IPART

Independent Pricing and Regulatory Tribunal
New South Wales

OPAL FARES

2020-2024

EXTERNAL BENEFITS AND COSTS

Technical paper

February 2020

Public transport external benefits and costs

When people use public transport, they generate benefits for and impose costs on others. Economists call these 'externalities' or external costs and benefits because they are impacts that are not considered by the person when they decide how to travel.

The external *benefits* of a public transport journey reflect avoided costs to society such as reduced congestion on roads when a person chooses to take public transport instead of driving. When people use public transport they also impose some external *costs* on others including environmental pollution (eg, air pollution and greenhouse gas emissions). The externalities created by using public transport are:

▼ Avoided road congestion costs as a result of people using public transport instead of driving

▼ Environmental benefits including avoided air pollution, greenhouse gas emissions and noise pollution as a result of people using public transport instead of driving

▼ Avoided road accident costs as a result of public transport use instead of driving

▼ Scale benefits, which are the time savings to existing public transport passengers when new services are put on to meet increased public transport demand

▼ Active transport benefits, which are avoided costs on the health system as a result of increased walking/cycling to catch public transport.

Our previous analysis of transport externalities has found that, on average, each additional journey made by public transport generates a net benefit for society.

As part of this Opal review, we updated our measures of externalities from our 2016 review, and took into account submissions to our Issues Paper. We used our updated estimates to investigate the impact of different fare changes (both increases and decreases) on public transport externalities.

We expect our fare recommendations to have minimal impact on public transport externalities

We also investigated the impact on externalities of our other recommendations. If all of our recommendations were implemented as a package, we do not expect a significant net change in overall demand over the next four years, holding all else constant. As a result, there is not likely to be a significant impact on the community benefits of public transport use resulting from these fare changes. Introducing off-peak fares for buses and light rail would lead to some movement in travel between modes of transport, and from peak to off-peak travel.[1] However, overall this is likely to have only a minimal impact on public transport externalities.

---

[1] Bus trips currently comprise about 40% of all Opal trips and about 60% of them occur during off-peak periods. The resulting increase in off-peak travel (a combination of its own price elasticity of demand, cross price elasticity of demand between peak and off-peak and from other modes of transport) was about a 2% increase and did not result in a material impact on our estimates of public transport externalities.

Large increases in public transport fares would lead to a material increase in road congestion

Our modelling suggests that to have a material impact on the value of externalities, substantial changes in fares are required. This is because people tend not to switch their mode of transport in response to small fare changes, particularly in the peak (for further details on our elasticity assumptions see *Technical Paper – Demand and elasticity*).

Of the public transport externalities, avoided road congestion costs are the largest. All else being equal, our modelling suggests that doubling public transport fares (for single journeys), could add about 10 minutes to a driver's commute on Parramatta Road in the morning peak as people switch from public transport use to private car use – which would further add to the significant congestion already experienced by many drivers during morning peak traffic hours on this road.[2]

Road congestion costs are the largest public transport externalities

Large increases in public transport fares are required to increase road congestion.

We also modelled the impact if the fares for single trips were increased by 5% per year over four years without any offsetting discounts being introduced[3] and found that the impact on increased congestion was relatively small – could add less than 5 minutes to a driver's commute on Parramatta Road in the morning peak.

Road congestion savings from large fare reductions are less significant and may also exacerbate crowding on public transport services

Congestion and crowding on Sydney's public transport services during the peak is a growing problem. Public transport use has been growing faster than the rate of population growth in recent years. If this trend continues then there is likely to be increased crowding in peak periods on a number of train, bus and light rail services.[4] Thus, large fare reductions would exacerbate crowding on public transport services. However, we note that infrastructure investment is in place such as the Metro Stage 2 (second harbour crossing) which would alleviate some pressure on the train network in the medium to longer term, and that the NSW Government has previously announced plans for additional bus services to meeting increasing demand.[5]

---

[2] In our modelling, we have maintained all weekly and weekday caps, including the Gold Opal card cap at $2.50 per day.

[3] Including inflation.

[4] For trains, services on the T1 Western/North Shore line and T4 Illawarra line are already experiencing load factors potentially in excess of 180% (measured as a percentage of seat capacity) on certain services in the morning peak. For buses, maximum capacity is already reached for certain services (eg, B1 Mona Vale to Wynyard, M30 Taronga Zoo to Sydenham, T80 Liverpool to Parramatta) and so there would be increased travel times as passengers would need to wait for subsequent services. For light rail services, capacity is up to 80% on some services and so there is scope to increase loadings in the short term, but we note that passengers may feel discomfort and crowding at current levels.

[5] See https://nsw.liberal.org.au/Shared-Content/News/2019/COMMUNITIES-TO-GET-THOUSANDS-OF-EXTRA-BUS-SERVICES, accessed 4 November 2019.

Large fare reductions are unlikely to significantly reduce road congestion

Large fare reductions would exacerbate crowding on public transport particularly during peak periods.

We also found that large fare reductions do not significantly reduce road travel times. Whilst additional cars can increasingly add to congestion and cause substantial delays to travel times, the savings in travel time resulting from fewer cars is limited by the time it takes to travel to a particular destination under free flow traffic conditions.
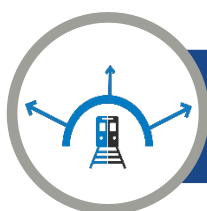
We have further developed our estimates of external benefits and costs

We reviewed our externality estimates so that when considering fare changes we had an updated understanding of the external benefits and costs that public transport use provides. Our approach in this review is generally consistent with our 2016 Opal fare review and the work we did to refine our calculations in 2014 in our *Review of external benefits of public transport*.[6] We have:

▼ Attempted to better understand the impact of pricing decisions on externalities through measures other than just monetary impacts. For example, the impact on travel times (in extra minutes) on arterial roads in Sydney as a result of increased road congestion, rather than only expressing the avoided road congestion cost as dollars per km or per journey.

