Independent Pricing and Regulatory Tribunal
New South Wales

OPAL FARES

2020-2024

LONG RUN MARGINAL COST

Technical paper

February 2020

What is the long run marginal cost?

The long run marginal cost, or LRMC, is the cost of serving a sustained increase in passenger demand over a timeframe where supply is not constrained by existing vehicles and infrastructure.

Who uses LRMC estimates?

The LRMC is commonly used in economic regulation as the basis for usage charges. Markets where prices are equal to marginal cost maximise allocative efficiency. This makes sure purchases reflect costs and preferences.

The LRMC is the basis of our water usage charges and the AER's determinations of electricity network usage.[1] This is because in monopoly industries it will give customers efficient incentives to invest and consumer relative to the costs of water and electricity.

Operators can use LRMC in system planning. In particular, the LRMC may be a key component in cost benefit analysis, particularly involving demand management.

Why estimate the LRMC for public transport?

LRMC may not be an efficient basis for public transport prices. The use of long run marginal cost in public transport pricing is complicated. Public transport, unlike water and electricity distribution, faces significant competition from other transport businesses and private vehicles. Public transport also has relatively large external benefits (as we discuss in our technical paper – external benefits and cost). Competition to public transport is not necessarily priced at long run marginal cost and generally does not account for all external costs. Therefore, setting prices at long run marginal cost would not necessarily increase the efficiency of customer travel decisions.

However, estimating the LRMC for public transport is useful for establishing:

- How LRMC varies by time of day, day of week and differences by mode
- How LRMC varies with different levels of demand (eg. if some people will shift their travel out of the peak, what difference does that make?).

These pieces of information are useful for considering different fare structures, such as peak/off-peak pricing and estimating cost savings or additional costs associated with different fare options.

1 National Electricity Rules 6.18.5(f)

Why did we decide not to publish LRMC estimates?

In other industries, such as energy and water, there is a greater level of stakeholder agreement on the approach, assumptions and key inputs to estimating long run marginal cost. We think further discussion around the methodology is necessary before publishing estimates. In this paper we are presenting our preferred methodology to help advance this discussion.

As noted above, we have not used LRMC as the basis for the fares in our determination. The LRMC analysis has provided useful information about the cost differences between modes of transport and on the relativities between the different modes. However, the analysis required a significant number of assumptions and inputs including the costs of building new railway lines in Sydney (see appendix B for more information). While we have undertaken sensitivity modelling, we consider that there is a substantial degree of uncertainty attached to the estimates. Unlike in other industries such as energy and water where there is a greater level of stakeholder agreement on the key assumptions and inputs to estimating a forward looking LRMC, this is not the case in public transport

There are significant changes to the public transport network, that change how the public transport system operates:

- In 2019 two new light rail lines (Newcastle and the L2 Sydney to Randwick) opened with two more opening in the near future (L3 Sydney to Kingsford and the Parramatta Light Rail). These light rail lines have led to changes in bus routes and train routes (eg, Newcastle Station and the Carlingford Line), and also impact interactions with the Stockton Ferry.
- In 2019 NSW's first metro opened between Tallawong and Chatswood, with its extension to Bankstown expected to open in 2024 and construction of Sydney Metro West expected to start in 2020.

These changes make it difficult to model LRMC. Our model services demand for one product with more of that product, so instead of moving passengers to the new light rail or building Metro West, it models extra bus services and replicating the existing railway between Wynyard and Westmead, respectively). There will be differences in costs of the different approaches, and converting heavy rail to metro or light rail has cost implications that are very difficult to accurately model.

