

# Passenger Benefits of Sydney Metro

Neil Douglas<sup>1</sup> and Peter Thornton<sup>2</sup>

<sup>1</sup> Douglas Economics, New Zealand

<sup>2</sup> Transportation Associates, Australia

Email for correspondence: [Douglaseconomics@gmail.com](mailto:Douglaseconomics@gmail.com)

## Abstract

Transportation Consultant and Civil engineer Peter Thornton debates with transport economist Neil Douglas the benefits of Sydney Metro using the experience of one particular passenger. The dialogue between Peter Thornton and Neil Douglas, explains the contemporary approach of calculating benefits by attaching 'willingness to pay' values to journey attributes such as stations, train fleet, travel time, service frequency, reliability, seating and interchange. Given Peter's engineering and planning interests, the discussion also digresses over some of the construction, operational and network aspects of Sydney Metro.

## 1. Introduction

Peter Thornton, a Transportation consultant and civil engineer is like many other Sydneysiders, interested in the performance of the 36km Sydney Metro Northwest from Rouse Hill to Chatswood (Figure 1) which opened to revenue service on 26 May 2019.

Many people ask Peter questions about the way such projects are assessed. Recently, a public sector worker (the Epping commuter<sup>1</sup>) who lives in Epping and works in Milsons Point summarised his morning commute. In this paper, Peter relays the details to Dr Neil Douglas, a transport economist and who, over a period of twenty years, has helped NSW Rail develop a demand forecasting and evaluation methodology.<sup>2</sup>

On the opening of Sydney Metro, the Epping commuter was faced with a choice. He could continue to use the T9 service and travel via Strathfield, Central and CBD stations to finish at Milsons Point shown as the red line in Figure 1. Alternatively, he could use Sydney Metro, change at Chatswood onto a North Shore train and travel onto Milsons Point which is shown as the blue then green line.

In the morning peak, it would take him 47 minutes (7:29 – 8:16 AM) if he travelled via Strathfield or 28 minutes plus a transfer at Chatswood via Sydney Metro. With both services on the OPAL fare system, there would be no difference in fare (\$5 per trip).

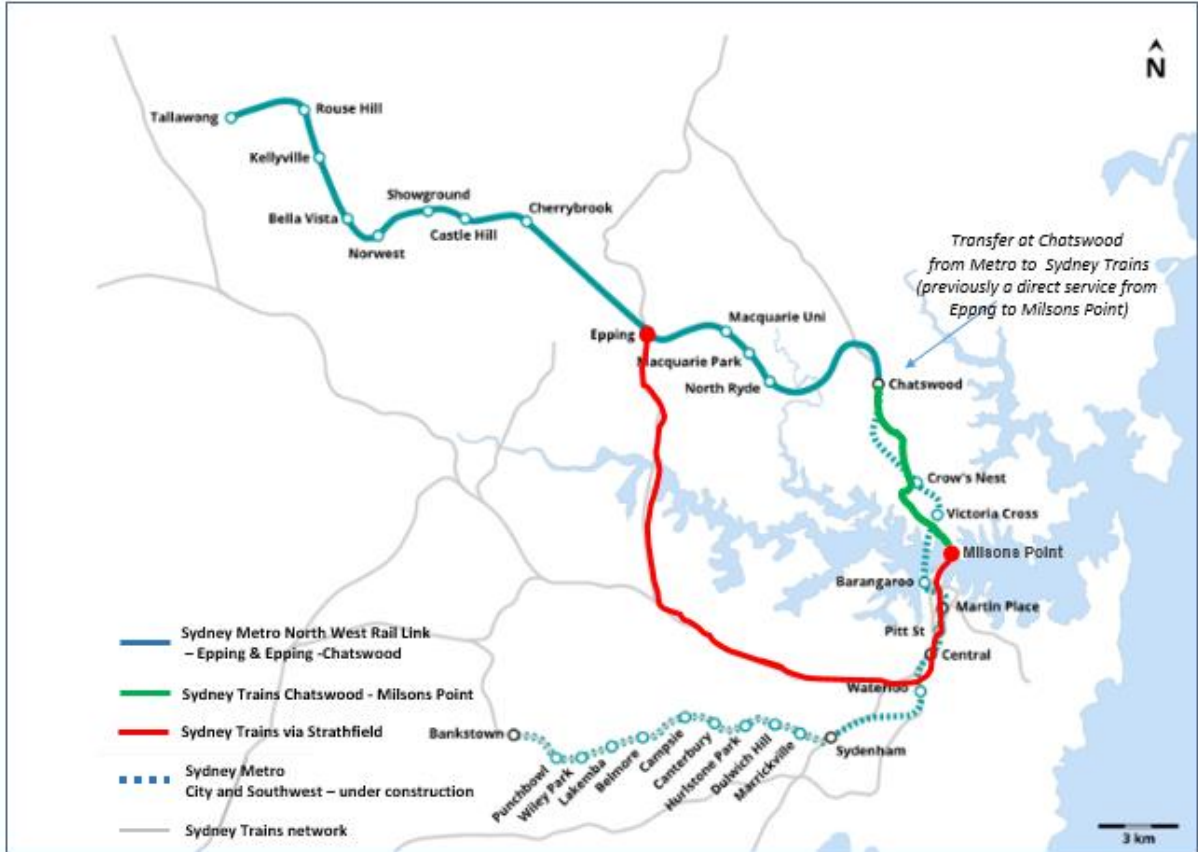
Given the difference in travel time, the choice is pretty clear for our Epping commuter. It's to use Sydney Metro. A summary of the trip is provided in Figure 2.

---

<sup>1</sup> Who happens to be male though the matters discussed could apply to both genders alike.



<sup>2</sup> Neil also undertook the 2006 Economic Evaluation of North West Transport Link which looked at bus, Light Rail and heavy rail options for connecting the north-west sector to the Sydney rail system, Douglas Economics (2006).

Figure 1: Sydney Metro route and stations



Base map courtesy of Wikipedia

Figure 2: Choice between Sydney Metro and Sydney Train

	Sydney Metro	Sydney Trains
		
Frequency	Every 5 mins	Every 15 mins (direct service) <sup>3</sup>
Travel Time	28 mins plus Transfer at Chatswood	47 mins via Strathfield and CBD
Fare	\$5	\$5
Capacity	378 Seated / 806 Standing	894 Seated / 258 Standing

Estimated tare weights of the two trains is Metro 240 tonnes & Double decker 400 tonnes.

Whilst the Epping commuter’s decision ‘today’ is clear cut, Peter wanted to understand the transport economist’s interpretation. Peter was also interested in whether the Epping commuter was better off with Sydney Metro since before it was constructed,

<sup>3</sup> There are many intermediate service that are available to this passenger but require cross platform interchanging.

he could travel ‘direct’ by Sydney Trains to Milsons Point without changing at Chatswood.

Peter asked Neil how the various aspects of the passenger’s journey including the amenity of the stations and trains could be included in an overall net benefit figure used in Economic Appraisals that can play a pivotal role in Government decision-making.

## 2. Valuing a Modern Station

**Peter Thornton:** My Epping commuter friend uses a modernised station and has exclaimed that he *“feels proud to be a Sydneysider, with the privilege of being in the first group of passengers in Sydney, and probably in Australia, using, what is proclaimed to be by Government, “world class public transport facilities”.*

The Northwest Sydney Metro line has eight new stations: Tallawong, Rouse Hill, Kellyville, Bella Vista, Norwest, Showground, Castle Hill and Cherrybrook. Figure 3 presents some photographs. Other stations such as Epping, the Macquarie stations, North Ryde and Chatswood have been modified for the single deck driverless trains.

