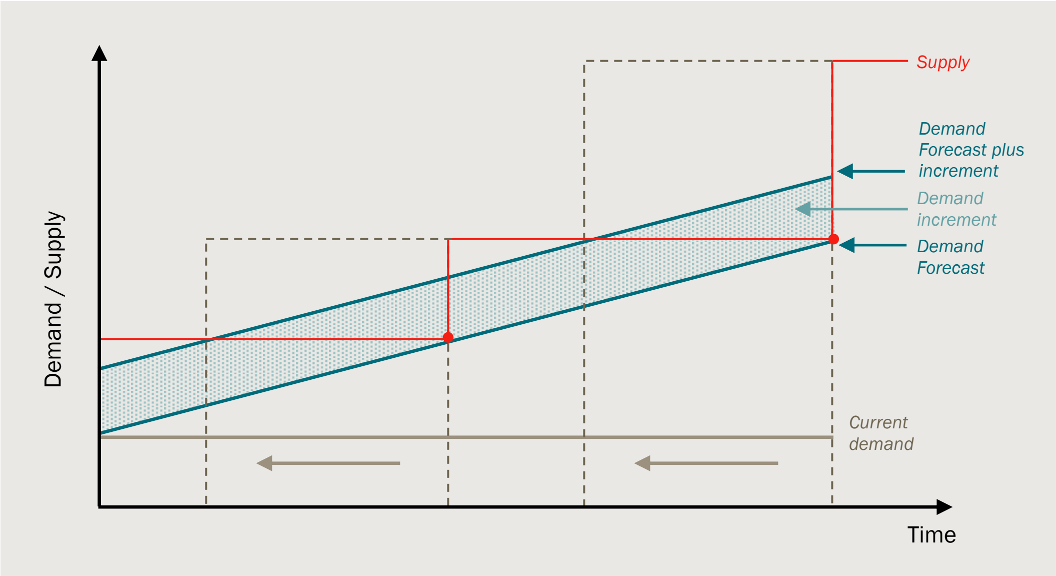
The perturbation method measures marginal cost by considering how changes in demand affect the timing of investments. It is implemented as follows:[12]

1. forecast public transport demand by mode over some time horizon
2. develop a least cost investment program to meet this demand profile overtime to some standard, recognising existing capacity in the public transport network
3. increase or decrease forecast demand by some amount permanently and recalculate the least cost investment program to meet this revised demand profile. This may simply bring forward planned investment, or may result in a different investment
4. calculate marginal cost as the change in the present value of the least cost capital program plus the change in operating costs, divided by the present value of the revised demand forecast compared to the initial demand forecast (i.e. the present value of the demand increment). The ratio of these two values provide information regarding the rate at which costs change as demand changes:

$$Perturbation\ MC = \frac{PV(revised\ optimal\ capex\ plus\ opex - optimal\ capex\ plus\ opex)}{PV(revised\ demand - initial\ demand)}$$

The demand increment and infrastructure capacity are illustrated in figure 3.1.

3.1 Perturbation method to estimate marginal cost



Data source: CIE.

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12 NERA 2011, Estimating Long Run Marginal Cost in the National Electricity Market, prepared for AEMC.

This approach requires selecting a permanent change in demand – this may be a permanent increase (as shown in figure 3.1) or decrease. The demand increment (represented by the shaded area) brings forward the timing of the investment program as supply capacity is exceeded earlier (the dashed line).[13] Discounting future costs by the social discount rate converts the lumpy investment profile into a single value in today's dollars. The demand increment is also discounted so that we are comparing like with like.

This approach measures the cost of demand increasing by the assumed increment, given the original demand projection. It is forward looking, as it focuses on costs required to balance demand and supply into the future, and only measures the costs of that are caused by higher than projected demand. This implicitly assumes that higher levels of demand are unavoidable.

This perturbation method can be implemented over short, medium and long run, with different optimal investment programs depending on the time period and may not be symmetric for an increase or decrease in demand.

A common concern in applying this approach is that marginal cost estimates may be influenced by the size of the of the demand increment used.[14] This is because discrete time steps are used for the analysis (i.e. years) and small differences in the size of the demand increment can bring forward or push back specific capacity investment costs. Previous studies have used sensitivity testing to assess how marginal costs vary with the size of the increment and some have proposed selecting the permanent change in demand to match the growth rate in demand so the effect of the permanent change being tested is to bring forward (or back) by a year.[15]

For this study the size of the increment will be based on the change in demand associated with the fare change modelled in VITM; this is a 30 per cent change in the fare. We do not anticipate the lumpiness of investments to be an issue in the measure of marginal costs, as demand will be allowed to move forward or backwards by small increments (i.e. an increase in demand may bring forward a new project by a few days). In addition to this, sensitivity testing will be conducted to assess the impact of the increment on calculated marginal financial costs.

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13 The example illustrated in in figure 2.2 assumes that the revised investment program is the same as the original investment program, only brought forward. This is not a necessary feature as the least cost investment program may be materially different depending on the timing of investment.

14 NERA 2011, Estimating Long Run Marginal Cost in the National Electricity Market, prepared for AEMC, and Sapere 2014, LRMC Pricing for Water Services - Background Paper on LRMC Pricing, prepared for the Essential Services Commission of South Australia.

15 If demand increase by 1 000 trips per year, then it is convenient to use 1 000 trips as the demand increment. Sapere 2014, LRMC Pricing for Water Services - Background Paper on LRMC Pricing, prepared for the Essential Services Commission of South Australia.

AIC method

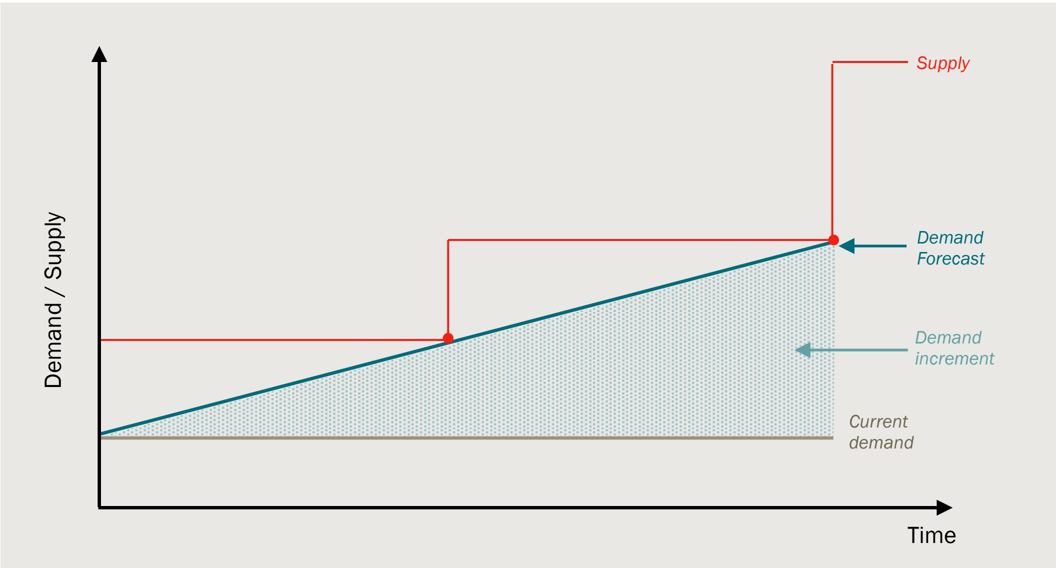
The AIC approach measures marginal cost by considering how the investments required to meet expected increase in demand from current levels. It is implemented as follows:[16]

1. forecast public transport demand by mode over some time horizon
2. develop a least cost investment program to meet this demand profile overtime to some standard, recognising existing capacity in the public transport network
3. calculate marginal cost as the present value of the expected costs of least cost investment program divided by the present value of additional demand (i.e. the present value of the demand increment):

$$AIC\ MC = \frac{PV(optimal\ capex\ plus\ opex)}{PV(demand\ increment)}$$

The demand increment and infrastructure capacity are illustrated in figure 3.2.

3.2 AIC method to estimate marginal cost



Data source: CIE.

Here the marginal cost is the present value of the expenditure associated with the optimal capital program plus the marginal operating costs divided by the present value of the change in demand. The main difference between the AIC and perturbation method is the size of the demand increment. The AIC method's demand increment is the difference between future and current demand.

Comparison of approaches

Our preference is to use the perturbation approach as we believe it makes theoretical sense to measure the marginal cost based on deviations in demand from the base case.

16 NERA 2011, Estimating Long Run Marginal Cost in the National Electricity Market, prepared for AEMC.

The base case is expected future public transport demand, which we expect are determined based on a range of socioeconomic drivers (e.g. population growth, employment growth, incomes etc.) and assumptions (e.g. existing public transport fares and fare structure). This is also aligned to VITM's Reference Case. For calculating the marginal social cost of public transport to inform public transport fares, it makes sense for the demand increment to be relative to expected demand, as any changes in fares would seek to either increase or decrease demand relative to the forecast.

Previous studies have generally shown a preference for the perturbation method as:

- The perturbation method is more closely aligned to the principles underpinning the concept of LRMC, as it focuses on how costs change in response to a specific permanent change in demand while AIC focuses on meeting expected demand.[17]
- The perturbation method gives equal weight to future marginal costs as the increment is constant overtime, while the AIC method places a greater weight to additional demand in the near term as the demand increment increases overtime.[18]

Both the perturbation and AIC methods are used to estimate marginal infrastructure costs, the results for metropolitan trips across the different modes are shown modes are shown in table 3.3.

The AIC estimate is significantly larger than the perturbation estimate, which as noted above appears to be due to the AIC placing greater weight on demand in the near term.

3.3 Metropolitan marginal infrastructure costs, by mode

	Rail	Tram	Express bus	Bus
	Cost per trip	Cost per trip	Cost per trip	Cost per trip
Perturbation (Turvey)	$12.09	$2.31	$1.34	$1.36
AIC	$28.26	$5.83	$3.73	$3.43
Difference between AIC and Turvey	$16.17	$3.51	$2.40	$2.07
Percentage difference between AIC and Turvey	234%	252%	279%	252%

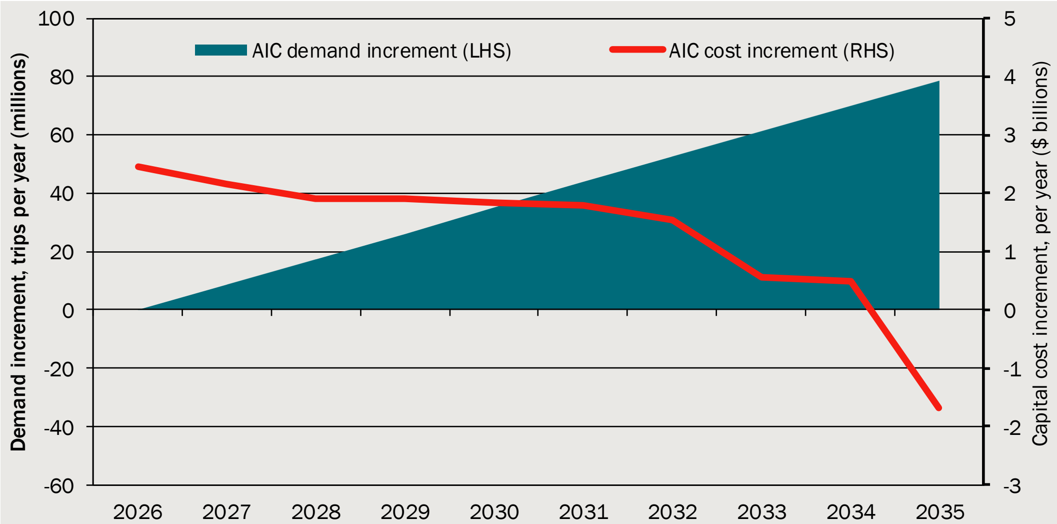
Source: CIE and Jacobs.

By construction, the AIC demand increment is very small during early periods before increasing steadily over time, while the cost increment in this case is large at the start of the evaluation period and falls (chart 3.4). The cost increment for the AIC is the expected future capital investment profile given projected increases in demand.

17 NERA 2011, Estimating Long Run Marginal Cost in the National Electricity Market, prepared for AEMC

18 Sapere 2014, LRMC Pricing for Water Services - Background Paper on LRMC Pricing, prepared for the Essential Services Commission of South Australia.

3.4 Metropolitan train demand and cost increment, AIC method

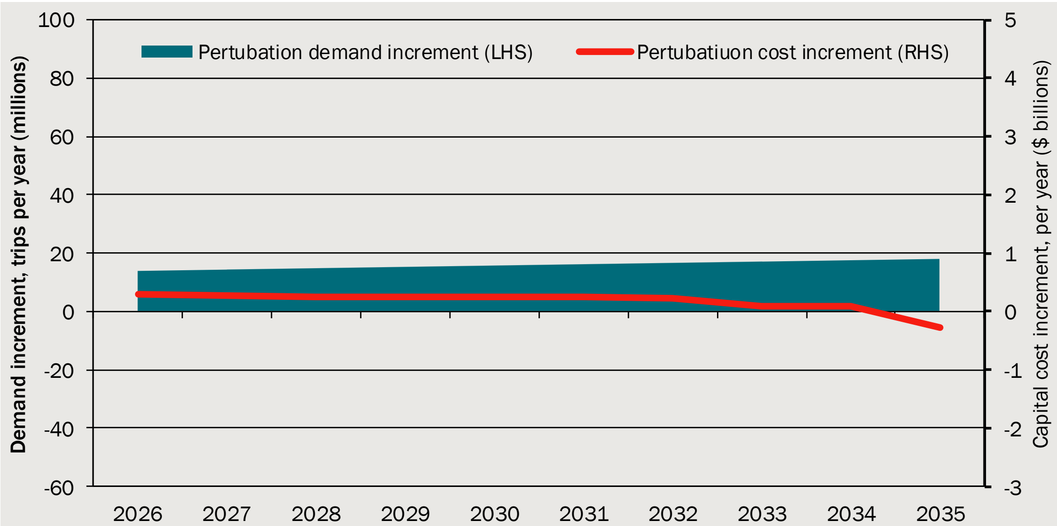


Note: The negative cost increment in the last period reflects the residual value of the capex considered over the 10-year period.

Data source: CIE.

In contrast, the demand and cost increment for the perturbation method are relatively small and constant over time (chart 3.5). This means when the present value of incremental capital costs is divided by the present value of increment demand, the AIC results in larger estimates. If the capital investment profile were flatter overtime, or decreasing, this result could be reversed (i.e. if capex were falling overtime, the AIC estimate could be smaller than the perturbation estimate).

3.5 Metropolitan train demand and cost increment, perturbation method



Note: The negative cost increment in the last period reflects the residual value of the capex considered over the 10-year period.

Data source: CIE.

Operating cost estimates

Costs are broken into two categories with their treatment in the mode summarised in table 3.6:

- Operating costs per service km; these are the costs associated with increasing the number of public transport services. These costs are only relevant for the scenario which allows service levels to increase so that there is no increase in crowding from additional trips (i.e. where timetabled services change).
- Operating costs per trip; there are the costs which are related to the number of trips taken, such as authorised officers and operations costs. These costs are incurred for every additional trip, however there is variation across different timer periods (i.e. trip costs are greater during peak periods).

3.6 Treatment of costs in model

Cost category	Current services scenario	Service expansion scenario
Operating cost per service km	Not included	Included
Operating cost per trip	Included, costs differ for peak and off-peak periods	Included, costs differ for peak and off-peak periods

Source: CIE.

Marginal operating costs have been collected from a range of sources, with the MSC model allowing users to select their preferred source for operating costs per service km and costs per trip separately, noting that for some sources only cost per service km or cost per trip were available. The sources of cost data were as follows:

- Jacobs' estimates are based on actual balance sheet costs for Metro Trains Melbourne, Yarra Trams and a bus operator which were provided by DoT. This data was rationalised into cost per service km using information on service km, and includes maintenance, power consumption/fuel and the cost of drivers – costs are only available per service km. Costs based on balance sheet data can be interpreted as average costs.
- Franchise agreements; these agreements for metropolitan rail, tram and bus services specify the cost to the Government of variation in timetabled services. This is the marginal cost to Government of additional services. MR4 Train[19] and tram franchise agreements[20] are available in unredacted forms, and marginal costs have been estimated directly from these. The marginal costs in the current franchise agreement with Transdev are redacted,[21] so we have instead used the values reported by Sapere (2017). Costs are only available by service km.
- Sapere (2017); has previously undertaken analysis of the benefits and costs of public transport for the Department of Economic Development, Jobs, Transport and

19 Allens 2017, MR4 Franchise Agreement - Train Payments module, schedule 4.

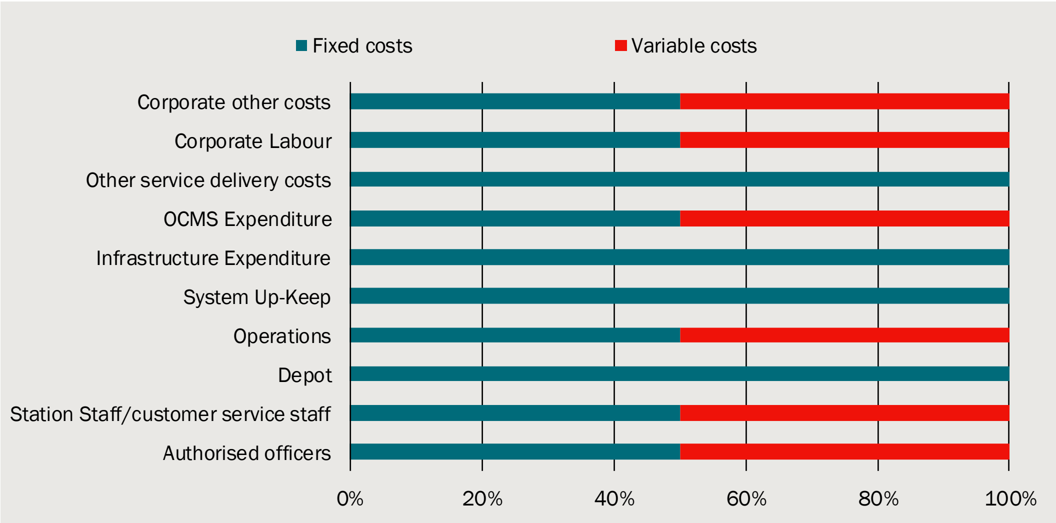
20 Allens 2017, MR4 Franchise Agreement - Tram Payments module, schedule 4.

21 Minter Ellison 2013, Franchise Agreement Melbourne Metropolitan Bus Services.

Resources.[22] Operating costs have been included in the model from this previous work to allow comparison with more recent estimates, adjustment for inflation. Data is available for both cost per service km and per trip.

- IPART efficient costs (2016) reports actual and efficient costs per service km and trip for NSW. [23] Actual reported costs are used in the model, as opposed to the efficient costs which were estimated in the analysis.
- Balance sheet analysis of operating costs was undertaken to demine the cost per trip. This analysis was undertaken using data to generate estimates of costs per trip and is based on the Business Performance Reporting Template (BPRT) data collected by PTV. This provides data for Melbourne Metro, Yarra Trams, and Transdev along with information of the number over a fixed period. Costs which were captured by per service km costs, such as driver costs and electricity/fuel were excluded from the analysis. Costs were then allocated to being either fixed or variable. Fixed costs, which were determined to not vary with patronage, were excluded from the analysis (chart 3.7). Where costs were determined to have a fixed and variable component, only the variable share of the costs has been attributed as a cost per trip.

3.7 Share of costs assumed to fixed and variable



Note: In the balance sheet data used for this analysis, data was not available for a number of cost components listed above.

Data source: CIE

During capacity constrained periods, the financial costs of an additional passenger are likely to be higher than the financial cost of an additional passenger during the off-peak period. For this reason, we disaggregate costs into peak and off-peak costs, this is the same approach taken by IPART[24]:

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22 Sapere 2017, benefits and costs of public transport – Final report, prepared for Department of Economic Development, Jobs, Transport and Resources.

23 The CIE 2016, Efficiency of NSW public transport services – Public Version, Prepared for IPART.

24 IPART 2016, Medium-run marginal financial costs (MFC), Final report – Information Paper 5.

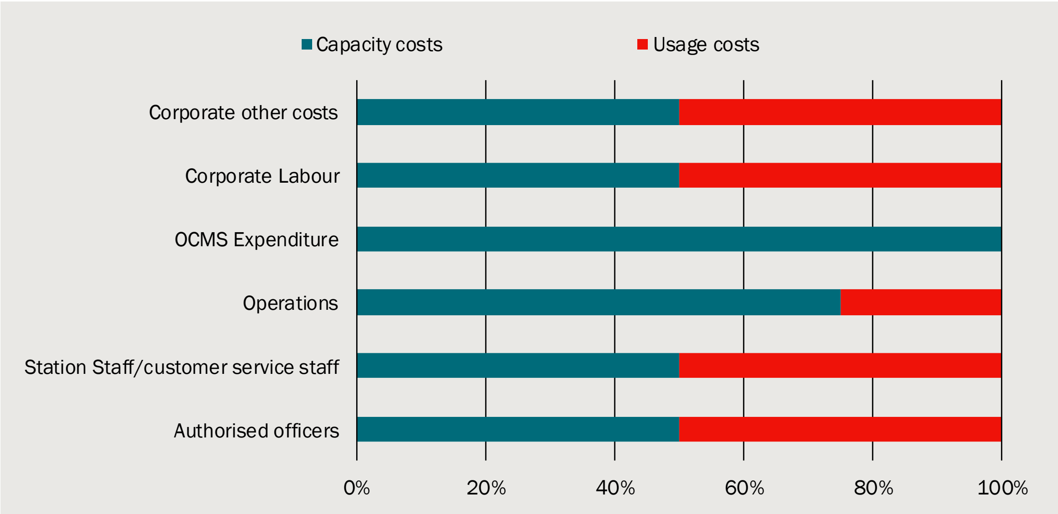
The remaining variable costs were then further disaggregated into:

– usage costs, which vary with the total number of passenger trips travelled and may include station staff. Usage costs re are allocated to additional trips for all time periods (i.e. peak and off-peak periods)
– capacity costs, which are the costs required to meet the largest peak demand and do not vary with usage at other times and include infrastructure related expenditure and systems upkeep. Capacity costs are only allocated to trips which occur during peak periods

Some costs will have both capacity and usage costs (e.g. timetabling and service planning and administrative overheads), as costs may vary along both dimensions.

The cost allocations between capacity and usage are outlined in chart 3.8.

3.8 Attribution of per trip costs as capacity and usage costs



Note: In the balance sheet data used for this analysis, data was not available for a number of cost components listed above.

