Modelling the Ability of Fare Incentives to Spread AM Peak Passenger Loads

May 2012

For

Infrastructure NSW

By

DOUGLAS Economics

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Foreword

DOUGLAS Economics was engaged Infrastructure New South Wales to model the ability of fare discounts and surcharges to 'spread' peak passenger loads more evenly across the AM peak. The forecasts use a 'rooftops' model developed by Douglas Economics in association with Southern Cross University (SCU) as part of a wider study undertaken by SCU for the CRC for Rail Innovation: funded Project R1.107 *"Urban Rail Demand Management Strategies"*. A summary of the study was published at the 2011 Australasian Transport Research Forum held in Adelaide.

This report presents a non-technical description of the model. Some forecasts of the effect of introducing fare discounts on early morning and late AM peak trains and of fare surcharges on peak hour trains are presented.

The forecasts are compared with the Melbourne Early Bird and Sydney SmartSaver fare.

Disclaimer:

The model was developed as a 'proof of concept' rather than a detailed timetable assessment model tailored to the characteristics of individual rail lines. The forecasts presented should be considered with this in mind.

Executive Summary

DOUGLAS Economics was engaged by Infrastructure New South Wales (INSW) to model the ability of fare discounts and surcharges to 'spread' peak passenger loads more evenly across the AM peak. The forecasts use a 'rooftops' model developed in 2010 by Douglas Economics in association with Southern Cross University. The model was developed using timetable and patronage data for the Illawarra line. In this study, the forecasts for the Illawarra line have been used to derive patronage and revenue estimates for the CBD as a whole.

The 'rooftops' approach originates from work in spatial economics by Hotelling in the 1920s. In the 1970s, the approach was used to assess passengers' choice of train services. The name 'rooftops' reflects the shape of the train choice graphs which resemble streets of rooftops.

The parameters used in the model were based on market research undertaken in 2010 across the Sydney suburban rail network. A total of 786 passengers travelling in the peak were interviewed. The survey found passengers to value late displacement higher than early displacement. Travelling an hour earlier was treated the same as spending 32 minutes longer on the train whereas travelling an hour later was treated the same as 56 minutes extra on the train.

The survey also estimated a marked difference in how passengers value travel time depending on whether a fare surcharge or discount is levied. Passengers were found to be willing to pay a surcharge of $13.85 to save an hour of travel time but require a much larger discount of $33.80 to travel an extra hour. The surcharge value was reasonably precisely estimated and was similar to the peak value of $12.85 per hour used by CityRail. By contrast, the discount value had a wide survey error and was nearly three times higher than the CityRail value. Therefore in the forecasting model, although the 'surcharge' value of time was used, a lower 'discount' value of time of $20 per hour was substituted for the survey estimate.

The model was used to model the patronage and revenue impact of a range of fare incentives. Two incentives were designed to be similar to actual incentives introduced in Melbourne and Sydney. All the incentives were modelled assuming an adult average fare of $3.30 per trip.

Table 1: Predicted Change in Patronage and Revenue

Percentage and absolute change in CBD rail trips and revenue (2009 base figures)

		Peak Hour Patronage		AM Peak 3.5hr Revenue	
	Incentive	Percent	Trips	Percent	$m p.a.
1	Free Travel before 7am	-2%	-1,600	-11%	-13
2	Free Travel before 7.30am	-6%	-4,900	-22%	-26
3	Free Travel before 8am	-11%	-9,000	-37%	-44
4	50% Discount before 0715 & after 0915	-4%	-3,300	-15%	-18
5	25% Discount before 8am & after 9am	-4%	-3,300	-14%	-17
6	25% Surcharge 8-9am	-6%	-4,900	10%	12
7	10% Surcharge 8-9am & 10% Discount Before/After	-4%	-3,300	-1%	-1
8	10% Surcharge 8-9am & 30% Discount Before/After	-8%	-6,600	-13%	-15
9	25% Surcharge 8-9am & 25% Discount Before/After	-11%	-9,000	-5%	-6

Offering free travel on trains arriving Central before 7am was forecast to reduce CBD patronage by 2%. If applied to all passengers exiting CBD stations, 1,600 fewer trips would be made in the peak hour. The percentage reduction is of a similar magnitude, albeit slightly higher than the response to the Melbourne Early Bird ticket (free travel for trips completed before 7am) which has been forecast to have reduced peak hour patronage by an estimated 1.2% to 1.5%. In terms of revenue, offering free travel before 7am for all CBD-bound trips would reduce AM peak 3.5hr CBD ticket revenue by 11% or $13 million per year. This compares with $6 million estimated for Melbourne.