**Figure 3: Sydney Metro Stations**



Clockwise from top left Castle Hill, Rouse Hill, Macquarie University & North Ryde

All the stations are fully accessible with lifts and level access between platforms and trains. The stations also have glass safety screen doors along the edge of the platforms keeping people, luggage, bicycles, prams and the like away from the platform edge and possible accidents and allowing trains to arrive and depart quickly. Certainly to my eye they all look very nice and shiny with good vertical transport with some stations also having large multilevel carparks. They also look to have very good public toilet facilities – male, female and unisex, which to me is the mark of a progressive society. Well not the fact that they are unisex but that there are plenty of toilets for both sexes and, of course, for people who don’t identify as either sex.

So Neil, how does a transport economist value the benefit of a modern station like Epping to a passenger?

**Neil Douglas:** Economists are often tagged, unfairly I suggest, with Oscar Wilde's observation that we "*know the price of everything but the value of nothing*". I'd say the tag is unfair since economists try hard to put values on goods and services but possibly too hard in transport Cost Benefit Appraisal nowadays.<sup>4</sup> We do it in Gross Domestic Product (GDP) measures for instance by looking at prices and market shares. Indeed over here in New Zealand, the Government's latest 2019 'budget has emphasised the 'well-being' of people via rating measures of the 'quality of life'.

State Rail and then RailCorp pioneered the use of ratings to value the quality of rail service. George Karpouzis, the chief economist during the noughties deserves credit for undertaking research that established a set of values for stations and trains, see Douglas and Karpouzis (2006). Essentially, passengers were asked to rate the stations they used in terms of attributes like weather protection, seating, information, toilets, lighting, cleanliness, ease of getting to the platform and boarding the train and so on and also give an overall rating for the station they use. 'Willingness to Pay' surveys were also conducted to value the rating changes. These surveys were continued over a period of two decades until TfNSW took over rail planning. The last rating surveys were undertaken in 2014, Douglas Economics (2016).

Macquarie Park and Macquarie University which were the newest stations in 2014 scored 88% compared to the average station rating of 63%.

It is likely that the new North West rail line stations would achieve similar ratings to the two Macquarie stations. So compared to the average station, the Sydney Metro stations could be 25 percentage points higher. Taking account of people's 'willingness to pay' for a higher station rating (which is non-linear reflecting peoples' greater willingness to pay to improve poorly rated as opposed to highly rated stations) I would value the new stations at 70 cents per trip or 2.7 minutes of time spent travelling on the train. A station's quality rating does decline over time however. The Sydney research has established a drop of one percentage point a year over the first decade of a station's life.

Now for your Epping commuter, the board and alight stations would be exactly the same travelling by Metro or Sydney Trains; they'd be Epping and Milson's Point! So unless the Metro platform with its platform doors is a noticeably nicer waiting environment than the Sydney Trains platform, he should be indifferent. For interest sake, the ratings for Epping and Milson's Point were 77% and 78% respectively when they were surveyed in 2014. Chatswood, where our Epping commuter now has to interchange, was rated at 77%. From the Sydney Trains research, the platform area accounts for around a quarter of the total station experience. Epping station platform

---

<sup>4</sup> Lord Darlington described a cynic to Cecil Graham in '*Lady Windermere's Fan*' as "*a man who knows the price of everything and the value of nothing*". Cecil Graham, replied that a sentimentalist is "*a man who sees an absurd value in everything and doesn't know the market price of any single thing*". I think transport Cost Benefit Analysis in Australia has been heading towards sentimentalism and away from cynicism with 'Wider Economic Benefits' and 'Social Exclusion Benefits'.

rated at 75%. If we assumed it increased to 85% with the Metro, then I calculate a benefit of 13 cents per trip (allowing for halo effects).

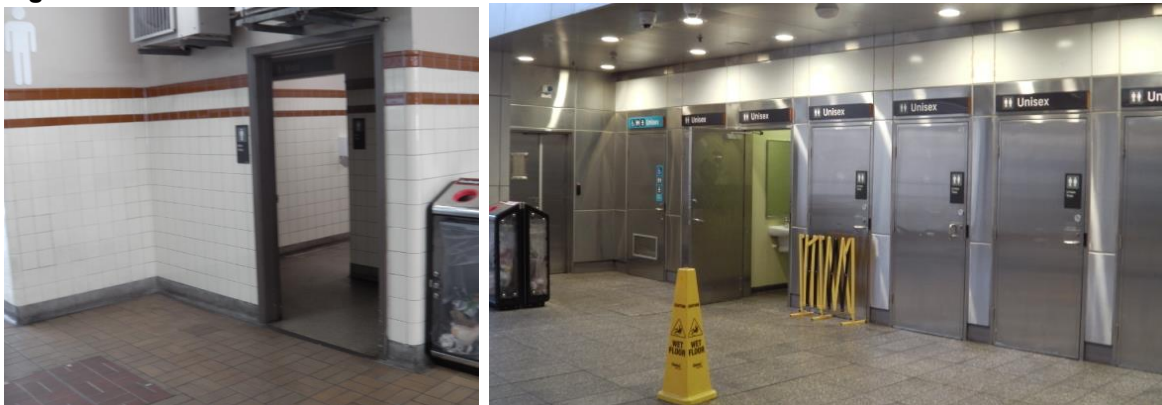
An important aspect in station design is accessibility for wheel-chair passengers and users who have sight, hearing or other mobility impairments. All the new stations are wheelchair accessible meeting obligations under the Disability Discrimination Act 1992. RailCorp undertook some path breaking research in the early 2000s which not only estimated the value of passenger lifts but now many people were likely to use them.

Moving on to station toilets. Well, Sydneysiders just don't know how lucky they are Peter! In New Zealand, only 18 out of 87 rail stations on the Auckland and Wellington networks had a toilet when surveyed in 2012 and passengers didn't view the ones that were provided highly either giving them a lowly rating of 44% on average (the highest rated toilets were at Newmarket with 71%), Douglas Economics (2016). In Sydney, the toilets at Macquarie University rated the highest across the network scoring 81% versus a system average of 51% and a low of 22% at Newtown station.

Station toilets are often forgotten about until you need one! Milsons Point's toilets, which are outside the gated area, have been a welcome relief to me on several occasions when I stayed in Kirribilli; that's except at night when they were invariably and inconveniently closed. Given the distance from the city, it's sensible for toilets to be installed at the new North West stations since there aren't any on the Metro trains.<sup>5</sup>

From an efficiency standpoint, the male urinal has a lot going for it. People don't want to miss their trains queuing for a unisex toilet and women will also benefit, indirectly at least, from male urinals reducing excess demand. So although unisex toilets may indeed *'mark the move to a progressive society'* it's not going to be such an efficient, economical and sustainable society if it's at the expense of the utilitarian male urinal.

**Figure 4: Milson's Point Male Toilet & Parramatta's Unisex Toilets**



Photographs courtesy of T. Brooker

**Peter Thornton:** It sounds like New Zealand is heading in the same direction as another small mountainous country, Bhutan, which believes that *"Gross National Happiness is more important than Gross Domestic Product"* but Bhutan doesn't have

---

<sup>5</sup> Neil Douglas undertook the economic evaluation of the outer-suburban Tangara G sets which did have toilets until they were removed to accommodate wheelchairs and extra seating for suburban operations.

railways. Here in Sydney, though, we would certainly be concerned about the gross happiness of passengers on our new train and rail service products. Maybe you should measure that as well? RailCorp's path breaking research does not sound too helpful to wheel chair passengers though? Don't they need smooth surfaces?

**Neil Douglas:** I helped with some research in the early 2000s when RailCorp installed passenger lifts into more than a hundred stations in Sydney. There were different types of lift (hydraulic and machine room less lifts). We summarised our research at two ATRF conferences. A noteworthy statistic is that wheelchair passengers make up 0.5% (i.e. 1 in 200) of lift users. Just under 15% were old or infirm but nearly three-quarters were able bodied passengers without any heavy luggage, Douglas et al (2010). The provision of lifts does encourage the use of rail. For Sydney, 35% of mobility challenged passengers replied that lifts had increased their use of rail and that if lifts were removed, 9% would stop using rail, Douglas (2011).