Data source: CIE

Note the allocations above are based on a mixture of analysis and judgment – for this reason, the model has been structured to allow different cost to be chosen for the model.

Train operating cost rates

There is significant variation in operating cost rates across the cost sources for costs (table 3.9).

Sapere and IPART efficient costs are significantly higher that the Jacobs estimate. Peak and off-peak costs were only available from the franchise agreement and Sapere. Given franchise rates are the actual marginal cost faced by Government this is the default cost used in the model per service km costs.

Train marginal costs per trip vary significantly across sources. The BPRT average cost analysis implies cost during peak periods close to IPARTs, but much lower costs for off-peak periods. BPRT average costs are set as the default cost per trip in the model.

3.9 Train operating costs

	Weekday (peak)	Weekday (off peak)	Weekend	Weekday (peak)	Weekday (off peak)	Weekend
	$ per service KM	$ per service KM	$ per service KM	$ per trip	$ per trip	$ per trip
Jacobs	13.86	13.86	13.86			
Franchise agreements	10.73	10.73	13.59			
Sapere (2017)	15.61	15.61	19.59	1.41	1.41	1.41
IPART efficient costs	22.67	22.67	22.67	2.99	2.99	2.99
BPRT average costs				1.57	0.31	0.31

Notes: IPART efficient costs are based on information for Sydney Trains.

Source: CIE and Jacobs, and as noted in table.

Tram operating cost rates

Tram operating costs per service km are lower than the train operating costs (3.10). Jacobs costs are again very similar to Franchise and Sapere costs, however, do not make allowances for higher weekend costs due to increased labour costs. The IPART costs are very high, which likely reflects the specific conditions in Sydney, and are not likely to reflect marginal costs for Melbourne tram services. Franchise agreement costs have been used as the default cost per service km in the MSC model.

Tram operating costs per trip are relatively high for Sapere and low for IPART, with BPRT average costs calculated as part of this analysis lying between the two during peak periods and significantly below IPART estimates during the off-peak. This reflects the approach taken to split out capacity related usage costs and applying them only during peak periods. BPRT average costs are set as the default cost per trip in the model.

3.10 Tram operating costs

	Weekday (peak)	Weekday (off peak)	Weekend	Weekday (peak)	Weekday (off peak)	Weekend
	$ per service KM	$ per service KM	$ per service KM	$ per trip	$ per trip	$ per trip
Jacobs	6.14	6.14	6.14			
Franchise agreements	6.91	6.91	10.82			
Sapere (2017)	6.85	7.39	12.09	1.31	1.31	1.31
IPART efficient costs	20.13	20.13	20.13	0.28	0.28	0.28
BPRT average costs				0.65	0.09	0.09

Source: CIE and Jacobs, and as noted in table.

Bus operating cost rates

There are relatively small differences in bus operating costs (table 3.11). Sapere (2017) costs have been used as the default cost per service km in the MSC model.

BPRT average costs again lie between the high Sapere and low IPART costs during the peak period but are significantly lower than the IPART estimates during off-peak periods. This reflects the approach taken to split out capacity related usage costs and applying them only during peak periods. BPRT average costs are set as the default cost per trip in the model.

Note the same costs have been used for express bus and normal bus services in the analysis. Jacobs and franchise agreement operating costs were not available for this analysis.

3.11 Bus operating costs

	Weekday (peak)	Weekday (off peak)	Weekend	Weekday (peak)	Weekday (off peak)	Weekend
	$ per service KM	$ per service KM	$ per service KM	$ per trip	$ per trip	$ per trip
Sapere (2017)	5.94	4.29	4.29	0.84	0.38	0.38
IPART efficient costs	7.73	7.73	7.73	0.28	0.28	0.28
BPRT average costs				0.51	0.11	0.11

Note: In the model franchise agreement and Jacobs costs are set equal to Sapere (2017) costs.

Source: CIE and Jacobs, and as noted in table.

Capital cost projections

Capital cost estimates have been prepared by Jacobs – the approach to develop the capital cost for each mode is detailed in the following section. The capital cost profile has been developed from 2016 through to 2037. Marginal financial costs are estimated using the capital cost for projects which are completed between 2026 and 2035. It is over this 10-year period which we measured the marginal capacity cost of additional trips.

In making an ex ante fare setting decision, we assume that it is possible to affect projects which would increase capacity during the evaluation period, including those which have commenced before 2026. We have also made assumptions around the share of capital costs which are attributed to capacity. For instance, the purchase will consist of:

- rolling stock expansion, which increases the capacity of the public transport network
- rolling stock asset replacement, which allows old rolling stock, at the end of its economic life, to be retired – assess replacement does not increase capacity and occurs independent of additional demand.

Similarly, other infrastructure investments, such as Melbourne Metro, are constructed for reasons other than capacity increases (i.e. improvements in station access, higher consumer surplus from higher quality stations and stops). These costs not directly related to capacity increases should be excluded from marginal capital cost projections. For each cost item we have made an assumption as to the proportion of costs which are related to capacity and included in marginal capital cost calculations.

The modelled outcomes are highly sensitive to cost assumptions. For instance, assuming a specific cost item is capacity related will necessarily result in a relatively lower MSC for peak trips compared to off-peak trips, holding all else equal. Also, the choice of which costs to include (i.e. whether to include infrastructure projects such as Melbourne Metro 2 and what proportion of this cost is related to capacity) has a very large impact on the level of marginal financial costs and MSC. Because of the uncertainty around the level of marginal financial costs, care should be taken in inferring optimal prices directly from MSC estimates.

Train capital costs

The capital costs valuations for upcoming rail projects have been assessed based on known actual costs and forecast costs. We have also utilised our collective knowledge on planned projects, and the associated publicly known estimated cost. Several future projects already have high-level target costs assigned, often based on the total price which is published in the public domain and as published by print media.

Planned projects and programs include:

- Melbourne Metro Rail Project – in progress
- Level Crossing Removals – in progress, future projects planned
- Rolling stock purchasing, HCMTs – in progress, future purchasing planned
- Melbourne Metro 2 & 3 – future projects
- Airport Rail Link – future project
- Melbourne Suburban Rail Loop – future project

There are also number of ongoing projects such as train stabling expansions, new substations, and improvements to overhead electrification, which are expected to continue. In these instances, we have utilised our knowledge of recent projects through the prior 10 years to project a similar level of spend forward. Train capital expenditure is expected to be considerably higher than trams and buses. This is due to the expense of heavy rail infrastructure, tunnels, level crossing removals and high expenses for delivering rail projects within an operational rail network. These high costs are partially offset by the higher volume of passengers transported by heavy rail, when it comes to consideration operating capital costs per additional train trip or passenger km.

Projects included in the model, and the share of capital costs attributed to capacity are summarised in table 3.12 and the total capital cost profile is shown in chart 3.13.

3.12 Train capacity costs include in the model

	Share attributed to capacity
	per cent
Melbourne Metro Project 2	50%
Other Projects (e.g. substation and overhead line equipment upgrades)	50%
High capacity metro trains (rolling stock)	50%
Depot works	50%

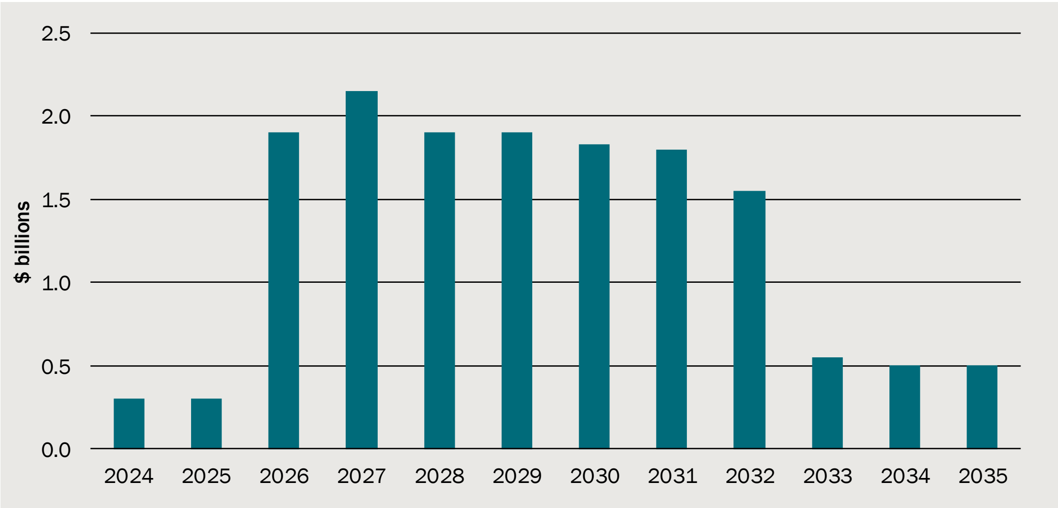
Note: Only capital costs between 2026 and 2035 are included in the analysis.

Source: CIE and Jacobs.

Melbourne Metro, the Airport Rail Link and some rolling stock procurement was excluded as it is expected to be completed prior to 2026. Level crossing removals was excluded as this was determined to not be related with capacity. Melbourne Metro 3 and the Melbourne Suburban Rail Loop were excluded as they are expected to be competed after 2035 – the Melbourne Suburban Rail Loop was also excluded as it is not related to capacity. Across the included cost elements, we have assumed that 50 per cent of costs are related to capacity, reflecting the fact these projects have asset renewal elements as well as delivery other benefits for users.

Where costs are incurred prior to 2026, but are not sunk, they are discounted to 2026 using the selected social discount rate.

3.13 Total train capex profile attributed to capacity



Data source: CIE and Jacobs.

Tram capital costs

Tram CAPEX Costs are based upon the provided list of current expenditures by Yarra Trams, plus additional known projects which are known to be in the planning or pre-planning phase.

Known projects include:

- Ongoing new Super Stops for Trams
- Depot expansion projects
- Continued purchasing of new rolling stock
- Rolling stock upgrades
- Assumed route extensions

Costs for these additional projects are based on known current costs, published costs, and projections of known current costs. Cost sources included PTV, TfV/DoT, Melbourne Print Media, and also included project costs which Jacobs have been involved with. The costs are estimated on an annual basis, and reflect the average annual capacity enhancement costs for trams.

Projects included in the model, and the share of capital costs attributed to capacity are summarised in table 3.14 and the total capital cost profile is shown in chart 3.15.

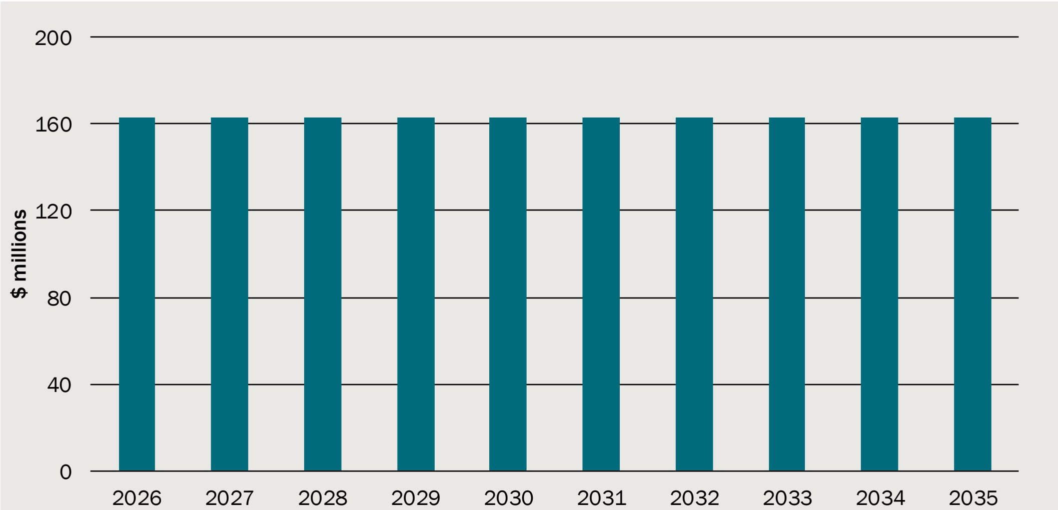
3.14 Tram capacity costs include in the model

	Share attributed to capacity
	per cent
Yarra Trams infrastructure spending	100%
Super Stop construction	10%[a]
Other infrastructure	0%[a]
Depot works	0%[a]
Route upgrades	0%[a]
Route extensions	100%
Rolling stock upgrades	25%[a]
Rolling stock procurement	50%

[a] Value was chosen based on advice from TfV.

Source: CIE and Jacobs.

3.15 Total tram capex profile attributed to capacity



Data source: CIE and Jacobs.

Bus capital costs

Roadworks have not been considered as a cost for buses, as these improvements are primarily driven by car traffic as opposed to public transport.

Bus capital costs are limited to the following;

- Assumed contributions towards additional bus lanes – estimated by assuming 30 to 50 km of dedicated bus lanes added within other roads projects per year
- New bus stops, and bus stop enhancements – estimated by assuming that 250 bus stops are added, enhanced, re-built, replaced per year
- Bus procurement, assuming 30 new buses per year

Projects included in the model, and the share of capital costs attributed to capacity are summarised in table 3.16 and the total capital cost profile is shown in chart 3.17.

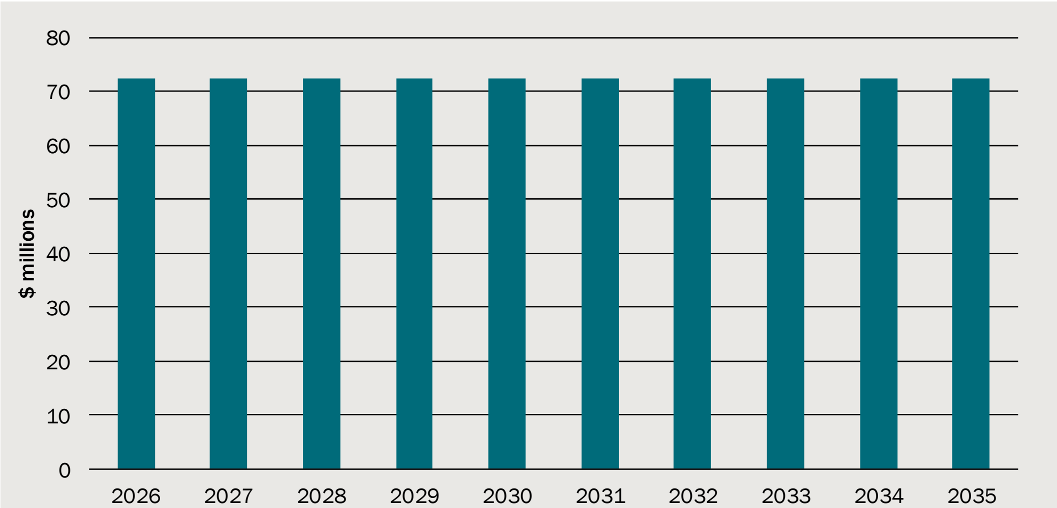
3.16 Bus capacity costs include in the model

	Share attributed to capacity
	per cent
Bus lanes	75%
Bus stops	50%
Bus procurement	50%

Note: Only capital costs between 2026 and 2035 are included in the analysis. The cots reported in this table are the undiscounted the total cost over the 10-year period.

Source: CIE and Jacobs.

3.17 Total bus capex profile



Data source: CIE and Jacobs.

Residual values

In order to measure the marginal capacity costs, we need to also estimate the residual value of capacity investments. The demand increment applied brings forward capital investments over the 10-year period considered in the analysis, however these assets continue to provide value following the evaluation period – we include residual values in our marginal cost estimates to account for the trips which will be serviced in the future by the infrastructure.

Residual values have been calculated using straight line depreciation from the investment’s completion. The assumed asset lives used in the analysis are summarised in table 3.18.

3.18 Assumed asset lives for residual value calculations

Asset lives	Asset life (years)	Source
Tunnel	100	Australian Transport Council (now ATAP)
Rail	100	Australian Transport Council (now ATAP)
Other projects	20	Australian Transport Council (now ATAP), assumed to be consistent with rail signals and communications
Train and tram stations	50	Australian Transport Council (now ATAP)
Bus stops	20	Australian Transport Council (now ATAP)
Road pavements	60	Australian Transport Council (now ATAP)
Buses	18	PTV annual report
Train rolling stock	30	Deloitte Access Economics
Tram rolling stock	30	Deloitte Access Economics

Source: ATAP 2006, National Guidelines for Transport Systems Management in Australia, p. 44; Deloitte Access Economics 2013, Opportunities for Greater Passenger Rolling Stock Procurement Efficiency, prepared for Australasian Railway Associations p 14; PTV 2018, Annual Report 2017/18, p 88; CIE.

Estimated marginal financial costs per trip

Estimated marginal financial costs per trip are reported in table 3.19 for peak periods and table 3.20 for off-peak periods.

3.19 Peak marginal financial costs per trip

	Rail	Tram	Express bus	Bus
	$ per trip	$ per trip	$ per trip	$ per trip
Current service (no new services)				
Usage cost	1.41	1.31	0.84	0.84
Cost of additional services (capacity)	0.00	0.00	0.00	0.00
Infrastructure cost (capacity cost)	0.00	0.00	0.00	0.00
Total	**1.41**	**1.31**	**0.84**	**0.84**
Service expansion (additional services)				
Usage cost	1.41	1.31	0.84	0.84
Cost of additional services (capacity)	0.25	0.24	1.87	0.36
Infrastructure cost (capacity cost)	12.09	2.31	1.34	1.36
Total	**13.75**	**3.87**	**4.05**	**2.56**

Note: The AM period costs have been used to report peak marginal costs per trip. There is little variation between marginal costs during the AM and PM peak. Usage costs are based on BPRT average costs. The cost of running additional services is included in capacity costs; marginal service costs per km are based on franchise agreement service costs.

Source: CIE and Jacobs.

Usage costs are the costs associated with increased number of trips and are constant across the current service and service expansion scenarios. During peak periods, capacity costs are only measured for the service expansion scenario, where services are increased to maintain crowding at current levels. The capacity cost is significantly lower during the off-peak periods as we have assumed that the marginal cost of constructing infrastructure is only attributed to peak periods; the small capacity cost during off-peak periods reflects the cost of additional services during those periods. Similarly, off-peak usage costs are lower than peak usage costs, as these do not include usage costs associated with capacity.

Usage and capacity costs are greatest for rail, followed by tram and the bus, reflecting the difference in operating costs and the required fixed infrastructure to operate services and to increase capacity.

3.20 Off-peak marginal financial costs per trip

	Rail	Tram	Express bus	Bus
	$ per trip	$ per trip	$ per trip	$ per trip
Current service (no new services)				
Usage cost	1.41	1.31	0.38	0.38
Cost of additional services (capacity)	0.00	0.00	0.00	0.00
Infrastructure cost (capacity cost)	0.00	0.00	0.00	0.00
Total	**1.41**	**1.31**	**0.38**	**0.38**
Service expansion (additional services)				
Usage cost	1.41	1.31	0.38	0.38
Cost of additional services (capacity)	0.12	0.10	0.13	0.05
Infrastructure cost (capacity cost)	0.00	0.00	0.00	0.00
Total	**1.53**	**1.41**	**0.51**	**0.42**

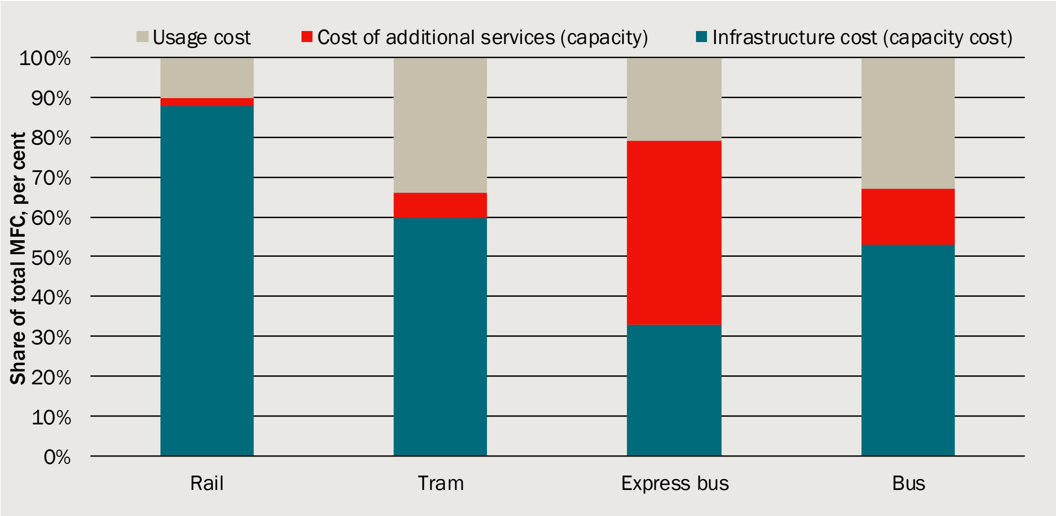
Note: The inter peak period costs have been used to report off-peak marginal costs per trip. There is little variation between marginal costs during the inter peak and other off-peak periods. Usage costs are based on BPRT average costs.

Source: CIE and Jacobs.

The cost of providing additional services is very large for express buses compared to other modes (chart 3.21). This is because:

- around 83 per cent of the increase in patronage for express buses occurs on already crowded services, compared to only around 33 per cent for bus trips. This means that a small increase in patronage results in a large increase in the number of services to prevent an increase in crowding (see table 3.22)
- express bus services tend to be longer than total bus services, covering on average 27 km compared to 13 km for buses. Because VITM reports crowding for the entire line or bus route, the number of service kms is assumed to increase proportionally with crowding, such that longer average route distances will result in higher costs for some increase in crowding.

3.21 Share of marginal financial cost – metropolitan trips



Data source: CIE and Jacobs.

3.22 Change in services to prevent crowding during AM peak

	Metro rail run	Metro tram run	Metro express bus run	Metro bus run
	Per cent	Per cent	Per cent	Per cent
Rail	2.6%	0.0%	0.0%	0.2%
Tram	0.1%	8.1%	0.0%	0.1%
Express bus	2.3%	1.6%	10.0%	8.1%
Bus	0.2%	0.0%	0.0%	0.6%

Note: Columns are for the run relating to the mode and region of interest (i..e metropolitan rail), and rows are the change in service for each mode.

Source: CIE and Jacobs.

Another interesting finding is that express bus run results in a larger increase in express bus services than the bus run (which includes express bus, see table 3.22). This appears to be due to substitution from bus to express bus when only express bus prices are reduced.

4 Externalities

One of the rationales for public transport subsidies is the existence of externalities. An externality is a cost or benefit that affects an individual other than those making the transport decision. Because these costs are external to the decision maker, they do not necessarily factor into the decision maker's choice, resulting in sub-optimal social outcomes. Allocative efficiency is maximised by charging users for the externalities they generate; in the absence of universal road pricing, providing a subsidy for public transport can improve allocative efficiency.

