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Developing a train crowding economic costing model and estimating passenger crowding cost of Sydney CityRail network

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Abstract

This paper develops a crowding cost model for the Sydney CityRail network and estimates the economic cost of passenger overcrowding. The unit costs of a crowded seat and passenger standing on the train have been updated from the stated preference surveys undertaken by RailCorp NSW and Douglas Economics. Train load statistics collected from CityRail surveys have been used to analyse the train crowding. The crowding cost model has been developed for 12 CityRail Lines and all 581 trains operating in AM and PM peak hours. For the financial year 2010-11, given passenger demand levels adjusted for trip seasonality and day to day trip volatility, the cost of overcrowding cost has been estimated at $82 million per annum. This cost is forecast to escalate quickly with the assumed base case given that travel demand is expected to increase with the Sydney population growth and no rail passenger capacity expansion. The model has been applied in the context of the NSW State Plan that targets the public transport share of commuter trips from current 76% to 80% in 2016. It has been estimated that this will incur an additional $25 million overcrowding cost by 2015/16. Finally, the de-crowding benefits of a hypothetical rail link in Sydney northwest area have been estimated at $69 million by 2022/23.

1. Introduction

On a typical weekday, CityRail runs 299 trains in the morning peak (6:00 AM to 9:30 AM) and 292 trains in the afternoon peak (3:00 PM to 6:30 PM) (RailCorp 2010A). Many of these services are crowded. Packed trains are a daily experience in Sydney peak hours. Crowded trains have negative impacts on passengers and service operators:

- Discomfort: Travel on a crowded train is less pleasant as ‘personal space’ is lost or groups cannot travel together (Wardman and Whelan (2010). Having to stand on trains makes rail travel a less pleasant experience and crowded seating is also less pleasant than uncrowded seating (Douglas and Karpouzis 2006).
- Reliability and delays: Time taken for passengers to alight from and board a train may exceed the stopping time allocated in the timetable, and cause train delays.
- Failure to board: At a certain crowding threshold, it becomes impossible for more passengers to board a service, or the train is so full that passengers prefer to wait for a subsequent service that might be less crowded. CityRail uses double the seat capacity as the maximal load. Beyond that, it is considered that passengers cannot board anymore. In Japan, ‘train pushers’ were employed at stations in peak hours to push more passengers onto the cramped trains (Schmocker 2006).
- Safety: Station overcrowding poses accident risks on the platforms, staircases and escalators.

Overall, overcrowding on trains happens more regularly than unreliability and low service frequency. The CityRail Customer Charter survey in 2011 suggested that the train crowding was an important issue for customer satisfaction, with 36% respondents indicated that managing crowding was the most concerned issue, as shown in Table 1.

Table 1 CityRail customer charter survey 2011

Attributes	Most concerned issues
Manage crowding	36%
On-time running	14%
Fast, accurate, useful information	14%
Clean trains and stations	11%
Fast ticket sales	8%
Quick and fair complaints handling	7%
Accessible services and facilities	5%
Secure and safe travel	5%

Similarly, in the Survey of CityRail Customer 2010 undertaken by the Independent Transport Safety and Reliability Regulator (ITSRR 2010), 51% of interviewed passengers were dissatisfied with "crowding in trains at peak commute times". A UK survey (Baker et al. 2007) indicates that overcrowding was seen as a bigger issue when compared to reliability and poor frequency, as shown in Table 2. However, only a quarter of respondents claimed that they would use or consider using an alternative mode of transport if the problem increases. For those considered to change to another mode of transport, 70% would transfer to the car, and 20% would use the bus, suggesting that overcrowded trains might change travel behaviour such as altering the time of travel, travelling less or even changing the mode. Given the availability of parking space and prohibitive parking cost in Sydney CBD, it is unlikely that people will shift the travel mode from train to private car.

Table 2 Most important train attributes to user

Attributes	Average survey score
Level of crowding in train	19.8%
Train cancellations / delays	15.8%
Punctuality of trains	15.5%
Cost / value for money	15.3%
Frequency of services	8.5%
Provision of information	7.0%
Safety on-train and at-station	4.8%
Cleanliness on train and at-station	4.3%
Toilet facilities on train and at-station	2.8%
Staff	2.0%
Ticketing services	2.0%
Accessibility	1.0%
Cycle facilities	0.8%
Catering on-train and at-station	0.3%
Total	**100%**

Source: Adapted from Baker et al. (2007)

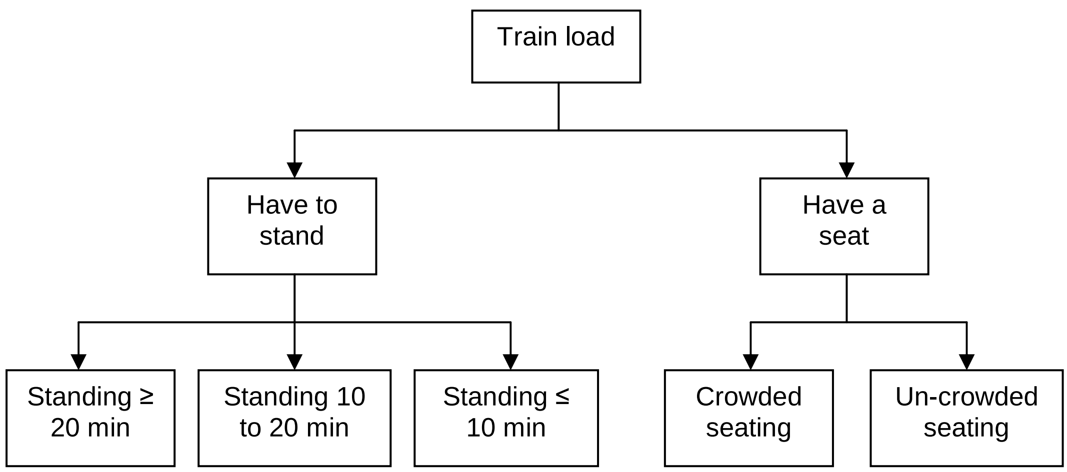
2. Unit costs of train crowding

The first step in modelling the cost of train overcrowding is to determine how many passengers are in uncrowded seating, crowded seating or standing at various crowding levels.