Some of the new stations are so far underground Peter that lifts and escalators are essential. It must certainly have been a feat of civil engineering to have buried them so far underground. Have you got any comments on the civil engineering involved in building the Sydney Metro project? I've heard the new stations being described as "*underground cathedrals to public transport*".

**Peter Thornton:** For starters Neil, they were not buried as for example were Museum and St James Stations on the City Underground but were constructed by excavating caverns in the underlying rock. They are significant feats of engineering and architectural design whose construction is greatly helped by the magnificent Hawkesbury Sandstone which can be cut like hard cheese. These stations are around 25m – 30m below ground level which, as I understand it, is thought to be the maximum depth that can be effectively served by escalators but, probably more importantly, the maximum depth that can be evacuated in the times now specified by Fire and Life Safety Engineers in the event of fire or other reasons. Cathedrals are, of course, places to pray and our Epping Commuter doesn't want to be praying that he's going to get out when a fire starts raging – which do occur on underground railways and for that matter cathedrals, as we saw at Notre Dame. In other places they are not so concerned – apparently the Pyongyang Metro has an average depth of 110 metres, has bomb shelters inbuilt and there are rumours that the system also secretly serves hidden government bases and nuclear bunkers.

I do think that the Metro stations facilitate good pedestrian flows which is critical to the Epping Commuter and others ease of access to and from the system as well as providing enjoyable spaces in which to be whilst waiting for a train.

**Neil Douglas:** I think we should mention Kings Cross London here as the 1987 fire on the underground escalator (due to a lighted match<sup>6</sup>) led Gerry Weston of London Transport Operations Research developing a station pedestrian model to calculate the likely evacuation time of stations on the London Underground. The model, developed in the 1980s, was then calibrated for rail stations like Kings Cross-St Pancras for the

---

<sup>6</sup> Smoking had already been banned in 1984 at all London Underground stations but passengers still 'lit up' on their way out of stations. This practice was banned in the aftermath of the fire. Wooden escalators were also replaced with metal ones, McNulty (1997).

Channel Tunnel station (I helped in the estimation of parameters and model calibration). The model was then bought by a consultancy firm and has been used with other similar simulation models like Legion to model passenger flows, congestion and alternative layouts at major stations in Australia such as Town Hall, Wynyard and Central. Indeed, the difficulties in increasing the passenger handling capacity of Town Hall (without major disruption to the network) was a justification for the Metro project.

### 3. Value of More Frequent Services

**Peter Thornton:** In the morning peak, a Metro train comes along every 5 minutes. My Epping commuter says he doesn't check a timetable or whether it's the right train since all services are 'all stops'. He doesn't wait long either but of course the train he travels on is what turns up and it could be very full with no free seats. In fact, he says that he rarely gets a seat and often has to stand. So how do you value service frequency?

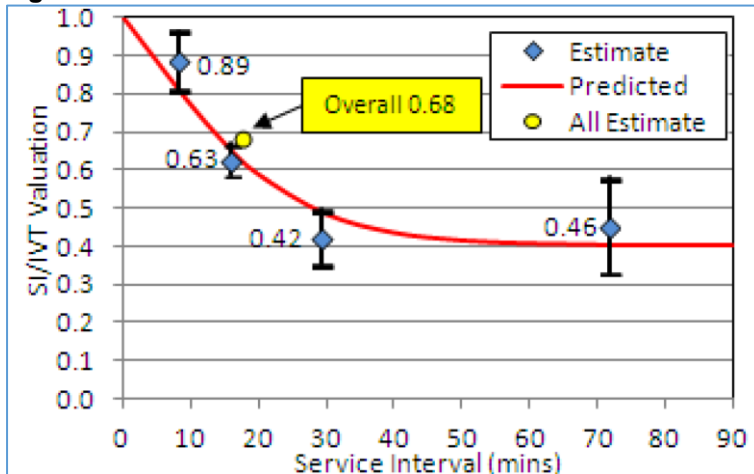
**Neil Douglas:** More frequent services means less waiting time (let's leave train crowding till later). If passengers arrive at a station at a constant rate, the average wait would be half the headway. So if trains are every six minutes, the average wait would be three minutes. When services are less frequent (a threshold used by Transport for London is 5 per hour i.e. every 12 minutes), passengers will tend to refer to a timetable (nowadays on their smart phones). In this case, the waiting time would be less than half the headway. Sydney Trains developed a model to forecast the most likely waiting time. For example, with a 15 minute headway, the waiting time would be around 5.5 min, Douglas Economics (2016). What has been the experience of your Epping commuter friend?

**Peter Thornton:** Before Sydney Metro, my Epping commuter friend on average waited six minutes for the direct service operating every 15 minutes. He could have caught other services and changed trains. The service interval for Sydney Metro is now 5 minutes (12 services per hour) and is planned to reduce to 4 minutes (15 services per hour) in the future. Service interval from Chatswood to Milsons Point is 3 minutes (including both T1 and T9 services).

**Neil Douglas:** Platform waiting time is issue here as the amount of inconvenience from the timetable (not being able to travel exactly when you want to) is pretty negligible. Research shows that passengers dislike waiting time. A convention has been to value a minute of platform waiting time the same as 2 minutes travelling on the train. Transport economists call this a "*waiting time penalty*". Figure 5 combines the waiting time and timetable displacement aspects of service interval into a curvilinear function. As it's a marginal function (i.e. the value changes with the level of the variable itself), we should average the values for the Sydney Train and Metro service intervals (15 and 5 minutes). The valuations are 0.9 and 0.65 so the average is 0.775. The value of the 10 minute reduction in service interval is therefore 7.75 minutes in equivalent time spent travelling (seated comfortably).

It's worth pointing out that there are now two train services from Epping so if you missed the Metro you could consider catching a Sydney Train service especially if one was just about to arrive.

Figure 5: Service interval valuation



Source: Douglas Economics (2016)

**Peter Thornton:** Well only an economist would say that because, of course, it's difficult to sprint between the vertically separated platform levels for the two different services, let alone see when the services are coming on the different lines.

**Neil Douglas:** I just do what economists love to do Peter; I've just made an assumption!

#### 4. Value of Travel Time Savings

**Peter Thornton:** My friend says his travel time has been cut from 47 mins to 28 mins, measured from Epping to Milsons Point. How do you value the travel time saving?

**Neil Douglas:** Time is money Peter! In this example, your Epping commuter saves 19 mins a trip, 38 mins per week-day, 3 hours a week and 150 hours a year! He can use the extra time for leisure, like watching TV, gardening, playing with the kids or he could use it to stay longer at the office.

In 1997 a workshop of experts led by John Taplin<sup>7</sup>, recommended that 'private' travel time in Australia by all modes (car, rail, bus etc.) be valued at 40% of average hourly earnings, Rainey (1997).

In NSW, SRA, RailCorp and Sydney Trains have undertaken surveys of how passengers value travel time. Between 2012 and 2014, TfNSW (with the assistance of Sydney Trains) undertook a survey of car, bus, Light Rail, ferry and rail users. The aim was to test how appropriate the 40% wage rate assumption was. As can be seen from Table 1, the 40% wage rate is appropriate for car travel (perhaps a little low) and is very appropriate for commuting by bus, rail and ferry, Douglas and Jones (2018). For 'other' purpose trips by public transport, the value of time was only around a quarter of the wage rate however.

<sup>7</sup> John Taplin was a pioneer in Australian transport economics research and practice. He sadly died this year in 2019.