‒ However, updating the external benefits and costs in monetary terms provided us important guidance on the externalities that would be most impacted by public transport use.

▼ Included discussion on crowding in public transport as this is an increasing issue.

▼ Refined our approach to calculating scale benefits.

We also provide our Excel workbook on our website which details how we have calculated our estimates (including comprehensive information on our all inputs and their sources).

In Table 1 below we provide our updated estimates of each of the externalities for both peak and off-peak periods for all modes. The costs are presented as a negative and the benefits as a positive so that they may be aggregated to present net benefits for each mode of travel. The values for cars are the avoided road congestion, pollution and accident costs to existing motorists (cars and trucks) if someone chooses to catch either a train, bus, ferry or light rail instead of driving – we have presented them as positive values as they are the external benefits of catching public transport if someone would have otherwise driven.

---

6   IPART, *Review of external benefits of public transport – Draft Report*, December 2014.

Table 1 shows that our estimates of externalities are highest during the weekday peak periods[7] as this is when both public transport use and road use is most concentrated. It also shows that avoided road congestion costs are the largest of the externalities that we measure, and that environmental pollution, active benefits and accident costs are the smallest.

Table 1   Estimates of external benefits and costs by mode ($2019)

		Rail	Bus	Ferry	Light Rail	Avoided Car Use
Congestion costs						
Peak	$/ptrip	n/a	-0.14	n/a	n/a	2.22
	$/pkm	n/a	-0.02	n/a	n/a	0.40
Off-peak	$/ptrip	n/a	-0.04	n/a	n/a	0.62
	$/pkm	n/a	-0.01	n/a	n/a	0.15
Environmental pollution costs						
Peak	$/pkm	-0.005	-0.02	-0.11	-0.01	0.07
Off-peak	$/pkm	-0.01	-0.03	-0.25	-0.01	0.07
Accident costs						
Peak	$/pkm	n/a	n/a	n/a	n/a	0.01
Off-peak	$/pkm	n/a	n/a	n/a	n/a	0.01
Scale benefits						
Peak	$/ptrip	0	1.32	0	1.11	n/a
	$/pkm	0	0.12	0	0.10	n/a
Active transport benefits						
Peak	$/ptrip	0.10	0.07	0.11	0.07	n/a
Off-peak	$/ptrip	0.10	0.07	0.11	0.07	n/a
Net benefit (combined)						
Peak	$/ptrip	0.10	1.24	0.11	1.18	2.22
	$/pkm	-0.005	0.08	-0.11	0.10	0.48
Off-peak	$/ptrip	0.10	0.03	0.11	0.07	0.62
	$/pkm	-0.01	-0.03	-0.25	-0.01	0.23

Most externalities are a combination of the number of journeys and the distance travelled. This means they have a value per passenger and a value per kilometre (km). For certain externalities, such as environmental pollution, there are no per passenger values as the driver of the cost is distance travelled. This is because the key cost driver for pollution is the (km) each mode of transport travels and not necessarily the number of passenger journeys. We outline our approach to allocating externalities in Box 1.

---

[7]   For our externalities calculations, peak periods are between 7am-9am (AM peak) and 3pm to 7pm (PM peak) consistent with the Sydney STM (Strategic Transport Model) assumptions (see section below on 'Congestion costs – Avoided car use' for further details on the STM). Off-peak is defined as the period outside of these hours.

Box 1   Externalities are allocated based on passenger trips and km.

Based on our view of what the key cost driver is for each of the externalities we estimate, we allocate them between passenger journeys (PJ) and passenger km (Pkm). This is helpful when considering fare changes, as changes to the base charge (lowest distance band) have the greatest impact on the externalities that are driven by passenger journeys, and changes to the higher distance charges impact the externalities that are driven by passenger km.

▼   Congestion costs – 50% to PJ and 50% to Pkm. We note that congestion depends on where and when the avoided car travel occurs – if congestion is in a particular location, the number of cars entering the bottleneck drives the external cost, not the distance travelled; however, if the congestion is widespread, the distance travelled drives the external cost. Therefore, we have conservatively applied an equal allocation between journeys and km travelled.

▼   Scale benefits (Mohring effect) – 50% to PJ and 50% to Pkm. We note that not all passengers catch a single service to reach their destination and that a certain proportion transfer at different stations or between modes to reach their destination (and this can increase as the distance travelled is greater). Therefore, we have conservatively applied an equal allocation between journeys and km travelled.

▼   Environmental pollution – 100% to Pkm as emissions depend on the distance travelled.

▼   Accident costs – 100% to Pkm as we have assumed that traffic accidents are likely to increase as more vehicle km are travelled (accident costs are the smallest externalities we measure).

▼   Active transport benefits – 100% to PJ as the health benefits of catching public transport (if someone walks or cycles to where they catch public transport) does not depend on the distance travelled by the mode of public transport.

We received submissions to our Issues Paper and our Draft Report which we discuss, including our responses, in Box 2.

Box 2   Submissions received in response to our Issues Paper and Draft Report

In response to our Issues Paper we received submissions indicating that we should include additional external costs and benefits in our estimates. With the exception of including noise pollution (which we have decided to include in our environmental pollution estimates) we do not consider that the additional externalities suggested should be included. We outline the issues and our reasons below.

▼ **Increased parking availability** - that we should consider the impact of public transport usage on parking availability. [a]

We consider that increased public transport usage can improve parking availability, if car travel is completely substituted. However, in other cases a car journey will be substituted with a public transport journey that involves driving to a local train station or a bus stop etc (or places with higher service frequencies). Whilst this would improve parking availability at their final destination, it would reduce parking availability in the area in which they catch public transport (ie, there would be reduced parking availability in commuter car parks or in local streets near more convenient bus stops etc).