Train crowding can be measured by the load factor or the number of standing passengers per square metre (pax/m^2). In CityRail performance goals (RailCorp 2010B), the crowding is defined as the number of standing passengers per square metre, with the international benchmark of 4 pax/m^2 and the RailCorp performance target of 1.9 pax/m^2. Based on CityRail survey (RailCorp 2010B), the crowding in morning peak had improved as the number of standing passengers reduced from 1.1 – 1.3 in 2009 to 1 in 2010.

The load factor is the ratio of passengers to the number of seats. For example, if the number of passengers on a train is half the number of seats, then the load factor is 50%. The train load determines the proportion of passengers in uncrowded seating, crowded seating and standing, as showing in Figure 1. Crowding starts to occur when the loading is 80% as passengers are normally not equally distributed among carriages. Some literature refers to it 'crush standing' when the train load is 160% or above. Hensher[1] commented that the 'crush standing' cannot be defined universally in terms of a load factor, because load factors depend on the allocation of space to seating and standing, which depends on the design of a train or bus. Wardman and Whelan (2010) defined rail crowding by both load factors and standing passengers per square metre (pax/m^2). The latter is important since different trains have different interior layouts with varying amounts of seating and standing space. A given load factor will have different levels of discomfort of standing across different train types. Passengers per square metre is a better indicator of the disutility of standing and possibly of the different degree of discomfort experienced by seated passengers due to others standing.

Figure 1 Passenger segments for costing train crowding



Douglas and Karpouzis (2006) modelled the proportion of passengers standing and in crowded seating in relation to the train load factor, as shown in Table 3 (columns 2-4). All passengers can choose to find a seat if the train load is less than 80%. Some passengers have to stand if the train load is between 80% and 100%, as passengers are unequally distributed between carriages, although the passenger load is still less than capacity at this train load level. When the load factor is more than 100%, some passengers have to stand. In

[1] Based on David Hensher's comments on an early draft of this paper, December 2011

NSW, an indicator of the Rail Performance Agreement between the Minister for Transport and RailCorp relates to peak period trains with load factors in excess of 135%, referred to as a notional maximum train load (ITSRR 2009). However, RailCorp loading surveys suggest a maximum passenger load of 200%. Beyond this load, passengers will be unable to board and have to wait for the next train.

The crowded seats are those next to a corridor in that a person sitting there will be close to the standees when the train is crowded. It is assumed that the crowded seats start to occur when the train load is 80%, and the number of crowded seats reaches the maximal 30% of total seats when the train load is 120% or above. The number of crowded seats is estimated based on linear increase when the train load is between 80% and 120%.

The process of allocating passengers into uncrowded seating, crowded seating or standing can be illustrated by an example. Supposing there are 1,134 onboard passengers on an 8car Tangara train (T-Set) with a capacity of 840 seats (i.e., load of 135%), 294 passengers have to stand (26%), and 840 passengers sit (assuming that the distribution of passengers along train cars is uniform enough to occupy all seats along the train). Among those who are seated, 252 passengers are in crowded seats (30% of total sitting passengers), and 588 passengers are in uncrowded seats.