So for your Epping public transport commuter, his value of time would be \$14.98/hr. Now this was in 2013/14 when the surveys were done and as you can see it was exactly 40% of the wage rate.<sup>8</sup>

**Table 1: Value of travel time (VTT) by mode (\$/hour, in 2013/14 prices)**

Trip Purpose	Value of Time \$/hr			Percent of Wage Rate <sup>^</sup>			Av. Income \$000 p.a.		
	Car	PT	ALL	Car	PT	ALL	Car	PT	ALL
Commuting	16.58	14.98	16.13	44%	40%	43%	68	64	67
Other Trips#	14.14	8.94	13.57	37%	24%	36%	52	38	50
ALL	14.63	11.32	14.13	39%	30%	37%	55	48	54

# excludes company business travel; ^ calculated as a percentage of \$37.85 (the average hourly wage). Source Douglas and Jones (2018)

Based on 2019 Australian Bureau of Statistics' Average Weekly Earnings, the hourly wage rate (full time equivalent – 8 hrs per day) would be \$40/hr. Taking 40% of this gives a value of time of \$16/hr. The 19 minute shorter Sydney Metro trip would therefore be worth \$5.07.

The acid test would be whether he'd catch the Metro if the fare was actually \$5 more than the Sydney Train service. Imagine you were standing at Epping station, with your OPAL card and it cost \$5 if you went through the Sydney Trains barrier and \$10 if you through the Metro barrier. If you plumped for the Metro every time, it would cost you \$10 a day, \$50 a week and \$2,434 a year. This would be the acid test turning 'stated preferences' into 'real preferences' backed by actual money outlay. I can't see this happening however. The Metro has not been set up like the Airport Rail Link with a supplementary access charge over and above the standard Sydney Train fare and, of course, passengers getting on at Domestic and International pay the supplementary charge (to the consternation of many) regardless of the train they use. As Figure 1 showed, its \$5 to get from Epping to Milsons Point whether you go by Metro or by Sydney Trains.

Now I must say I'm puzzled by the travel time 'saving' for your Epping commuter! He must have a short memory! I presume he used the Epping-Chatswood line (ECL) before it was closed in order that the stations and control systems could be re-gigged to accommodate driverless single deck trains? Wouldn't the Metro train time now be much the same as it was before the ECL was closed (that's excluding the transfer at Chatswood)? This would surely have been the valid comparison in the Economic Appraisal. So constructing the Metro actually lengthened your Epping commuter's trip by 19 minutes and imposed a cost of \$5.07 during the eight months of reconfiguration. I make that a total disbenefit of \$1,600 for your Epping commuter.

It must have surely have come as a shock to the NSW Treasury to have spent \$2.3 billion (ABC News, 2009) building the Epping-Chatswood line so it could open in February 2000 only for it to be closed just nine years later in September 2018 in order to rejig it for smaller single deck driverless trains. I'm curious as to your opinion as a

<sup>8</sup> As well as mode and purpose, values of time usually reflect income. The greater a person's income, the greater the willingness to pay to save time. TfNSW's research also showed that PT users entitled to a fare concession value their travel time savings less than standard fare payers.

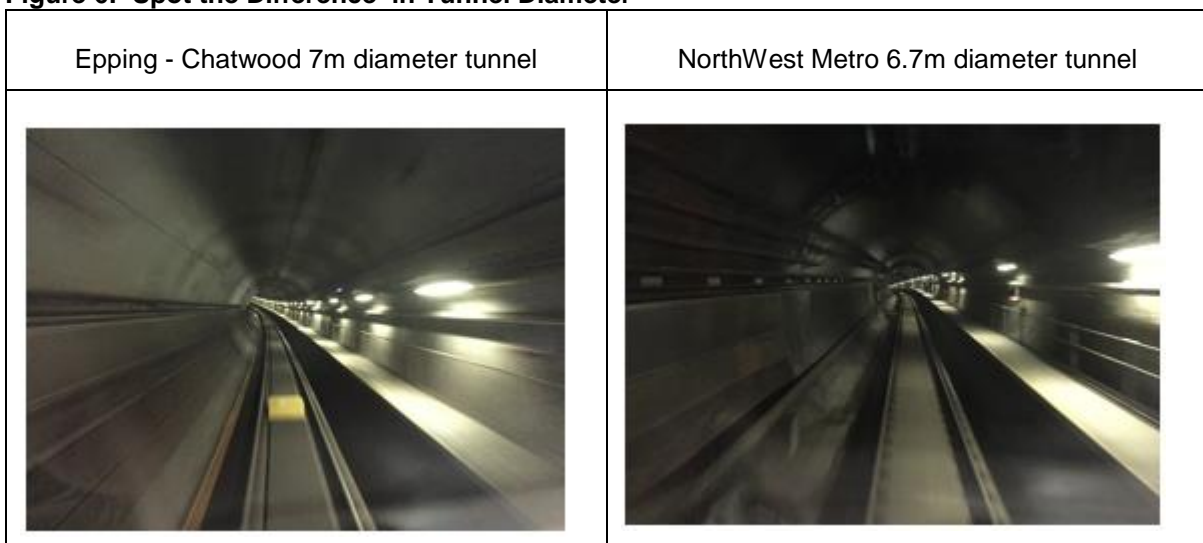
civil engineer and transport consultant Peter. What do you see as the benefit of building a smaller diameter tunnel that's not able to fit double decker trains?

**Peter Thornton:** Yes Neil! Well firstly our Epping commuter would have virtually the same train time but with a transfer at Chatswood. Given the heavy trains loads that are on the North Shore line by the time they pull into Chatswood, he'll be lucky to get a seat in the peak period unless he targets a local starter train, of which there are quite number, albeit spread thinly. There is then his return journey to consider in the PM peak.

And onto your second question, there are many people in Sydney especially amongst transport professionals who were dismayed at the decision to deliberately limit the tunnels to diameters which would preclude double deck rolling stock from ever operating on Sydney metros lines. The ability of Bradfield's city railway tunnels to accommodate double deckers is the stuff of railway transport legend and has enabled major increases in seated passengers to be accommodated. While it is possibly fair to say that right now out in the burgeoning dormitory suburbs of the northwest there are not enough commuters as yet to warrant hauling the heavier double deckers around especially at high frequencies, it's not likely that this will remain the case for the next 100 years. While, as we will discuss later, Sydney Metro can be capacity upscaled by increasing frequency and increasing train length, it will require a rolling stock refurbishment or replacement to provide more seated capacity to give an equivalent service to its passengers (who even now travel up to 30 kms and over 50 minutes into the CBD) to those who travel into the CBD from say Blacktown – 35 kms and 43 minutes and who probably have more chance of getting a seat. Railways like the RER in Paris which started out as single decker only are increasing the operation of double deckers on their network, not reducing them.

The data is a bit scratchy but my rough estimate is that it would have cost about another \$50 million (or 15%) to increase the tunnel diameter to 7m from the 6.7m it is now locked in at. That would have enabled future decision makers the luxury of choosing which way to upscale the service. As can be seen from Figure 6 it's quite hard to tell the difference just looking down the tunnels but one thing is certain – it will be nigh on impossible to ever enlarge them.

**Figure 6: 'Spot the Difference' in Tunnel Diameter**



It has been reported that the Metro project has come in \$1 billion under budget so future proofing it, as did Bradfield for his railways, was well within reach cost wise. To paraphrase John Ruskin: *"It's unwise to pay too much, but it's worse to pay too little. When you pay too much, you lose a little money - that's all. When you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing it was bought to do"*.<sup>99</sup> Clearly, the 6.7 metre diameter tunnels haven't lost everything but will preclude Sydney's excellent heavy uplift double deckers from ever going through them.

In terms of the system benefits, it is excellent that high capacity public transport has finally been introduced into the Northwest. Whether it is the right configuration only time will tell but there will probably be several PhDs written about it and lots of consultancy reports. Of course it is a totally standalone system so the only way it interacts with the existing suburban system is at stations where you can interchange. At Epping, the platforms are at different levels, at Chatswood interchanging is cross platform and in North Sydney, the stations are totally separated. Commuters will figure out what works best for them.