Further, parking rates (cost per hour or daily rates) at key destinations may adjust in response to changing demand (to induce new demand) such that overall car parking availability is not necessarily reduced.

▼ **Cost of new roads** – that we should take into account the reduced need for new roads and in doing so, we should also consider the avoided 'urban heat island effect'. [b, c]

We consider that including the reduced need for new roads in addition to our estimate of reduced congestion would double count the effects of reduced car demand on roads. This is because the value of reduced congestion can be considered as a proxy for how much motorists are willing to pay for a new road to reduce their travel times by an equivalent amount. Therefore, to include the avoided cost of a new road (which can be represented by reduced congestion costs as a proxy) in addition to reduced congestion costs (brought about by increased public transport use) would double count the external benefit that public transport provides on reducing car demand on roads.

The **urban heat island effect** occurs when natural permeable surfaces including grass, plants or bush land are replaced with concrete, asphalt and infrastructure (as a result of human activity) and causes a greater absorption of the sun's heat, leading to higher temperatures than in surrounding areas. This has been an increasing issue particularly in Western Sydney. Efforts are being made to use reflective colours, plant trees, install more water features etc to deal with the increase in heat. [d]

We consider that the reduced need for new roads may contribute to an avoided heat island effect, if the new road would have otherwise replaced natural permeable surfaces. However, this is not always the case and is project and location specific. For example, the WestConnex had an impact on reducing some permeable surfaces to widen roads, whereas the widening of the M4 to reduce congestion around Granville, Clyde and Auburn had minimal impact on its surrounding areas given it was an already highly urbanised area.

Further, while the augmentation of the public transport system (eg, new metro line) can also reduce the need for new roads, this is also project and location specific, as natural permeable surfaces can be replaced with concrete and asphalt to make way for new public transport infrastructure.

Without specific information on where a road would potentially be avoided, and the potential avoided impact it would have on natural permeable surfaces (which can vary widely), we are unable to reliably estimate a reasonable avoided cost.

▼ We also note that changes in vehicle usage in the short to medium term are not strongly correlated with changes in road provision and so would not impact the current urban heat island effect.

▼ **Aesthetic benefit from less cars** - that we should consider the aesthetic benefits of removing cars. [e]

We consider that it is unclear what level of car usage would constitute an appropriate level of aesthetics. Given the difficulty in defining an appropriate level of aesthetics (which is likely to be quite subjective), we consider that it would be difficult to reliably measure what the willingness to pay would be. We are also currently unaware of any studies that have examined the willingness to pay for such benefits.

▼ **Liveability** – that we should take into account the role of public transport in shaping Sydney and producing prosperous, connected, and liveable suburbs eg, the success of the central and western cities are contingent on adequate, affordable transport in these areas. [f]

We consider that all modes of transport to city centres can play an important role in shaping Sydney and producing prosperous and connected suburbs, which includes both the public transport and road systems. Having affordable and adequate public transport will not only directly benefit users to move between suburbs and city centres, but will also benefit car users through reduced congestion in reaching their destinations.

We consider that fare changes at the margin are likely to have a larger influence on the mode of transport that people choose when travelling to city centres, rather than determining whether they travel at all. Therefore, we consider that we have captured the external benefit that public transport provides through our estimation of avoided road congestion costs.

However, we note that the availability and affordability of an efficient public transport system is important in promoting liveability, particularly for those on low incomes. We have further considered these issues in *Information Paper – Ensuring Affordability*.

In response to our Draft Report we received the following submission.

▼ **Difficulty measuring externalities accurately** – that despite there being community benefits arising from the use of public transport, it is difficult for these externalities to be measured with any great accuracy, as many costs and benefits are intangible and are unable to be quantified. Further, given this uncertainty, externalities should not be used as the basis for price differentiation between modes. [g]

Our view is that the community benefits arising from public transport use are an important consideration when examining the impact of fare changes. We note that it is difficult to measure externalities precisely and that the values shown in this technical paper represent our best estimates. Using our best estimates, we found that whilst large fare changes may have a significant impact on community benefits, relatively smaller fare changes (up to 5% per year) have minimal impacts. We have taken this into account, along with cost and demand information, when considering prices for each mode of transport.

---

a Ryan E, submission to IPART Issues Paper, p 2.

b Bullivant F, submission to IPART Issues paper.

c Ryan E, submission to IPART Issues Paper, p 2.

d See https://www.abc.net.au/news/2018-03-01/how-western-sydney-is-tackling-the-heat-island-effect/9361156, accessed 13 August 2019.

e Ryan E, submission to IPART Issues Paper, p 2.

f Ibid.

g Sandell R, submission to IPART Draft Report, p 2.

In the sections below, we discuss each of the externalities that we have estimated and how we have estimated them, including how they differ from our previous 2016 estimates.

Congestion costs – Avoided Car Use

The use of public transport services rather than private cars reduces road congestion. Lower congestion benefits existing road users and is an external benefit of using public transport.[8] Having fewer cars on the road also reduces vehicle operating costs (as operating costs are higher at lower speeds)[9] and improves the reliability of journey times.

We used information from TfNSW and Roads and Maritime Services (RMS) to estimate the likely impact of fare increases on travel times across Sydney roads (see Box 3 for further details on our approach) – this is the first time we have obtained road congestion data from RMS.[10]

In updating our estimates, we were also able to obtain from RMS' Strategic Traffic Forecasting Model (STFM) a better understanding of the impact of road congestion on travel times in Sydney. We found that fare increases, which would lead to some people switching from public transport to private car use and adding to road congestion, had the greatest impact on travel times on Parramatta Road – particularly between Haberfield and Central. For example, we estimate that a 20% increase in all public transport fares, could add about 15,000 additional cars (about 1%) to the weekday morning peak period, and could increase travel times on Parramatta Road between Haberfield and Central by around 5 minutes, holding all else constant.[11]

We also found that fare decreases, which led to some people switching from private car use to public transport use, did not result in significant time savings on arterial roads. This is because there is an asymmetric relationship between changes in car demand and travel times - whilst additional cars can increasingly add to congestion and cause substantial delays in travel times, the savings in travel time resulting from reducing car demand is limited by the time it takes to travel to a particular destination under free flow traffic conditions.