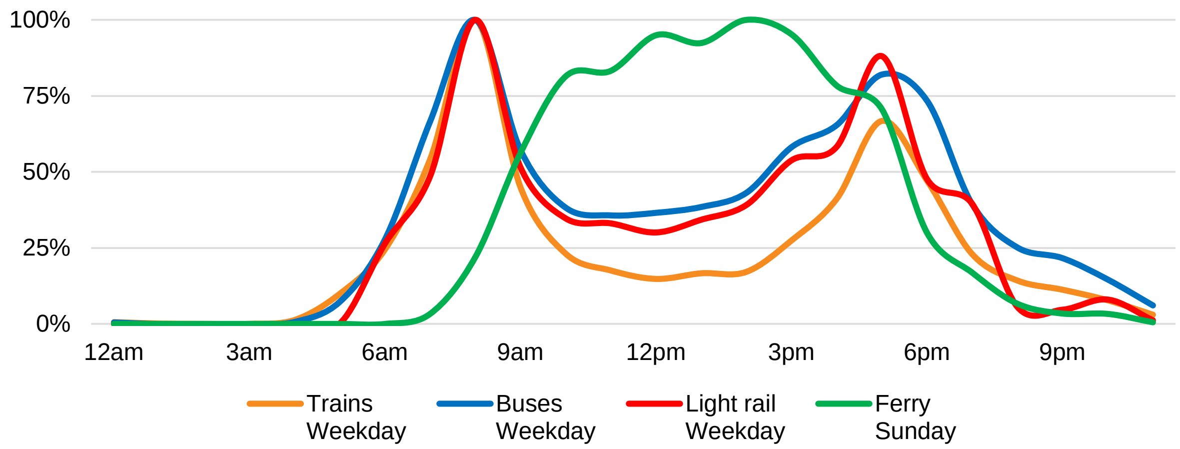
On balance, we consider that the relatively small benefits from publishing LRMC figures are outweighed by the need for further consultation on methodology, and the difficulty in producing accurate LRMC estimates within a changing network. We have instead decided to publish our preferred methodology for calculating LRMC and what information we have relied upon from this analysis.

How did LRMC influence off-peak prices?

We have recommended maintaining off-peak prices for trains and allowing off-peak prices for buses and light-rail (in periodic passes or subscription package). This decision was influenced by our LRMC modelling which found that most costs of expanding the network are driven by peak demand and that the peak demand for these modes is fairly closely aligned with the current peak times for trains.

This can be seen by looking at data on when most passengers use the network, pushing it close to capacity (see figure below). This figure shows that peak demand on trains, buses and light rail occur in the weekday morning peak between 6am and 9am. Ferry demand has a different profile with peak demand for the network occurring on Sunday afternoon.

Demand profile of each mode on peak day of the week



Note: We have shown Ferry demand on Sunday as that is when its peak demand occurred in the data provided by Transport for NSW.

Data source: IPART analysis of Transport for NSW data.

Our work on elasticities (see our Information paper on patronage and elasticity estimates) suggests that off-peak charges may incentivise some customers to change when they travel. This can lead to cost savings as it alleviates cost pressures on the network at times when capacity is constrained (ie. where new investment is required) and improves utilisation of the network at quieter times, when spare capacity already exists and additional demand can be met either on existing services or by comparatively small changes to service frequency.

How did we model LRMC?

We built LRMC models for:

- The entire OPAL rail network
- The top 100 OPAL bus routes
- The ferry network, and
- The Central to Dulwich Hill light rail.

We modelled the additional services, vehicles and tracks needed over the next 30 years. Our model calculates individual routes and system wide LRMC using two approaches: perturbation and average incremental costs. This analysis is more sophisticated than what we have done previously as we now have access to Opal data. By comparison, in 2015 we modelled the average incremental costs of the Chatswood to Bankstown metro, and the Sydney CBD to South-East light rail. By focusing on major augmentations (and demand serviced by them), this approach leads to higher LRMC estimates than the approach we have taken at this review, which aims to look at as much of the network as possible.

Further information on our approach to modelling LRMC is included at Attachment A and details of our modelling inputs at Attachment B.

A Our approach to modelling LRMC

The OPAL public transport system is complex. It has 4 modes of transport, millions of passengers each year, thousands of services each day, in a region with a population over 6 million people.[2] This complexity is reflected in our modelling.

Our model uses actual transport routes

We have built four independent models, for each mode of transport and each route (or for trains each section of track between stations). Data limitations and complexity have meant that we have not modelled passengers moving between modes or on multi-modal journeys.

The services included in our models are outlined in Table 2 below.

Table 2 The services we modelled

Mode	Services modelled
Trains	All weekday Sydney Trains, NSW Trainlink Intercity Train and Metro services. We have incorporated the completed Metro line from Chatswood to Bankstown and removed T3 services between Bankstown and Sydney (see Box 1 below). We have not included the Parramatta metro as we have insufficient information on the location of stops, and because it less closely follows existing train lines it is more difficult to make realistic assumptions.
Buses	We included all existing weekday services on the 100 busiest bus routes this accounts for 36% of all bus trips. These bus routes include: ▼ 95 routes within Greater Sydney ▼ 3 routes in Newcastle, and ▼ 2 routes in Wollongong. Around 80 of the Greater Sydney routes go in or near the Sydney CBD. Our decision to model 100 routes was based on the data provided by Transport for NSW.
Light rail	We modelled the existing weekday services of the Central to Dulwich Hill light rail route. We did not model the Sydney CBD and South East light rail or the Newcastle light rail. Our decision to only model the Central to Dulwich Hill light rail route was based on the data provided by Transport for NSW.
Ferries	We modelled all Sydney ferry services. We did not model the Stockton ferry in Newcastle.