**Neil Douglas:** I agree Peter! Economics is more than just picking the financially cheapest option. That's the domain of accountancy! I recall the anguish of Dr Dick Day, the chief planner of RailCorp when the master-plan he'd spent years developing was ruined by the decision to go for single decker trains with an enforced transfer at Chatswood: *"the adverse impact on the very large number of passengers forced to interchange makes the minister's decision to support the metro alternative without detailed public discussion truly heroic"* Day (2012).

## 5. Value of a Modern Train

**Peter Thornton:** The new trains are obviously very clean and modern (Figure 7).

**Figure 7: Sydney Metro Train Fleet**



Photos: Peter Thornton

They have level access between the platform and train; they have three double doors on each side of the carriage, albeit smaller than on the Sydney Trains fleet, that are claimed to providing faster loading and unloading; they are climate controlled with heating and air-conditioning; they have two multi-purpose areas per train for prams,

<sup>99</sup> Known as the Common Law of Business Balance. The quotation has been widely attributed to Ruskin but never sourced to any of his works.

luggage and bicycles; and they have continuous mobile phone coverage throughout the metro network. But they only have about 378 seats longitudinally arranged and everyone else has to stand. How would you put a dollar value on these features?

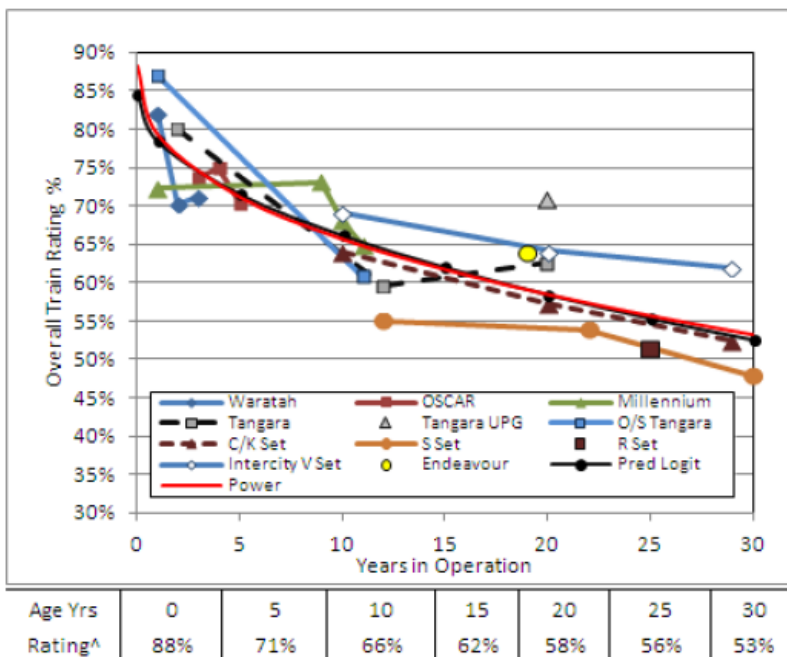
**Neil Douglas:** There does not look to be anybody on the train, not even a driver, so I guess you were near Tallawong station?

**Peter Thornton:** Yes correct Neil – I’d gone to the end of the line.

**Neil Douglas:** In NSW, trains have been valued via passenger ratings like stations as we discussed earlier. Surveys have asked passengers to rate a list of train attributes such as outside appearance, ease of getting on and off, seat availability & comfort, etc. and rate the train overall. Surveys, undertaken for over two decades, have enabled Sydney’s different trains to be assessed over time as Figure 8 shows.

At nearly 90%, brand new trains rate highly. Ratings then decline over time reflecting wear and tear and also the introduction of newer trains with higher specifications. The Endeavour rail car is the only single decker rolling stock ever surveyed in NSW and they were nearly 20 years old so there is not much to go on. In New Zealand, the Wellington Matangi electric multiple units scored 82% in 2012 when they were one year old, Douglas (2016).

**Figure 8: Trend in Sydney Train Passenger Ratings**



<sup>^</sup>Power model

I’m going to put the rating of a brand new Metro at 90% and if we assumed that the Sydney Trains’ train was 15 years<sup>10</sup> then a rating of 62% would be reasonable. The value you put on train quality increases the longer you spend on the train and given the ‘Metro’ trip would involve a transfer onto a Sydney Trains’ train at Chatswood, I’m going to estimate a benefit of \$0.72 for his brand new shiny Metro train trip.

<sup>10</sup> Peter: well In fact it’s actually 16 years old on a weighted average basis of the fleet operating around the suburban network so in this instance your assumptions are not too bad, Neil.

**Peter Thornton:** Great, I could buy two cups of coffee a week if I could get my hands on that benefit in cash!

**Neil Douglas:** It's hypothetical Peter and it's what your Epping commuter would hypothetically be 'willing to pay'. If it wasn't 'hypothetical' he might need to forsake two cups of coffee a week to pay for his trip on a brand new Metro train (*ceteris paribus*).

## 6. Value of Seat Availability and Train Crowding

**Peter Thornton:** My friend says he could always get a seat on the Sydney Trains service, but it was crowded from Rhodes to Wynyard. On Sydney Metro, he's been able to get a seat on six out of ten trips. How would an economist value the difference in seat availability and train crowding?

**Neil Douglas:** It's quite tricky to evaluate the cost of crowding and has usually been based on people's 'stated preferences' obtained from surveys.<sup>11</sup> Three levels of crowding were assessed in survey by RailCorp: crowded seating, standing and crush standing. The dis-utility of crowding was expressed as an In-Vehicle Time (IVT) multiplier. Table 2 presents the multipliers.

**Table 2: Value of train crowding (per minute of travel (1.0 = comfortably seated))**

Crowding level	Crowded seat	Standing	Crush standing
Equivalent IVT (min)	1.23	1.57	1.86

Based on your Epping commuter's experiences, I'm going to estimate the cost of crowding as adding 8.25 minutes to the Metro trip. This figure comprises a standing cost of 0.57 per minute experienced on 60% of your trips and a crowded seating cost of 0.23 per minute that is experienced 40% of the time. It compares with 6.44 minutes on the Sydney Train trip over the Rhodes and Wynyard section where crowded seating (0.23/min) lasts for 28 minutes. The difference is therefore 1.8 minutes which is worth \$0.48 in favour of Sydney Trains.

There are other aspects to train and station crowding as I'm sure you are aware of from your railway project planning experience Peter. Indeed, I think some of the decision to go for Metro style operation was the claims of shorter boarding and alighting times and a greater capacity per hour in moving passengers compared to double deckers. I recall a rather heated debate over the claims in the Sydney Morning Herald reported by Jacob Saulwick (2013).

Within Sydney Rail there were senior managers, often ex British Rail or London Underground who preferred single deck rolling stock and didn't care so much about seat provision. Barry Garnham was one manager and I recall one meeting where he was rolling his eyes at the implications of my research for his Chief Economist. He thought people didn't mind standing as much as the research suggested so I asked him "*why is then that we are all sitting down. Perhaps we should do away with office chairs and stand?*" "*Don't be facetious Neil*" he said.

---

<sup>11</sup> London Underground did some interesting work in the 1980s by observing passengers waiting on platforms and seeing how many would not get on a crowded train but wait for a less crowded one.

**Peter Thornton:** Well in its publicity, Sydney Metro made much use of the diagram shown in Figure 9 to try to persuade us that its single decker trains could carry more people per hour than could the most modern Sydney Trains Double decker trains.

**Figure 9: Comparison of Metro Single Deck and Sydney Train Double Deck Capacities**



Source Sydney Metro

I think it was an unfortunate way to help justify the decision to go for single deckers as it is not an ‘apples with apples’ comparison. It is also technically incorrect as Table 3 below helps demonstrate. It all depends on the assumptions but what is clear is that Double deckers deliver far more seated passengers on an ‘apples for apples’ basis.