We have also estimated the cost of congestion that is saved by each public transport journey. This is measured in terms of three avoided costs - travel times, vehicle operating costs and increased reliability, for both cars and trucks on the road (someone choosing to take public

---

8   As the benefit is external to those using public transport.
9   Vehicles experience greater wear and tear (through increased stops and starts) at lower average speeds.
10   In our previous review, we used outputs from the Transport Performance and Analytics' (TPA) Sydney Strategic Transport Model (STM) to calculate our congestion estimates. For this review we sought to update our estimates from its model, however, TPA advised that Roads and Maritime Services (RMS) have a Strategic Traffic Forecasting Model (STFM) which would provide more accurate measures of congestion on the Sydney road network. We note that the STFM has a better representation of the road network compared with the SSTM, especially access points and is better able to model intersection delays. Therefore, we have used the outputs from the STFM in estimating our congestion measures.
11   We found that various sections of Parramatta Road are impacted differently during the two hour 7am-9am weekday morning period. Our estimate of 4.5 minutes is the most congested section between Haberfield and Central.

transport and not driving provides an external benefit to existing motorists, both cars and trucks).

We also apply occupancy assumptions to derive costs on a per passenger trip and per passenger km basis. For our occupancy assumptions, for motor vehicles we have updated them from the outputs provided by the Sydney Strategic Transport Model (STM), and for buses we have used Opal data to calculate its average occupancy for peak and off-peak periods.

Box 3   Measuring congestion costs

We measure congestion costs by examining the impact that additional (marginal) motorists have on existing (inframarginal) motorists (change in travel times, vehicle operating costs and reliability of travel). To do this, we first asked TPA to run public transport fare change scenarios (eg, an increase in all public transport fares) using their STM to estimate which people are likely to switch from catching public transport to driving, from their origin to destination[a]. We then asked RMS to use their STFM to calculate the vehicle kms travelled and travel times for both scenarios:

▼ where there is no change in public transport fares (baseline scenario) – where vehicle kms and travel times are calculated only for people who originally travel by car from origin to destination, and

▼ where there is a change in public transport fares - vehicle kms and travel times are recalculated for all motorists and factor in both those who maintain driving from their origin to destination and those who switch from public transport to driving.

From the above outputs we calculated our congestion cost (time) using the following formula:

$$\Delta CX = \Delta TT / \Delta CT . VoT$$

where ΔCX is the change in congestion costs, ΔCT is the change in car travel (either trips or kilometres), VoT is the value of time (a weighted average of business and non-business car users sourced from the TfNSW appraisal guidelines) and ΔTT is the change in travel time from a specific scenario calculated as:

$$\Delta TT = \left(\frac{\text{VKT}^B}{S^S} - VHT^B \right) . OC$$

where VKT^B is the vehicle kilometres in the baseline, S^S is speed in the scenario, VHT^B is vehicle hours travelled in the baseline and OC is occupancy (number of passengers per vehicle and is sourced from the STM outputs).

In the above formulas we are calculating the change in travel times for existing (inframarginal or baseline) motorist by applying the new recalculated average speed (for all motorists, both existing and new) to the original distance (kms) travelled by the existing motorists. This is then multiplied by a value of time, sourced from the TfNSW appraisal guidelines, to estimate the impact that additional motorists have on existing motorists, in terms of the cost of changes in travel time. The formulas are the same as what we used in our 2016 review, however, the input data used is now sourced from RMS' STFM.

Our estimates of the cost of changes in travel times are the largest of our congestion costs and currently comprise 83% of our total congestion costs. For vehicle operating costs we also obtain from the STFM changes in travel times by various speed (separated into different speed bands) and apply estimates of operating costs for travel at different speeds from the latest TfNSW appraisal guidelines. For our estimate of the reliability of travel, we calculated the value of the change in the standard deviation of travel time using average travel times (calculated from STFM outputs) and costs for reliability measures, also sourced from the TfNSW appraisal guidelines.

a Origin and destinations are sourced from the Household Travel Survey and form a baseline from which fares can be adjusted to examine whether people are likely to switch their mode of travel to reach their destination.

Avoided road congestion costs are the largest external benefits of using public transport

The congestion cost estimates for cars shown in Table 2, are the costs of adding an additional car onto the road system. Therefore, it represents the avoided congestion costs if someone chooses to catch public transport instead of driving, and is applicable for all modes of public transport.

▼ For example, our updated estimates are about $2.22 per car journey (per passenger) and about $0.40 per km (for each passenger) during the peak periods on a weekday.[12,13]

▼ This means that if a person who would have driven 20 km chooses public transport and replaces that car trip with:

  – A train trip, then that person's train travel provides an external benefit to continuing motorists by avoiding road congestion costs of about $10.28 in aggregate[14].

  – A bus trip, then the congestion saving would be around $9.73 in aggregate. This is less than if they had used the train as buses themselves add to some road congestion (see below).