We incorporate externalities into our measure of the MSC by quantifying the marginal external costs and benefits of different transport modes. These are measured based on traffic modelling outputs from VITM modelling runs, however they can also be set to other benchmark externality parameters.

The externalities that are considered in this study are summarised in table 4.1.

4.1 Externalities included in analysis

Externality	Description
Congestion cost (time)	Changes in transport times for existing car users from changes in the amount of car and bus travel
Congestion cost (vehicle operating cost)	Changes in vehicle operating costs (such as fuel) from changes in journey times induced by changes in the amount of car travel
Congestion cost (reliability)	Changes in the variability of travel times from changes in the amount of car travel
Congestion cost (additional services)	Impact of new public transport services (bus and tram) on travel time, vehicle operating cost and reliability of car travel
Accidents	Changes in the number and costs of accidents from changing travel patterns
Environmental externalities	Impacts from car emissions from changes in vehicle kilometres
Active transport	Changes in health costs (borne by others such as public health system costs) from changes in the amount of walking and cycling – low fares will result in some individuals substituting from active transport to public transport
Crowding of public transport	Impacts on the comfort/cost of travel for public transport users from decisions by others to use or not use public transport
Scale/frequency	Changes in the waiting times for services as they become more or less frequent in response to changes in demand
Excess burden of taxation	Changes in the costs of taxation reflecting the Government contribution to public transport services (costs less revenues). This includes: ▪ reduced excess burden of taxation from the revenue associated with the new trip ▪ the excess burden of taxation associated with the MFC of the new trip ▪ the excess burden of taxation from changes in fuel excise, parking revenue and tolls

Source: CIE.

Parameters to quantify externalities

Values for externalities are readily available for most externalities from the Australian Transport Assessment and Planning (ATAP) guidelines and other guidelines. Sources used in this study are shown in table 4.2.

The model is designed to allow these parameters to be updated over time or replaced with alternative estimates. For instance, if an alternative Victoria specific parameter is available we will make use of that.[25] Results are also subject to sensitivity testing to assess the importance of critical parameters to the model's results.

4.2 Values for externalities

Item	Source
Value of time	ATAP Guidelines (M1 Public Transport, PV2 Road Parameter Values)
Time change for existing road users	VITM modelling
Marginal costs of congestion	Value of time and time changes from VITM modelling Other cross-checks from a range of benchmarks Estimates are also applied to buses and trams where these are not separated from car traffic
Behavioural responses between modes (elasticities)	VITM modelling Other cross-checks from a range of benchmarks
Crowding disutility/reliability of public transport (vehicle and station)	ATAP Guidelines (M1 Public Transport) for station and train crowding Crowding in vehicle hours from VITM modelling Crowded station hours from VITM modelling
Value of reliability for private vehicles	VITM modelling IPART 2016 review based on United Kingdom Department for Transport, Transport Analysis Guidance A1.3, January 2014
Vehicle operating costs	VITM modelling; VOC benefits are reported in VITM outputs, which are based on Austroads 2008 (Guide to project evaluation Part 4)
Service frequency (waiting time cost)	ATAP Guidelines (M1 Public Transport)
Environmental externalities	Private vehicles and buses: ATAP Guidelines (PV2 Road Parameter Values) for air emissions, TfNSW Guidelines/NGTSM 2006 for other environmental externalities Arup - Cost of emissions for NSW Light Rail, Final Report, 19 November 2014 Arup – Cost of emissions for Sydney Trains, Final Report, 2 April 2015 Note that the environmental externalities are in some cases long out of date and should be used with caution
Accidents	TfNSW Principles and Guidelines 2018
WEBs	Not measured
Social inclusion and equity	Note measured

[25] For example, Vic Roads publishes information on car occupancy rates: https://public.tableau.com/views/TMIndex/Index?:embed=y&:showTabs=y&:showVizHome=no&%3Adisplay_count=yes&%3Atoolbar=no#1

Item	Source
Excess burden of taxation	KPMG Econtech 2010, CGE analysis of the current Australian tax system, prepared for Department of Treasury, 26 March; KPMG Econtech 2011, Economic analysis of the impacts of using GST to reform taxes; Australian Treasury 2015, Understanding the economy-wide efficiency and incidence of major Australian taxes
Social discount rate	Victorian Department of Treasury and Finance Technical guidelines on economic evaluation
Economic life of assets	ATAP Guidelines, PTV annual report and Deloitte Access Economics 2013, Opportunities for Greater Passenger Rolling Stock Procurement Efficiency, prepared for Australasian Railway Associations

Source: As noted in table.

The following section discusses the approaches to measure benefit categories in greater detail.

Road congestion costs

Road congestion costs measure the impact on the road network due to changes in travel behaviour. This generally consists of substitution away from (towards) road transport where fares are lowered (increased), but may also include the marginal impact of public transport services (i.e. an additional bus service) on road congestion. The measure of congestion relates to three specific benefit categories:

- changes in travel time, which measures the change in travel time for individuals who use a car for their trip in the base case and the after the change in fares. This is calculated as:

  $$\Delta Car\ travel\ time = VoT \times \Delta CTT$$

  where VoT is the value of time and ΔCTT is the change in car passenger travel time. The change in car travel time is only for continuing car users. This benefit is measured for private and business travel, as well as commercial vehicles and freight, with different values of time attributed to these types of trips.

- changes in vehicle operating costs, which measures the change in vehicle operating costs arising from different levels of congestion. Congestion affects vehicle speeds, which in turn affect operating costs which tend to be higher in slow stop-start traffic. The change in VOC is measured as:

  $$\Delta VOC = \sum_{S} VKT_B^S \left[\frac{(1 + \%\Delta VKT^S)}{(1 + \%\Delta VKT)} - 1\right] \times C^S$$

  where VKT_B^S is the vehicles km travelled in a given speed band S for the base case and C^S is the vehicle operating cost per km travelled in speed band S.

  This is measured directly from the VITM model. Note that for our main results we apply a lower vehicle operating cost saving, as the modelled results from VITM are not plausible.

- changes in travel time reliability, which measures how the variability in travel times in effected by changes in traffic levels and is calculated as:

$$\Delta Travel\ time\ reliability = -\frac{0.0018}{2}\sum_{ij}\frac{t_{ij\ Scenario}^{2.02} - t_{ij\ Base}^{2.02}}{d_{ij}^{1.41}} \times T_{ij} \times VOR$$

Where $t_{ij}$is the time between origin i and destination j, d_{ij} is the distance between the origin and the destination, T_{ij} is the distance between the origin and destination and VOR is the value of reliability, which is calculated by multiplying VoT by the reliability ratio which is generally set to 0.4. The parameters used to measure travel time reliability, used in the above formula, are based on the UK appraisal guidelines.[26] Travel time reliability is calculated for an average trip, given we do not have information for every origin destination pair.

Road congestion impacts from VITM are quantified per avoided VKT – i.e. the externality benefit entering the MSC model is $X per avoided car VKT. This approach was chosen, as distinct from directly quantifying benefits per new public transport trip or pkm, to allows road congestion costs to be benchmarked against other models, which generally report decongestion in terms of avoided car VKT. This also allows the MSC model to easily be updated with alternative publicly available externality estimates. Externalities are translated into per public transport trips and pkm, using the distance per marginal car trips and car occupancy (to express the externality per new public transport trip) and the distance per marginal public transport trip (to express the externality per public transport pkm).

Marginal impact of bus, tram and train services on road congestion

Within VITM, bus and tram vehicles are modelled as taking up space on the road and therefore feed into congestion. However, no account is taken for them stopping and blocking traffic at on road bus and tram stops, or delay associated with priority traffic lights. The modelling does not increase services, and hence does not include congestion costs from additional services to meet additional demand.

Studies have estimated bus queuing delay functions at bus stops as a function of bus frequency, passenger transfers and fare payment technology, but again do not consider car-bus interactions at stops which is likely to be important.[27]

Delays associated with level crossings are incorporated into VITM for metro areas and is based upon average number of times the barrier comes down and average time they are closed. This is not measured for regional areas where it is assumed that traffic levels are too low for level crossings to cause a material delay.

Within the model, the congestion from a bus, tram and rail services should be accounted for in MSC as an externality of additional public transport services, and should account

26 UK Department of Transport 2017, TAG Unit A1.3 User and Provider Impacts, March, p. 13-14.

27 Tirachini, A. and Hensher, D.A. 2011, Bus congestion, optimal infrastructure investment and the choice of a fare collection system in dedicated bus corridors, Transportation Research Part B 45(5), 828-844.

for the changes in travel time, vehicle operating cost and travel time reliability. This includes:

- marginal road congestion caused by an additional bus service — this is applied to the additional service kilometres for buses (in the case of service expansion) and it is assumed that each bus kilometre has the same impact as three car kilometres
- marginal road congestion caused by an additional tram service — this is applied to the additional service kilometres for trams (in the case of service expansion) and it is assumed that each tram kilometre has the same impact as three car kilometres

The assumption of a three times congestion impact is likely to be somewhat understated if buses and trams are stopping on roads.

The delay costs of bus and tram are only applied to service kilometres that are on roads shared with cars. If services are on separated roads, then no congestion cost is applied. We assume that 18 per cent of bus and tram service kms are operated separate to road traffic.[28]

Impacts on existing public transport users

Changes in patronage are likely to have two main impacts on existing public transport users:

1. crowding impacts, which measure the discomfort or delay caused by greater use of existing public transport services — this can occur in vehicles and on platforms. At an extreme, this could lead to people having to wait for the next service
2. user-related economies of scales, also referred to as a the Mohring effect, where the cost of waiting at transit stops or access costs fall as service frequency increases in response to higher demand.

How these externalities play out depends on how policy makers respond to higher patronage. For instance, in response to higher patronage, policy makers may timetable additional services, resulting in user economies of scale while avoiding crowding impacts. Alternatively, policy makers could leave timetables unchanged and allow the increased patronage to be absorbed by greater levels of congestion, with no user economies of scale benefits.

The overarching methodology used allows for flexibility in the policy maker's response to higher levels of patronage, measuring costs for either providing additional services and if no additional services are provided (see chart 2.3). Conceptually, the minimum of these is the MSC, which assumes that the policy maker responds to higher patronage in a way which minimises MSC. However, typically we find that crowding costs are substantially smaller than new service costs — potentially the costs of crowding do not measure the full range of costs.

28 Rail Futures Inc 2015, Trams and Light Rail in Melbourne's Transport Future, p 10. This document reports the share of Melbourne's tram network which is segregated from traffic. We assume that this same rate holds for bus and express bus services.

The trade-off between the Mohring effect, crowding and service costs are summarised in table 4.3 for the two demand pathways considered in this study.

4.3 Relationship between demand response pathways and impacts

Demand response pathway	Mohring effect	Crowding	Determinant of change in service	Cost increase
No increase in services	No Mohring effect	Increased crowding, as there are more people using the same number of services	No change in service	Small cost increase from catering for more passengers
Additional services	Mohring effect, as additional services reduce waiting times for existing users	No crowding, as additional services are provided where crowding occurs	Proportional to demand growth for services that are above a crowding threshold	Large cost increase to cover new services and new infrastructure where required

Source: CIE.

The relationship between demand and public transport services is likely to be highly dependent on how capacity is defined. For instance, if capacity is defined as 70 per cent utilisation (the point at which crowding costs generally occur), investment to allow higher levels of demand will be required earlier than if capacity is defined as 100 per cent utilisation. Most metropolitan services during peak periods operate at greater than 70 per cent utilisation, which indicates capacity is above this level.

Public transport externality impacts are measured per new public transport pkm, for each of the modes considered. This feeds directly into MSC estimates per pkm and are translated into per trip terms by multiplying the externality per pkm by the average distance of the marginal public transport trip.

Measuring crowding

There are four key effects of public transport crowding on passenger journeys:[29]

1 in-vehicle discomfort; perceived disutility from travelling in crowded conditions

2 excess wait time; additional passenger wait time from not being able to board a service

3 increased dwell time; increased journey times caused by vehicles having to remain stationary for longer at stations to facilitate boarding and alighting

4 platform crowding; perceived disutility from waiting in crowded conditions

In the VITM model, the first and last of these are measured. However, changes in train dwell time (and reliability) and having to wait for the next train are not measured.

29 SKM 2009, Critical Review of Transport Modelling Tools (Implementation Options), prepared for National Transport Modelling Working Group, p. 39.

VITM measures crowding as a component of the generalised cost of travel. When crowding becomes severe, the generalised cost increases and passengers substitute to other modes. The crowding externality can therefore be measured as follows:[30]

$$\Delta PT\ Crowding\ cost = PHT_B \times \sum_c \frac{PHT_P^c}{PHT_P} \times C^c$$

where PHT is public transport passenger km travelled, subscript B denotes the base case and P the project case, superscript c denotes the crowding band and C^c denotes the crowding cost for crowding band c. The VITM modelling results are highly aggregated, and only provide total crowding hours, rather than the amount of crowding at particular levels. We apply an impact of 45 per cent value of time penalty for each crowded hour, based on ATAP guidelines for the cost of standing versus the cost of being seated in a train above 70 per cent capacity.

Ideally, we would apply a more differentiated view of crowding costs. However, VITM does not report hours by crowding band.

We also apply a penalty of 50 per cent to crowded waiting hours.

There is a potential risk that the crowding cost is understated. Severe crowding could compromise the reliability of the services and hence lead to delays for everyone, or lead to some passengers having to wait for another service.

Measuring the Mohring effect

The Mohring effect is the observation that as demand increases the frequency of public transport services increases, which shortens the waiting time for existing passengers.[31] This is a positive externality of higher demand for existing users, proving them with a benefit in terms of time savings. The Mohring effect can be ignored where increase in demand are assumed to not result in additional services, but only increased crowding.

In measuring this benefit we need to be able to relate the change in the frequency of services provided to the timing of when individuals arrive at a station or stop. For instance, if there is currently a 10-minute headway between services, but all passengers arrive 3 minutes before departure doubling the service frequency (reducing the headway to 5 minutes) will result in no user scale benefit for existing users. If in contrast, all passengers arrive 7 minutes before the service, doubling of service frequency will result in a user scale benefit for all existing users.

These two examples are extreme cases, as in practice arrivals at a station or stop will follow some distribution over the time between services. In VITM wait time is applied based upon frequency; there is a curve that assumes that during peak periods, when headways are low, people operate on a turn-up-and-go basis and during off-peak periods

30 This is consistent with IPART 2015, Guide to the Transport Externality Model, February, p. 10-11. However, bands are aggregated into not crowded and crowded, rather than into different levels of crowding.

31 Mohring, H. 1972, Optimization and scale economies in urban bus transportation, American Economic Review, 62(4).

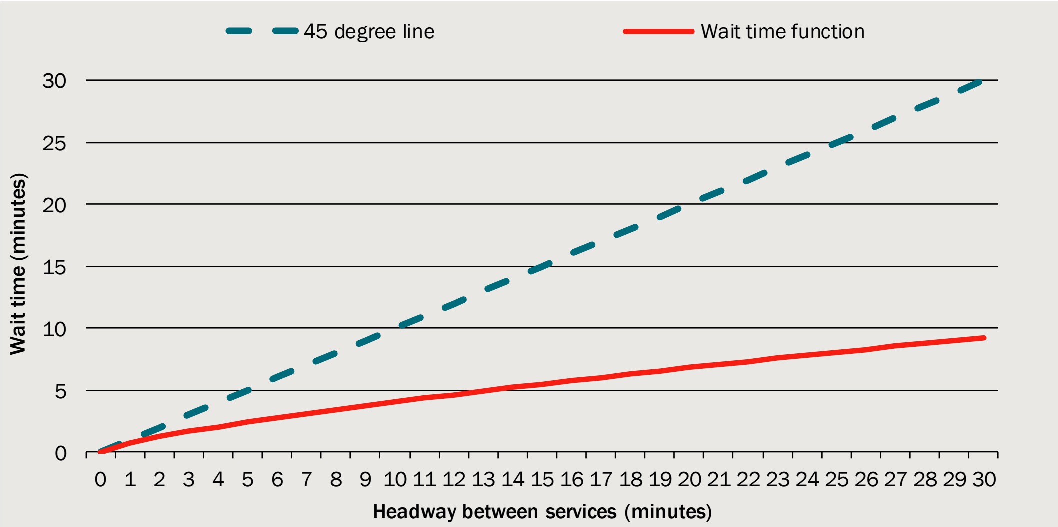
it is assumed that people know the timetable and plan to arrive a set time before departure. This is consistent with empirical observations that a headway of 10 minutes or less usually makes most passengers ignore timetables, with passengers arriving at stations or bus stops randomly at generally a constant rate.[32] There is likely to be significant value for passengers who can transition from having to consult timetables to being able to turn up and go.

Accordingly, we take the following approach:

$$\Delta Wait\ Cost = (RT_B + TT_B + BT_B) \times VOT \times WTP \times \frac{0.72}{60}\left[\left(\frac{60}{SPH_B}\right)^{0.75} - \left(\frac{60}{SPH}\right)^{0.75}\right]$$

Where $(RT_B + TT_B + BT_B)$ is the sum of rail trips, tram trips and bus trips under the base case, SPH is services per hour, subscript B denotes the base case, VoT is the value of time, WTP is the wait time premium which is normally set at 1.4. The wait time function of $0.72\left(\frac{60}{SPH_B}\right)^{0.75}$ relates the number of services per hour to the unweighted wait time.[33] This function allows the wait time to vary according to the size of the headway between services (chart 4.4). Passengers using high frequency services arrive at stations and bus stops randomly, while passengers for services with larger headways passengers consult timetables and plan their arrival to more closely coincide with the service. This pattern of behaviour is consistent with the observation that the proportion of passengers who plan their arrival at a station or bus stop based on the timetable is larger at longer headways than short headways.[34]

4.4 Wait time function



Data source: ATC 2006, CIE.

32 Tirachini, A. and Hensher, D.A. 2012, Multimodal transport pricing: first best, second best and extensions to non-motorized transport, Transport Reviews, 32(2), 181-202.

33 Australian Transport Council 2006, National Guidelines for Transport System Management in Australia, Volume 4 Urban Transport, p. 73-74.

34 Nygaard, M. F. and Tørset, T. 2016, Waiting Time Strategy for Public Transport Passengers, Proceedings from the Annual Transport Conference at Aalborg University.

Note that this approach is likely to understate the actual externality because separately from the reduced waiting time benefit, passengers are also likely to benefit from services more closely aligned with their desired departure and arrival time. For example:

- assume passengers have a fixed arrival time of 9:00 am and select services which arrive at or before that time and only incur a waiting time at their destination (i.e. they arrive at the station just in time for their train)
- the trip time is 45 minutes and trains depart at 8:00 am and 8:30 am
- under the base case, passengers take the 8:00 am train and incur a wait time of 15 minutes at their destination
- assume now that service frequency is doubled, and a train now departs at 8:15 am
  - the passenger therefore has a travel time saving of 15 minutes by allowing them to more closely match their desired arrival time
  - our methodology for measuring the wait time saving, would imply a travel time saving of around 4 minutes[35], understating the benefit

The benefit of public transport services being able to more closely match desired journey times cannot be measured as this would require detailed information around individuals fundamental travel preferences. However, in some cases increased services may result in a disbenefit. As demand increases the length of the peak period may increase which may result in scheduled delay costs at the destination becoming larger where passengers are forced onto earlier services.[36]

Other benefits

Accident costs

Accident costs measure the change in the in the number and costs of accidents because of changing travel patterns. The change in costs is estimated by relating changes in vehicle kilometres travelled to changes in accident costs:[37]

$$\Delta Accident\ costs = \Delta VKT \times \frac{Acost}{VKT}$$

where VTK is vehicle kilometres travelled and $Acost$ is the average accident costs.

Accident costs enter the MSC model in per VKT terms.

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35 Calculated as $0.72\left(\frac{60}{2}\right)^{0.75} \times \left(1 - \frac{1}{(1+1)^{0.75}}\right)$

36 Tirachini, A. and Hensher, D.A. 2012, Multimodal transport pricing: first best, second best and extensions to non-motorized transport, Transport Reviews, 32(2), 181-202. They argue that the impact of scheduling considerations on average costs is not as important for high frequency services, where passengers arrive at stations more or less randomly.

37 This formula is based on IPART 2015, Guide to the Transport Externality Model, February, p. 10.

Environmental costs

Environmental impacts measure the change in car and public transport environmental impacts from changes in vehicle kilometres and public transport kilometres. This is measured as:

$$\Delta Envionmental\ externalities = \Delta VKT \sum_i \frac{X_{cost,i}}{VKT}$$

where $X_{cost,i}$ is the average environmental externality for externality i and VKT is the vehicle kilometres travelled by private road vehicles or different public transport modes. Using this approach many environmental externalities can be measured, however published environmental externalities are in some cases long out of date and should be used with caution.

Environmental costs enter the MSC model in per VKT terms.

Active transport benefit

Active transport measures the changes in health costs (borne by others such as public health system costs) as a result of changes in the amount of walking. VITM does not model active transport as a separate mode, so we only focus on changes in access, egress and transfer walking for public transport.[38] This is measured as:[39]

$$\Delta Active\ transport\ benefit = \left[\Delta RT \frac{A}{RT} D^r + \Delta TT \frac{A}{TT} D^t + \Delta BT \frac{A}{BT} D^t\right] \times Xwalking$$

where $\Delta PKTW/\ \Delta PKTC$ are the change in passenger kilometres travelled for walking/cycling, $\Delta RT/\ \Delta TT/\ \Delta BT$ is the change in rail/tram/bus trips, $\frac{A}{RT}/\frac{A}{TT}/\frac{A}{BT}$ is the share of respective public transport trips with walk access, D^i is the average walking distance to access public transport mode i and $Xwalking$ is the health cost saving per kilometre travelled.

This specification only measures active transport benefits relating to public transport for walking access.

The health cost saving per kilometre of walking used is 18 cents (2014/15 dollars), then escalated to 2018$, based on IPART's externality estimates. Note that ATAP guidelines use $2.77 per kilometre benefit for walking, however we believe that only a small part of this parameter measures the external impact of activity on publicly funded health care costs.[40] A large proportion of the benefits of high activity levels are not likely to be

38 Active transport is not included in VITM as a stand-alone mode; walking km is measured for public transport access and cycling is not included in the model.

39 This formula is based on IPART 2015, Guide to the Transport Externality Model, February, p. 10.

40 ATAP 2016, ATA Guidelines M4 Active Travel, p. 38, https://www.atap.gov.au/mode-specific-guidance/active-travel/files/m4_active_travel.pdf. Note that these values appear to be in 2013$.

externalities, as the benefits are captured directly by the user through improved quality of life, which is not relevant for social marginal cost.