For buses, light rail and ferries we have modelled entire routes, it is typically simple to identify which bus, light rail route or ferry route a passenger is on based on OPAL data collated by Transport for NSW.

However, it is more complicated for trains to identify which train route is being used (for example, a passenger travelling from Epping to Central could take the Metro and T1 via Chatswood, the T9 or the Central Coast Newcastle Line), so we have looked at segments between stations. We have used raw OPAL data with each passengers tap on and tap off

2 The population of Bathurst, Bowral-Mittagong, Central Coast, Goulburn, Lithgow, Morisset – Cooranbong, Muswellbrook, Newcastle – Maitland, Nowra – Bomaderry, Sydney and Wollongong was greater than 6 million in 2018, source: ABS, *3218.0 Regional Population Growth, Australia, 2017-18, Population Estimates by Significant Urban Area (ASGS 2016), 2008 to 2018*, *https://www.abs.gov.au/AUSSTATS/subscriber.nsf/log?openagent&32180ds0003_2008-18.xls&3218.0&Data%20Cubes&B4D56493CB2A7D66CA2583C9000DF27D&0&2017-18&27.03.2019&Latest* accessed 26 February 2020

station. We estimated the route the passenger took using Dijkstra's algorithm[3] to calculate the shortest time between the tap on and tap off. The modelling assumes that there is always a train ready to leave when a passenger arrives (this was a simplifying assumption to remove the need to incorporate a timetable). We have included a 5 minute switching time, to reflect the likely time that it takes passengers to change trains.

Box 1 The Chatswood to Bankstown metro line

We decided to include the Chatswood to Bankstown metro (currently under construction) in our calculations. This line is currently being constructed. We decided it was important to include the Chatswood to Bankstown metro line because it will likely have a dramatic impact on the LRMC of the train network:

- The Chatswood to Bankstown metro removes the T3 line going through the city circle line, this will allow significant increases in frequency for the T2 and T8 lines that also use the city circle line.
- The additional harbour crossing from the Chatswood to Bankstown line will facilitate much greater capacity between Sydney and the Lower North Shore.

Having decided that it is important to include the Chatswood to Bankstown metro line we needed to make assumptions on how passengers will use the line. Our assumptions are:

- The metro line will be more convenient for one-third of passengers at each of the following stations:
  - St Leonards (preferring to use the Crows Nest station)
  - Wollstonecraft (preferring to use the Crows Nest station)
  - Waverton (preferring to use the Victoria Cross station)
  - North Sydney (preferring to use the Victoria Cross station)
  - Wynyard (preferring to use the Barangaroo station)
  - Town Hall (preferring to use the Pitt St station)
  - Redfern (preferring to use the Waterloo station).
- All passengers currently catching the T3 where it will be replaced by the Metro will catch the Metro.
- Passengers can walk between the above station and their substitute in 3 minutes (when calculating routes between locations).
- There are no additional passengers that are not currently using the trains.

We consider that these are very conservative assumptions. The Sydney Metro City & Southwest Final Business Case Summary does not identify what proportion of passengers the NSW Government forecasts will transfer from the conventional rail to the metro rail. In general, by only moving one third of passengers it is likely that this will increase the LRMC estimate as conventional train lines have a lower capacity for passengers.

3 Dijkstra's algorithm is an algorithm for finding the shortest path between two points. For further explanation see: https://www.sciencedirect.com/topics/computer-science/dijkstra-algorithms

Our model is forward looking

For each mode and route we modelled expected demand and what is needed to supply demand over the 30-years from 2020 to 2050. Demand is modelled by looking at existing demand, based on data provided by Transport for NSW (and raw OPAL data for Trains). We forecast demand in future years based on the NSW Department of Planning's forecast population growth rates.[4] To calculate demand growth we have:

- For buses, light rail and ferries applied the average population growth rate in the Council the route starts and the Council the route ends. We multiply this by a factor based on historical demand growth compared to population growth.
- For trains applied the average population growth rate in the Council the passenger starts his or her journey and the Council the passenger ends his or her journey. We multiply this by 2, which is based on historical demand growth compared to population growth.