Table 3 Train load, percent of standing and crowding factors

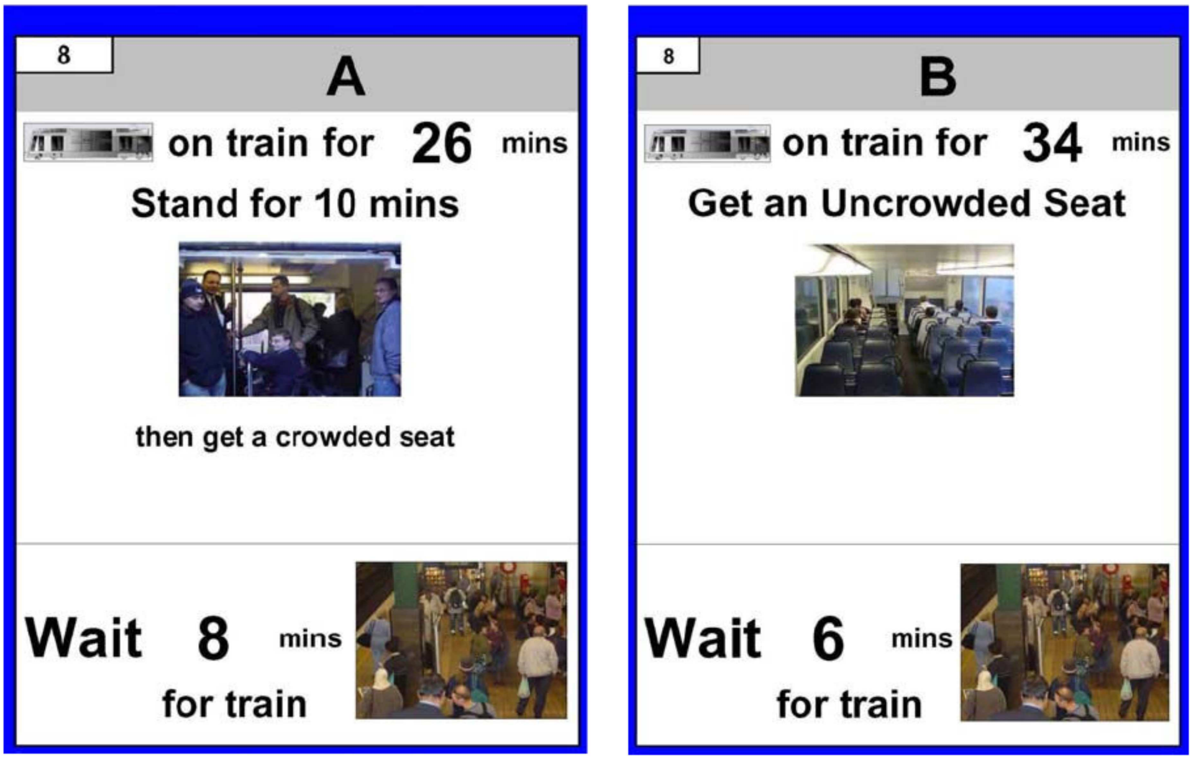
Train load (1)	Percent Stand (2)	Percent Sit (3)	Percent Crowded Seats of total seats (4)	Crowding factor per minute of on-train time			
				Crowded seat (5)	Stand 10 mins (6)	Stand 10-20 mins (7)	Stand ≥ 20 mins (8)
80%	2%	98%	0%	0	0.34	0.57	0.81
85%	4%	96%	4%	0	0.34	0.58	0.82
90%	6%	94%	8%	0.01	0.35	0.59	0.82
95%	7%	93%	11%	0.02	0.36	0.60	0.84
100%	9%	91%	15%	0.04	0.38	0.62	0.86
105%	11%	89%	19%	0.07	0.40	0.64	0.88
110%	13%	87%	23%	0.10	0.43	0.67	0.91
115%	15%	85%	26%	0.13	0.47	0.71	0.95
120%	17%	83%	30%	0.17	0.51	0.75	0.99
125%	20%	80%	30%	0.17	0.56	0.80	1.04
130%	23%	77%	30%	0.17	0.61	0.85	1.09
135%	26%	74%	30%	0.17	0.67	0.91	1.15
140%	29%	71%	30%	0.17	0.73	0.97	1.21
145%	31%	69%	30%	0.17	0.80	1.04	1.28
150%	33%	67%	30%	0.17	0.88	1.12	1.36
155%	35%	65%	30%	0.17	0.96	1.20	1.44
160%	38%	62%	30%	0.17	1.04	1.28	1.52
170%	41%	59%	30%	0.17	1.04	1.28	1.52
180%	44%	56%	30%	0.17	1.04	1.28	1.52
190%	47%	53%	30%	0.17	1.04	1.28	1.52
200%	50%	50%	30%	0.17	1.04	1.28	1.52

Source: Based on Douglas and Karpouzis (2006) Estimating the passenger cost of train overcrowding

Estimating the overcrowding cost requires a good understanding of how passengers value or trade off service frequency, punctuality, train crowding and travel time. Much of the evidence is drawn from Stated Preference (SP) research. In 2006, RailCorp administered the passenger survey for valuing the cost to passengers of train crowding (Douglas & Karpouzis

2006, Douglas Economics 2008). The core of the survey was a set of SP questions in which respondents were asked to choose between two hypothetical journeys that differed in terms of on-train travel time, waiting time and on-train crowding (Douglas & Karpouzis 2006). A total of sixteen choice scenarios were presented to respondents to elicit the passenger preference data, where the time and crowding trading-off could be established statistically. Figure 2 presents an example of an SP question:

Figure 2 Examples of Stated Preference survey question



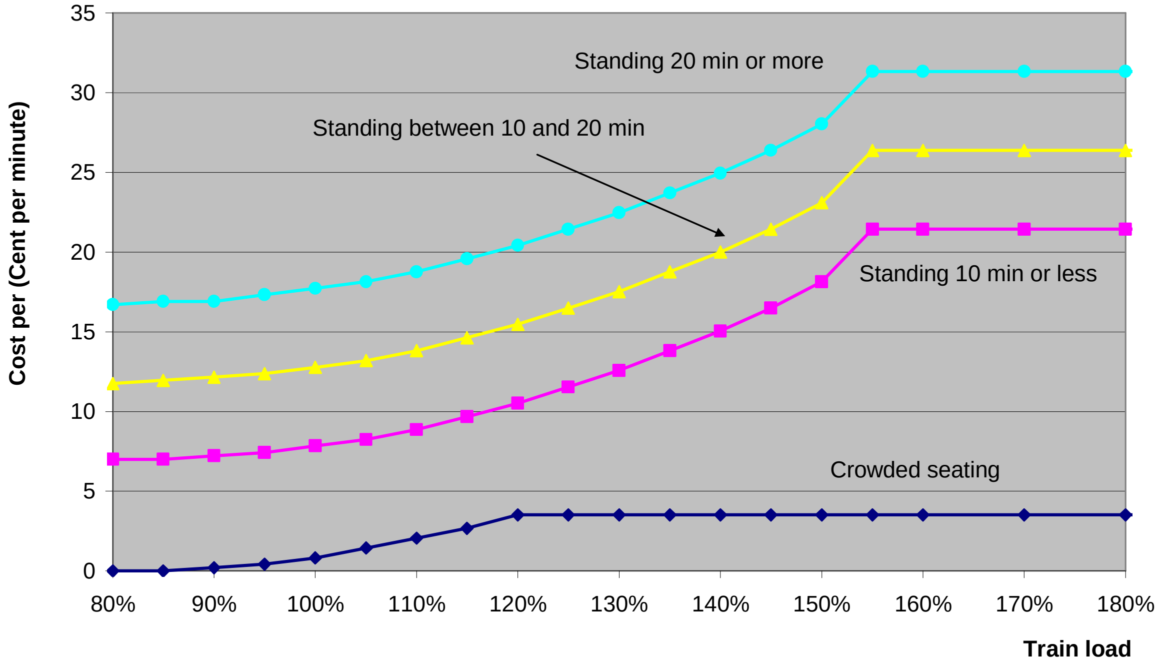
The data collected from 4,603 responses were used to estimate a binomial logit choice model. The utility of respondent's choice was specified in terms of platform waiting time, onboard train time, passenger time in a crowded seat, and passenger time as onboard standing. The passenger standing time is further categorised into three segments: standing more than 20 minutes, standing between 10 and 20 minutes and standing less than 10 minutes, as it was expected that passengers' disutility increases with a longer standing time. The relativities of coefficients for crowded seating and standing to uncrowded on-train time were estimated from the utility model and presented in Table 3 (Columns 5-8).