The active transport benefit enters the MSC model in per public transport pkm terms.

Wider economic benefits (WEBs)

Wider economic benefits (WEBs) are not measured to estimate MSC.

WEBs relate to market imperfections in sectors using transport which can give rise to impacts on welfare in excess of the direct savings to transport users. More specifically, there are normally three WEBs which are sometimes considered in infrastructure cost benefit analysis (WEBs are sometimes generically referred to as agglomeration benefits as it is generally the most significant of the three):

- agglomeration economies – this relates to the positive externalities from individual decisions of businesses and households to locate near each other, such knowledge spill overs, labour market pooling, sharing fixed costs to a name a few.[41] Reduction in travel times may increase effective density, which measures accessibility from one location to another, which is used to proxy agglomeration
- labour supply – when people face lower commuting times then they may divert some of the time savings to additional work or may be able to access higher paying jobs located further away. Together this results in additional tax revenues from labour markets, which can be measured as a benefit
- output change in imperfectly competitive markets – a reduction in transport costs to business allows firms to increase the output of goods and services that use transport in production. If prices exceed costs, there will be a welfare gain to businesses

Changes in fare structure may generate agglomeration economies and labour supply benefits through the reduction in road congestion and travel times which may in turn increase effective density, or the number of locations which can be accessed in a given time. Persistent changes in fare structure may also result in residents and businesses making relocation decisions, which in turn may affect the level of agglomeration.

In contrast it is unlikely that changes in fare structure would result in a benefit from output changes in imperfectly competitive markets. This benefit is arbitrary and there is no strong reason to use this for transport, as it is not used for CBAs for other sectors. For example, there is no general assumption that providing water or energy more cheaply leads to an expansion in output, and that this expansion in output costs less than the output is worth. Instead, value is measured based on direct willingness to pay for energy and water.

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41 Duranton, G. and D. Puga 2003, Micro-foundations of urban agglomeration economies, NBER Working Papers, No. 9931.

Estimating WEBs

There is a significant literature seeking to measure the impacts of agglomeration using constructed measures of employment or labour market density. Essentially, these studies are seeking to estimate a relationship as follows:

$$A_i = f(EJD_i, X_i)$$

Where A is a measure of or proxy for productivity in region i, and f is a function of effective job density (EJD) in region i or another measure of density and other control factors (X) for region i.

In seeking to measure such relationships, there are several significant issues.

- Causality between agglomeration measures and productivity
  - direction of causality between density measures and impacts (such as productivity) is not always clear.[42] As noted by Glaeser (2010),

    > The basic problem with estimating agglomeration effects on productivity is that population density is not itself exogenous. People move to places that are more productive.[43]

  - causality may also be an issue in using transport costs to weight densities.[44] This is because transport might have been designed to provide access to the most productive place, implying reverse causality between productivity and accessibility.
- Developing production functions or alternative approaches that account for other factors that are likely to be correlated with agglomeration measures.
  - It is often difficult to capture the quality of the labour ('human capital') used by firms or within regions. Returns to human capital are an important driver of productivity and are likely to be correlated to measures of density.
  - The public capital relevant for a business or region is not typically measured. If public capital has been allocated towards particular regions then a productivity differential may measure the return from public capital rather than an additional productivity impact from agglomeration. For example, if public expenditure is focused on providing access to the CBD then businesses in the CBD may benefit from this through a productivity advantage over other less well-connected businesses.

The relevance with regards to measuring MSC

Modelling to illustrate agglomeration effects has been largely in the context of changes that would lower commuting costs through infrastructure investment rather than

42 Graham, D., S. Gibbons and R. Martin 2010, The spatial decay of agglomeration economies: estimates for use ion transport appraisal, Imperial College London, p 2.

43 Glaeser, E. 2010, Agglomeration Economics, Chicago University Press, p. 13

44 Graham, D., S. Gibbons and R. Martin 2010, The spatial decay of agglomeration economies: estimates for use ion transport appraisal, Imperial College London, p 12.

transport pricing/subsidisation. One potential exception is Venables 2004.[45] This paper, estimates productivity elasticity effects using a 20 per cent reduction in fares on one of London's four commuter lines. Venables finds substantial external agglomeration benefit responses based on the productivity link. This *could* be interpreted as equivalent to the result of a *subsidy* rather than necessarily being the result of a (conceptual) upgrade to the line. However, there are dangers in extrapolating such findings from modelling based on assumed benefits of infrastructure improvement to the Victorian public transport system.

Perhaps the biggest challenge in accommodating WEBs is providing convincing evidence of, and causality for, the productivity effect postulated to underlie it. There are a range of estimation and identification issues in the empirical work which is often used to measure WEBs in Australia and overseas, as discussed above.

IPART takes a similar view of the inclusion of WEBs in measuring MSC. Their review of public transport externalities excludes WEBs reasoning that:

- The external benefit portion is difficult to measure with any degree of confidence.
- The value of the external benefit is more closely linked with the availability of services (scope and frequency of services) than it is with the level of fares. As a result, the necessary link between the value of the benefit and the level of fares has not been demonstrated.[46]

This second point alludes to the fact that after accounting directly for the externalities of changing fares, such as the reduced road congestion, WEBs will generally be small and that WEBs are more likely to be realised by transport infrastructure investments rather than fare changes. They also argue that many of benefits related to agglomeration are private benefits as opposed to external benefits, in the sense that most of the benefits are captured by the user, who has already accounted for the benefit in making their decision on how to travel.

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45 Venables A.J. 2004, Evaluating Urban Transport Improvements: Cost Benefit Analysis in the Presence of Agglomeration and Income Taxation, Centre for Economic Performance Discussion Paper No. 651, London School of Economics, September

46 IPART 2014, Review of external benefits of public transport, December, p. 7

Equity and social inclusion

Equity and social inclusion have not been measured in this analysis. Social exclusion is a lack of participation in social and economic life, equity reduces disparity between people, places and generations (and is the opposite of social inclusion).

They have not been accounted for directly as the methodology of measuring externalities and marginal financial costs focuses on maximising economic efficiency and does not consider equity impacts. Equity considerations should be accounted for separately from this analysis.

Marginal excess burden of taxation

The marginal excess burden of taxation (MEBT) is an externality measured in MSC and is associated with Government raising funds to subsidise public transport trips. It measures the loss of consumer welfare from each dollar of tax revenue raised due to taxes distorting economic behaviour. It is calculated per dollar change in the Government contribution, which includes changes in public transport costs, changes in public transport fare revenue and changes in revenue received from the fuel excise, parking revenue and toll revenue.

This benefit is estimated using the following expression:

$$\Delta MEBT = MEBT \times (\Delta PTR + \Delta CPR + \Delta TR + \Delta FX - \Delta PTC)$$

Where $MEBT$ is the marginal excess burden of taxation per dollar of tax revenue, ΔPTR is the change in public transport fare revenue, ΔCPR is the change in car parking revenue, ΔTR is the change in toll revenue, ΔFX is the change in fuel excise revenue and ΔPTC is the change in public transport costs.

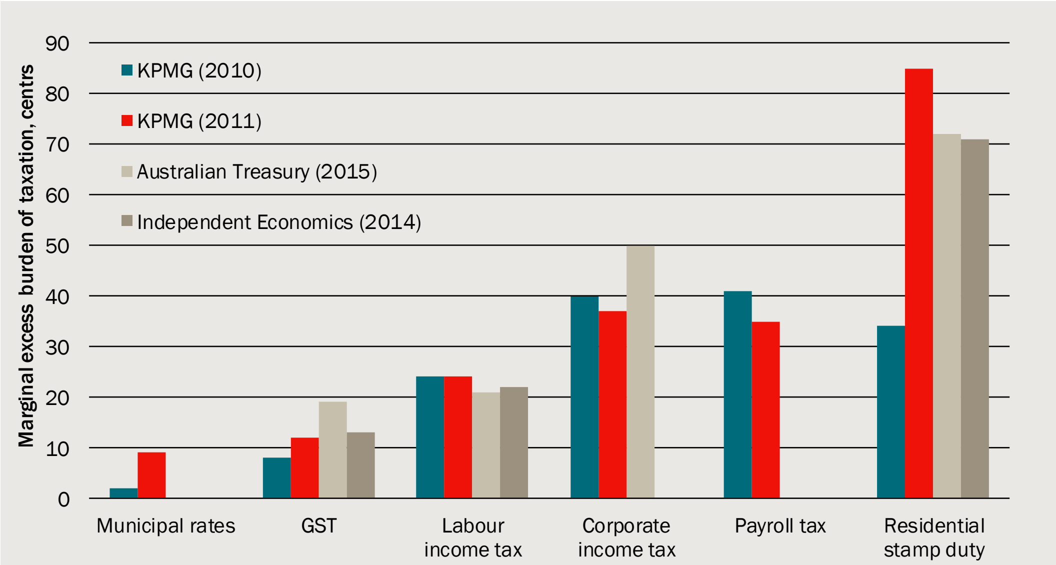
The change in fare revenue consist of three parts:

- the lost fare revenue from existing users due to the reduction in fares, which is used to induce new users
- the additional fare revenue from new trips due to lower fares, and
- the change in fare revenue for other public transport modes, whose fares are held constant.

The number of new trips due to the change in fares is sensitive to the elasticity of demand, as this affects the number of new public transport trips in response to the lower fare.

The choice of parameter to measure the excess marginal burden of taxation is important because, the larger the excess burden the larger the welfare cost of the government subsidy for public transport. Chart 4.5 shows MEBT estimates across a range of studies. There is considerable variation in MEBT across different types of taxes and across studies.

4.5 Marginal excess burden of taxation estimates



Data source: KPMG (2010), KPMG(2011), Australian Treasury (2015), Independent Economics (2014)

The choice of parameter to measure the excess marginal burden of taxation is important because the larger the excess burden the larger the welfare cost of the government subsidy for public transport. At very high levels there may be a case for no public subsidy at all.

Selecting the appropriate MEBT is difficult as it should reflect the efficiency cost of the marginal source of funds (i.e. where additional revenue would come from). It is difficult to ascertain precisely which tax or combination of taxes would be used to raise additional funds. The approach taken has been to allow users of the model to select the MEBT from a range of estimates:

- Low – 8 per cent. This is assumed to be the lowest estimate of the marginal excess burden of GST, from KPMG 2010
- Medium – 25 per cent. This is the weighted average MEBT, including all taxation revenue sources for the state Government and is calculated using marginal excess burden estimates from KPMG 2010, and revenue share from the 2018/19 Victorian State Budget as weights. This is the default MEBT set in the model
- High – 52 per cent. This is a weighted average MEBT, excluding GST grants from the Commonwealth Government. This uses tax revenue share from the 2018/19 Victorian State Budget, excluding GST grants, and marginal excess burden estimates from KPMG 2011[47]
- Own MEBT. This allows users to select their own MEBT, by entering it into a specific cell in the model

47 Using KPMG 2010, excluding GST gives an average MEB of 37 per cent.

5 VITM modelling results

Jacobs has undertaken transport modelling in order to estimate externality parameters and elasticities for a range of scenarios. This enables MSC to be calculated across a number of different scenarios, varying by:

- time periods (VITM models AM, interpeak, PM and off-peak periods)
- modes
- location of trips (e.g. metropolitan, trips ending in the CBD etc.)
- distance of trips.

Estimating MSC for different scenarios, allows consideration of the dimensions along which it may be appropriate to vary fares.

The modelling exercise has used VITM, and the scenarios run by Jacobs are summarised in table 5.1.

5.1 VITM scenarios

Run Number	Name	Description
-	Base Case	2026 VITM Reference Case with fare structure adjustments
Core model runs		
1	All Vic – Train	-30% train fare changes across all of Victoria
2	Metro – Train	-30% train fare changes across only trips both starting and ending in metropolitan Melbourne
3	Peri-Urban – Train	-30% train fare changes across trips starting or ending in peri-urban areas, excluding trips between peri-urban and regional areas
4	Regional – Train	-30% train fare changes across trips starting or ending in regional areas
5	Non-CBD – Train	-30% train fare changes across all of Victoria excluding trips starting or ending in the CBD
6	Metro – Tram	-30% tram fare changes across only trips both starting and ending in metropolitan Melbourne
7	Non-CBD – Tram	-30% tram fare changes across all of Victoria excluding trips starting or ending in the CBD
8	All Vic – Bus	-30% bus fare changes across all of Victoria
9	Metro – Bus	-30% bus fare changes across only trips both starting and ending in metropolitan Melbourne
10	Regional & Peri-Urban – Bus	-30% bus fare changes across trips starting or ending in peri-urban or regional areas

Run Number	Name	Description
11	Non-CBD – Bus	-30% bus fare changes across all of Victoria excluding trips starting or ending in the CBD
Additional model runs		
12	Metro – Express Bus	-30% fare changes across only trips both starting and ending in metropolitan Melbourne for express bus services only
13	Free Tram Zone (CBD) - Tram	Fare for travel within CBD by tram set to match what fares would be without free tram zone
Distance based model runs		
14	Melbourne distance-based fare system	Created a distance band-based fare system for Melbourne, with similar $ value fares to the current system
15	Metro bus – all distance fares	Reduced metropolitan bus fares for all trips by 30% within the distance-based fare system
16	Metro tram – all distance fares	Reduced metropolitan tram fares for all trips by 30% within the distance-based fare system
17	Metro train – all distance fares	Reduced metropolitan train fares for all trips by 30% within the distance-based fare system
18	Metro bus – short (<4km) distance fares	Reduced fares for only metropolitan bus trips less than 10 km by 30% within the distance-based fare system
19	Metro tram – short (<2km) distance fares	Reduced fares for only metropolitan tram trips less than 10 km by 30% within the distance-based fare system
20	Metro train – short (<10km) distance fares	Reduced fares for only metropolitan train trips less than 10 km by 30% within the distance-based fare system

Source: Jacobs.

The results from the VITM model are extracted using the economic module provided by TfV. Through this project a number of issues with the economic module were identified and rectified by TfV, however we understand work on the economic module is ongoing. There may be extant issues which we have not been able to identify through simple sense checks.

The following section outlines the results of the VITM model runs.

Elasticities and substitution rates

Elasticity estimated from VITM are shown in table 5.2. Bus and tram elasticities are broadly in line with IPART estimates for NSW, but the train elasticity from VITM are about half as large as IPART estimates (table 5.3). The rail elasticity is also lower than estimates provided by Litman (2019), reporting a rail elasticity of -0.35 and bus elasticity of -0.29 for Australia.[48]

Most elasticities are negative and tend to be relatively stable across different times of day. However, trips during interpeak and off-peak periods are in some cases larger than peak

48 Litman, T. 2019, Understanding Transport Demands and Elasticities, How Prices and Other Factors Affect Travel Behavior, Victorian Transport Policy Institute, p. 21.

elasticities, potentially reflecting changes in levels of road congestion and willingness to switch from public transport to car. This may be due to non-routine trips, which are more likely to occur during off-peak times and be more price sensitive than routine trips. The exception to this is tram trips which have slightly larger elasticities in off-peak periods compared to peak periods and non-CBD tram trips.

Elasticities vary considerably across modes. For metro trips, rail elasticities are significantly lower than tram, bus and express bus trips. This is consistent with other studies as different public transport modes serve different markets.[49]

5.2 Own price elasticities from VITM

Period	All Vic	Metro	Peri-urban	Regional	Non-CBD	Short trips
Train						
AM	-0.18	-0.18	-0.24	-0.14	-0.11	-0.12
IP	-0.25	-0.24	-0.29	-0.49	-0.14	-0.14
PM	-0.21	-0.21	-0.29	-0.35	-0.13	-0.11
OP	-0.23	-0.23	-0.15	-0.23	-0.11	-0.16
Tram						
AM	na	-0.40	na	na	-0.34	-0.14
IP	na	-0.33	na	na	-0.28	-0.09
PM	na	-0.41	na	na	-0.35	-0.18
OP	na	-0.31	na	na	-0.22	-0.12
Express bus						
AM	na	-0.51	na	na	na	na
IP	na	-0.49	na	na	na	na
PM	na	-0.49	na	na	na	na
OP	na	-0.49	na	na	na	na
Bus						
AM	-0.45	-0.44	-0.48	-0.48	-0.42	-0.11
IP	-0.44	-0.44	-0.68	-0.68	-0.40	-0.13
PM	-0.48	-0.47	-0.52	-0.52	-0.44	-0.17
OP	-0.50	-0.47	-1.29	-1.29	-0.41	-0.41

Note: Regional and peri-urban are estimated jointly for buses.

Source: CIE, Jacobs.

5.3 IPART Elasticity estimates

	Train	Light rail	Bus
Peak	-0.35	-0.38	-0.38
Off peak	-0.44	-0.51	-0.51

Source: IPART 2016, Elasticities - Public Transport Fares Final Report IP 9, 10 May

49 For instance, see Litman, T. 2019, Understanding Transport Demands and Elasticities, How Prices and Other Factors Affect Travel Behavior, Victorian Transport Policy Institute, p. 22.

VITM outputs are provided for the whole of the state (i.e. the total number of rail trips for Victoria in the scenario), so an adjustment is required for runs which reduced fares for only some trips in the state (i.e. metropolitan trips only) to calculate externalities. To do this, Jacobs have extracted the number of trips from VITM for a 24-hour period (table 5.4), with elasticities calculated as follows for regional rail trips:

$$\left(\frac{\Delta Rail\ trips_{regional}}{Base\ case\ Rail\ trips_{regional}} \times \frac{Rail\ trips_{total}}{Rail\ trips_{regional}}\right) \times \frac{1}{\%\Delta Fares}$$

There is variation across different trip types. The elasticity for all Victorian rail trips is significantly larger than more specific trip types.

For bus and train metropolitan elasticities tend to be around the same as whole of state elasticities or slightly lower, while peri-urban and regional trips tend to be more elastic and Non-CBD and short trips tend to have smaller elasticities. Regional AM train trips tend to be less elastic than the whole of the state, however this result may reflect convergence issues for VITM.

5.4 Demand by trip type

	All state	Metro	Non-CBD	Peri-urban and regional	Peri-urban	Regional
	Number of trips	Number of trips	Number of trips	Number of trips	Number of trips	Number of trips
Rail	1 557 976	1 466 803	1 039 153	na	40 861	50 312
Tram	na	1 057 803	592 855	na	na	na
Bus	602 907	575 849	553 046	27 058	na	na

Note: Demand is extracted from VITM for a 24-hour period.

Source: Jacobs.

Modal substitution rates

Modal substitution rates describe how travellers substitute between modes and are summarised in table 5.5 for peak metropolitan trips. On average, an additional train trip results in 0.52 fewer car trips, 0.10 and 0.02 additional bus and express bus trips respectively and 0.02 fewer tram trips. These substitution rates, in particular in relation to car trips, is used to determine the amount of decongestion externalities to be attributed to an additional public transport trip. The model substitution rates summed across all modes would zero if there was a perfect one for one relationship between trips in each mode. The modal substitution rates from VITM do not add up to zero as across modes because of:

- trip inducement, VITM allows for some inducement of trips however the amount of inducement in the model is likely to be small[50]

50 VITM allows for trip inducement, but only in part – many of the trip generation aspects are fixed and not directly related to cost, some however are related to cost and so trips are induced if costs fall.

- the way modal substitution is calculated from VITM. It is calculated based on the change in passenger trips between the fare scenario and the base case for each run. Although there may be a decrease in, for instance car trips in response to additional rail trips, some of the additional rail trips may leave car trips unchanged as people drive to a train station to use rail, as opposed to driving to their ultimate destination. In this case, an additional rail trip will not be perfectly be offset by lost trips from other modes.

Modal substitution rates are generally stable across the day, however, vary somewhat across different trip types.

Across modes rail has the highest substitution rate from car, implying that car trips rail trips are closer substitutes for car trips. Rail and bus trips tend to be complementary, as an increase in bus trips increases the number of rail trips. This may reflect passengers using bus trips to access train stations.

In contrast, tram appears to be a substitute for rail and bus. The tram network is cantered on Melbourne's CBD, which provides may different transport options. Because of this, tram trips may often displace other public transport modes as they service similar purposes of connectivity to the CBD.

5.5 Peak metropolitan substitution rates

	Rail only	Tram only	Express bus only	Bus only
Rail only	1.00	-0.06	0.06	0.16
Tram only	-0.02	1.00	-0.09	-0.19
Express bus only	0.02	0.00	1.00	0.22
Bus only	0.10	-0.05	-0.05	1.00
Car	-0.52	-0.28	-0.41	-0.49

Note: Substitution rates are calculated based on passenger trips reported by VITM.
Source: CIE and Jacobs.

Table 5.6 summarises the modal substitution rates used by IPART.[51] The substitution rate from car is higher for the IPART model, implying more trip diversion from car to public transport in response to an increase in public transport.

5.6 IPART substitution rates

	Rail	Tram	Express bus	Bus
Rail	1.00	-0.20	-0.05	-0.05
Tram	-0.01	1.00	-0.05	-0.05
Express bus	-0.05	-0.05	1.00	-0.05
Bus	-0.05	-0.05	-0.05	1.00
Car	-0.90	-0.60	-0.60	-0.60

Note: Substitution between bus and express bus assumed to be the same
Source: IPART.

51 IPART 2016, Elasticities – Public Transport Fares Final Report Information Paper 9, 10 May.

Modal substitution rates for rail across different trip types are shown in table 5.7. Peri-urban and trips neither starting or ending in the CBD tend to have high diversion rates from car to rail than all trips and metropolitan trips. Regional, peri-urban and trips to elsewhere than the CBD have much higher diversion rates for car than metropolitan trips. This is consistent with expectations that the main substitute for public transport trips from these arears are car trips. Also, all rail trips see an increase in bus trips which indicates that these modes are complementary.

5.7 Peak rail substitution rates

	All trips	Metropolitan	Peri-urban	Regional	Destination elsewhere than CBD
Rail only	1.00	1.00	1.00	1.00	1.00
Tram only	-0.03	-0.02	0.00	0.00	0.01
Express bus only	0.02	0.02	0.01	0.05	0.07
Bus only	0.11	0.10	0.15	0.05	0.24
Car	-0.55	-0.52	-0.80	-0.80	-0.75

Note: Substitution rates are calculated based on passenger trips reported by VITM.

Source: CIE and Jacobs.

Distance of marginal trips

Externalities enter the MSC in two ways:

- car related externalities are calculated from VITM and enter the MSC model in terms of externality value per car VKT
- public transport related externalities enter the MSC model in terms of externality per public transport pkm.