In calculating costs, our models only consider future avoidable costs, and assume that existing services will continue to be provided. The avoidable costs include:

- Those created by additional passengers riding existing public transport services (primarily additional fuel costs on buses)
- Those created providing additional train, bus, light rail, and ferry services using the existing fleet (primarily fuel and staffing costs)
- Those created buying additional trains, buses and trams to provide these additional services (the costs of buying the vehicle), and
- Those created increasing the capacity of the rail (the costs of building new tracks and platforms for trains).

Any costs of running the existing timetable and supplying existing customers were not included in the analysis.

Additionally, the models only allowed the number of services, vehicles and/or tracks to grow – it did not factor in any reductions in these. This means that poorly used services continue to operate, including in areas with a negative growth rate.

Service frequency comes from timetable data

Our models use the existing timetable to calculate how frequent services are at present. We use the timetable published on Transport for NSW's Open Data. We extracted each service and recorded which hour each bus, light rail and ferry service occurred. For trains we extracted how many services stopped at each station and where the service goes next.

Service frequency was used in the bus model to estimate how many buses are needed. Because the bus model only considers the 100 busiest bus routes in the OPAL network, we could not use actual bus fleet numbers. Therefore we modelled an appropriate fleet size for the services (assuming they all operated an equal distance from the depot). A similar approach was used for expanding the Metro to include Chatswood to Bankstown.

4 https://www.planning.nsw.gov.au/Research-and-Demography/Population-projections/Projections

For ferries, light rail and trains we used actual fleet numbers.

The model estimates annual costs by route then aggregates

The models use the population forecasts to grow demand (see above). For the perturbation calculations the model creates additional demand scenarios where demand starts 5-10% higher than current demand. As demand grows, the models add additional services necessary to meet that extra demand. As service numbers grow the models will add additional vehicles and infrastructure (such as tracks and bus depots) that is needed to accommodate the extra services. Where possible, additional vehicles are shared by all routes that could use them. The model allocates costs to the routes that need the additional vehicle or infrastructure.

This creates an estimate of the costs of supplying additional demand for each route for each hour on a weekday (for our ferry model we have also included weekends in order to capture the peak demand). These costs are multiplied out to reflect how many weekdays there are each year.

The models calculate the LRMC by route and hour using both the perturbation and average incremental cost approaches (see Box 2). These are then aggregated into system-wide peak and off-peak LRMC estimates. We have adopted the existing peak and off-peak hours for Sydney Trains because the pattern of demand on buses and light rail shows that the peaks for these services are similar to that of trains.

Box 2 The perturbation and average incremental cost approaches to LRMC

There are two common approaches to calculating the LRMC. Our model uses both approaches to reflect the inherent uncertainty in calculating LRMC.

Perturbation uses a marginal change in demand

The perturbation approach estimates the change in costs over the period by comparing the expected costs forecast under the base demand growth expected with a scenario where the forecast demand is ‘shocked’ (ie, increased or decreased by a small amount in each year of the scenario). The shock represents a marginal permanent change in demand. The perturbation LRMC formula is:

$$\mathrm{LRMC}_{\mathrm{perturbation}}=\frac{\mathrm{NPV}[\mathrm{Costs}_{\mathrm{shocked}}\text{-}\mathrm{Costs}_{\mathrm{Forecast}}]}{\mathrm{NPV}[\mathrm{Passengers}_{\mathrm{shocked}}\text{-}\mathrm{Passengers}_{\mathrm{Forecast}}]}$$

Perturbation approaches are typically more data intensive. The perturbation approach focuses on the costs of bringing forward new services, vehicles and infrastructure.

Average incremental cost looks at average change in costs with forecast demand changes

The average incremental cost (or AIC) approach involves estimating the average unit cost of meeting all growth in demand over a forward period. The estimate is compared to scenario of static demand. Over the long term, average costs of serving additional demand is often similar to the marginal cost.

$$\mathrm{LRMC}_{\mathrm{AIC}}=\frac{\mathrm{NPV}[\mathrm{Costs}_{\mathrm{Forecast}}\text{-}\mathrm{Costs}_{\mathrm{Current}}]}{\mathrm{NPV}[\mathrm{Passengers}_{\mathrm{Forecast}}\text{-}\mathrm{Passengers}_{\mathrm{Current}}]}$$

The AIC approach is easier to model. It only requires one forecast of future demand and costs, and knowledge of existing costs.