The crowding factors in Table 3 are essentially conversion factors that convert the passenger time in crowded seating or standing into equivalent uncrowded on-train time. They represent an additional cost to the on-train time. For example, at the 150% train load, the crowding factor for standing 10 minutes is 0.88, which means that passengers are willing to pay the same cost for 1 minute standing or 1.88 minutes uncrowded seating time. Wardman and Whelan (2010) reviewed 17 studies in train crowding and found that the conversion factor for standing ranges from 1.3 to 4.2.

The factor of crowded seating is 0.17 when the train load is 120% or above. It is scaled up from 0 to 0.17 when the train load is between 80% and 120%. The factors for standing reach their maximal values when the train load is 160%. Crowding factors for standing gradually increase between 80% and 160% of the train load. Wardman and Whelan (2010) found that the multiplier of crowded seats was as high as 1.78.

The crowding factors in Table 3 are monetised by applying the value of on-train time savings, as they are the relativities of coefficients for crowded seating or standing to on-train time in the utility model. The value of on-train time savings was estimated from the RailCorp 2004 survey (see Douglas Economics 2004 for details) as $8.76 per passenger hour in 2002/03, and was indexed to $12.37 per hour by RailCorp Economic Analysis Team (RailCorp 2011). It is noted that this value relates to the average level of crowding experienced in the peak period and therefore will include some passengers standing. If crowding has increased from 2004, the average value of time will have increased because of the increased crowding. By applying the value of on-train time savings and crowding factors in Table 3, the unit costs of crowded seating and standing are estimated in Figure 3. It shows that the cost of standing on the train is much higher than in crowded seating.

Figure 3 Unit costs of train crowding



3. Train load data

CityRail undertakes surveys to count the number of passengers for all trains. The number of passengers for a train was surveyed at the CBD cordon stations and other selected stations. The CBD cordon stations of 12 CityRail lines are:

- Illawarra Line: Sydenham
- Eastern Suburbs: Kings Cross
- Airport and East Hills Lines: Wolli Creek for Airport Line and Redfern for East Hills Line via Redfern
- Bankstown Line: Redfern
- South Line: Redfern
- Inner West Line: Redfern
- Western Line: Redfern
- Northern Line: Redfern
- North Shore: St Leonards
- South Coast: Hurstville
- Newcastle & Central Coast: Strathfield
- Blue Mountains: Strathfield

Train load data was extracted for all trains on the 12 Lines surveyed from 19 October 2010 to 21 May 2011 from the RailCorp train loading database. Table 4 presents the summary statistics of AM and PM peak services and passengers.

One hour peak is defined as the busiest hour for passenger volumes. The peak hour occurs at a different time depending on the CityRail Line. The morning peak is most likely to occur between 7:45 AM and 8:45 AM, while the afternoon peak hour tends to occur between 5:15 PM to 6:15 PM. The number of passengers in the AM peak hour is more than 35% in the PM peak. Commuters and educational trips account for the majority of AM peak trips. These passengers have relatively less flexibility to change travel time. Thus, it is important to provide sufficient capacity in the morning peak hour to meet passenger demand.

Table 4 indicates that, in terms of AM peak hour passengers, the highest travel demand occurred on the Illawarra Line (18,299 passengers), the North Shore Line (18,203 passengers), and the Western Line (18,127 passengers). They are not necessarily the most crowded lines since more trains are running on these lines. The most crowded Line is the Bankstown Line, where six trains are run in the AM peak hour with an average train load of 145%.

Table 4 also reveals that all CityRail Lines except the Eastern Suburbs Rail (ESR) Line are operating at or above seat capacity in the AM peak hour. Table 5 shows the busiest train on each CityRail Lines. The maximum train load reaches 180% on the Illawarra and Western Lines. Passenger crowding is substantial in peak hours.