The bus congestion costs in Table 2 represent the additional congestion cost buses impose on the road network if someone chooses to catch a bus (on a per passenger basis). This value is netted off the congestion cost for cars to establish the avoided road congestion costs, if someone chooses to catch a bus instead of driving. For example, our updated estimate is $0.14 per bus journey (per passenger) and $0.02 per km (per passenger) during the peak periods on a weekday. This means that as a result of public transport fare changes, if a person chooses to catch a bus instead of driving (eg, 20km to their destination) then that person's bus travel contributes $0.54 towards road congestion, but avoids $10.28 – thus, the person's decision to catch a bus provides a net external benefit to continuing motorists of $9.74 in aggregate, in avoided road congestion costs.

We also maintained our approach of estimating the impact that buses have on congestion by assuming that each bus has twice the congestion impact compared to a car (adjusted for the proportion of time not spent on bus lanes[15]).

---

12   The avoided congestion costs have been averaged over the morning and afternoon peak periods.
13   We present our estimates on per 'passenger' trips and per 'passenger' kms, where 'passengers' are based on the average occupancies for each mode of transport. This is to recognise that each passenger in a vehicle faces a cost when the whole vehicle is delayed – for example, if a car with three passengers is delayed by 1 minute due to congestion, then all three passengers in the vehicle face a delay cost of 1 minute each and so the total cost (for time) is 3 minutes multiplied by a value of time.
14   If the number of vehicle trips travelled in the morning peak in Sydney is around 1.4 million, then the value to each continuing motorist for the marginal passenger that decides to take a train instead of driving is $10.28/1.4 million.
15   We have assumed that when buses are on dedicated bus lanes, they do not contribute to congestion. Hence, we only consider the proportion of time not spent on bus lanes as contributing to road congestion.

Table 2   Congestion costs ($2019)

	2019		2016	
	Bus	Car[a]	Bus	Car[a]
Peak - $/passenger trip	-0.14	2.22	-0.90	3.27
Peak - $/passenger km	-0.02	0.40	-0.10	0.48
Off-peak $/passenger trip	-0.04	0.62	-0.24	0.76
Off-peak $/passenger km	-0.01	0.15	-0.03	0.14

a Includes congestion estimates for trucks. That is, if there is an additional car on the road, then it would also impact on time, reliability and vehicle costs for trucks as well.

Note: The above estimates include congestion costs for time, reliability and vehicle operating costs.

Our congestion estimates are lower than what we previously estimated in 2016. The main driver of the difference is:

▼   The latest results use RMS' STFM to calculate the congestion impacts and this has resulted in lower estimates compared with before. Compared with TPA's STM, the STFM has a better representation of the road network, especially access points and road congestions, and is better able to model intersection delays. There have also been updates to the road network (eg, WestConnex projects), which the latest estimates for 2019 incorporate and these projects would have contributed to reducing congestion impacts.[16]
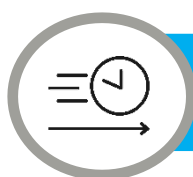
Scale benefits (Mohring effect)

As patronage increases, there may be an external benefit (to existing passengers) if service frequency is increased in response to this higher patronage. As service frequency increases, average waiting times for services decrease, and given that waiting time is a major component of the total journey time of public transport, this leads to travel time savings for existing public transport users. That is, each new passenger that chooses to take public transport provides an external benefit to existing users through reduced wait times (if service frequency is increased in response). Therefore, this external benefit justifies a subsidy where the reduction in fares generates demand that then creates this benefit.

In the section below we outline our updated scale estimates, including our adjustment to reflect a possible increase in services in response to increased demand (based on historical data). We then discuss implications of crowding on the public transport network.

We have broadly maintained our approach in calculating scale benefits from our previous review and have updated the inputs, with the exception of making an adjustment for how service frequencies are likely to change in response to changes in demand (discussed below).

---

16   In producing outputs for 2016, RMS applied the 2018 Sydney road network, which includes updates to the road network including some WestConnex projects that have been completed (eg, widening of the M4). In estimating congestion outputs for 2019, we have interpolated between the results for 2016 and 2021 (both the STM and STFM produce outputs at five-yearly intervals).

We calculate our estimate of scale benefits using STM outputs (including waiting times experienced by passengers) and TfNSW's appraisal guidelines for the value of time (including a premium of 1.45x for waiting time vs in-vehicle time). Specifically:

▼   We estimate the change in demand with respect to changes in public transport fares and multiply the result by existing wait times for public transport (including a value of time and an additional premium for wait time vs in-vehicle time) – for example, if there is a 5% increase in demand for public transport, then average wait times would reduce by 4.8%,[17] if additional services were put on to meet that additional demand.

–   The latest STM results suggest that the own-price elasticities for certain modes have slightly increased, and hence the potential to achieve scale benefits is higher than our previous estimates (eg, the own-price elasticity for buses is 0.44 in peak periods whereas it was previously 0.42).

▼   We have also adjusted our estimates to incorporate the likelihood of service frequencies increasing in response to increased demand. We used historical data to calculate the percentage change in service frequencies per percentage change in demand (this has resulted in 83% for buses, 70% for light rail and negative value for ferries as overall scheduled services have declined in recent years). To the extent that changes in service frequencies in the future are different from the past, our estimated results would be different from what actually takes place. Our previous approach did not include this adjustment.

We present our updated estimates in Table 3 below. For example, if there were an increase in an additional bus passenger, and services were increased to meet that demand, then that passenger would provide an external benefit of reduced wait times for other passengers of $1.32 per trip in aggregate.[18]

We have not estimated scale benefits for trains as there is limited capacity to make services more frequent due to constraints on the network at this point in time. If there is increased demand and additional services are unable to be put on to cater for the demand, then it would lead to crowding, which we discuss further below. However, we note that the Metro Stage 2 (second harbour crossing) and the Metro West (Parramatta to Sydney CBD) would provide additional capacity in the medium to longer term, and so scale benefits would be available once these projects are completed.

We have also not estimated scale benefits for ferry services as scheduled services have been reduced overall (and patronage has been fairly stable on average)[19] –if there are increases in demand, then this would be met by existing capacity in services.