Perturbation and average incremental cost both provide signals of marginal costs

The perturbation and AIC approaches both have benefits. The perturbation approach more closely reflects a marginal change, however is computationally more difficult to calculate as models need to calculate how the system will react to demand. The AIC approach can use significantly less data, with the assumption that all additional future costs are due to additional demand for public transport.

The AIC and perturbation approaches will lead to different estimates. The two approaches should result in similar estimates where there are many relatively frequent, small augmentations, but more differences where there are large and infrequent augmentations. Because of this, using the same data for both approaches we would expect similar estimates for buses, but divergence between the two estimates for trains (with perturbation being more accurate provided that the underlying data is good enough).

There is a wide range of input data and assumptions

The train and light rail networks are characterised by very large and infrequent investment in new lines. These investments reduce the usefulness of using an average incremental cost approach (see Box 2). While theoretically the perturbation approach is preferable, it requires a great deal more input data and assumptions to be made that the average incremental cost approach, which can be estimated relatively easily if good forecasts of demand growth and future costs are available.

However, even for the average incremental cost approach, there is limited information on forecast long-run demand and costs. We have also seen significant uncertainty in cost estimates with large projects often not running to budget (eg, Metro from Tallawong to Chatswood under budget by $1 billion and the light rail from the Sydney CBD to South East is reportedly over budget by $1.3 billion[5]).

We built a perturbation model that would estimate costs based on a range of demand forecasts and unit costs. These unit costs are a best estimate, but are likely very different than real life costs. Such a high degree of uncertainty regarding significant inputs means that the modelling could create inaccurate estimates for the LRMC.

5 The Australian, *Small business turns a corner as Sydney's light rail gets moving,* 27 January 2020, https://www.theaustralian.com.au/business/small-business-turns-a-corner-as-sydneys-light-rail-gets-moving/news-story/fe703139989e1cac8708f35ed9e4edbc accessed 21 February 2020; The Guardian, *Sydney light rail project blows out to $2.9bn, almost double original cost,* 23 November 2017, https://www.theguardian.com/australia-news/2019/nov/23/sydney-light-rail-project-blows-out-to-29bn-almost-double-original-cost accessed 21 February 2020.

B Inputs to our LRMC models

Many of the inputs used in our LRMC analysis came from information provided by Transport for NSW (as indicated in the tables below). This information was provided on a confidential basis.

Buses

Table 1 Inputs to our bus LRMC model

Cost input	Source/basis
Purchase cost – standard bus	Provided by Transport for NSW.
Purchase cost – articulated bus	Provided by Transport for NSW.
Purchase cost – double decker bus	Provided by Transport for NSW.
Purchase cost – additional depot	Provided by Transport for NSW.
Vehicle useful life	Provided by Transport for NSW.
Capacity – standard bus	Transport for NSW, *Sydney's bus future Simpler, faster, better bus services,* December 2013, p 23, https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/sydney-bus-future-final-web_0.pdf accessed 27 February 2020.
Capacity – articulated bus	Transport for NSW, *Sydney's bus future Simpler, faster, better bus services,* December 2013, p 23, https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/sydney-bus-future-final-web_0.pdf accessed 27 February 2020.
Capacity – double decker bus	Transport for NSW, Five brand new double decker buses for Sydney, 12 June 2013, https://www.transport.nsw.gov.au/newsroom-and-events/media-releases/five-brand-new-double-decker-buses-for-sydney, accessed 28 November 2019.
Capacity – additional depot	Provided by Transport for NSW.
Casual bus driver wage	Provided by Transport for NSW.
Bus driver high capacity loading	Provided by Transport for NSW.
Cleaning costs	State Transit Authority Bus Operations Enterprise (State) Award 2018, average of Bus Cleaner levels 1, 2, 3 & 4, assuming 1.5% of a vehicles time is spent being cleaned.
Diesel cost	Provided by Transport for NSW.
Fuel efficiency – standard bus	Provided by Transport for NSW.
Fuel efficiency – articulated bus	Provided by Transport for NSW.
Fuel efficiency – double decker bus	Provided by Transport for NSW.
Maintenance	Provided by Transport for NSW.