Table 4 shows that passengers in the AM peak hour account for 53% of total passengers in three and half AM peak hours. In the AM peak period (3.5 hours), the average train load factor is 88%. While one hour peak trains are already overcrowded, there is unused capacity in the remaining 2.5 peak hours. This suggests that there is room for spreading travel demand through demand management measures such as flexible working hours. With the introduction of a Smart Card, the ticket fee structure can be designed to shift some trips from the peak hour to other times. Douglas et al (2011) developed a “rooftop” model, and investigated how fare discount in off-peak hours or fare surcharge in peak hours could spread peak-hour trips. This study shows that

- A 10% fare discount before 8:00AM will reduce trips in peak hour (8:00 – 9:00AM) by 0.6%.
- A 10% fare discount after 9:00AM will reduce trips in peak hour by 0.4%.
- A 10% fare discount both before 8:00AM and after 9:00AM will reduce trips in peak hour by 1%.
- A 10% fare surcharge in peak hour can reduce trips in peak hour by 2.6%, suggesting that people are more sensitive to a surcharge than to a discount.

Table 4 Train load by CityRail lines by peak hours

CityRail Lines	One hour peak				Three and half hour peak			
	Trains	Seats	Pax *	Average Load	Trains	Seats	Pax	Average Load
Morning								
Illawarra	15	13084	18299	140%	38	33106	35770	108%
Eastern Suburbs	16	13897	10869	78%	38	33059	17038	52%
Airport & East Hills	12	10824	13801	128%	33	28275	26408	93%
Bankstown	6	5330	7749	145%	17	14120	14402	102%
South	8	7153	9554	134%	23	20553	18493	90%
Inner West	4	3616	4167	115%	16	13966	8923	64%
Western	15	12737	18127	142%	40	33806	36862	109%
Northern	5	4554	6216	136%	13	11801	10431	88%
North Shore	18	15602	18203	117%	43	37628	30614	81%
South Coast	5	2773	2780	100%	10	5921	4514	76%
Newcastle & Central Coast	5	4224	5058	120%	12	9248	9455	102%
Blue Mountains	3	1872	2021	108%	9	5893	5988	102%
Morning Total	**112**	**95667**	**116845**	**122%**	**292**	**247376**	**218897**	**88%**
Afternoon								
Illawarra	12	10377	13160	127%	39	33720	33109	98%
Eastern Suburbs	11	9648	5912	61%	38	33053	11920	36%
Airport & East Hills	11	9564	9708	102%	35	30135	22355	74%
Bankstown	6	5105	5444	107%	17	14803	12462	84%
South	5	4402	5900	134%	19	16029	17161	107%
Inner West	4	3593	4570	127%	14	12674	8796	69%
Western	14	12279	15754	128%	37	31697	36206	114%
Northern	4	3624	4301	119%	14	12686	10558	83%
North Shore	14	12401	14120	114%	45	39202	31681	81%
South Coast	5	3488	3030	87%	9	5381	4737	88%
Newcastle & Central Coast	4	3056	3002	98%	13	10088	9156	91%
Blue Mountains	3	1595	1857	116%	9	5893	5988	102%
Afternoon Total	**93**	**79132**	**86758**	**110%**	**289**	**245361**	**204126**	**83%**
Total	**205**	**174798**	**203603**	**116%**	**581**	**492737**	**423024**	**86%**

* This represents the maximal passengers on a train. The numbers in the Table are different to RailCorp (2010) due to different data sources and counting rules

Table 5 The most crowded trains on CityRail Lines

CityRail Lines	Run No	Arrival Time at Central Station	Seats	Maximal Passengers	Train Load
Illawarra	318E	8:09:00 AM	864	1555	180%
Eastern Suburbs	320D	8:45:00 AM	864	1170	135%
Airport & East Hills	679B	8:40:00 AM	920	1426	155%
Bankstown	41-E	8:18:00 AM	920	1501	163%
South	701C	8:05:00 AM	904	1323	146%
Inner West	712E	8:26:00 AM	904	1114	123%
Western	112B *	8:25:00 AM	840	1512	180%
Northern	164C	8:34:00 AM	893	1294	145%
North Shore	138C	8:14:00 AM	920	1311	143%
South Coast	320C	8:12:00 AM	864	1086	126%
Newcastle & Central Coast	298B	8:37:00 AM	864	1220	141%
Blue Mountains	W528	8:45:00 AM	832	939	113%

* This train was 11 minutes late thus the crowding level experienced by this train may not represent normal operating.

4. Overcrowding cost model

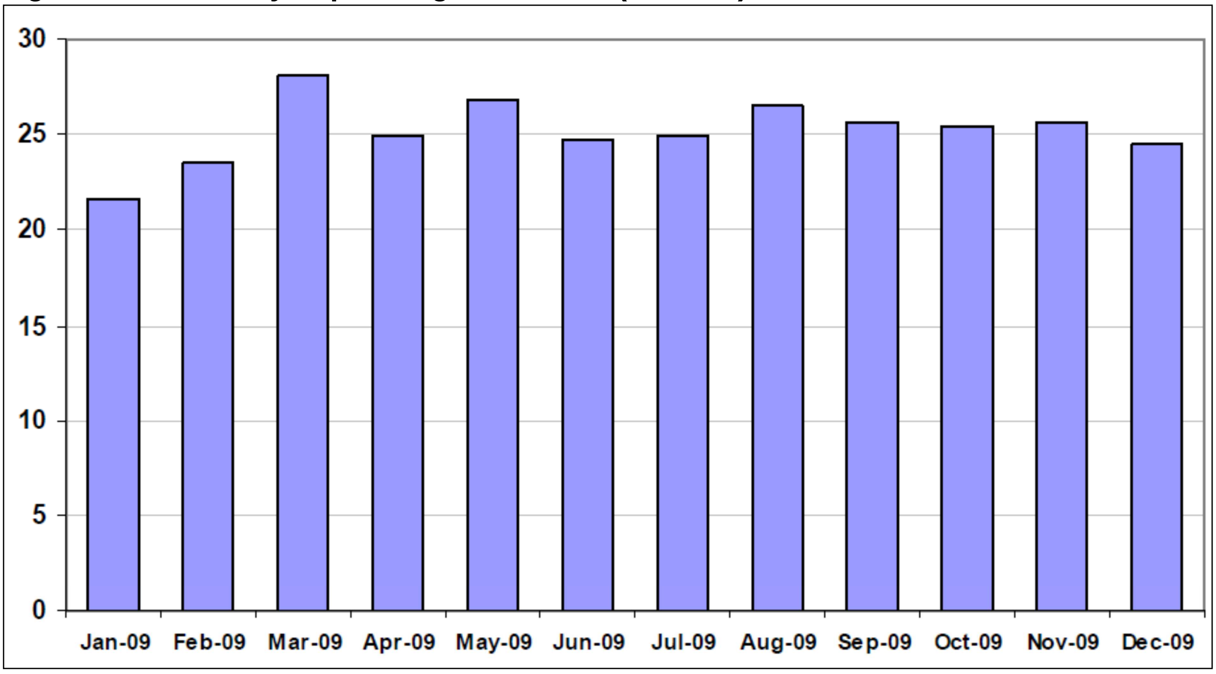
An overcrowding cost model has been built with the following steps:

- The Model covers all CityRail trains in the AM peak (6:00 AM to 9:30 AM) and the PM peak (3:00 PM to 6:30 PM).
- In the AM peak, the model is based on inbound services (train to CBD), and in the PM peak, and model is based on outbound services.
- Cost was analysed for each individual train. To reduce calculation burden, trains with a load less than 60% have been excluded from the model as it is assumed that no crowding cost will incur. If crowding continues to increase, some passengers may choose to travel on these lighter loaded trains. This effect is not included in the current model.
- The number of passengers at any time between two stations has been used in the model.
- For stations at which the passenger number was surveyed, the actual passenger number was used. For a train where the passenger numbers were repeatedly surveyed on different days, the average passenger number was used. For stations not surveyed by CityRail, the number of passengers was calculated using interpolation or extrapolation methods.
- For any given train at a given time, the number of passengers in uncrowded seats, crowded seats and standing are estimated from the percentages in Table 3 and the total number of passengers.
- The numbers of passengers standing for 10 minutes or less, between 10 and 20 minutes and 20 minutes or above are not directly calculable, given the dynamic nature of passenger movements. Following Douglas and Karpouzis (2006), it is assumed that for those passengers who could not find a seat, 30% would stand for 10 minutes or less, 30% would stand between 10 and 20 minutes, and the remaining 40% would stand 20 minutes or more. It is likely that as crowding increases, the length of standing will increase. To more accurately reflect reality, the length of standing is checked against the remaining travel time to central station. The length of standing is also adjusted with the travel time between two stopping stations. For example, if the travel time between two stops was 15 minutes, then it is assumed that 60% standing passengers stand between 10 and 20 minutes, and 40% stand more than 20 minutes.
- The cost is modelled on a typical weekday, which is annualised by 251 days (excluding weekends and public holidays).
- Any crowding occurring in off-peak hours, weekends and public holidays is excluded from the model. Thus, the model may underestimate the crowing cost. Off-peak, weekends and public holidays should be excluded because if trains are crowded in those periods, the operator can easily reduce crowding by increasing frequency. In addition, the overcrowding for special events (e.g., New Year’s Eve and sports events) is excluded.

Adjustment of seasonality and day of week variation and other random variation

The number of passengers in a particular train varies between days. Firstly, the variation can be categorised by systematic and random factors. Systematic variation refers to regular changes due to school holidays and seasonal travel patterns. Figure 4 shows the passenger journeys by month of year in 2009. In January, many people take recreational leave; thus number of trips is reduced. In March, the passenger number increases due to the Sydney Royal Easter Show. Overall, the monthly variation for a 12 month average was 4.6%.

Figure 4 Seasonality of passenger numbers (millions)



Source: A Compendium of CityRail Travel Statistics, Seventh Edition, June 2010

Table 6 presents the day of week passenger journey distributions. Mondays and Fridays have lower passenger numbers during weekdays, while passenger numbers are relatively stable on Tuesdays, Wednesdays and Thursdays.