Extending free travel half an hour to 7.30am increased the shift out of the peak hour threefold with peak hour loads falling 6%. The loss in AM peak revenue was forecast to be significant at 22% or $26 million per year. Offering a 50% fare discount on trains arriving Central before 0715 and after 0915 (scenario 4) matches the fare conditions of the Sydney Smart Saver which was trialled for ten weeks on the Western line in 2008. The model forecasts that peak hour CBD trips would reduce 4% which is double the 2% reported for the Smart Saver trial. Revenue was forecast to reduce by 15% or $18 million.

The disadvantage of these early discounts is that they are not focussed on the crucial 8-9am period when CBD station capacity is most stretched. Extending free travel up to 8am (scenario 3) shifts 11% of passengers out of the peak hour but would reduce revenue in this morning period by 37% or $44 million p.a. (if applied to all lines into the CBD). If similar incentives were offered to customers with non-CBD destinations and/or to those avoiding the evening peak then the revenue loss would be even greater. This fare structure could also be practically difficult to implement as it could create a large customer build up behind CBD barrier exits shortly before 8am. The remaining scenarios therefore adopt a more focussed approach to fare incentives with a lesser level of discount.

A 25% discount on trains before 8am and after 9am (scenario 5) produced a 4% reduction in peak hour patronage, similar to the more generous but less focussed 50% discount of scenario 4. A 50% larger shift out of the peak hour of 6% was forecast for a 25% fare surcharge on trains arriving between 8-9am (scenario 6). The higher demand response reflected the lower 'surcharge' value of time estimated by the market research. Unlike the other incentives modelled, the revenue effect was positive with AM 3.5hr peak revenue increasing by 10% or $12 million a year.

Scenarios 7-9 combine surcharges and discounts. A 10% surcharge on peak hour trains combined with a 10% discount on early and late trains produced a 4% reduction in peak hour patronage and had a near neutral revenue impact. Increasing the fare difference to 25% (scenario 9) produced the largest patronage shift out of the peak hour with CBD trips falling 11% or 9,000 trips. Revenue was forecast to reduce by 5% or $6 million annually. Scenario 8 adjusts this fare structure to give a greater discount (30%) than surcharge (10%), which more than doubles the revenue loss (to 13%) but reduces the patronage shift to 8%.

In conclusion, the model demonstrates how differential fares can spread peak loads. The results provide guidance on the best structure of peak hour fare incentives, but the accuracy of the forecasts is naturally dependent on a range of assumptions. It should be noted that the model was developed as a 'proof of concept' with several simplifications made in the treatment of fare and the description of passenger journeys. The model was also developed for only one line - the Illawarra line. The accuracy by which the results can be generalised to other rail lines depends on the similarity of the timetables, demand and fare profiles. Finally, the forecasts were based on the stated response of passengers to hypothetical situations presented in a market research questionnaire rather than actual behaviour. Sensitivity tests of key parameters suggest actual demand shifts could be greater than forecast, although the forecasts are slightly higher than the observed response to actual fare initiatives in Melbourne and Sydney.

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1. Introduction

DOUGLAS Economics was engaged Infrastructure New South Wales (INSW) to model the ability of fare discounts and surcharges to 'spread' peak passenger loads more evenly across the AM peak. The forecasts rely on a model developed in 2009-10 by Douglas Economics in association with Southern Cross University (SCU) as part of a wider study undertaken for the CRC for Rail Innovation: funded Project R1.107 *"Urban Rail Demand Management Strategies"*. A summary of the study was presented at the 2011 Australasian Transport Research Forum.[1]

The model was developed as a 'proof of concept' rather than a definitive assessment tool and used the Illawarra line including South Coast intercity services as a case study.[2] Some simplifications were made in developing the model. Of particular relevance is the modelling of fare. The model assumed that all adult passengers pay the same average fare of $3.30 per trip (i.e. the fare was not related to trip length). Fare discounts and surcharges were then modelled as percentage changes to the average fare. Thus a 10% discount was modelled as a 33 cent fare reduction applying to all adult trips.