---

17   Reduction in waiting times are calculated as 1- 1/(1+ %change in demand). Eg, for a 100% increase in demand (ie, doubling in demand), wait times would reduce by half (or 50%) if additional services were placed to meet the change in demand.

18   In reality, demand would need to increase by at least the capacity of a new bus service (ie, more than 60 passengers) for an additional service to be put on at a bus stop.

19   Patronage increased by 2.7% over 2016-17 to 2017-18 then decreased by 2.2% in 2018-19; scheduled services have decreased by 3% on average over 2016-17 and 2017-18.

Table 3   Scale benefits ($2019)

	2019			2016		
	Bus	Ferry	Light rail	Bus	Ferry	Light rail
Peak - $/passenger trip	1.32	0	1.11	1.25	1.25	1.25
Peak - $/passenger km	0.12	0	0.10	0.11	0.11	0.11
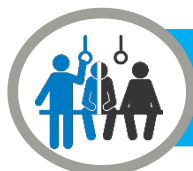
Crowding on public transport

If transport services are not increased in response to increases in demand, there may be an external cost as a result of an increase in public transport crowding. When a bus, train or ferry is crowded, services become less comfortable, there are increases in alighting and boarding times, and waiting times will increase as some passengers have to wait for the following bus, train or ferry. An increase in the number of passengers using public transport in peak times imposes a cost on other users.

Increased demand leading to crowding is particularly an issue in train services where there are physical constraints on the network and it is potentially very costly to increase the number of services to accommodate new demand. However, even for bus and light rail services where substantial investment is not required, there is a cost of purchasing new buses and trams to service additional demand. Using Opal data, we were able to observe that during the weekday morning peak periods:

▼   For train services going into the Sydney CBD the T1 Western line (from Strathfield), T4 Illawarra/Cronulla line (from Hurstville) and the T1 Northern lines (from Chatswood) are particularly congested with load factors potentially in excess of 180% (measured as a percentage of seat capacity) on services.[20]

▼   For bus services, maximum capacity (seated and standing)[21] is reached for various services (B1 Mona Vale to Wynyard, M30 Taronga Zoo to Sydenham, T80 Liverpool to Parramatta, 333 North Bondi to City Circular Quay, B1 Mona Vale to Wynyard, 343 Kingsford to Chatswood, 400 Bondi Junction to Sydney Airport and M52 Parramatta to City Circular Quay) – most of these services are also to transport passengers to the CBD. For light rail services we have observed up to 80% capacity on some services (this means that all 80 seats are occupied and 149 passengers are standing; max capacity is 80 seated and 206 standing) and so there is capacity to cater for additional patronage in the short term, although passengers may feel discomfort and crowding at current levels.[22]

---

20   Load factors are a percentage of seat availability. For example, if a carriage has seat capacity of 122, then a load factor of 180% would mean that every seat is occupied and that 98 people are also standing

21   Max passenger capacity (seated and standing) varies for the different buses that are used: from a combined seating and standing capacity of 65 up to 110 for articulated two or three-door buses.

22   The latest TfNSW Customer Satisfaction Index shows 81% satisfaction for personal level of space on light rail services. TfNSW, Customer Satisfaction Index, May 2019, p 10.

▼ • For ferries we have observed capacity of up to 80%[23] on services with relatively higher demand such as the F3 Parramatta River and F1 Manly services and so there is capacity to cater for additional demand in the short term (however, services are up to full capacity on Sundays).

There is currently limited capacity to put on additional services for trains due to constraints on the rail network[24]. Although, for buses the NSW Government has announced additional services to meet increasing demand and so there is some scope to ease crowding on these services.[25]

Population growth is likely to have a bigger impact on crowding on public transport than changes in fares

As discussed in the separate information on paper on public transport demand (see *Information Paper – Elasticity and Patronage Growth* for further detail), public transport use has risen substantially in recent years, around 5% per year, which is slightly more than twice the rate of population growth[26]. Under the fare changes we are recommending we do not anticipate that fares will have a significant impact on this rate of growth.

The NSW Government expects that the T1 Western Line, one of the busiest lines in Sydney, would reach full capacity by 2030 based partially on population growth in the West.[27]

Hence, we consider that population growth is likely to lead to increased patronage on the public transport system and increase crowding in peak periods. We note that crowding in public transport, and the road network, due to population growth has been an increasing issue and has also been raised by Infrastructure Australia in its recent audit work.[28] We also note that the Metro Stage 2 (second harbour crossing), the Metro West (Parramatta to Sydney CBD) and the work being done by the Greater Sydney Commission in encouraging greater economic activity in western Sydney and the greater Parramatta area (to increase work opportunities outside of the Sydney CBD)[29] would help to alleviate some crowding pressures in the medium to longer term.

---

23 Capacities differ between services depending on the fleet used. The fleet used for the F1 Manly service has a passenger capacity of 1,100 whereas the F3 Parramatta River service can have a passenger capacity of 230. See https://en.wikipedia.org/wiki/List_of_Sydney_Ferries_vessels, accessed 24 September 2019.
24 The extension to the metro (stage 2 and the second harbour crossing) will provide additional rail capacity.
25 See https://nsw.liberal.org.au/Shared-Content/News/2019/COMMUNITIES-TO-GET-THOUSANDS-OF-EXTRA-BUS-SERVICES, accessed 24 September 2019.
26 See https://www.planning.nsw.gov.au/Research-and-Demography/Demography/Population-projections, accessed 23 September 2019. We note that about half of this increase is projected to be from a natural increase (births less deaths) and the other half net migration.
27 TTF L.E.K., *Public transport barometer*, June 2018, p 4.
28 See https://www.infrastructureaustralia.gov.au/publications/urban-transport-crowding-and-congestion, accessed 14 August 2019.
29 See https://gsc-public-1.s3-ap-southeast-2.amazonaws.com/s3fs-public/greater-sydney-region-plan-0618_0.pdf, accessed 14 August 2019.