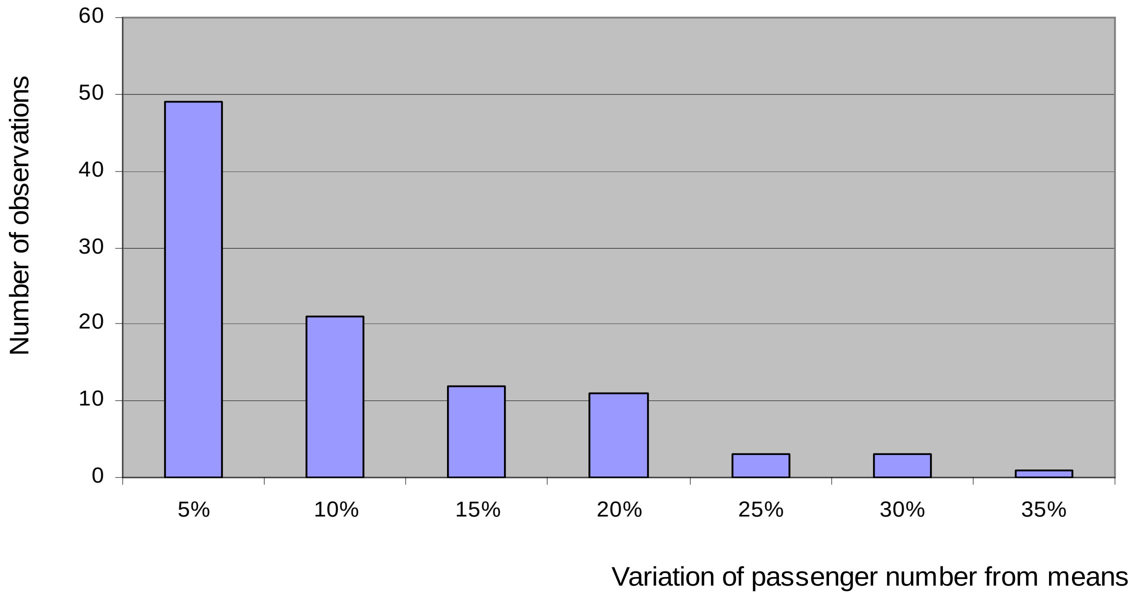
Table 6 Weekly passenger proportions

Day	**Percentage**
Monday	16.8%
Tuesday	17.5%
Wednesday	17.6%
Thursday	17.8%
Friday	17.1%
Saturday	7.5%
Sunday	5.6%
Total	**100%**

Source: A Compendium of CityRail Travel Statistics, Seventh Edition, June 2010

To investigate the extent of daily passenger fluctuation, a sample of 100 repeatedly surveyed trains were selected. The histogram in Figure 5 shows the percentage of passenger number variation from the average. Almost half of the trains surveyed show a passenger variation between days of less than 5%. However, the number of passengers for the same train on different days could vary as much as 25% to 35%. The average variation was estimated at 8%.

Figure 5 Histogram of passenger number variation between days



The volatility of passengers imposes an additional crowding cost, because some trains are more crowded and others are underutilised. Using the train crowding cost model developed in this research, it is estimated that an 8% passenger variation between days will increase overcrowding cost by 12%. This factor has been built into the model.

Table 7 presents the crowding cost by CityRail Lines. The Western Line incurs the highest crowding cost ($21 million), followed by the Illawarra Line of $13 million. The higher cost on the Western Line is because the crowding condition could start from Blacktown and end at Central, with 39 minute train running time, while on the Illawarra Line, crowding could usually start at Hurstville and end at Central, with a train running time of 26 minutes.

Table 7 Crowding cost of CityRail services, $2010/11

City Rail Lines	AM peak	PM peak	Total
Western	$13,035,623	$8,374,454	$21,410,077
Illawarra	$8,992,576	$4,188,081	$13,180,657
Airport & East Hills	$7,824,993	$4,024,348	$11,849,341
South	$5,043,073	$3,869,468	$8,912,541
North Shore	$4,552,725	$3,689,025	$8,241,750
Northern	$4,907,718	$1,236,416	$6,144,134
Bankstown	$3,631,850	$573,065	$4,204,916
Newcastle & Central Coast	$2,322,258	$1,338,825	$3,661,083
Blue Mountains	$914,772	$936,073	$1,850,845
Inner West	$350,566	$854,505	$1,205,071
South Coast	$350,706	$619,341	$970,047
Eastern Suburbs	$194,006	$114,048	$308,054
Total	**$52,120,867**	**$29,817,649**	**$81,938,516**

Source: Estimated from overcrowding cost model[2]

[2] Hensher suggested that some services from the Eastern Suburbs could be diverted to the crowded Illawarra or Western lines. However, there are train path limitations on the crowded lines. Train paths are the maximum number of train movements that are possible or required, over a section of the track, at a given time of the day.

5. Policy simulation

The following policy scenarios are modelled:

- Train overcrowding cost is forecast to 2023/24, assuming travel demand increases with population growth
- Meet the State Plan 2016 target: 80% public transport share of commuter trips to/from CBD
- Overcrowding cost reduction by a hypothetical rail infrastructure project in Sydney northwest area.

Scenario 1: base case, travel demand increases with population growth

The ‘base case’ (Scenario 1) is defined as ‘do minimum’. It is assumed that CityRail capacity will remain the same as the 2010/11 level, but passenger demand will increase with population growth. The Australian population growth rate is assumed at 1.5%, based on ABS demographic statistics (ABS 2010). On a typical weekday, there are 218,897 trips in the AM peak. Assuming that the travel demand increases at the same rate, the number of trips is forecast in future years, as shown in Table 11. The trip increase rates to the base year are estimated. Using the overcrowding cost model, the passenger crowding cost is estimated for each year from 2010/11 to 2024/25 as shown in Table 11. In the base case, passenger crowding will increase from $81.9 million in 2010/11, to $111.9 million in 2014/15, and increase further to $224 million in 2024/25.

Scenario 2: NSW State Plan public transport target

NSW State Plan targets the public transport share of commuter trips to increase from 76% in 2008/09 to 80% in 2016. As shown in Table 8, this requires the CityRail passenger share increases from 49% in 2008/09 to 51.6% in 2015/16, a 5.3% increase over 7 years or an annual increase of 0.75% from 2010/11 to 2015/16.

Table 8 CityRail passenger share

Mode	**2008/09**	**2015/16**
Rail	49.0%	51.6%
Bus	27.0%	28.4%
Other	24.0%	20.0%
Public Transport	76.0%	80.0%
Total	**100%**	**100%**

After adding additional commuter passengers on the CityRail network, and assuming there is no network capacity expansion, rail passengers would have to endure additional overcrowding, with the estimated incremental overcrowding cost of $24.7 million in 2015/16, and $37.9 million in 2024/25, as shown in Table 12[3].