And this is compounded by the fact that there are only a few stations e.g. North Sydney, Wynyard and Town Hall on the existing network where dwell times are a ‘problem’. Moreover, Sydney Metro does not use the track-work through these problem stations so it does not particularly need short dwell times per se (other than to achieve minimal running times).

It should be noted that until the Metro line is completed under the harbour “big brother” Sydney Trains is having to carry “little brother” Sydney Metro’s CBD bound passengers through those very same stations that are already the most heavily loaded seem to be doing quite successfully although I note your observations about Town Hall station congestion you alluded to earlier.

**Table 3: Comparison of Single and Double Decker on an “Apples for Apples” Basis**

	Headway (mins)	Seats per train	Standeers per train See Note 1	Total Passengers	Seats per hour	Standeers per hour	Total Pax per hour	% Standees
Sydney Metro Trains at Start-up	4.0	346	381	727.00	5,190	5,715	10,905	52%
Sydney Metro Trains NW Capacity	2.4	346	381	727	8,650	9,525	18,175	52%
Safeguarded Capacity metro trains ( 8 cars)	2.0	461	508	969	13,830	15,240	29,070	52%
Waratah DDs	4.0	894	418	1,312	13,410	6,270	19,680	32%
Waratah DDs – ERTMS	2.4	894	418	1,312	22,350	10,450	32,800	32%
Waratah DDs - ERTMS	2.0	894	418	1,312	26,820	12,540	39,360	32%

Note 1: Standees calculated at a comfortable 2 persons per square metre with Waratah A Set 8 cars

Standing room at 209 p/sm. Back figured based on

[https://www.downergroup.com/Content/cms/media/2018/PDF/23288\\_EP\\_D\\_for\\_Sydney\\_Growth\\_Trains\\_FA\\_v5.pdf](https://www.downergroup.com/Content/cms/media/2018/PDF/23288_EP_D_for_Sydney_Growth_Trains_FA_v5.pdf)

and Metro Sydney Metro 6 cars Standing room at 190.3 square metres back figured from A Wardrop personal communication and Oliver Fried in <https://www.ara.net.au/sites/default/files/u16/Oliver%20Fried%20-%20Sydney%20Metro.pdf>

Source: Transportation Associates analysis.

So I think it would be better to not use such easily challenged comparisons and rather focus on the real merits of single deck rolling stock opening up rail transport in areas where at present passengers loads don't require the uplift capacity of double deckers. We will have to wait to see whether and how vociferously Sydney Metro's passengers demand more seats like their commuter colleagues on lines served by double deck trains.

## 7. Value of Transfer

**Peter Thornton:** The Sydney Suburb Train service is direct (no transfer from Epping to Milsons Point). Using Sydney Metro, there is a transfer from Sydney Metro to Sydney Suburban Train at Chatswood Station. How would this factor be dealt with in benefit realisation?

**Neil Douglas:** Market research, has unsurprisingly found that passengers prefer direct services to ones involving a transfer. A transfer penalty is often added in demand models to reflect the inconvenience and extra anxiety of having to get off and on. RailCorp estimated a penalty equivalent to 7 minutes of onboard train time for transfers by commuters on shorter duration trips, Douglas Economics (2008). Transfers not involving a change of platform had a penalty of 5 minutes, 2 minutes less than for a 'standard' transfer. Does the transfer at Chatswood Station require a change of platform?

**Peter Thornton:** No, the transfer from Sydney Metro to the Suburban Train is cross platform, undercover and around 4-5 metres away and services are well integrated. Both Metro and Suburban Trains have a frequency of around 3-4 minutes through Chatswood.

**Neil Douglas:** I would therefore add a transfer penalty of 5 minutes (equivalent to \$1.33) for your same-platform transfer at Chatswood. This value is based on market research that TfNSW undertook as part of developing demand forecasts for the interchange at Chatswood, Douglas and Jones (2013).

**Peter Thornton:** Of course, every passenger's journey is different and we all make decisions based on relative convenience or inconvenience to us. I have another friend who could use Sydney Metro but prefers to still use the freeway express bus because it is more direct to his destination in the CBD.

**Neil Douglas:** Is your other friend female as the TfNSW market research found females to be significantly more adverse to transfers than males? Indeed, many females preferred their direct Castle Hill bus to a rail service involving a transfer, Douglas and Jones (2013).

**Peter Thornton:** No, in fact he's a railway engineer!

## 8. Value of Reliability

**Peter Thornton:** A key aim for the Sydney Metro is reliability due to its high frequency and lack of any interaction with any other part of the rail system. Is there a way to capture this benefit in the economic analysis?

**Neil Douglas:** Unreliability has definitely got a high cost. Surveys of Sydney rail passengers have valued the cost of train lateness at 3.7 times 'normal' rail time, Douglas Economics (2016). And this didn't include the inconvenience to people kept waiting for the passenger at the station, at home or at the office.

The punctuality rate for Sydney Suburb Train services is around 92% for peak operation.<sup>12</sup> This means that 8% of services are delayed by 5 minutes or longer. Sydney Metro's target is 98% but it's probably too early to judge its reliability on one week's experience. If Sydney Metro lives up to its target then there could be a benefit for the Sydney Metro component of the trip worth maybe \$0.6<sup>13</sup> but the Metro trip also involves changing to a Sydney Suburb Train so I think it best to put this one down as neutral Peter.

## 9. Value of Skyway, Tunnel and Surface Rail Travel

**Neil Douglas:** Looking at the route it would appear that a substantial part of the Metro trip journey is underground. Research by Sydney Trains shows that where Sydney rail passengers do have a choice of tunnel versus surface travel they prefer surface travel. Of the 347 passengers surveyed in 2014, 29% had a strong preference for surface travel and 17% a weak preference but 39% had no preference and 9% had a strong preference and 7% a weak preference for underground travel, Douglas (2016b). The average preference worked out as a cost of 5% for tunnel travel. So for your Epping commuter, I'd estimate 20 minutes spent underground, which implies a cost of \$0.27 (for an extra perceived minute) would be appropriate.

There was a range of opinions amongst those surveyed however reflecting, amongst other things, the activities they undertook whilst travelling.

**Peter Thornton:** Sydney Metro route comprises skyway (railway on a long Viaduct) and tunnel.

Personally speaking I enjoyed the section of the route where it ran on the skyway far more than the tunnel section but then I was travelling to look at Sydney Metro as a project. Even so, I think above ground is much preferable but a quick and smooth journey has much to commend it and if being in tunnel is the trade-off then I suspect many passengers will be happy with that.

My friend's trip would be entirely underground but I don't think he minds much whether he's above or below ground as he is continually on his mobile phone reading the news, listening to podcasts or watching YouTube videos, hopefully with earbuds on.

What Australians do seem to mind is having to look at other people which is why our suburban trains have had to revert to rollover seat backs. In the case of Metro, they may be more accepting as at least the faces of the passengers looking back at them are not 'in their face' so to speak.

**Neil Douglas:** I think the train design of the single deckers is similar to the vestibule of double deckers with people looking at each other from opposite sides of the train. I

---

<sup>12</sup> See <https://www.transport.nsw.gov.au/data-and-research/passenger-travel/sydney-trains-and-nsw-trainlink-intercity-performance-reports>

<sup>13</sup> Punctuality stats usually fail to report the amount of lateness so I've made an economist's assumption of 10 minutes.



do think some people may worry more about the train being driverless than the person they are sitting opposite.

I think you told me your Epping commuter colleague is not one of them having travelled on Hong Kong and Singapore underground metros. Didn't he tell you "*I've got full confidence in automated control*" and has told you that "*some passengers can even stand at the front to see the front tracks and outside*"!

**Peter Thornton:** That's all well and good, Neil, but I'm an engineer and I know engineering has a nasty habit of going wrong when you least expect it. I tend to cringe when I hear people and especially non-engineering people trumpeting the virtues of 'smart' systems. I am moved to remind them that one such 'smart' system was so "smart" that it decided the best way to safeguard people was to fly them into the ground at several hundred kilometres per hour whereupon it destroyed itself as well. Not so 'smart' after all!