Cost input	Source/basis
Maximum proportion of buses operating	Provided by Transport for NSW.
Add a new service when existing services are at what capacity	Provided by Transport for NSW.
Average trip distance as a proportion of total route	Provided by Transport for NSW.
Growth rate	Population growth as calculated by NSW Department of Planning by Council area. For bus routes the growth rate is calculated as the average of the Council area the route begins and the Council area the route ends in. We have calculated LRMC using our growth rate multiplied by the Department of Planning's main, low, and high population growth scenarios.
Perturbation shock	The aim of a perturbation shock is to be the smallest shock that has a meaningful impact on the timing of costs. Sensitivity testing suggests that a figure of 5% is appropriate.
Discount rate	IPART's pre-tax real WACC for buses (consistent with February 2020 bi-annual update).

Trains

Table 2 Inputs to our train LRMC model

Cost input	Source/basis
Purchase cost – conventional train	Provided by Transport for NSW
Purchase cost – Metro train	We estimated $20 million per train based on reviewing the range of prices that Alstom Metropolis Trains from purchases between 2010 and 2015. Railway Technology, Alstom Metropolis Trains, https://www.railway-technology.com/projects/alstom-metropolis-trains/ accessed 15 January 2020.
Purchase cost – Underground track	Provided by Transport for NSW
Purchase cost – Underground platform	Provided by Transport for NSW
Vehicle useful life	Provided by Transport for NSW
Capacity – conventional	Provided by Transport for NSW
Capacity – Metro	The Sydney Metro Business Case Summary states metro trains have a design capacity of 1,152. Sydney Metro, Sydney Metro city & southwest Final Business Case SUMMARY, October 2016, p 24.
Capacity – conventional trains per hour	Provided by Transport for NSW
Capacity – metro trains per hour	The Sydney Metro Business Case Summary states the metro lines are designed for capacity of up to 30 trains per hour. Sydney Metro, Sydney Metro city & southwest Final Business Case SUMMARY, October 2016, p 24.
Fleet size – conventional trains	Provided by Transport for NSW
Casual crew wage	Provided by Transport for NSW
Cleaning costs	Provided by Transport for NSW
Electricity cost	Provided by Transport for NSW

Cost input	Source/basis
Fuel efficiency – conventional train	Provided by Transport for NSW
Fuel efficiency – metro train	Assumed to be the same as conventional trains.
Maintenance	Provided by Transport for NSW
Maximum proportion of trains operating	Provided by Transport for NSW
Add a new service when existing services are at what capacity	We performed sensitivity testing on this variable in the sensible range (75% to 100%) and found it was not very sensitive to this assumption. As for buses and ferries, we adopted 90% based on our assumption for light rail.
Additional distance/duration for positioning	Provided by Transport for NSW
Growth rate	Transport for NSW identified expected growth of 3% per year over the next 10-years.The NSW Department of Planning's main population growth estimate for Sydney is 1.7% per year (both from 2021-2031 and from 2016-2041). Therefore, we have adopted 1.8 times population growth, as calculated by NSW Department of Planning by Council area. This is calculated by the average of the passengers' origin council and destination council. We have calculated LRMC using our growth rate multiplied by the Department of Planning's main, low, and high population growth scenarios.
Perturbation shock	The aim of a perturbation shock is to be the smallest shock that has a meaningful impact on the timing of costs. Sensitivity testing suggests that a figure of 5% is appropriate.
Discount rate	IPART's pre-tax real WACC for rail (consistent with February 2020 bi-annual update).

Ferries

Table 3 Inputs to our ferry LRMC model

Cost input	Source/basis
Purchase cost – Freshwater ferry	The Freshwater ferries cost $8.5 million in 1982. Assuming costs increased in line with inflation a new Freshwater class ferry would cost $32 million. Transdev Sydney Ferries, *Freshwater,* http://www.beyondthewharf.com.au/stories/freshwater/ accessed 11 February 2020.
Purchase cost – First Fleet/Emerald ferry	According to ABC news Incat Tasmania was contracted to build 6 Emerald Class ferries (with the same capacity as the First Fleet ferries) for $50 million in 2015. This equates to $8.3 million per ferry, or $9 million in 2019 dollars. ABC News, *Incat Tasmania wins $50m contract to build six new Sydney ferries,* 23 September 2015, https://www.abc.net.au/news/2015-09-23/incat-wins-contract-to-build-six-new-sydney-ferries/6797850 accessed 11 February 2020