Scenario 3: Impact of a hypothetical rail infrastructure project in Sydney northwest area on overcrowding

This hypothetical rail infrastructure project comprises of around 25 kilometre rail line in Sydney northwest area of around $9 billion investment. The project includes construction of eight new stations to capture potential train users. The project will provide rail access for the

[3] People would use the rail less if the service is not improved. They use rail only because of no increase in road capacity or constraints of car parking or car ownership.

first time from the growing region to major employment centres in Norwest Business Park, Macquarie Park, St Leonards, Chatswood, North Sydney and the CBD. The transport modelling and economic appraisal report of this infrastructure project provided the following trip forecast:

Table 9 Trip forecast (million trips per year) by 2021

New trips	9
Abstracted trips[4]	19
Total trips	**28**

The rail infrastructure project is proposed to run eight trains per hour from 2018/19, and 12 trains per hour from 2022/23. The 19 million abstracted trips to the new rail link will reduce the train load on the Western (Richmond) Line, the Northern Line and the North Shore Line. (On the other hand the new rail link might increase crowding in the CBD due to new train passengers going to the city). It has been estimated that 21,111 rail trips would be abstracted from existing rail lines to the new rail link by 2021/22, and the abstracted rail trips would ramp up from 2018/19 to 2021/22, then remain unchanged over future years, as shown in Table 10 below.

Table 10 Abstracted rail trips by new rail link, three hour AM peak

Year	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**
Abstracted trips	5,278	10,556	15,833	21,111	21,111

The abstracted passenger trips would significantly reduce train crowding on the Western Line (Richmond to City Sections), the Northern Line (Epping to City Sections) and the North Shore Line (Chatswood to City Sections). Using the passenger crowding cost model, it has been estimated that the new rail link would reduce the overcrowding cost by $18.9 million by 2018/19, and $69.2 million by 2022/23, with the total NPV of $416 million over a 30 year evaluation period.

[4] Abstracted trips are diverted trips from other existing rail services

Table 11 Scenario 1 - Base case, travel demand increases with population growth

Year	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
Annual growth rate		1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
Passengers	218,897	222,180	225,513	228,896	232,329	235,814	239,351	242,942	246,586	250,285	254,039	257,849	261,717	265,643	269,628
Increase from base year		1.5%	3.0%	4.6%	6.1%	7.7%	9.3%	11.0%	12.6%	14.3%	16.1%	17.8%	19.6%	21.4%	23.2%
Crowding cost ($m)	$81.9	$88.7	$96.2	$103.9	$111.9	$121.1	$131.0	$141.2	$150.7	$161.5	$173.7	$185.3	$198.1	$210.8	$224.0

Table 12 Scenario 2 - Travel demand increase + State Plan mode switch

Year	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
State Plan mode switch		0.75%	0.75%	0.75%	0.75%	0.75%									
Annual growth rate		2.25%	2.25%	2.25%	2.25%	2.25%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
Passengers	218,897	223,822	228,858	234,007	239,273	244,656	248,326	252,051	255,832	259,669	263,564	267,518	271,531	275,604	279,738
Increase from base year		2.3%	4.6%	6.9%	9.3%	11.8%	13.4%	15.1%	16.9%	18.6%	20.4%	22.2%	24.0%	25.9%	27.8%
Crowding cost ($m)	$81.9	$92.9	$103.9	$116.5	$131.0	$145.8	$155.6	$167.1	$179.5	$191.3	$203.4	$216.5	$230.0	$245.8	$261.9
Increase from Scenario 1 ($m) (Cost increase if State Plan target is met)	$0.0	$4.2	$7.7	$12.6	$19.1	$24.7	$24.6	$25.9	$28.8	$29.8	$29.7	$31.2	$31.9	$35.0	$37.9

Table 13 Scenario 3 - Travel demand increase + State Plan mode switch + A New Rail Link in Sydney Northwest Area

Year	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
The abstract trips									5278	10556	15833	21111	21111	21111	21111
Trips without new rail link (Western, North, North Shore Line)	77,907	79,660	81,452	83,285	85,159	87,075	88,381	89,707	91,052	92,418	93,804	95,211	96,640	98,089	99,561
Trips with new rail link (Western, North, North Shore Line)	77,907	79,660	81,452	83,285	85,159	87,075	88,381	89,707	85,775	81,863	77,971	74,100	75,529	76,978	78,449
Increase from base year (Western, North, North Shore Line)		2.3%	4.6%	6.9%	9.3%	11.8%	13.4%	15.1%	10.1%	5.1%	0.1%	-4.9%	-3.1%	-1.2%	0.7%
Trips on other lines	140,990	144,162	147,406	150,723	154,114	157,581	159,945	162,344	164,779	167,251	169,760	172,306	174,891	177,514	180,177
Increase from base year (Other Lines)		2.3%	4.6%	6.9%	9.3%	11.8%	13.4%	15.1%	16.9%	18.6%	20.4%	22.2%	24.0%	25.9%	27.8%
Crowding cost ($m)	$81.9	$92.9	$103.9	$116.5	$131.0	$145.8	$155.6	$167.1	$160.6	$154.9	$152.1	$150.1	$160.8	$173.5	$186.5
Increase from Scenario 2 ($m) - cost reduction due to new rail link	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$18.9	$36.4	$51.3	$66.4	$69.2	$72.3	$75.4

NPV of de-crowding benefits over 30 years was estimated at $416 million at 7% discount rate

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