Environmental pollution costs

Environmental pollution costs measure the impact that each mode of transport has on air pollution, greenhouse gas emissions and noise pollution.

In our previous review, we included air pollution and greenhouse gas emissions but did not include noise pollution because we did not have access to a good dataset at that time.[30]

In response to stakeholder submissions to our Issues Paper[31] and our own investigation, we have now included noise pollution as part of our estimates based on the latest TfNSW appraisal guidelines for various modes of transport.[32] The noise pollution estimates are relatively small compared with air pollution and greenhouse gas emissions.

▼   For example for rail ($2019), the cost of air pollution is $1.40 per vehicle km and for greenhouse gas emissions it is about $1.10 per vehicle km, whereas noise pollution is about $0.03 per vehicle km.

▼   For cars ($2019), air pollution is about $0.03 per vehicle km and for greenhouse gases it is about $0.03 per vehicle km, whereas noise pollution is about $0.01 per vehicle km.

We have also updated our estimates for air pollution and greenhouse gas emissions from the latest TfNSW appraisal guidelines as well. In updating our estimates we also used the latest information we had available from Opal data to calculate the average occupancy for each mode of transport for peak and off-peak periods (due to the lack of specific data in our 2016 review, we previously used a daily average for each mode and did not account for the higher occupancies during peak periods relative to off-peak periods). The occupancy data is used to convert the vehicle based km costs to a per passenger km cost.

Our updated estimates in Table 4 below show that environmental pollution is the highest for ferries, both in the peak and off-peak periods. For example, a person choosing to catch a ferry for a distance of about 11.3 km (Manly to Circular quay - about 7 nautical miles) imposes a pollution cost of about $1.25 per passenger in the peak periods and about $2.85 per passenger in the off-peak periods. However, someone who catches a train imposes relatively less environmental pollution – for an equivalent distance they impose $0.05 per passenger in the peak and $0.11 per passenger in the off-peak[33].

---

30   IPART, *Review of external benefits of public transport – Draft Report*, December 2014, p 42.
31   We received a submission indicating that we have not included the avoided noise pollution from reduced cars on the road if people choose to catch public transport instead of driving.
32   The latest TfNSW appraisal guidelines do not have costs of noise pollution for light rail and ferry and so we have not included an estimate for these modes.
33   The off-peak values per passenger can be higher than the peak values due to lower occupancies per vehicle in off-peak periods.

Table 4   Environmental pollution costs ($2019)

	2019					2016				
	Rail	Bus	Ferry	Light rail	Car	Rail	Bus	Ferry	Light rail	Car
Peak – $/passenger km	**-0.005**	**-0.02**	**-0.11**	**-0.01**	**-0.07**	**-0.02**	**-0.07**	**-0.14**	**-0.04**	**-0.06**
- Air pollution	*-0.003*	*-0.014*	*-0.101*	*-0.003*	*-0.032*	*-0.010*	*-0.047*	*-0.124*	*-0.022*	*-0.031*
- GHG emissions	*-0.002*	*-0.006*	*-0.010*	*-0.003*	*-0.025*	*-0.008*	*-0.019*	*-0.012*	*-0.017*	*-0.025*
- Noise pollution **a**	*0.000*	*-0.001*	*0.000*	*0.000*	*-0.010*	*-*	*-*	*-*	*-*	*-*
Off-peak- $/passenger km	**-0.01**	**-0.03**	**-0.25**	**-0.01**	**-0.07**	**-0.02**	**-0.07**	**-0.14**	**-0.04**	**-0.06**
- Air pollution	*-0.005*	*-0.017*	*-0.230*	*-0.007*	*-0.035*	*-0.010*	*-0.047*	*-0.124*	*-0.022*	*-0.031*
- GHG emissions	*-0.004*	*-0.007*	*-0.023*	*-0.005*	*-0.027*	*-0.008*	*-0.019*	*-0.012*	*-0.017*	*-0.025*
- Noise pollution	*0.000*	*-0.001*	*0.000*	*0.000*	*-0.011*	*-*	*-*	*-*	*-*	*-*

a   The TfNSW appraisal guidelines currently do not have estimates of noise pollution for ferry and light rail. However, their overall impact on the community is likely to be small relative to the other transport modes.

Note: We previously did not include noise pollution costs in our 2016 estimates. We also used an average daily occupancy for each transport mode to convert the environmental pollution costs to per 'passenger' km values (hence the peak and off-peak estimates were the same in the 2016 review), whereas now we have used detailed information to differentiate between peak and off-peak occupancies.

Our updated estimates are generally lower than our previous estimates. Whilst the unit pollution costs per vehicle km have not changed substantially, the updated occupancy figures for each mode are higher than before – hence, when the pollution costs (per kms) per vehicle are translated into costs per passenger km, the resulting figures are lower.

▼   For example, for rail we used a daily average of 142 passengers for both peak and off-peak periods,[34] whereas the latest Opal data we have suggests an average of 580 passengers in the peak (per vehicle) and 270 in the off-peak (per vehicle) (which suggests a daily average of about 400 passengers).

However, for ferries, our updated estimate is higher in the off-peak period because of the lower occupancy suggested by the latest Opal data we have – about 50 passenger in the off-peak (95 in the peak) compared with a daily average of 79 passengers (applied to both the peak and off-peak periods).

Active transport benefits

Public transport use encourages greater levels of physical activity – primarily when people walk or cycle to and from public transport. Our active transport benefits estimate the external benefits (avoidable health care costs) that arise when people choose to catch public transport.