The effect on patronage was measured in terms of the change in train passenger load at Sydenham rather than at CBD stations such as Town Hall. Individual train loads were aggregated according to the arrival time at Central with trains grouped into early peak (before 8am), peak hour (8-9am) and late peak (9-9.30am).[3]

On the request of INSW, the model was used to assess a set of nine fare incentives ranging from free travel on early trains to a surcharge of 25% on peak hour trains. Three of the tests matched actual fare trials undertaken in NSW (Smartsaver) and Victoria (Early Bird) in 2008 and a discount fare ticket offered on non peak trains in Wellington. In this way, the model predictions could be compared with the observed response to actual fare changes.

INSW requested that the patronage and revenue impacts be estimated for North Shore, Main services and all services to the CBD. This was done indirectly by applying the Illawarra forecasts to patronage and revenue estimates for other lines derived from the Compendium of CityRail statistics.

It should be noted that the model only assesses the impact on train choice. A key assumption was that the total volume of rail patronage remains the same. That is, fare discounts or surcharges did not affect overall AM peak rail patronage, only when trips are made within the period.

The parameters used in the model to describe the response of passengers to changes in travel time and fare were based on market research undertaken in 2010 on suburban services across the CityRail network. A sensitivity analysis was undertaken to assess the impact of variations in the parameter values.

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[1] Douglas N.J., Henn L. and Sloan K *"Modelling the ability of fare to spread AM peak passenger loads using rooftops"* Paper presented at Australasian Transport Research Forum 2011 Proceedings 28 - 30 September 2011, Adelaide, Australia.

[2] The 2009 AM Illawarra timetable was modelled. The timetable was changed in October 2010).

[3] Central station was chosen because all trains (suburban and intercity) pass through or terminate at this station. By contrast, most intercity trains do not go to Town Hall and Wynyard is not directly served.

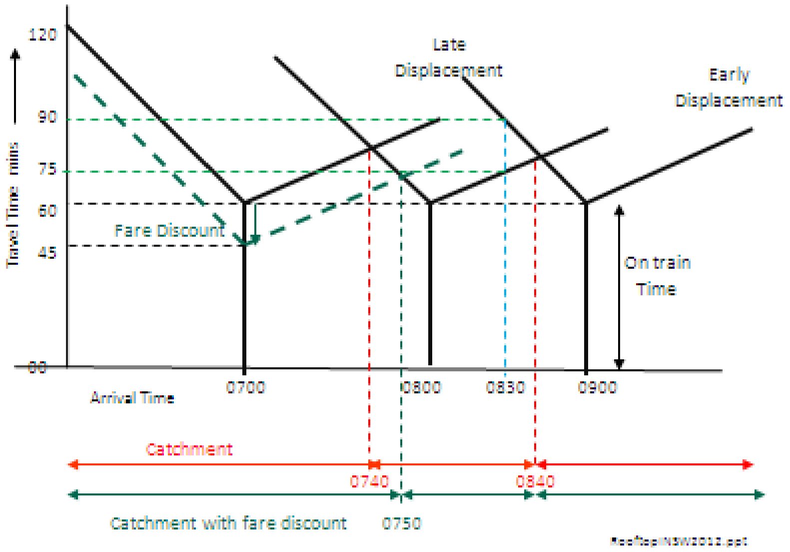
2. Model Overview

2.1 Rooftops Approach

The model uses a 'rooftops' approach that originates out of work by Hotelling in the 1920s. A half century later the technique was applied to modelling the passenger choice of train services by Tyler and Hassard in the 1970s.[4] In Australia, Ashley and McPherson used the approach in 2004 to model fast regional rail services in Victoria[5] and in Sydney, Douglas Economics used the technique in 2009 to model the Sydney rail timetable for the Independent Transport Reliability and Safety Regulator (ITSRR).[6]

Figure 2.1 shows the approach. As can be seen, the train choice graphs look like a street of roof-tops. On the horizontal axis, the arrival time of the train at the destination station is shown. There are three trains which arrive at 7am, 8am and 9am; they all take 60 minutes. The vertical axis gives the travel time for the passenger and includes the time spent on the train and the displacement time which is the difference between when the passenger wants to arrive and when the trains are timetabled to arrive.

Figure 2.1: The Rooftops Approach



A passenger who wants to arrive at 8am can catch the 8am train and arrive exactly when they desire. There is therefore no displacement time and the total travel time is the sixty minutes spent on the train.

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[4] Tyler J and Hassard R (1973) "Gravity/elasticity models for the planning of the inter-urban rail passenger business, PTRC Annual Meeting University of Sussex.

[5] Ashley D. and McPherson C (2004) *"Estimating Passenger Demand for Fast Rail Services with the Rooftop Model",* ATRF Adelaide, 2004.