Cost input	Source/basis
Purchase cost – Catamaran	According to the Sydney Morning Herald, the NSW Government estimated that the costs of seven RiverCat vessels, two HarbourCat vessels and nine First Fleet Ferries would cost $120 million. Based on our estimate that nine First Fleet ferries would cost $81 million (above), we estimated that catamarans would cost $5 million each. Sydney Morning Herald, *Purchase of new ferries for Sydney's busy Parramatta River shelved,* 2 January 2019, https://www.smh.com.au/national/nsw/purchase-of-new-ferries-for-sydney-s-busy-parramatta-river-shelved-20181221-p50nr3.html accessed 11 February 2020.
Vehicle useful life	Existing ferries are quite old, with Freshwater ferries launched in 1982. It is not clear how long they remain serviceable. We have decided to treat the ferries as non-depreciable.
Capacity – Freshwater ferry	Transdev Sydney Ferries, *Freshwater,* http://www.beyondthewharf.com.au/stories/freshwater/ accessed 11 February 2020.
Capacity – First Fleet/Emerald ferry	First Fleet ferries have a capacity of 403 or 393 passengers and Emerald class ferries have a capacity of 400 passengers. Transdev Sydney Ferries, *Bungaree,* http://www.beyondthewharf.com.au/stories/bungaree/ accessed 11 February 2020; Transdev Sydney Ferries, *Golden Grove,* http://www.beyondthewharf.com.au/stories/goldenn-grove/ accessed 11 February 2020; Transdev Sydney Ferries, *Alexander,* http://www.beyondthewharf.com.au/stories/alexander/ accessed 11 February 2020.
Capacity – catamaran	Transdev Sydney Ferries, *Evonne Goolagong,* http://www.beyondthewharf.com.au/stories/evonne-goolagong/ accessed 11 February 2020.
Fleet – Freshwater ferry	Transdev Sydney Ferries, *Freshwater Class,* http://www.beyondthewharf.com.au/freshwater-class/ accessed 11 February 2020
Fleet – First Fleet/Emerald ferry	Transdev Sydney Ferries, *First Fleet Class,* http://www.beyondthewharf.com.au/first-fleet-class/ accessed 11 February 2020; Transdev Sydney Ferries, *Emerald Class,* http://www.beyondthewharf.com.au/emerald-class/ accessed 11 February 2020.
Fleet – Catamaran	Transdev Sydney Ferries, *RiverCat Class,* http://www.beyondthewharf.com.au/rivercat-class/ accessed 11 February 2020; Transdev Sydney Ferries, *HarbourCat Class,* http://www.beyondthewharf.com.au/harbourcat-class/ 11 February 2020; Transdev Sydney Ferries, *SuperCat Class Vessels,* http://www.beyondthewharf.com.au/supercat-class/ accessed 11 February 2020.
Crew wage – Freshwater ferry	FairWork Commission, *Harbour City Ferries Maritime Agreement 2018,* 7 March 2019, https://www.fwc.gov.au/documents/documents/agreements/fwa/ae502182.pdf accessed 11 February 2020; FairWork Commission, *Harbour City Ferries Outer Harbour Engineers' Agreement 2018,* 7 March 2019, https://www.fwc.gov.au/documents/documents/agreements/fwa/ae502179.pdf accessed 11 February 2020.
Crew wage – First Fleet/Emerald ferry	FairWork Commission, *Harbour City Ferries Maritime Agreement 2018,* 7 March 2019, https://www.fwc.gov.au/documents/documents/agreements/fwa/ae502182.pdf accessed 11 February 2020;