In calculating these estimates we have maintained our approach from our previous review but have updated our inputs with the latest publicly available information. Our approach is to use

---

34   We calculated this estimate by dividing the total number of passenger kms (from our 2016 marginal cost work) by the total number of vehicle kms (sourced from the annual accounts of TfNSW).

estimates of the avoidable health care costs due to inactivity and divide this by an estimate of the value of deaths due to inactivity[35] to establish an approximate avoidable health care cost per mortality (due to inactivity). This is then applied to the benefit (reduced mortality) from an additional km of walking or cycling from the World Health Organisation's Health Economic Assessment Tool[36].

We also adjust our estimates for the proportion of people estimated to have private health insurance, as a proportion of the additional health care costs would be met through insurance. We also use from the latest information available from the Household Travel Survey, the average distance people walk or cycle to and from public transport to translate the benefits to a value per trip.

We provide our updated estimates in the table below. It shows that those who catch the ferry provide greater external benefits than other modes of transport. This is largely driven by a greater average distance (access and egress) walked to and from wharfs (about 840 meters) compared with those who catch the train (720 meters), bus (530 meters) and the light rail (530 meters).

Table 5   Active transport benefits ($2019)

	2019				2016			
	Rail	Bus	Ferry	Light rail	Rail	Bus	Ferry	Light rail
Peak - $/passenger trip	0.10	0.07	0.11	0.07	0.23	0.18	0.25	0.18
Off-peak- $/passenger trip	0.10	0.07	0.11	0.07	0.23	0.18	0.25	0.18

Our updated estimates are lower than our previous estimates. Key drivers of the differences are:

▼   The average distance walked to and from points of public transport has decreased (eg, the average walk distance to a bus stop was previously 610 meters whereas the latest information from the TPA Household Travel Survey data suggests about 530 meters)

▼   The latest publicly available information suggests that the health costs savings from walking and cycling are lower than previously estimated.

–   In the 2016 review we used work that Econtech did for Medibank private in 2007 that found that physical inactivity was costing the Australian healthcare system an avoidable $1.5 billion per year

–   However, in September 2016, research undertaken by Sydney University on the global estimate of the financial cost of physical inactivity, estimated the avoidable healthcare system costs in Australia as $640 million ($2013).

---

[35]   We use the statistical value of life from the TfNSW appraisal guidelines and estimate mortality due to inactivity from ABS data.

[36]   Is an online tool where users can input the value of statistical life (which we source from the TfNSW appraisal guidelines) and uses a crude death rate (that is similar to ABS figures for Australia) to provide various estimates of measures such as reduced mortality risk and annual economic benefit of additional km walked or cycled.

Accident costs

In our estimates we also include the avoided cost of accidents as a result of people choosing to catch public transport instead of driving. Our estimates measure the external benefits arising from the avoided cost of taxpayer funded services, such as ambulance and police services and also uninsured fatality costs.[37]

We have maintained our approach from our previous review and have updated our inputs. There have been some variations in the inputs, eg the willingness to pay to avoid death or injury in car accidents has increased from $7.0 ($2019) to $7.7 million ($2019) in the latest TfNSW appraisal guidelines[38], however, on a per passenger km basis, our estimate is still about $0.01 per passenger km.

Table 6   Accident costs ($2019)

	2019	2016
	Car	Car
Peak - $/passenger km	0.01	0.01
Off-peak- $/passenger km	0.01	0.01

Road user charges

Our external benefits calculations include an adjustment for road user charges. This is because these charges (fuel excise, tolls and parking levies) increase the private cost of driving and internalise some of the external costs imposed on society. Hence, we use these charges to offset some of the external costs that driving imposes on the community – otherwise, we would be overstating the external benefits of avoiding private car use.

We have maintained our approach from our previous review and have updated our estimates (fuel excise which is now 41.60 cents per litre, tolls which now include the new M4, and updated parking levies). Our updated estimates are generally higher than our previous estimates. The key driver of the differences are the increase in toll revenues - have increased by around 40% since 2016, and include new revenues from the widening of the M4 (new M4) – this has led to an increase in road user charges per passenger km and trip.

---

37   Severe accidents require ambulance and police services which are more likely to occur for collisions where vehicles are travelling at higher speeds – we have used kms travelled as a proxy (rather than vehicle trips).
38   TfNSW, *Principles and Guidelines for Economic Appraisal Guidelines*, June 2018. p 277.

Table 7   Road user charges ($2019)

	2019	2016
	Car	Car
Peak - $/passenger trip	0.17	0.16
Peak - $/passenger km	0.04	0.04
Off-peak - $/passenger trip	0.11	0.05
Off-peak- $/passenger km	0.05	0.04

In Table 7 above, the off-peak per passenger trip amount has the greatest change.[39] In calculating the road user charges, we used outputs from the STM to estimate the proportion of people that choose to no longer drive (and hence no longer use toll roads), but rather catch public transport. The latest STM outputs suggest that when public transport fares change (eg, a fare decrease), of the motorists that switched to public transport use, a greater proportion in the off-peak periods had previously used toll roads (eg, 0.6%) compared with our estimates from the 2016 STM outputs (eg, 0.3%).[40, 41] Further, we have also applied more detailed occupancy information for the off-peak period - the latest STM outputs indicates an average of 1.27 persons per vehicle - compared with a simple average of 1.44 persons applied previously, which now additionally increases the cost per passenger.

---

[39]   And also off-peak cost per passenger km, when examined proportionately against the 2016 STM results.
[40]   This is also the case for the PM peak period as well and passenger trips in the PM is also lower – these factors (in addition to higher toll revenues) also contribute to the higher $ per passenger cost in the peak period compared with the 2016 STM results.
[41]   For both the latest and 2016 STM results, a greater proportion (about 55%) of toll revenue is collected in the off-peak periods.