The fact is that accidents involving driverless trains do happen from time to time<sup>14</sup> and it's worth remembering that the last major passenger rail accident in NSW involved a driven train where the driver was incapacitated and the 'smart' systems of the day failed to stop the train so hopefully those systems on Sydney Metro will prove to be the best and we won't have a similar accident.

I did stand looking out the front of the driverless train and thought about whether that was such a good idea and what I would do if suddenly the rear end of another train appeared. There didn't seem to be an old fashioned 'pull chain to stop train' anywhere so I decided I would sprint down the long open tube of the train screaming 'get down'. I did speak to the train attendant who said he could drive the train in an emergency but he could be at the other end of the train so would be rather useless in that circumstance, although such attendants have already had to manually drive trains when the system has failed on Sydney Metro soon after start up.<sup>15</sup>

One benefit of driverless trains and platform screen doors is that trains drivers do not have to witness people committing suicide or being pushed on to the tracks as happened in Frankfurt in July 2019. So perhaps the savings in pain and suffering incurred by drivers and other observers from such event need to be measured as well, Neil?

**Neil Douglas:** Austroads is currently doing a market research study on the value of statistical life for use in economic appraisals. The value used in NSW at the moment is around \$6.6 million (2013/14 prices) for a road crash resulting in one fatality, TfNSW (2018). I haven't seen similar research done for railways which is probably because of the engineering advances that have made rail travel far safer than road travel.

**Peter Thornton:** That is possibly right, Neil but accidents still do happen on railways and, when they do, many people get hurt or killed at once as for example where the signalling system failed on a Chinese high speed line.

---

<sup>14</sup> <https://www.news18.com/news/world/14-injured-in-japan-after-driverless-train-goes-wrong-way-2169097.html>

<sup>15</sup> <https://www.theguardian.com/australia-news/2019/may/29/sydney-metro-driverless-train-breaks-down-and-has-to-be-driven-by-staff>

## 10. On the one hand and on the other

**Neil Douglas:** So on the one hand, your Epping commuter is much better off using Sydney Metro than making the convoluted trip via Strathfield but on the other hand, he's slightly worse off than he was before the Metro was constructed.

I calculate the benefit of travelling by Sydney Metro rather than Sydney Trains to be worth \$4.46 comprising \$5.07 for the 19 minute quicker trip, \$0.62 for the more frequent service, \$0.72 for the brand new Metro train and \$0.13 for the improved platform at Epping, see Table 4. These benefits are offset by greater on-train crowding costing \$0.48, \$1.33 from a transfer at Chatswood and \$0.27 for travelling underground.

**Table 4: Assessing the Benefit of Sydney Metro for travelling between Epping & Milsons Point**

Attribute	Metro 2019 versus Sydney Trains 2018	Metro 2019 versus Sydney Trains 2019	Comment
New Modern stations	0.13	0.13	Slight improvement in Metro platform area at Epping otherwise same stations. Users of new North West stations could benefit by \$0.70 compared to the average station although the benefit will decline as the stations age.
Improved service frequency	0.31	0.62	Metro every 5 minutes compared every 15 minutes for Sydney Trains. Passenger had a higher Sydney Trains frequency half the disbenefit assumed for Pre Metro v Metro.
Shorter Train Time	-	5.07	No noticeable improvement in travel time compared to 2018 but Metro is 19 minutes quicker than via Strathfield.
New Metro Train	0.72	0.72	Metro trains are brand new but travel from Chatswood is on Sydney Trains.
On-train crowding	-0.24	-0.48	Metro has less seats and more standing than Sydney Train double deckers. Half the disbenefit for the pre Metro v Metro situation.
Transfer at Chatswood	-1.33	-1.33	Enforced interchange at Chatswood imposes a transfer penalty from inconvenience and anxiety. Cross platform transfer reduces the cost to passengers.
Reliability Benefit	-	-	Passengers value reliability highly. Sydney Trains punctuality measured at 92%. Too early to evaluate Metro reliability and Sydney Trains are used for part of the trip.
Travelling Underground	-	-0.27	Metro trip from Epping is underground and based on Sydney research, passengers' value underground travel 5% higher than surface travel. No difference for pre Metro v Metro situation (both use Epping-Chatswood tunnel).
Fare	-	-	Same fare charged of \$5 per trip
Total	-0.41	4.46	

However our Epping Commuter is actually now worse off with Sydney Metro by \$0.41 than he was before Sydney Metro was built. Before the Metro there was a direct rail service between Epping and Milsons Point but now, he must transfer at Chatswood and may not get a seat for the remainder of his journey (until the cross harbour sector

is opened which should relieve the North Shore line). It is only the new train and slightly nicer platform at Epping that offsets his transfer.

**Peter Thornton:** I can see now why US President Harry S. Truman asked for a one handed economist! I see you have halved two of the benefits in the Table too. Is this the 'rule of a half' that I've seen mentioned in economic appraisals?

**Neil Douglas:** No Peter, the halving of benefit is just another working 'assumption'. Your Epping commuter seems 'wedded to rail' as he didn't 'divert' to car or the shuttle bus when the Metro was under construction and he didn't stop commuting to work either. He continued to use rail, even though his journey was 19 minutes longer. So there was no need to use the 'rule of a half' which Alfred Marshall, one of the greatest economists, created with his linear demand curves and notion of consumer surplus for measuring user benefit, Marshall (1890).

I have to say it's a good job your friend wasn't from north of Epping, say from around Pennant Hills as his trip would now involve two transfers at Epping and Chatswood. His morning trip to Milsons Point could still be reasonable given he could plan his arrival at Pennant Hills station and then have two quick transfers but going home at night he might face a 15 minute wait at Epping and the transfer involves different platforms on different levels. The difference by time period reminds me that transport planners tend to focus on getting people to work and not enough on getting them home again at night. I guess it reflects productivity at work rather than enjoyment at home.

**Peter Thornton:** Thanks for that Neil. I agree it's a good job he's not from between Epping and Hornsby stations and you're right the focus is on the morning rather than the evening peak. The morning peak is when passenger loads are heaviest so we engineers focus on it to determine infrastructure and operational capacity.

Now on the bright side, apparently, on the first day of opening, 21,000 people experienced the Metro Northwest line between 4.45am and 10am. The number was a third more than government expectations of 14,000 to 17,000 passengers, Sydney Morning Herald (2019).

So for the sake of argument, if everyone did benefit to the tune of \$4.46 per trip then annual benefit could total \$56 million.<sup>16</sup> Given the cost of building the Metro has been put at \$7 billion (that's allowing for the \$1 billion 'saving') then my maths says it would take 125 years to pay off the capital cost. Alternatively, with annual trips of 12.6 million, a benefit of \$18.50 per trip would be needed for Sydney Metro passenger related benefits over 30 years to equal the capital cost.

**Neil Douglas:** Not bad for a civil engineer Peter but you've forgotten about 'the time value of money', otherwise known as the 'discount rate'. It never seems to change in NSW having been stuck on 7% since the late 1980s (unlike NZ which has lowered its rate from 10% to 6%). With a discount rate of 7%, the benefit per trip would need to be \$42 (not \$18.50) to break even economically (*ceteris paribus*). This does remind me of the correspondence between Rodney Forrest of NSW Treasury who calculated

---

<sup>16</sup> I have used the expansion factors in the excellent 'Compendium of CityRail Statistics' that State Rail and RailCorp used to publish. The Compendium has unfortunately ceased with TfNSW taking over so the 2010 Compendium factors might be somewhat out of date.

a subsidy of \$80 per new North West Rail passenger in an email to Peter Crimp of RailCorp in October 2011.<sup>17</sup>

**Peter Thornton:** Of course, the biggest beneficiaries will not be Epping passengers but those living in the station catchments of Castle Hill to Rouse Hill who, if they feel it is to their advantage, can now walk or catch a bus to their new local rail station instead of making a long access trip to the Sydney Trains network at Epping or Parramatta or taking the motorway express bus.