Externalities are translated into per public transport trip and pkm using marginal trip distances calculated from VITM. The relevant marginal distances include:

- the average distance of lost car trips which are replaced by public transport trips. This is calculated as the change in car VKTs divided by the number of new public transport trips and divided by average car occupancy for each mode
- the average distance of new public transport trips, which are induced in each VITM run from lower fares. This is calculated for each public transport mode by taking the change in total pkm and trips between the run and the base case:

$$\frac{(pkm_{scenario} - pkm_{base})}{(trips_{scenario} - trips_{base})}$$

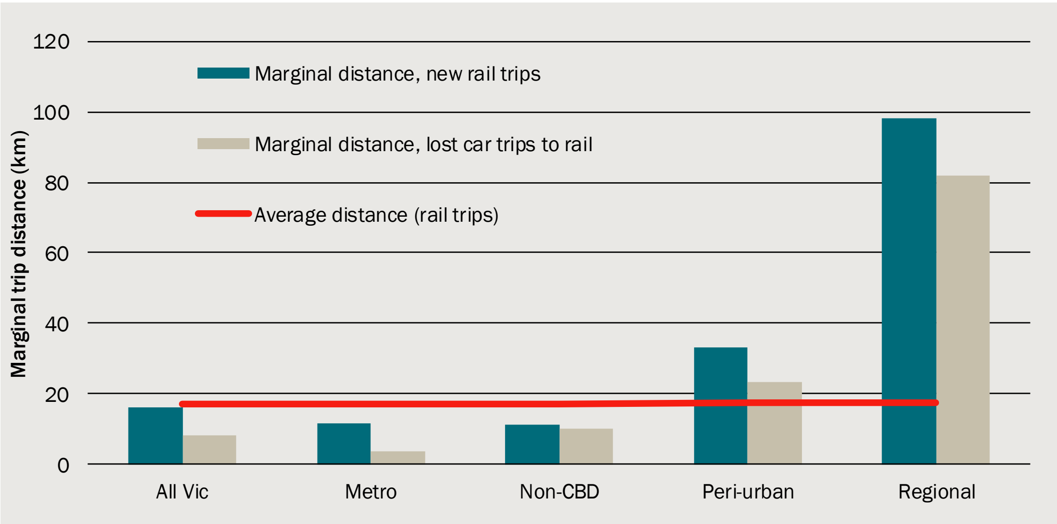
  This approach is potentially problematic as VITM only reports total pkm (for car it breaks distance travelled into continuing, new and lost users). If as a result of the shock, continuing users take longer or shorter trips, this will affect the estimate of the average distance of new trips. For instance, if existing users take longer trips, this will result in our estimate overstating the average distance of new public transport trips.

Marginal distances for each of the modes are shown in carts 5.8 through to 5.11. Lost metropolitan trips are generally shorter than the average trip distance measured across all trips, including continuing trips, while regional and peri-urban trips are generally longer, consistent with expectations. Similarly, distances of new rail trips are strongly correlated with the distance of lost car trips, as individuals change mode but maintain their origin and destination. The distances of new public transport trips are generally longer than the lost car trips

The difference between new bus peri-urban and regional trip distances and lost car differences is very large (chart 5.10). It is not clear, what is driving such as large difference in marginal distances, however it does not appear to be realistic. We have therefore set the distance of lost car trips for this trip type to 15 km.

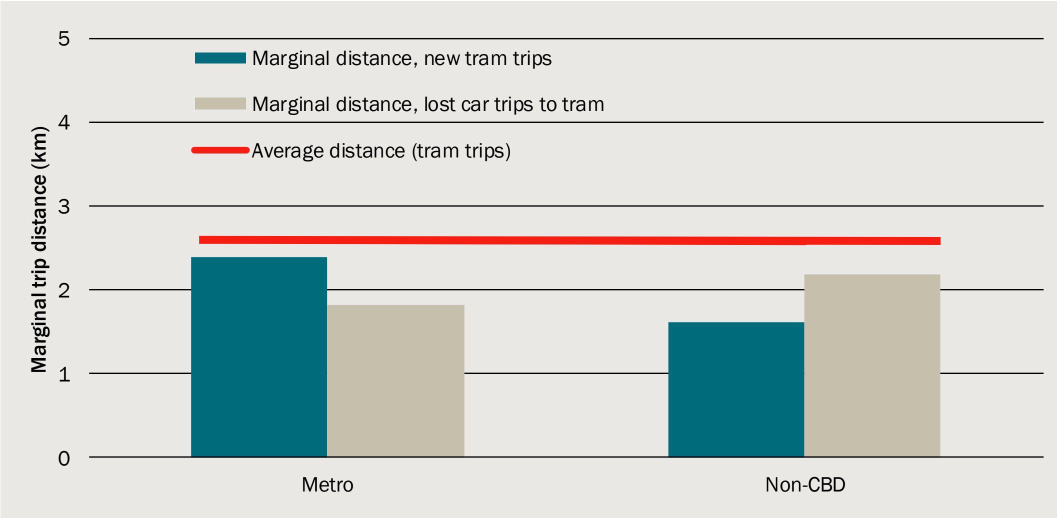
The difference between peak, off-peak and all-day marginal distances is shown in chart 5.11, and shows that across modes marginal trip distances are shorter during peak periods than off-peak periods.

5.8 Marginal distance rail, all day



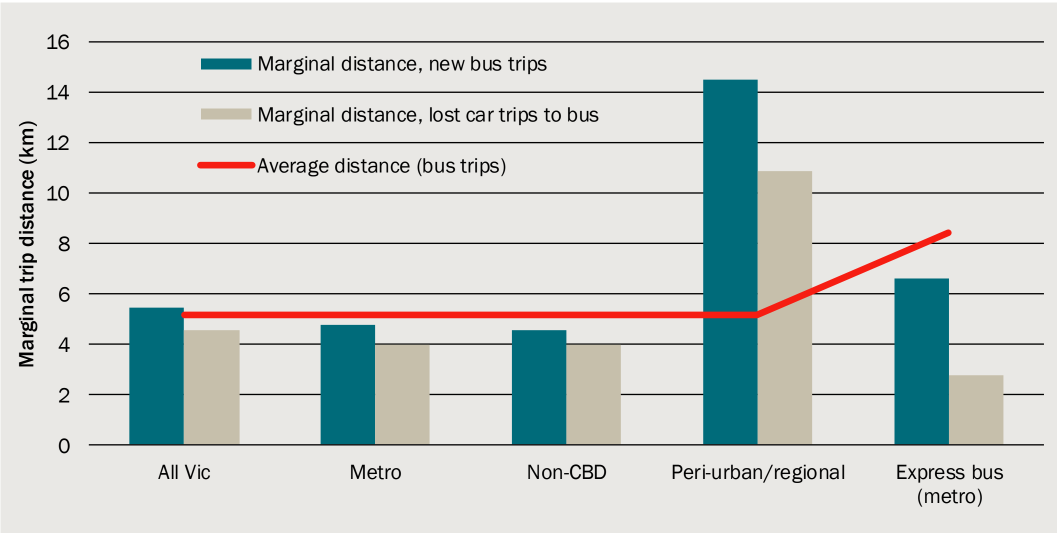
Data source: CIE and Jacobs.

5.9 Marginal distance tram, all day



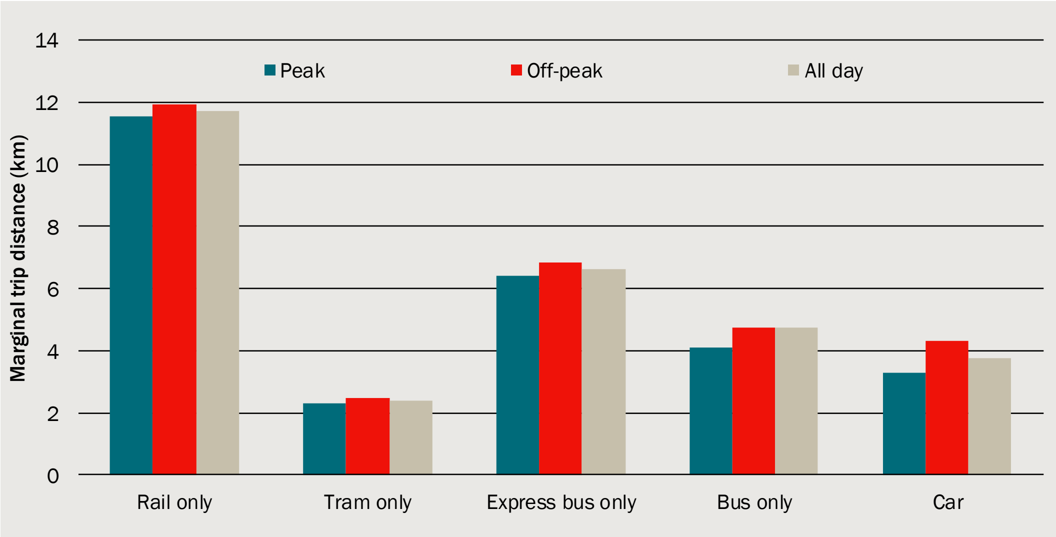
Data source: CIE and Jacobs.

5.10 Marginal distance bus and express bus, all day



Data source: CIE and Jacobs.

5.11 Marginal trip distance by mode and time period, metropolitan



Note: Car trip distance is for metro rail.

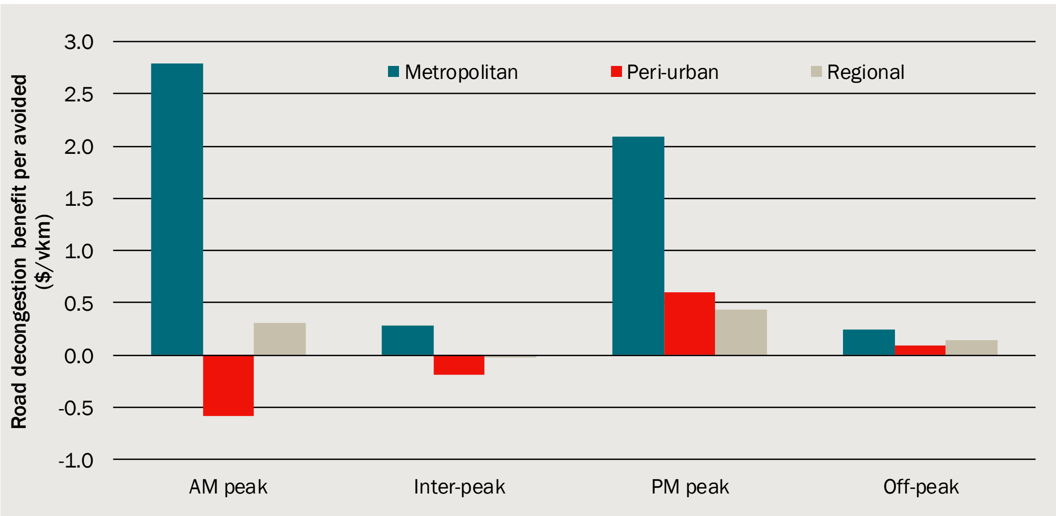
Data source: CIE and Jacobs.

Marginal cost of road congestion

The externalities from road use estimated from this project are shown in charts 5.12 through 5.14.

- Road externalities are highest in metropolitan Melbourne, lower in per-urban Melbourne and lowest in regional Victoria and sometimes negative (this is not a plausible result and implies issues with convergence in VITM, discussed below).
- Road externalities are highest in the AM peak, then the PM peak. They are lowest in the inter-peak and off-peak times.

5.12 Road decongestion impacts from rail fares scenarios



Note: This includes environmental impacts, accidents, time costs, reliability costs and vehicle operating costs.

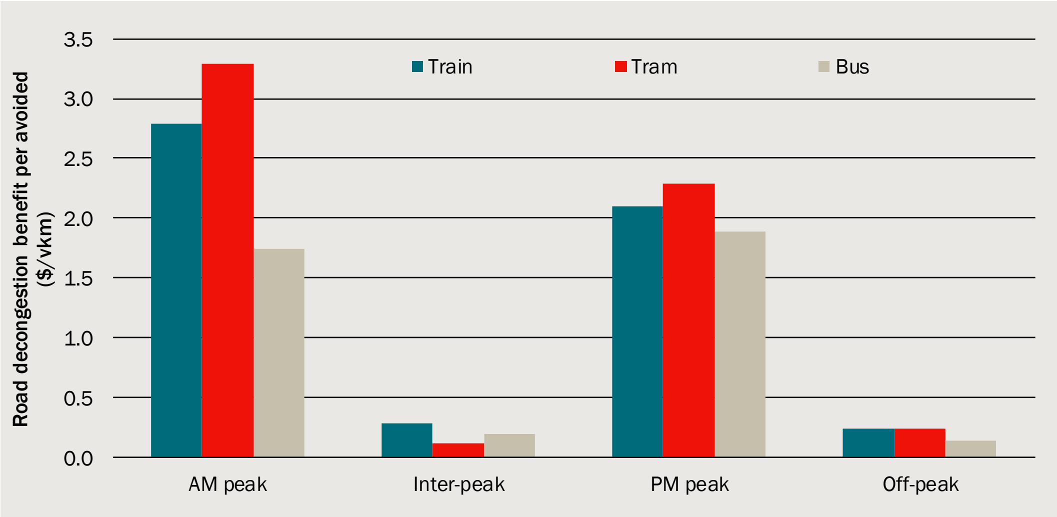
Data source: CIE and Jacobs.

Because of the convergence error in VITM (see executive summary) we have not been able to measure externality parameters reliability for a number of runs. This was the case for inter-peak, off-peak, regional and peri-urban runs:

- Note the change in travel time between the base case and the scenarios estimated in VITM was found to be within the VITM's convergence error for interpeak and evening periods. This has been interpreted as their being no road decongestion benefits during these periods and road decongestion benefits have been set to zero during the off-peak. This is a conservative approach, as there is likely to be some small decongestion benefit, however VITM does not allow us to estimate this.
- The change in travel times compared to the base case for regional and peri-urban runs was close to the convergence error of the model. This resulted in large decongestion benefits for these runs, which is not consistent with expectations. We have chosen to also set the decongestion benefits for regional and peri-urban trips to zero. Again, there is likely to be some decongestion benefit, especially for trips which go into metropolitan areas, however VITM does not allow us to estimate this.

Across different modes of public transport, the road externalities are generally lower for buses compared to rail and trams (chart 5.13). There are also different propensities to avoid car use for the different modes, discussed in earlier sections.

5.13 Road decongestion impacts across modes, metropolitan

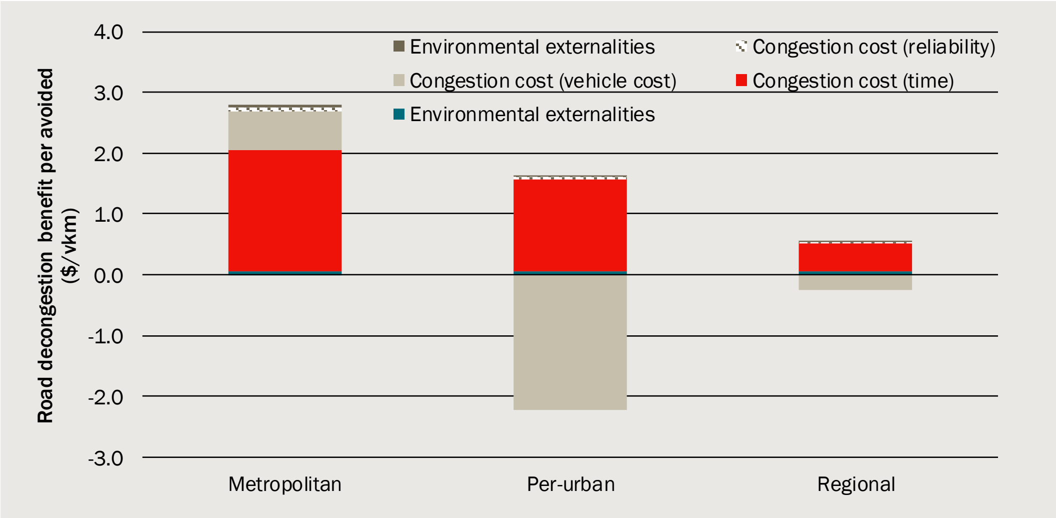


Note: This includes environmental impacts, accidents, time costs, reliability costs and vehicle operating costs.

Data source: CIE and Jacobs.

The largest road externality is time imposed on other road users, with reliability and additional vehicle operating costs being the next most important components (chart 5.14).

5.14 Composition of road decongestion impacts AM peak



Note: This is based on the rail fare scenarios.
Data source: CIE and Jacobs.

As noted above, the following road congestion benefits were set to zero for regional and peri-urban trips, as the results were inconsistent:

- Congestion cost (time)
- Congestion cost (vehicle cost)
- Congestion cost (reliability)

The estimates from VITM are generally higher than benchmarks, although relatively similar to estimates from Melbourne Metro rail project. Benchmarks for the marginal congestion cost of additional road vehicles are set out below and summarised in the table below.

- In Sydney, the costs of additional car passenger trips (for people diverted from public transport) was estimated $3.09 per trip in peak plus $0.51 per passenger km, and $0.71 per off-peak passenger trip and $0.20 per passenger km. On a weighted average basis, and converted to per car vehicle km, this is **$0.55 per vehicle km**. This figure includes additional time and vehicle operating costs for other users, plus poorer reliability, plus environmental externalities of road use.
- In Sydney, TfNSW recommends a rate of $0.36 per passenger car equivalent vehicle kilometre, accounting for travel time, travel time reliability, vehicle operating costs and environmental externalities.
- For Melbourne Metro, the avoided road user costs (time, reliability and vehicle operating costs) for 2031 were **$1.2 per vehicle km** taken off the road
- ATAP Guidelines report values from Melbourne guidance of off-peak $0.22 cents per vkm, light peak $0.22, moderate peak $0.84 and heavy peak $1.18 (2014 prices)
- New Zealand guidance cites numbers for different cities (Christchurch, Wellington and Auckland) of NZ$0.34 to NZ$1.56 per vehicle kilometre removed.

5.15 Benchmarks of road decongestion costs

City	Source	Description	Estimate of cents per avoided VKT	Year (year of prices)
Sydney	IPART	Avoided costs from reduced road use (time, VOCs, reliability and environmental externalities)	55	2016 (2016 prices)
Sydney	TfNSW	Costs of extra road use for other users (time, VOCs, reliability and environmental externalities)	36	2016 (2016 prices)
Melbourne	ATAP/Victorian Department of Infrastructure	Costs of extra road use for other users (time, VOCs and reliability)	22 (off-peak) 22 (light peak) 84 (moderate peak) 118 (heavy peak)	2005 (2014 prices)
Melbourne	CIE calculated based on Melbourne Metro business case	Costs of extra road use for other users (time, VOCs and reliability)	120	2031 (2015 prices)
Christchurch	New Zealand Transport agency	Costs of avoided vehicles because of diversion to public transport (time, VOCs, crash costs, environmental externalities)	NZ 34 cents	2008 (unclear)
Wellington	New Zealand Transport agency	Costs of avoided vehicles because of diversion to public transport (time, VOCs, crash costs, environmental externalities)	NZ 100 cents	2008 (unclear)
Auckland	New Zealand Transport agency	Costs of avoided vehicles because of diversion to public transport (time, VOCs, crash costs, environmental externalities)	NZ 156 cents	2008 (unclear)

Sources: IPART 2016, *External benefits and costs*, Final report — Information paper 7: https://www.ipart.nsw.gov.au/files/sharedassets/website/shared-files/pricing-reviews-transport-services-publications-review-of-public-transport-fares-in-sydney-from-july-2016/external_benefits_and_costs_-_public_transport_fares_final_report_ip_7.pdf; TfNSW 2016, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, Table 21, http://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/principles-and-guidelines-for-economic-appraisal-of-transport-investment.pdf; ATAP 2018, *Australian Transport and Planning Assessment Guidelines*: M1 — Public Transport, https://atap.gov.au/mode-specific-guidance/public-transport/files/M1_Public_transport.pdf, Table 11; Public Transport Victoria 2016, *Melbourne Metro business case: Appendix 5,* https://metrotunnel.vic.gov.au/__data/assets/pdf_file/0020/40484/MM-Business-Case-Feb-2016-APPENDIX-05.PDF and CIE calculations; New Zealand Transport agency 2018, *Economic evaluation manual*, p 3-49, https://www.nzta.govt.nz/assets/resources/economic-evaluation-manual/economic-evaluation-manual/docs/eem-manual.pdf.

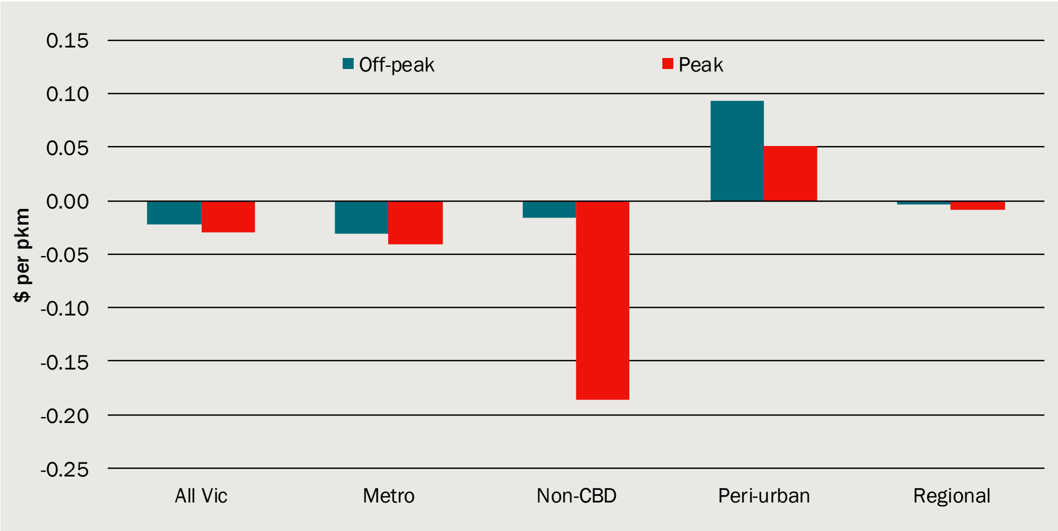
Marginal cost of crowding

Using the VITM modelling, we have estimated the marginal cost of crowding assuming no new services are provided. VITM crowding outputs are somewhat limited and include:

- total crowded IVT aggregated across all public transport modes, noting the VITM output does not report crowding for each mode separately
- total station crowding aggregated across all public transport modes
- maximum vehicle to capacity ratio by line for each public transport

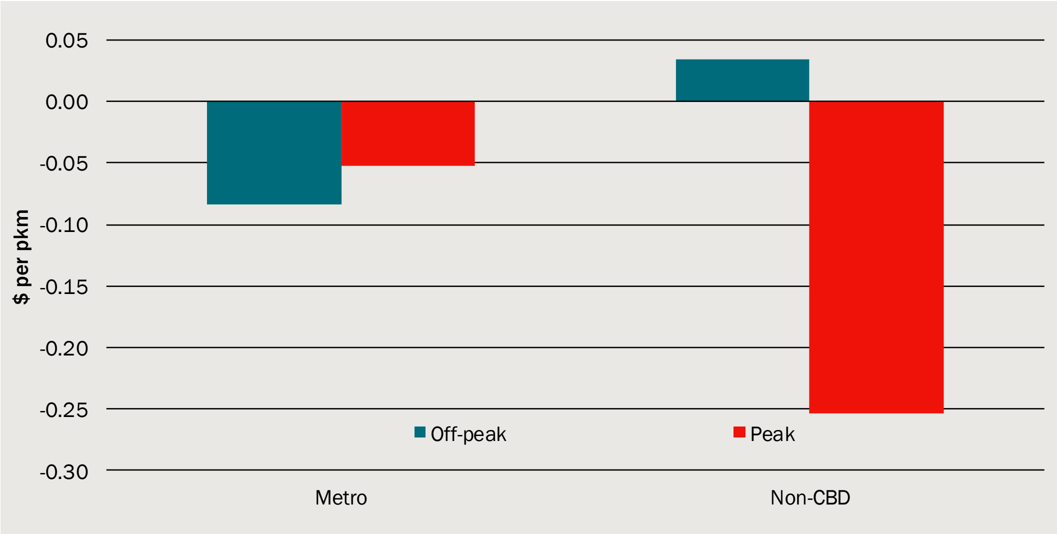
The VITM outputs limit the methodology to measure crowding and the change in crowding costs is not always in line with expectations. For instance, there is a positive crowding externality from additional peri-urban public transport trips for rail and bus (chart 5.16 and 5.18). Also, there is significant variation in the level of the crowding externality for different trip types. This variation is not consistent with expectations that trips in congested areas (i.e. in metropolitan areas and in the CBD) should have higher congestion costs and likely reflects the convergence error in VITM and are unlikely to be reliable estimates of crowding.