Cost input	Source/basis
Crew wage – Catamaran	FairWork Commission, *Harbour City Ferries Maritime Agreement 2018,* 7 March 2019, https://www.fwc.gov.au/documents/documents/agreements/fwa/ae502182.pdf accessed 11 February 2020;
Cleaning costs – Freshwater ferry	We have taken bus cleaning costs and scaled it up based on vehicle capacity.
Cleaning costs – First Fleet/Emerald ferry	We have taken bus cleaning costs and scaled it up based on vehicle capacity.
Cleaning costs – Catamaran	We have taken bus cleaning costs and scaled it up based on vehicle capacity.
Diesel cost	NRMA, Weekly fuel report, 12 month average for diesel, https://www.mynrma.com.au/membership/my-nrma-app/fuel-resources/weekly-report/17-06-19, accessed 28 November 2019.
Fuel efficiency – Freshwater ferry	Arup, *Cost of Emissions for NSW Ferry Networks,* Final report for IPART, 19 November 2014, p 8.
Fuel efficiency – First Fleet/Emerald ferry	Arup, *Cost of Emissions for NSW Ferry Networks,* Final report for IPART, 19 November 2014, p 8.
Fuel efficiency - Catamaran	Arup, *Cost of Emissions for NSW Ferry Networks,* Final report for IPART, 19 November 2014, p 8.
Maintenance – Freshwater ferry	A cost consultancy found that maintenance costs were similar to fuel costs. Without better data we have assumed they remain similar. L.E.K., *Sydney Ferries Cost Review,* 13 January 2012, p 10.
Maintenance – First Fleet/Emerald Ferry	A cost consultancy found that maintenance costs were similar to fuel costs. Without better data we have assumed they remain similar. L.E.K., *Sydney Ferries Cost Review,* 13 January 2012, p 10.
Maintenance - Catamaran	A cost consultancy found that maintenance costs were similar to fuel costs. Without better data we have assumed they remain similar. L.E.K., *Sydney Ferries Cost Review,* 13 January 2012, p 10.
Maximum proportion of ferries operating	IPART estimate. Assume ferry availability the same as availability of the other modes.
Add a new service when existing services are at what capacity	We performed sensitivity testing on this variable in the sensible range (75% to 100%) and found it was not very sensitive to this assumption. As for buses and trains, we adopted 90% based on our assumption for light rail.
Additional distance/duration for positioning	Adopted the figure provided by Transport for NSW for trains.
Growth rate	Population growth as calculated by NSW Department of Planning by Council area. For bus routes the growth rate is calculated as the average of the Council area the route begins and the Council area the route ends in. We have calculated LRMC using our growth rate multiplied by the Department of Planning's main, low, and high population growth scenarios. We adopted 2x population growth of the origin and destination councils given that the average growth of Sydney's population is greater than the harbourside suburbs. This accounts for people using ferries from across Greater Sydney.
Perturbation shock	The aim of a perturbation shock is to be the smallest shock that has a meaningful impact on the timing of costs. Sensitivity testing suggests that a figure of 10% is appropriate.
Discount rate	IPART's pre-tax real WACC for ferries (consistent with February 2020 bi-annual update).

Light rail

Table 4 Inputs to our Dulwich Hill to Central light rail LRMC model

Cost input	Source/basis
Purchase cost – tram	Provided by Transport for NSW.
Vehicle useful life	Transport for NSW noted a design life of 30-35 years. There are 244 services on a typical weekday, 202 on typical weekend, and 52 weeks in a typical year. Across the 12 trams in the Dulwich Hill to Central fleet this would mean travelling around 90,000km each year. Over 32.5 years this is around 2.9 million km
Capacity – tram	Provided by Transport for NSW.
Fleet – trams	Provided by Transport for NSW.
Casual drivers wage	Provided by Transport for NSW.
Cleaning costs	State Transit Authority Bus Operations Enterprise (State) Award 2018, average of Bus Cleaner levels 1, 2, 3 & 4, assuming 3% of a vehicles time is spent being cleaned.
Electricity cost	Provided by Transport for NSW.
Fuel efficiency – tram	Provided by Transport for NSW.
Maintenance	Provided by Transport for NSW.
Maximum proportion of trams operating	Provided by Transport for NSW.
Add a new service when existing services are at what capacity	We performed sensitivity testing on this variable in the sensible range (75% to 100%). We found that on figures lower than 90% this assumption alone was enough to result in a different number of vehicles required under the base and perturbation scenarios. We consider that 90% is a reasonable assumption and one that does not impact the results of the analysis.
Additional distance/duration for positioning	Provided by Transport for NSW
Growth rate	Population growth as calculated by NSW Department of Planning by Council area. For the Inner West light rail route the growth rate is calculated as the average of the Council area the route begins and the Council area the route ends in. We have calculated the low, base and high growth scenarios.
Perturbation shock	The aim of a perturbation shock is to be the smallest shock that has a meaningful impact on the timing of costs. Sensitivity testing suggests that a figure of 10% is appropriate.
Discount rate	IPART's pre-tax real WACC for light rail (consistent with February 2020 bi-annual update).