**Neil Douglas:** The rail system access benefits were, in fact, the main part of the 2006 Economic Evaluation that justified a heavy rail alignment as opposed to cheaper Busway or Light Rail solutions, Douglas Economics (2006). Admittedly, the cost of the heavy rail option was 'only' \$1.8 billion back with a Busway to Parramatta just under the price at \$760 million, Douglas and Brooker (2016). Costs of certainly escalated since then.

**Peter Thornton:** Thanks Neil for such an enlightening discussion – I understand much better why economics is called the “dismal” science – I think we engineers would be happy to just go to one decimal point! And, of course, we both should thank our friend the Epping Commuter for posing these interesting questions. It does seem, however, that after all the experts have done their analysis and given their learned advice there is another layer of decision making. That’s possibly why, after all your work, decisions were made to change the rail tunnel from at least being double deck capable to locking the infrastructure into a single deck train. Our Epping commuter friend seems quite happy to use the service as provided but many transport professionals are still dismayed about this. But there is a question that you haven’t answered and that is why, given all the focus on customers, their comfort and convenience, trains with so few seats have been provided, especially on a route that is now one of the longest commutes in the metro area. But perhaps that’s a paper for next year!

## References

ABC (2009) *"Now it's too loud: Rail budget blows out again"*. ABC News. Australian Broadcasting Corporation. 23 October 2008. Retrieved 22 February 2009.

Day D. (2012) *"Railroaded? Metro Rail Alternatives for Western Sydney"* Sydney Morning Herald 29th June 2012.

Douglas N. and Brooker T. (2013) *"A Review of Transport Project Appraisal in NSW Australia"* Australasian Transport Research Forum 2013 Proceedings 2 - 4 October 2013, Brisbane. [https://www.atrf.info/papers/2013/2013\\_douglas\\_brooker.pdf](https://www.atrf.info/papers/2013/2013_douglas_brooker.pdf)

Douglas N and Karpouzis G. (2006) *"Valuing Rail Service Attributes through Rating Surveys"* Australasian Transport Research Forum 2006 [https://www.atrf.info/papers/2006/2006\\_Douglas\\_Karpouzis\\_b.pdf](https://www.atrf.info/papers/2006/2006_Douglas_Karpouzis_b.pdf)

---

<sup>17</sup> E-mails originating within the NSW Treasury by Principal Financial Analyst, Rodney Forrest to RailCorp Manager of Finance, Peter Crimp were released as part of a Parliamentary Standing Order 52 in October 2011 indicating the North West Rail Link would have to be subsidised by the state government by about \$80 per passenger based on modelling by NSW Treasury which estimated the North West Rail Link would generate only 9 million new passengers annually. See Saulwick (2011).

Douglas N., Karpouzis G. and Rahman A. (2010) *"Forecasting the Use of Passenger Lifts at Rail Stations"* Australasian Transport Research Forum 2010  
[https://www.atrf.info/papers/2010/2010\\_douglas\\_karpouzis\\_rahman.pdf](https://www.atrf.info/papers/2010/2010_douglas_karpouzis_rahman.pdf)

Douglas N and Jones M. (2013) *"Estimating Transfer Penalties and Standardised Income Values of Time by Stated Preference Survey"* Australasian Transport Research Forum 2013 Proceedings 2 - 4 October 2013, Brisbane.  
[https://www.atrf.info/papers/2013/2013\\_douglas\\_jones.pdf](https://www.atrf.info/papers/2013/2013_douglas_jones.pdf)

Douglas N. and Jones M. (2016) *"Developing a Suite of Demand Parameters for Inner Sydney Public Transport"* Australasian Transport Research Forum 2016, Melbourne.  
[https://www.atrf.info/papers/2016/files/ATRF2016\\_Full\\_papers\\_resubmission\\_212.pdf](https://www.atrf.info/papers/2016/files/ATRF2016_Full_papers_resubmission_212.pdf)

Douglas N. and Jones M. (2018) *"Estimating the Value of Private Travel Time for NSW"*, Australasian Transport Research Forum 2018, Darwin.  
[https://www.atrf.info/papers/2018/files/ATRF2018\\_paper\\_82Rev.pdf](https://www.atrf.info/papers/2018/files/ATRF2018_paper_82Rev.pdf)

Douglas N. (2011) *"Estimating the User Benefit of Rail Station Lifts"* Australasian Transport Research Forum 2011 Adelaide.

Douglas, N. (2016) *"Pricing Strategies for Public Transport"*, NZTA Main Report Part 1 report 565. <https://www.nzta.govt.nz/assets/resources/research/reports/565/565-Pricing-strategies-for-public-transport-part-1-main-report.pdf>

Douglas, N. (2016b) *"Passenger Preferences for Surface versus Underground Rail Travel"*, Australasian Transport Research Forum 2016, Melbourne.  
[https://www.atrf.info/papers/2016/files/ATRF2016\\_paper\\_117.pdf](https://www.atrf.info/papers/2016/files/ATRF2016_paper_117.pdf)

Douglas Economics (2006) *"North West Transport Link Economic Evaluation"* Report to NSW Department of Planning, report dated January 2006.

Douglas Economics (2008) *"Value & Demand Effects of Rail Service Attributes"*, report by Douglas Economics to RailCorp.  
[https://www.researchgate.net/publication/316990013\\_Value\\_and\\_Demand\\_Effect\\_of\\_Rail\\_Service\\_Attributes](https://www.researchgate.net/publication/316990013_Value_and_Demand_Effect_of_Rail_Service_Attributes)

Douglas Economics (2016) *"Service Quality Values for Sydney Rail"* Report by Douglas Economics for Sydney Trains.  
[https://www.researchgate.net/publication/329327098\\_Service\\_Quality\\_Values\\_for\\_Sydney\\_Rail](https://www.researchgate.net/publication/329327098_Service_Quality_Values_for_Sydney_Rail)

Marshall A. (1890) *"Principles of Economics"*, First edition, London: Macmillan.

McNulty, D. and Rielly P. (March 1992). *"Kings Cross Fire in the London Underground November 18, 1987"* A Report for Dr A. Buchanan Dept. of Civil Engineering Canterbury University".  
[https://ir.canterbury.ac.nz/bitstream/handle/10092/8463/mcnulty\\_rielly\\_report.pdf](https://ir.canterbury.ac.nz/bitstream/handle/10092/8463/mcnulty_rielly_report.pdf)

Rainey D. (1997) *"Value of Travel Time Savings"* by D Rainey, AP-119/97, Austroads, 1997, Sydney, NSW.

Saulwick J. (2011) "North-west rail line costs revealed in emails" Sydney Morning Herald. <https://www.smh.com.au/national/nsw/north-west-rail-line-costs-revealed-in-emails-20111025-1mi4u.html>

Saulwick J. (2013) "*Secret Report Casts Doubt on Train Plan*" Sydney Morning Herald <https://www.smh.com.au/national/nsw/secret-report-casts-doubt-on-train-plan-20130922-2u7zq.html>

Sydney Morning Herald (2019) "*More commuters than Expected Ride Sydney's New Metro Line in First Test of Peak-hour Services*", published on May 27, 2019

Transport for NSW (2018) "*Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*" [file:///C:/Users/user/Downloads/Principles\\_and\\_Guidelines\\_for\\_Economic\\_Appraisal\\_of\\_Transport\\_Investment\\_and\\_Initiatives\\_Combined\\_0.pdf](file:///C:/Users/user/Downloads/Principles_and_Guidelines_for_Economic_Appraisal_of_Transport_Investment_and_Initiatives_Combined_0.pdf)

Wilde O. (1892) "*Lady Windermere's Fan*" published by Nick Hern Books, 2005. ISBN 978-1-85459-771-7