5.16 Rail crowding, IVT and wait



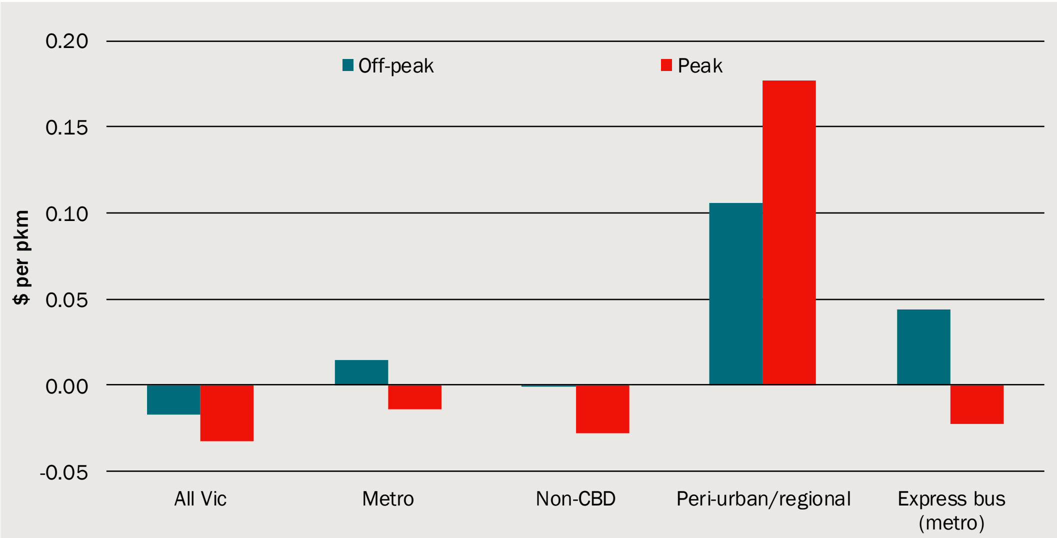
Data source: CIE and Jacobs.

5.17 Tram crowding, IVT and wait



Data source: CIE and Jacobs.

5.18 Express bus and bus crowding, IVT and wait



Data source: CIE and Jacobs.

VITM estimates of crowding by line

In addition to the aggregate crowding reported by VITM, vehicle capacity (VC) ratios by line have also been generated. This measures the maximum VC ratio, which is used by VITM for each line over the modelled period, which indicates the maximum level of crowding reached. We use adjusted VC ratios, which adjust capacity from the crush levels, which is the standard measure used by PTV (table 5.19). VITM uses adjusted capacity to detemin beahviour and giuves a more realistic measure of crowding.

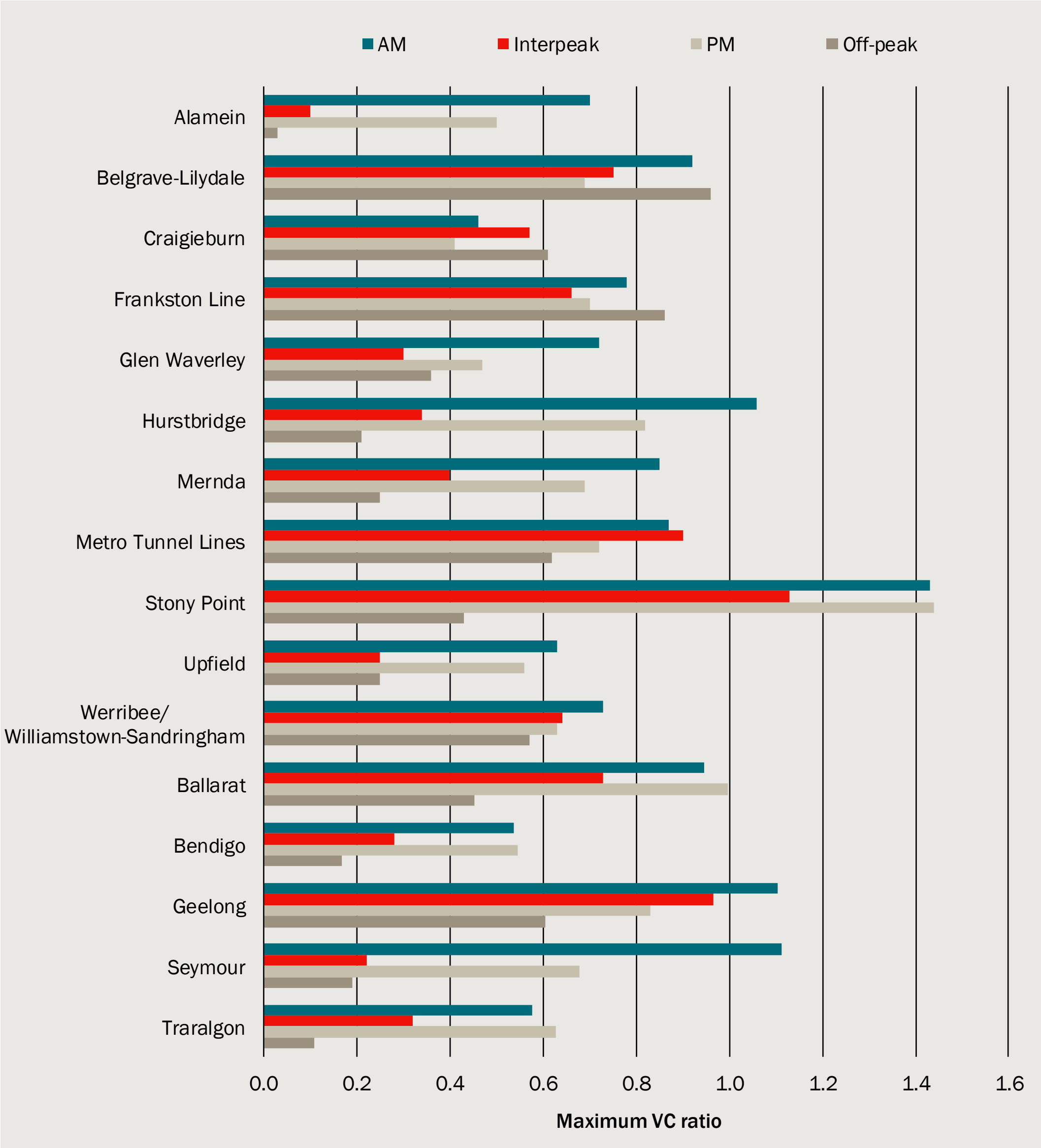
5.19 Adjusted capacity relationship to crush capacity

Mode	Per cent of Crush
Bus	90
Tram	50
Train (metro train)	70
VLine (regional train)	90

Source: Jacobs.

The results for rail lines are summarised in chart 5.20.

5.20 Train vehicle capacity rations by line, 2026 base case



Note: Vehicle capacity ratios are based on the adjusted crush used by VITM to determine levels of crowding and how the curves are applied

Data source: CIE, Jacobs.

Several of the results from VITM are puzzling:

- Werribee and Craigieburn lines have very low VC ratios, implying no crowding, despite frequent reports that these lines currently suffer from sever crowding. Some the crowding may be alleviated through infrastructure expected to be completed before 2026 (such as Melbourne Metro), however given these lines service population growth corridors, it seems highly unlikely crowding could completely be eliminated.
- Crowding across the day does not align with expectations – in some cases AM and PM crowding is reportedly lower than off-peak crowding.
- The overall levels of crowding appear to be low, which across the network does not seem realistic.

Crowding is likely low for the following reasons:

- The model assignment periods are 2 hours and all metrics are an average of the situation across this period. Average congestion is a lot lower than the congestion would be at the worse point during that period. For instance, over a two-hour peak period, severe crowding may only be experienced over a 30 minute period.
- Crowding metrics provided to you are also averaged across services that make up lines. On lines with many services there are big differences between crowding levels. For example, on the Frankston line is known that stopping services are usually very crowded whereas express services are typically a lot less busy.

The crowding measures from VITM appear to understate the actual levels of crowding. This result would imply the optimal response to increased patronage would be to leave services fixed and allow crowding to increase from already low level. We believe however, this approach will understate the crowding negative externality of increased patronage and in turn understate the MSC.

Other methods of estimating crowding costs

There are other ways to think about crowding costs intuitively. Suppose a new passenger boards a service at the start of the service. At this point, they will likely obtain a seat. However, closer to the CBD, as the service becomes more crowded, their obtaining a seat will mean someone who previous obtained a seat now has to stand. In table 5.21, we show the estimates of crowding cost from the displacement of someone from their seat. If someone is displaced for 15 minutes and a low disutility of standing is applied, this would be $1.9 per new passenger. A high estimate, assuming someone is displaced for 30 minutes and using a high disutility of standing gives $7.5.

5.21 Costs of crowding

	Low estimate	High estimate
Duration that service is crowded (minutes)	15	30
Cost of standing relative to seating (per cent)	45%	90%
Base value of time ($/hour)	16.63	16.63
Cost of crowding imposed on person losing their seat ($)	1.9	7.5

Note: The cost of standing of 45% is based on a standing factor of 1.65 less a crowded seating factor of 1.2. The cost of standing of 90% is based on a crush standing factor of 2.1 less a crowded seating factor of 1.2. (Sourced from ATAP M1, https://www.atap.gov.au/mode-specific-guidance/public-transport/files/M1_Public_transport.pdf.)

Source: CIE and sources noted above.

The externality from crowding will differ substantially depending on where the marginal person starts their service, particularly in the AM peak. If they start early in the service, they impose costs on others by taking their seat. If they start close to the CBD a large part of the crowding is internalised in the decision to use the service, as the person faces the crowding cost themselves.

Conclusions on crowding

The estimates of crowding from VITM are lower than the estimates of the cost of increasing services. However, there may be other ways crowding impacts that have higher costs:

- the above estimate focuses on the person losing their seat. However, others may also face impacts because their standing space is smaller/more crushed
- high levels of crowding may have negative impacts on station/stop amenity, as well as the crowding impacts on the vehicle itself
- high levels of crowding may disrupt the reliability of the service, because vehicles have higher dwell times as people try to exit and enter vehicles
- high levels of crowding may lead to people being displaced to the next service altogether.

Offsetting this is that many services will not have any crowding penalty. Only services in a small part of the AM and PM peaks going to the CBD will tend to be crowded.

Given the limitations in the VITM modelling of crowding, our view is that the social marginal cost estimates should focus on the scenario where services are increased where they reach a crowding threshold of 0.7, and additional capacity is provided for infrastructure as required.

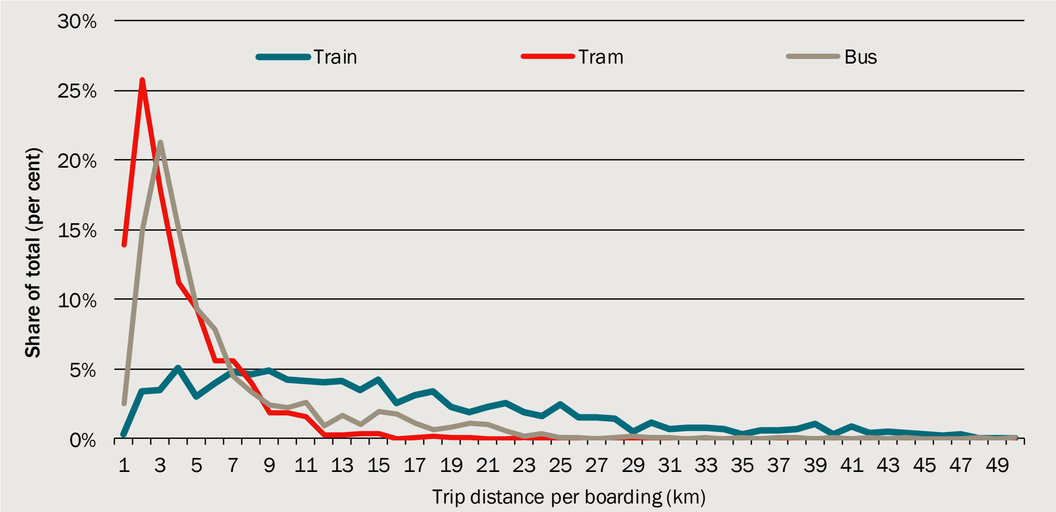
Distance based runs

VITM runs have been undertaken to assess MSC for short and long-distance trips. This consists of re-estimating VITM with a distance-based fare structure and then fares for trips below a certain distance threshold. This allows MSC to be estimated for short and long trips (this is done by taking the difference between reducing fares for all trips and for short trips).

Distance cut offs we based on median trip distances estimated from VISTA. The trip distance distributions vary considerably across public transport modes, with train distances more dispersed and tram and bus trips tightly distributed below 10km (chart 5.22).

Different cut-offs were chosen for each mode and are summarised in table 5.23, along with summary statistics calculated from VITM and VISTA data.

5.22 Distribution of trip distance by mode



Note: Trips above 100km have been excluded, and only distances below 50km are shown in the graph.

Data source: VISTA, CIE.

5.23 Trip distance per boarding

	Train	Tram	Bus	Train, tram and bus
	km	km	km	km
Mean (VITM)	14.7	2.6	5.9	na
Mean (VISTA)	16.4	3.4	5.9	11.2
Median (VISTA)	12.9	2.6	3.7	7.1
25th percentile (VISTA)	7.3	1.4	2.4	3.0
75th percentile (VISTA)	21.6	4.6	7.0	15.3
Distance cut-off modelled in VITM	**10**	**2**	**4**	

Note: VISTA data trips above 100km have been excluded from analysis.

Source: VISTA, Jacobs, CIE.

To undertake modelling Jacobs constructed a distance-based fare structure in VITM which approximates the current fare structure and provides enough flexibility to implement the distance-based fare structure scenarios. Base case and metropolitan scenarios (i.e. reducing fares for all metropolitan trips) were undertaken to provide a comparator with the same fare structure.[52]

Summary model outputs are shown in table 5.24.

The distance of marginal car and public transport trips for short trip scenarios compared to all metropolitan trips are generally as expected for marginal new public transport trips. However, marginal tram trips are very short (10 metres) which seems implausible. This likely reflects:

- the difficulty of modelling short public transport trips, which are close substitutes for walking, without VITM modelling walking as a separate mode
- convergence issues for public transport in VITM. The short trip tram scenario results in an additional 147 pkm travelled by tram during the AM peak, which we expect is within VITMs' convergence error and therefore unreliable. If the change in AM tram pkm was an additional 5 000 pkm travelled during the AM peak (the convergence error for the VITM road iterations), the marginal trip distance would be a more plausible 300 metres.

Similarly, the results for marginal car distances for the short trips run, appear to be implausible for tram and bus, with the distance of lost car trips significantly shorter than the new public transport trips. Where this is the case, we have assumed that the marginal distance of lost car trips is 75 per cent of the new marginal public transport trip distance.

The road decongestion parameters are similar for short and all metropolitan trip scenarios for rail and bus, while the road decongestion benefits are lower for short tram trips than all tram trips. We expect the tram result is related to longer marginal car trip distance noted above as well as VITM convergence issues.

5.24 Short trips compared to base case trips

AM peak		Rail	Tram	Bus
		km	km	km
Marginal car distance	Short	3.78	2.11	3.96
Marginal car distance	All metropolitan trips	8.78	1.33	3.53
		km	km	km
Marginal new PT trip distance	Short	0.33	0.01	1.38
Marginal new PT trip distance	All metropolitan trips	15.16	1.89	4.19
		$/VKT	$/VKT	$/VKT
Road decongestion	Short	-1.37	-2.08	-1.64
Road decongestion	All metropolitan trips	-1.48	-3.49	-1.61

Note: The base case results are based on the distance-based fare structure which approximates the current fare structure. This does not precisely match non-distance-based results because of the approximate nature of the distance-based fare structure.

Source: CIE and Jacobs.

52 The precise modelled outputs between the original VITM fare structure and the distance-based fare structure do not match perfectly because of the approximated nature of the distance-based fare structure.

6 Marginal social cost results

The marginal social cost of public transport is the marginal financial cost less the net externalities. For example, if the marginal financial cost is $10 per trip, and the net positive externalities from public transport use are $4 per trip, then the marginal social cost is $6 per trip.

The level and pattern of the marginal social cost is one indicator of the efficient level and variation of fares. It therefore provides a guide as to how fare structures should vary from an economic perspective across modes and different types of trips.

The marginal social costs only account for switching between modes. It does not account for switching between times of day. For example, having a lower off-peak rail fare may induce some people to switch from peak rail travel to off-peak rail travel. The impacts from this type of behavioural substitution are not measured.

Main results

Marginal financial costs

The marginal financial costs, allowing for an expansion of services on crowded services, are shown in tables 6.1 and 6.2.

On a passenger kilometre basis, the cost of additional rail patronage during peak periods is $0.90 across all regions. This is largely from additional capital costs.

Trams have a higher cost compared to rail per additional passenger kilometre, of which about two thirds capital costs. Infrastructure costs for tram are broadly in line with rail infrastructure costs, however usage costs per pkm for tram are significantly higher due to shorter marginal trip distances. Usage costs per trip are similar for rail and tram, although marginal tram trips tend to be much shorter than marginal rail trips.

Buses have a lower cost, as many bus lines do not require additional services, even in peak periods. This reflects:

- the significantly lower cost of bus infrastructure compared to tram and, in particular, rail infrastructure as it consists primarily of new buses
- the significantly lower cost per bus service km compared to train (service costs are similar to tram)
- the low level of crowding on bus services, many bus services operate at very low levels of crowding so are able to increase patronage with small, or no, increase in services.

This may imply that there could be a costs savings (with minimal impacts on existing users or external cost) from rationalising bus services, as capacity utilisation appears to be low.

During off-peak periods, marginal financial costs are low across all modes, at about 10 cents per pkm for bus and rail. Tram costs are again higher as usage costs per trip are similar to rail, but average trip distances are much shorter.

6.1 Marginal financial costs, allowing for service expansion, per pkm

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/pkm	$/pkm	$/pkm	$/pkm
Peak	Metropolitan	-1.2	-1.7	-0.6	-0.6
Peak	Peri-urban	-0.4	na	na	-0.3
Peak	Regional	-0.2	na	na	na
Peak	Destination elsewhere than CBD	-1.3	-2.2	na	-0.6
Peak	All trips	-0.9	na	na	-0.6
Off-peak	Metropolitan	-0.1	-0.6	-0.1	-0.1
Off-peak	Peri-urban	0.0	na	na	0.0
Off-peak	Regional	-0.1	na	na	na
Off-peak	Destination elsewhere than CBD	-0.1	-0.8	na	-0.1
Off-peak	All trips	-0.1	na	na	-0.1
All day	Metropolitan	-0.5	-1.0	-0.3	-0.3
All day	Peri-urban	-0.2	na	na	-0.1
All day	Regional	-0.1	na	na	na
All day	Destination elsewhere than CBD	-0.6	-1.4	na	-0.3
All day	All trips	-0.4	na	na	-0.2

Source: CIE and Jacobs.

Marginal financial costs per trip are shown in table 6.2. The reported values reflect the marginal trip distance for each mode. As regional trips tend to be much longer than other trips, financial costs per trip are significantly larger.

6.2 Marginal financial costs, allowing for service expansion, per trip

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/ trip	$/ trip	$/ trip	$/trip
Peak	Metropolitan	-13.8	-3.9	-4.0	-2.5
Peak	Peri-urban	-13.8	na	na	-3.1
Peak	Regional	-23.2	na	na	na
Peak	Destination elsewhere than CBD	-13.2	-3.6	na	-2.5
Peak	All trips	-13.9	na	na	-2.6

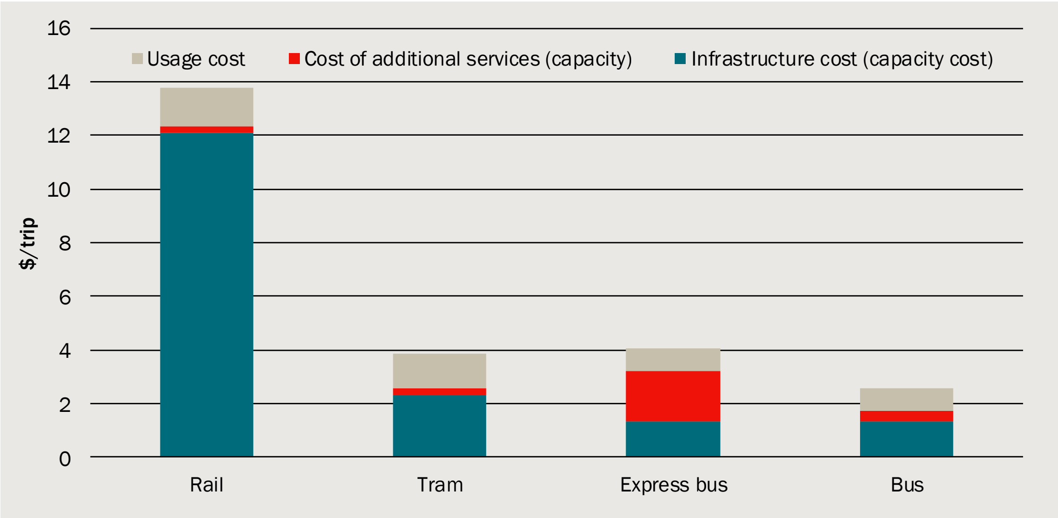
Time period	Region	Rail only	Tram only	Express bus only	Bus only
Off peak	Metropolitan	-1.5	-1.4	-0.5	-0.4
Off peak	Peri-urban	-1.4	na	na	-0.4
Off peak	Regional	-12.5	na	na	na
Off peak	Destination elsewhere than CBD	-1.4	-1.3	na	-0.4
Off peak	All trips	-1.7	na	na	-0.4
All day	Metropolitan	-6.4	-2.4	-1.8	-1.3
All day	Peri-urban	-6.4	na	na	-1.4
All day	Regional	-14.0	na	na	na
All day	Destination elsewhere than CBD	-6.2	-2.2	na	-1.2
All day	All trips	-6.6	na	na	-1.3

Source: CIE and Jacobs.

On a per trip basis, the marginal financial costs are significantly higher for rail than other modes (chart 6.3). This is primarily due to the large infrastructure costs associated with increasing infrastructure capacity.

Express bus also has a very large cost of providing additional services. This reflects the cost of providing additional public transport services to ensure crowding does not increase with an increase in demand. This cost is larger than the corresponding cost for all bus trips, as increased demand for express buses tends to result in additional crowding, as a greater proportion of express bus routes are currently crowded. Around 83 per cent of the increase in patronage for express buses occurs on already crowded services, compared to only around 33 per cent for bus trips. This means for each additional express bus passenger, a proportionally larger increase in services is required for crowding to remain at current levels.

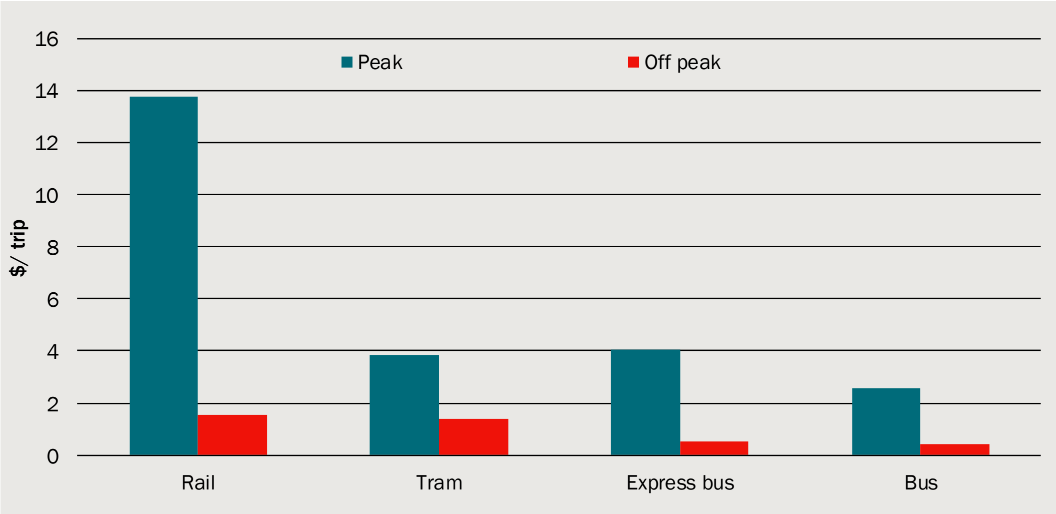
6.3 Marginal financial cost per trip – peak metropolitan



Data source: CIE and Jacobs.

The differences between modes are smaller during off-peak periods, which reflects less variation in usage costs across modes, compared to the difference in infrastructure costs (chart 6.4).

6.4 Marginal financial cost per trip- metropolitan



Data source: CIE and Jacobs.

Marginal externalities

The marginal externalities are shown in table 6.5. Marginal externalities are a mixture of positive and negative impacts from for public transport use relative to alternatives.

6.5 Marginal externalities, allowing for service expansion per pkm

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/pkm	$/pkm	$/pkm	$/pkm
Peak	Metropolitan	0.2	1.1	0.5	1.2
Peak	Peri-urban	-0.1	na	na	0.0
Peak	Regional	0.0	na	na	na
Peak	Destination elsewhere than CBD	0.1	2.1	na	0.9
Peak	All trips	0.3	na	na	0.8
Off-peak	Metropolitan	-0.1	-0.4	0.1	0.1
Off-peak	Peri-urban	0.0	na	na	0.1
Off-peak	Regional	0.0	na	na	na
Off-peak	Destination elsewhere than CBD	-0.2	-0.7	na	0.1
Off-peak	All trips	0.0	na	na	0.1
All day	Metropolitan	0.1	0.4	0.3	0.7
All day	Peri-urban	0.0	na	na	0.1

Time period	Region	Rail only	Tram only	Express bus only	Bus only
All day	Regional	0.0	na	na	na
All day	Destination elsewhere than CBD	0.1	0.7	na	0.5
All day	All trips	0.1	na	na	0.5

Source: CIE and Jacobs.

Positive benefits are generally related:

- reduced road decongestion
- reduced environmental externalities and reduced accidents from reduced private car use
- increase in the frequency of public transport
- reduced excess burden of taxation from the marginal public transport trip

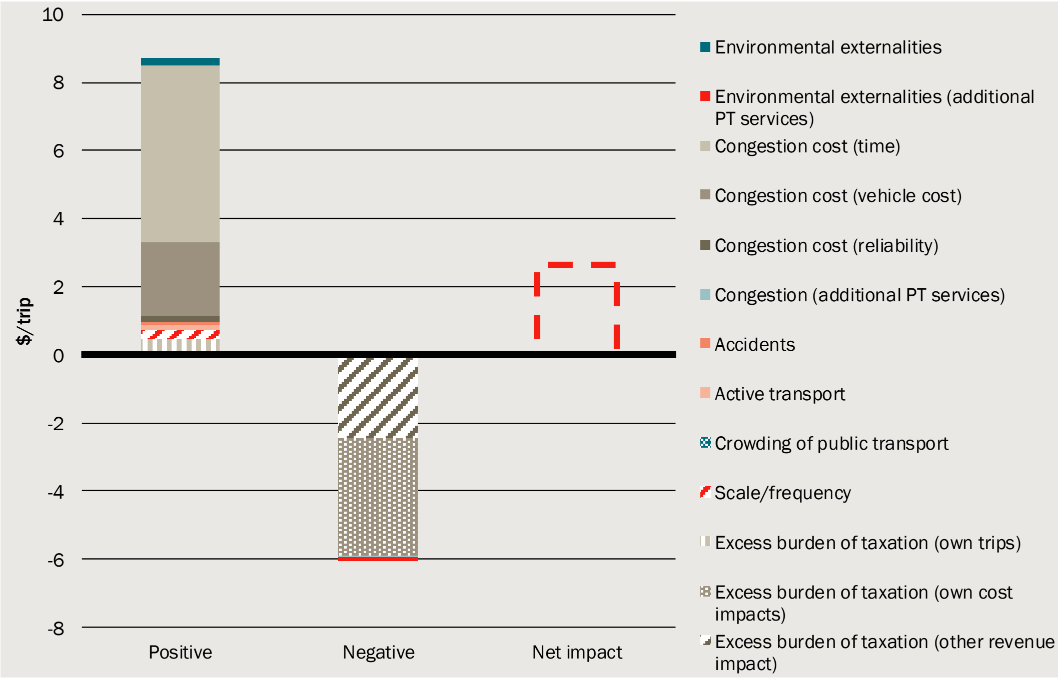
Negative benefits are generally related to:

- increased excess burden of taxation from the lower fare required to induce the marginal trip
- increased excess burden of taxation from higher infrastructure and operating costs
- increased environmental externalities and increased road congestion from additional public transport services.

Where externalities are positive, they tend to be dominated by road decongestion benefits (for instance for peak metropolitan rail trips). Where externalities are negative, they tend to be dominated by the marginal excess burden of taxation (for instance for peak peri-urban rail trips).

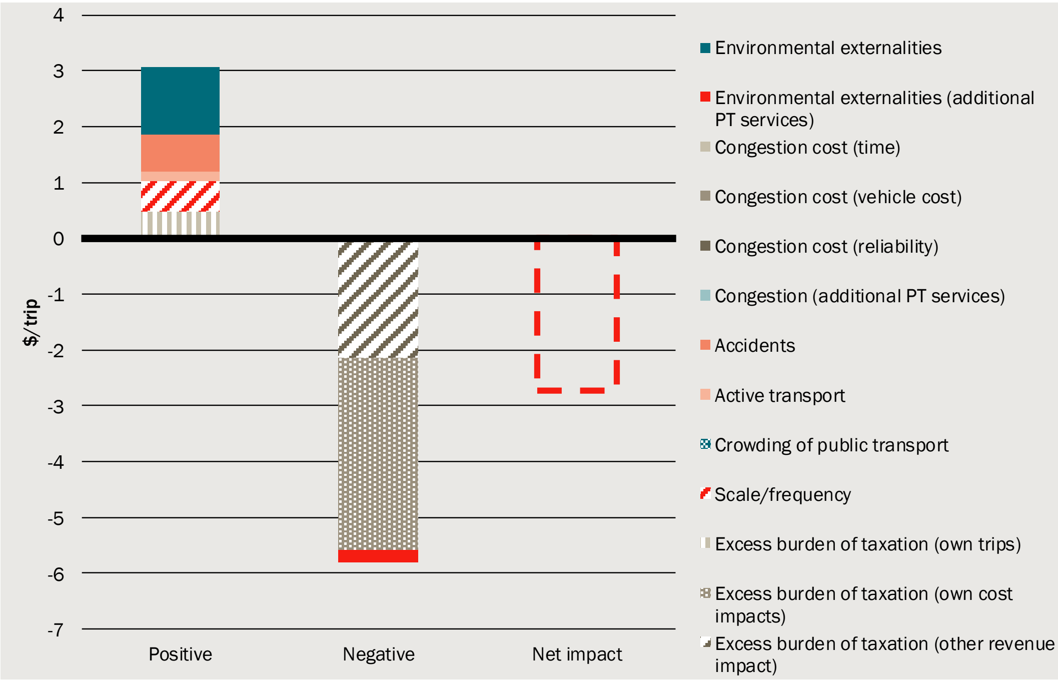
For example, each metropolitan peak rail trip travelled has a marginal external benefit of $2.7 (chart 6.6). However, a peak peri-urban trip has a negative externality of $2.7 per trip— because there are no road decongestion externalities, the positive impacts are estimated to be small and the financial costs result in a higher excess burden of taxation (chart 6.7).

6.6 Rail peak metropolitan externalities



Data source: CIE and Jacobs.

6.7 Rail peak peri-urban externalities



Data source: CIE and Jacobs.

Marginal external benefits for public transport use are substantially higher during peak periods than off-peak periods and higher for metropolitan trips compared to regional and peri-urban trips. This reflects the interpretation of the VITM modelling results:

- the change in travel time between the base case and the scenarios estimated in VITM was found to be within the VITM's convergence error for interpeak and evening periods. This has been interpreted as their being small or no road decongestion benefits during these periods; accordingly, road decongestion benefits have been set to zero during the off-peak. This is likely to understate positive externalities, as there is likely to be some decongestion benefit, however VITM does not allow us to estimate this with any precision.
- Similarly, the change in travel times compared to the base case for regional and peri-urban runs was close to the convergence error of the model. We have chosen to also set the decongestion benefits for regional and peri-urban trips to zero. Again, there is likely to be some decongestion benefit, especially for trips which go into metropolitan areas, however VITM does not allow us to estimate this accurately.

Because of these modelling results, the off-peak, regional and peri-urban trips, the externality result is primarily driven by the excess burden of taxation measure. The excess burden of taxation has a very large impact on the externalities for each mode and time period and the results are sensitive to the chosen excess burden of taxation parameter.

Externalities on a pkm basis tend to be larger for tram and bus trips than for rail. This is likely to reflect the impact of bottlenecks in the network. New tram and bus trips are likely to displace car trips from the CBD or other bottlenecks in the road network in which case the decongestion cost is large per pkm travelled, as tram and bus trips tend to be short. Although rail trips may displace car trips from the same bottlenecks, as average rail trips are longer, the decongestion benefit per pkm travelled is lower.

Externalities for metropolitan bus and tram trips per pkm travelled are similar during peak periods and are both more than two times the size of externalities for express bus trips per pkm travelled. VITM modelling suggests the change in express bus fares results in a very small decrease in the number of car trips, which is generally an important source of positive externalities for public transport. It is difficult to assess whether this finding is economically meaningful, as the change in car trips related to an express bus fare reduction lies within the convergence error of VITM (discussed in the executive summary).

Externalities are shown on a per trip basis in table 6.8. Like marginal financial costs, the differences across modes and trip types reflect a combination of the differences in externalities per pkm, as well as differences in marginal trip distances. Rail trips tend to have larger externalities per trip as car trips displaced by rail tend to be longer.

6.8 Marginal externalities, allowing for service expansion per trip

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/trip	$/trip	$/trip	$/trip
Peak	Metropolitan	2.7	2.4	3.3	4.9
Peak	Peri-urban	-2.7	na	na	0.1
Peak	Regional	2.4	na	na	na
Peak	Destination elsewhere than CBD	1.5	3.4	na	3.5
Peak	All trips	4.0	na	na	3.6
Off peak	Metropolitan	-1.1	-1.0	0.4	0.5
Off peak	Peri-urban	-0.4	na	na	1.3
Off peak	Regional	3.4	na	na	na
Off peak	Destination elsewhere than CBD	-2.2	-1.1	na	0.6
Off peak	All trips	-0.8	na	na	0.7
All day	Metropolitan	1.6	0.9	2.1	3.4
All day	Peri-urban	-1.3	na	na	1.0
All day	Regional	3.2	na	na	na
All day	Destination elsewhere than CBD	0.7	1.1	na	2.4
All day	All trips	2.3	na	na	2.7

Source: CIE and Jacobs.

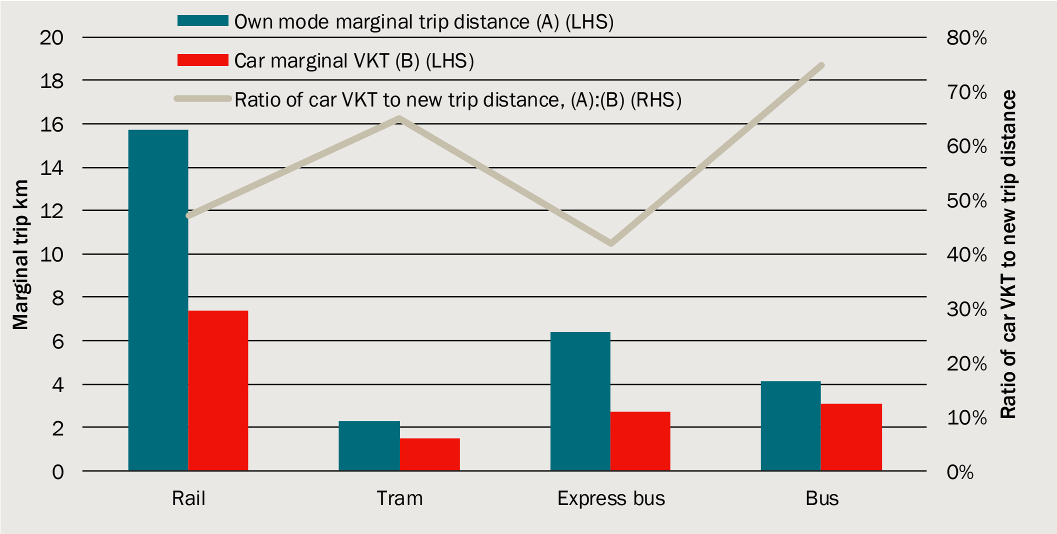
The externality for buses is generally larger than for rail, tram or express buses. This is due the large decongestion parameter per trip for buses, but also because of the response of VKT to an additional bus trip (chart 6.9).

A marginal bus trip is 3.4 km, and displaces a car trip of 3.1 km, which is around 90 per cent of the new public transport trip. If the marginal car trip was proportionally lower, like other public transport modes, the decongestion benefit would be lower as it is calculated as:

$$Decongestion\ benefit = Marginal\ car\ VKT \times marginal\ cost\ of\ congestion\ per\ VKT$$

In addition to this, the externality for buses is greater than for trams due to the shorter distance per tram trip, and express buses due to their proportionally small externality per express bus pkm.

6.9 Marginal trip distance, peak metropolitan trips



Data source: CIE and Jacobs.

Marginal social costs

The marginal social costs are presented in table 6.10. The marginal social cost in the peak for metropolitan rail is $1 per pkm. In contrast, the cost per passenger kilometre for trams is substantially higher, and for bus is close to zero.

6.10 Marginal social costs, allowing for service expansion

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/pkm	$/pkm	$/pkm	$/pkm
Peak	Metropolitan	-1.0	-0.6	-0.1	0.6
Peak	Peri-urban	-0.5	na	na	-0.3
Peak	Regional	-0.2	na	na	na
Peak	Destination elsewhere than CBD	-1.1	-0.1	na	0.3
Peak	All trips	-0.6	na	na	0.2
Off-peak	Metropolitan	-0.2	-1.0	0.0	0.0
Off-peak	Peri-urban	-0.1	na	na	0.1
Off-peak	Regional	-0.1	na	na	na
Off-peak	Destination elsewhere than CBD	-0.3	-1.6	na	0.0
Off-peak	All trips	-0.1	na	na	0.1
All day	Metropolitan	-0.4	-0.6	0.1	0.4
All day	Peri-urban	-0.2	na	na	0.0
All day	Regional	-0.1	na	na	na
All day	Destination elsewhere than CBD	-0.5	-0.7	na	0.3
All day	All trips	-0.3	na	na	0.3

Source: CIE and Jacobs.

On a per trip basis the marginal social cost is significantly larger for rail, compared to the other modes (chart 6.11). This is primarily due to longer marginal trips, and the significantly higher financial costs, in particular during peak periods.

6.11 Marginal social costs, allowing for service expansion per trip

Time period	Region	Rail only	Tram only	Express bus only	Bus only
		$/trip	$/trip	$/trip	$/trip
Peak	Metropolitan	-11.1	-1.4	-0.7	2.3
Peak	Peri-urban	-16.5	na	na	-3.0
Peak	Regional	-20.9	na	na	na
Peak	Destination elsewhere than CBD	-11.7	-0.2	na	1.0
Peak	All trips	-10.0	na	na	1.0
Off peak	Metropolitan	-2.6	-2.4	-0.1	0.1
Off peak	Peri-urban	-1.8	na	na	0.9
Off peak	Regional	-9.1	na	na	na
Off peak	Destination elsewhere than CBD	-3.6	-2.5	na	0.2
Off peak	All trips	-2.5	na	na	0.3
All day	Metropolitan	-4.8	-1.4	0.4	2.1
All day	Peri-urban	-7.7	na	na	-0.4
All day	Regional	-10.9	na	na	na
All day	Destination elsewhere than CBD	-5.5	-1.1	na	1.2
All day	All trips	-4.2	na	na	1.4

Source: CIE and Jacobs.

The key implication of these results are:

- MSC varies considerably across modes, which supports the use of more specific mode pricing. It implies that fares for rail should generally be greater than tram fares on a per trip basis, which in turn should be greater than bus fares.
- For bus the MSC is consistently positive. This suggests there is a enough bus capacity, such that the patronage could increase without incurring additional large infrastructure capacity costs. An alternative to increasing bus patronage on underutilised services, could be to rationalise existing services. The costs savings from reducing bus services could be larger than the social benefits of increasing demand.[53]
- For rail and express bus, MSC is higher during peak periods. This implies that peak fares should generally be greater than off-peak fares.
- For tram and bus only, MSC is lower during peak periods. On face value, this implies that prices should be lower during peak periods and higher during off-peak periods.

53 The analysis assumes the public transport services as is and does not assess whether the current public transport services are optimal. A positive MSC may imply there would be benefits from rationalising services.

These results do not consider the impacts of passengers changing their time of travel. We believe this result is due to the large decongestion benefits associated with tram and bus trips during peak periods. The model does not measure the negative externality of increased crowding, but instead assumes that services are increased to accommodate the increased demand. This may indicate that marginal financial costs are understated. This is assessed in sensitivity testing.

- The distance-based runs for rail and tram indicate that MSC is higher for short distances than for all metropolitan trips (table 6.12). This implies that financial costs increase slower than marginal costs, as distance travelled increases, and:
  - financial costs are related to capacity issues at the centre of the network (i.e. public transport capacity around the CBD) and are broadly the same regardless of the distance of the trip
  - congestion impacts are more widespread for the road network than for the public transport network, such that reducing car use across the network has a larger benefit than the negative externalities of additional public transport trips.

6.12 Marginal social cost distance-based runs

Time period	Trip type	Rail only	Tram only	Bus only
		$/trip	$/trip	$/trip
Peak	All metropolitan trips	-9.0	-1.7	1.2
Peak	Short distance trips	-15.5	-1.8	1.6
Off-peak	All metropolitan trips	-2.8	-2.4	-1.2
Off-peak	Short distance trips	-3.9	-2.2	-1.4
All day	All metropolitan trips	-3.8	-1.6	0.9
All day	Short distance trips	-8.0	-1.6	1.2

Source: CIE and Jacobs.

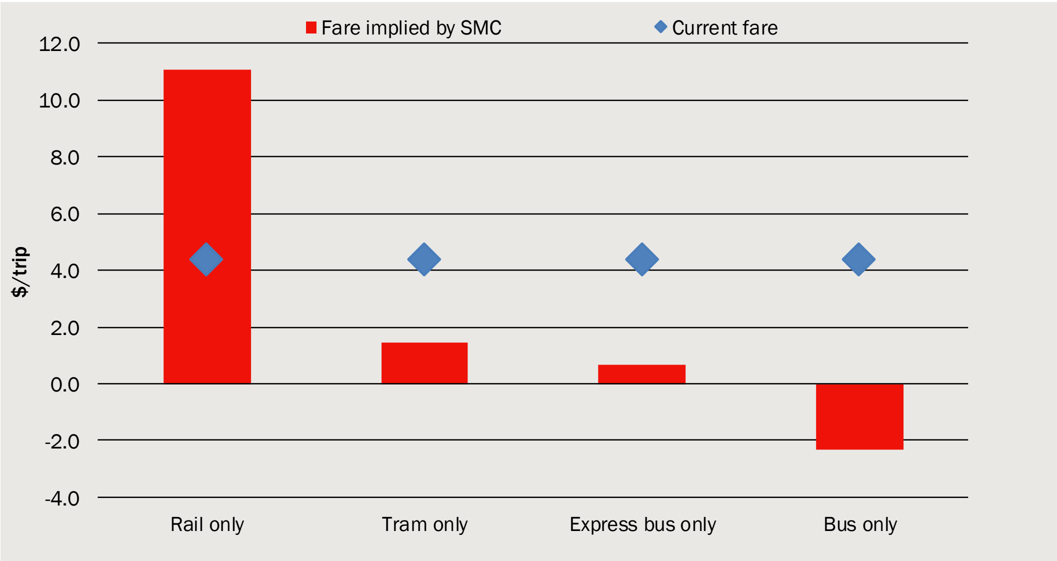
Comparison to the current fare structure

Fares implied by the MSC analysis are shown in charts 6.13 and 6.14 alongside current fares. Current fares are constant across different modes and times of day, reflecting the current fare structure.

The MSC estimated fares imply:

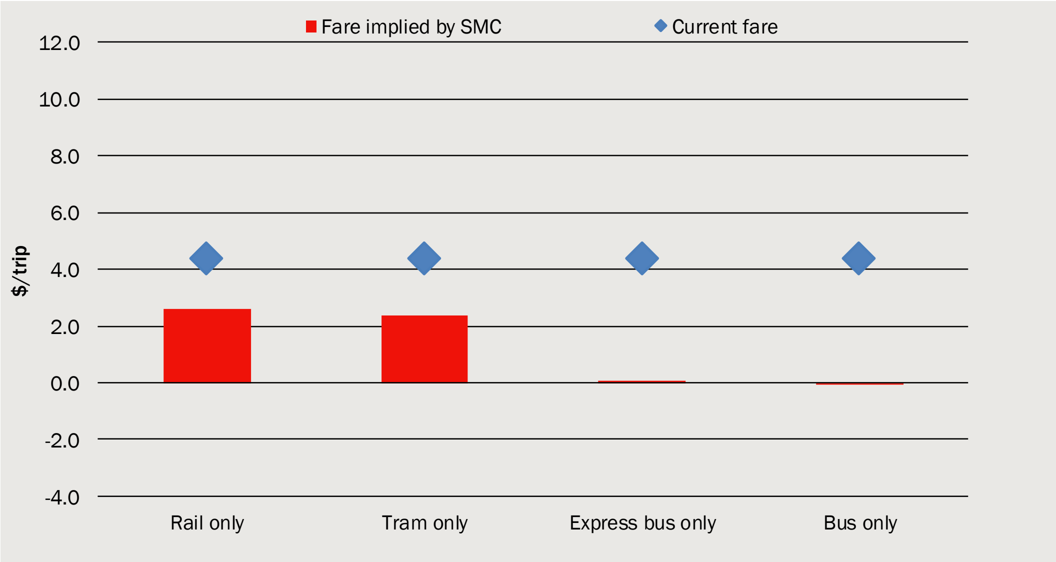
- peak rail fares should be significantly higher than the current fare structure
- tram, bus and express bus fares should be lower than the current fare structure during peak periods
- off-peak fares should than the current fare structure for all modes
- off-peak rail, bus and express bus fares should be lower than peak fares, while off-peak tram fares should be around the same level as peak fares.

6.13 Metropolitan, peak



Data source: CIE and Jacobs.

6.14 Metropolitan, off-peak



Data source: CIE and Jacobs.

The result of peak tram and bus fares implied by MSC being lower than the current fare structure appears to primarily be due to lower financial costs, compared to rail and capital costs, and higher road decongestion benefits per pkm.

Train trips have a decongestion benefit of $0.65 per pkm, compared to $1.69 and $1.30 per pkm for tram and bus respectively, which means that comparatively shorter bus and tram trips have a disproportionate impact on road congestion (table 6.15). This is based on the decongestion benefits measured from VITM and the marginal trip distances also measured from VITM.

If on a per km basis tram and bus trips had the same decongestion impact as a train trips, the implied fares would be around 150 per cent higher.

6.15 Peak metropolitan decongestion costs

	Train	Tram	Express bus	Bus
	$ per pkm	$ per pkm	$ per pkm	$ per pkm
Congestion cost (time)	0.45	1.06	0.51	0.92
Congestion cost (vehicle cost)	0.19	0.60	0.20	0.35
Congestion cost (reliability)	0.01	0.04	0.02	0.03
Total	**0.65**	**1.69**	**0.73**	**1.30**

Source: CIE and Jacobs.

The result of MSC implied off-peak tram fares being greater than peak fares is surprising as financial costs are much larger during peak periods (more than 2 times greater than off-peak tram costs). This result appears to be due to a large excess burden of taxation from lost changes in public transport fare revenue as well as toll, parking and fuel excise revenue; normally this negative externality is larger during peak periods, when more car trips are diverted to PT. Given this is related to estimated changes in road traffic from

VITM, which we have found are generally within VITM's convergence error during off-peak periods, we believe this result may be due to transport model convergence issues.

Main drivers of differences across modes and times of day

In the MSC cost model, there are three key inputs which drive differences across modes and time periods:

- parameters measured from VITM, including road decongestion and lost revenue for marginal excess burden calculations. Generally, these parameters are larger during peak periods and vary across modes.
- marginal trip distances for lost car trips, measured from VITM. Marginal car trips avoided tend to be smaller during peak periods compared to off-peak periods, which all else equal would increase MSC during peak periods and varies considerably across different modes.
- marginal financial cost estimates, which are driven by:
  - changes in demand from VITM,
  - cost estimates
  - costs attribution to peak and off-peak periods,
  - discount rates, and
  - the methodology used to measure marginal financial costs (Turvey method or the AIC method).

  Costs are generally higher for peak periods and vary considerable across modes.

All three components rely on estimates from VITM; insofar the results from VITM are not significant for some scenarios, we must be careful to not overinterpret results.

Sensitivity Testing

Given the main drivers of differences in MSC estimates, we have undertaken some sensitivity tested to assess the impact of these assumptions on results. This has considered:

- High and low MEBT estimates
- Using benchmark decongestion parameters
- Using AIC to estimate marginal financial costs as opposed to the Turvey method
- High and low discount rates

Results of the sensitivity testing are shown in tables 6.16 and 6.17 for metropolitan MSC for peak and off-peak periods respectively.

6.16 Metropolitan peak sensitivity tests

	Train	Tram	Express bus	Bus
	$ per trip	$ per trip	$ per trip	$ per trip
Core results	-11.1	-1.4	-0.7	2.3
Low MEBT (8 per cent)	-7.4	-0.4	-0.1	2.7
High MEBT (52 per cent)	-16.9	-3.2	-1.7	1.7
ATAP decongestion parameters for Melbourne	-13.8	-3.0	0.5	1.3
Use AIC to measure MFC	-31.3	-5.8	-3.7	-0.3
Low discount rate (4 per cent)	-3.4	0.1	0.2	3.2
High discount rate (10 per cent)	-19.6	-3.1	-1.6	1.3

Source: CIE and Jacobs.

6.17 Metropolitan off-peak sensitivity tests

	Train	Tram	Express bus	Bus
	$ per trip	$ per trip	$ per trip	$ per trip
Core results	-2.6	-2.4	-0.1	0.1
Low MEBT (8 per cent)	-1.4	-1.5	-0.1	0.2
High MEBT (52 per cent)	-4.5	-3.8	0.0	-0.1
ATAP decongestion parameters for Melbourne	-1.5	-1.9	0.6	1.4
Use AIC to measure MFC	-2.6	-2.4	-0.1	0.1
Low discount rate (4 per cent)	-2.6	-2.4	-0.1	0.1
High discount rate (10 per cent)	-2.6	-2.4	-0.1	0.1

Source: CIE and Jacobs.

Overall, these results demonstrate that results are very sensitivity to several assumptions.

- The choice of approach to measure marginal costs has the largest impact on MSC during peak periods (this impacts infrastructure capacity costs which are only attributed to demand in peak periods). The AIC results in a much higher marginal cost compared to the Turvey method (used for the core results). Using the AIC approach more than doubles the MSC across modes.
- Discount rates have an impact on MSC during peak periods as this is used to estimate the marginal financial costs of increasing public transport infrastructure capacity; this does not impact off-peak periods as capacity costs are only attributed to peak periods. Lower discount rates reduce MSC by reducing the cost of future infrastructure investments.
- MEBT has a large impact on MSC, as increasing patronage generally results in increased cost to government. The economic cost of raising taxes to finance higher public transport patronage, therefore has a large impact on results. Choosing higher or lower MEB has similar impacts across modes and between peak and off-peak periods.
- ATAP decongestion parameters imply significantly lower costs of congestion than estimates from VITM. This results in higher MSC during peak periods and lower MSC during off-peak periods, noting that the cost of congestion in the core results is set to zero for off-peak periods due to convergence issues in VITM.

The level of MSC is highly sensitivity to a number of methodological assumption, in particular the approach to measure marginal infrastructure costs. While we may prefer one approach to another, there is ultimately no right or wrong approach, as we use these techniques to approximate a marginal cost which is not observable. Therefore, caution must be used in directly mapping MSC cost estimates directly to fares, as these issues cast some uncertainty on the level of MSC.

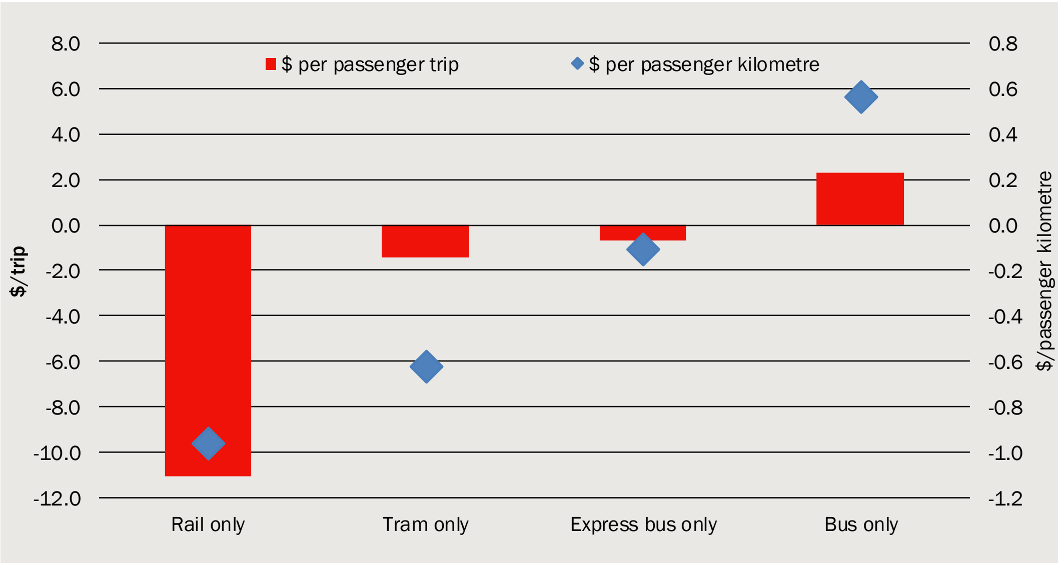
7 Policy implications

Is mode-based pricing justified?

The marginal social cost varies considerably across modes, which supports the use of more specific pricing. It implies that fares for rail should generally be greater than tram fares, which in turn should be greater than bus fares during peak periods (chart 7.1). During off-peak periods, the difference between rail and tram costs per trip is significantly lower, as tram as a much larger social cost per pkm (chart 7.2).

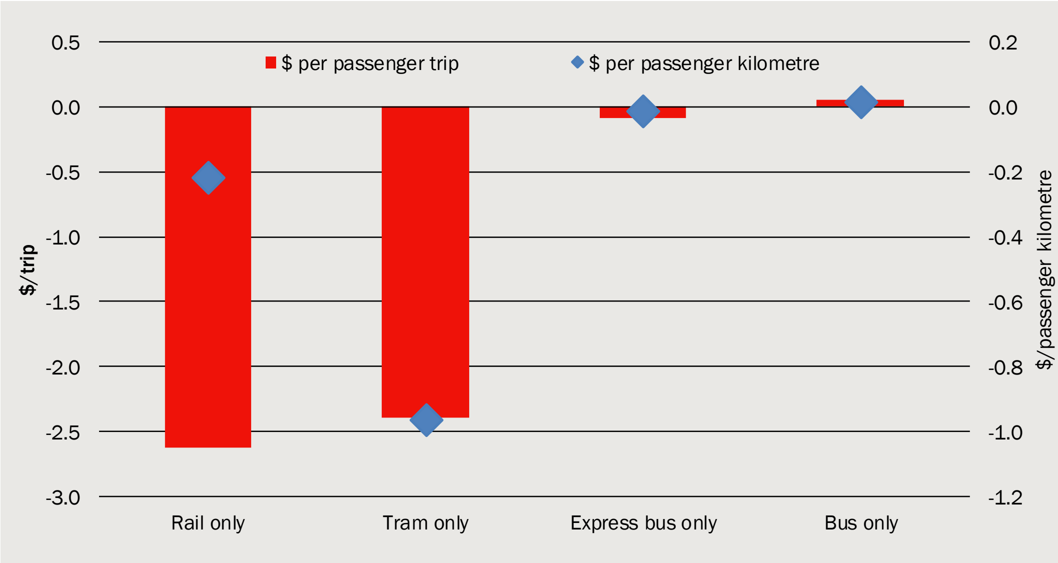
On a per passenger km basis many of the externality values are similar across mode, however the large differences in trip distances translate to differences in MSC across modes.

7.1 Social marginal cost – metropolitan peak



Data source: CIE and Jacobs.

7.2 Social marginal cost – metropolitan off-peak



Data source: CIE and Jacobs.

Is peak/off-peak pricing justified?

There is a case for peak/off peak pricing. This is somewhat presupposed by our (reasonable) assumption that marginal infrastructure capacity costs are only incurred during peak periods, in particular for rail for which these costs are large (chart 7.3).

- For rail and express bus, MSC is higher during peak periods, which implies that peak fares should be generally be greater than off-peak fares. For these modes this is primarily due to changes in marginal financial costs between peak and off-peak periods.
- For tram and bus, MSC is lower during peak periods. We believe this is due to the characteristics of the tram network and the VITM model.
  - During peak periods, we expect a large proportion of tram use to be in the CBD free tram zone, such that changes in prices will not result in a change in behaviour.
  - During peak periods, there is also little substitution from car to tram trips, with a reduction in tram fares (one additional tram trip reduces car trips by 0.28 in the peak and 0.38 in the off-peak). Externalities are driven by public transport reducing car use, such that if peak tram use reduces car use by less than off-peak tram use, we would expect peak tram trips to have lower externalities, all else equal.
- For bus MSC is positive in both the peak and off-peak, and is higher during the peak period. This appears to be due to a large road decongestion benefit, which is larger than the increase in financial costs between the peak and off-peak.
- Where we take a weighted average of the metropolitan results for individual modes, MSC is higher during the peak periods (table 7.4). This suggests that even without mode specific pricing, peak and off-peak pricing would be supported.

Note that the modelling does not consider the impact of people switching their time of travel. This would further strengthen the case for higher peak prices.

7.3 Peak and off-peak social marginal cost - $ per trip

Data source: CIE and Jacobs.

7.4 Social marginal cost – metropolitan all modes

	MSC per pkm	MSC per trip
	$ per km	$ per trip
Peak	-0.78	-5.31
Off-peak	-0.27	-2.05
All day	-0.34	-2.39

Note: MSC for all modes is a weighted average of mode specific results. This assumes that the likelihood of a marginal trip being a given mode is proportional to the current number of trips or pkms travelled by the that mode.

Source: CIE and Jacobs.

Is distance-based pricing justified?

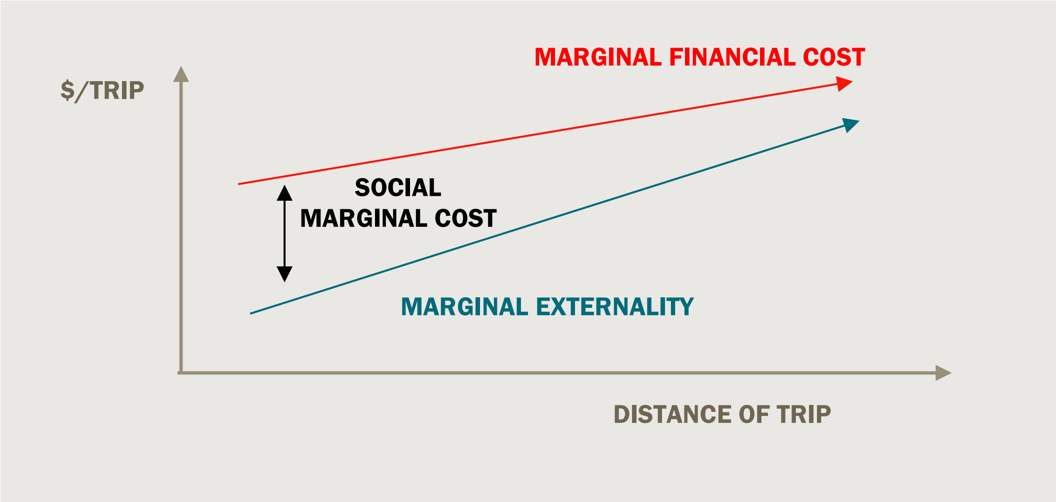
The case for distance-based pricing is not very strong. The externalities from public transport use tend to increase more steeply than the costs of providing services (chart 7.5).

- Marginal financial costs increase gradually for longer trips. However, a substantial part of these costs is for capacity issues in the centre of the network, are the same regardless of the distance of the trip, so long as it starts or ends in the CBD
- Marginal externalities increase more for longer trips than the marginal financial cost. This is because congestion impacts are more widespread for the road network than for the public transport network, and not just focused on the CBD

The outcome is that the marginal social cost may well be lower for longer trips. In this case there is no reason to support higher prices for longer trips.

These outcomes reflect that existing infrastructure is considered sunk, and we focus on the incremental costs required to address capacity. That is, we focus on the existing rail network. The costs of new infrastructure unrelated to capacity, such as the suburban rail loop, will tend to be much more costly per passenger trip for longer trips and locations more distant from the CBD.

7.5 Financial costs and externalities by trip distance



Data source: CIE.

The modelling result is consistent with this conclusion (table 7.6):

- For rail, short trip distances have a higher MSC than for metropolitan trips, which on average are longer.
- For bus and tram, MSC is broadly the same for short and metropolitan trips. This implies that financial costs increase broadly in line with externalities such that the MSC of different length trips is broadly the same.

7.6 Social marginal cost – metropolitan distance-based runs

Time period	Trip type	Rail only	Tram only	Bus only
		$/trip	$/trip	$/trip
Peak	All distance (short and long)	-9.0	-1.7	1.2
Peak	Short distance	-15.5	-1.8	1.6
Off-peak	All distance (short and long)	-2.8	-2.4	-1.2
Off-peak	Short distance	-3.9	-2.2	-1.4
All day	All distance (short and long)	-3.8	-1.6	0.9
All day	Short distance	-8.0	-1.6	1.2

Note: Externalities for all distance trips are measured using the same distance-based fare structure used to estimate the externalities for short distance trips.

Source: CIE and Jacobs.

A VITM modelling report

Please see attached Jacobs modelling report.

B Social marginal cost modelling assumptions

Table C.1 summarises the key assumptions used to quantify externalities.

C.1 Values for externalities

Item	Value	Sources
	Dollar values in June 2018 terms	
Value of time per occupant	Private: $16.63 per hour Business: $53.94 per hour Car occupancy: 1.39	ATAP Guidelines (M1 Public Transport 2018, PV2 Road Parameter Values) Escalated to June 2018 using all groups CPI for Melbourne Car occupancy from
Share of trips which are for business	Car: 5.0 per cent PT (all modes): 2.0 per cent	Calculated from VITM output of number of trips by type
Value time for heavy vehicles (includes freight and occupant)	$55.92 per hour	ATAP Guidelines (M1 Public Transport 2018, PV2 Road Parameter Values 2018), assumes: ▪ 50% of heavy vehicles are medium rigid trucks ▪ 50% of heavy vehicles are articulated 5 axle trucks
Crowding IVT factor (public transport)	IVT crowding factor: 1.45	ATAP Guidelines (M1 Public Transport 2018) for station and train crowding; calculated as the difference between standing and the crowding factor for services at 70-100 per cent of capacity
Crowded wait at station (public transport)	Wait crowding factor: 1.5	ATAP Guidelines (M1 Public Transport 2018)
Environmental externalities	See table C.2	Cars, trucks and buses: TfNSW Principles and Guidelines 2018 Tram: Arup - Cost of emissions for NSW Light Rail, Final Report, 19 November 2014 Train: Arup – Cost of emissions for Sydney Trains, Final Report, 2 April 2015
Accidents	$0.03 per VKT	TfNSW Principles and Guidelines 2018 Escalated to June 2018 using all groups CPI for Melbourne
Active transport health benefits	$0.19 per km	IPART External Benefits of Public Transport – Draft Report, December 2014, p 60 Escalated to June 2018 using all groups CPI for Melbourne
Social discount rate	7 per cent, with scope to specify alternative rates in the model	Victorian Department of Treasury and Finance Technical guidelines on economic evaluation

Item	Value	Sources
Evaluation period	10 years	

Source: As noted in table.

C.2 Environmental externality values

	Car	Rail	Tram	Bus	Truck	Included in analysis
	C/vkm	C/vkm	C/vkm	C/vkm	C/vkm	
Air pollution	3.3	137.8	41.7	37.3	12.5	Yes
GHG emissions	2.6	108.8	32.9	15.4	2.8	Yes
Noise	1.1	0.0	0.0	2.6	2.1	No
Water pollution	0.5	0.0	0.0	5.6	1.9	No
Nature and landscape	0.1	0.0	0.0	0.2	0.2	No
Urban separation	0.8	0.0	0.0	2.5	1.4	No
Upstream and downstream costs	4.5	0.0	0.0	23.1	11.1	No
Total	12.8	246.6	74.7	86.6	32.0	
Total included in analysis	5.9	246.6	74.7	52.7	15.3	

Note: All values are in June 2018 values

Source: TfNSW Principles and Guidelines 2018, Tram: Arup - Cost of emissions for NSW Light Rail, Final Report, 19 November 2014; Arup – Cost of emissions for Sydney Trains, Final Report, 2 April 2015

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