6 Douglas Economics & Trainbrain "Modelling Passenger Loads and the Impact of Changes to the CityRail Timetable", Report For the Independent Transport Safety and Reliability Regulator NSW, April 2009.

However, for a passenger who wants to arrive at 8:30 there would be a displacement time. If the passenger caught the 8am train, the passenger would be 30 minutes earlier than desired. If they caught the 9am train they would be 30 minutes later than desired. The cost of displacement is shown by the sloping lines. Early displacement has a flatter slope with a minute of displacement valued the same as half a minute spent onboard the train so if the passenger caught the 8am train, the 30 minutes displacement would be worth an extra 15 minutes spent on the train. The total travel time would therefore be 75 minutes (measured as equivalent in-vehicle time).

Late displacement typically has a higher cost and in the diagram it is valued the same as onboard train time. So if the passenger caught the 9am train, the 30 minutes displacement time would be worth 30 minutes onboard the train which would make the total travel time 90 minutes. To minimise total travel time, the passenger should catch the 8am train.

The passenger catchments for the three trains are determined by the intersection of the displacement lines. The 7am train would capture all passengers wanting to arrive before 0740. The 8am train would capture passengers wanting to arrive between 0740 and 0840 and the 9am train would capture passengers wanting to arrive after 0840.

In the diagram everything else is assumed to be the same for the three services. The services are all provided by the same type of train, they offer the same chance of getting a seat and the fares are the same.

The aim of this study was to model the effect of fare discounts and surcharges. Augmenting the model to accommodate fare required the conversion of any fare differences between trains into an equivalent travel time. This is done by applying a ‘value of time’. If passengers are willing to pay $12 to save an hour of travel time, a discount of $3 offered on the 7am train converts into an effective reduction of 15 minutes in the onboard travel time. The effect lowers the rooftop for the 7am train pushing out the catchment from 0740 to 0750 and attracting passengers who would otherwise have caught the 8am train.

Conventional rooftops models have used ‘all or nothing’ assignment. A train that offers a travel time advantage, no matter how small, captures all the patronage for that particular time interval. In this study, the probability of choosing a train service was modelled which introduced ‘fuzziness’ into the train catchments, reflecting the sensitivity of individual passengers to differences in travel time, displacement and fare between services.

2.2 Travel Time Profile

A travel time profile was developed to describe when passengers want to travel.[7] The profile, presented in Figure 2.2 was based on barrier exit data for Sydney CBD stations and gives the number of passengers wanting to exit during a particular minute.[8] The profile was multiplied by the predicted ‘rooftop’ catchments to allocate passengers to trains.

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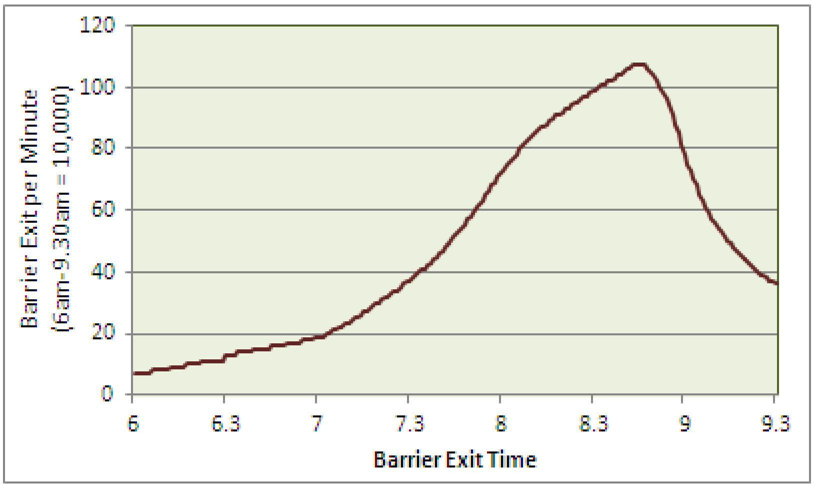
[7] In fact two profiles were developed: one for adult passengers and one for school children. The profile for school children, who account for 9% of total journeys, was developed to allow for their more peaked travel profile. Fare discounts and surcharges were only applied to adult passengers however.

[8] The profile has been scaled to 10,000 over the 3½ hour period. Thus if the exit profile had been constant, 48 adults would exited the ticket barrier per minute.

Barrier data can only be a 'proxy' for the ideal travel time profile. That said, the response to a self completion survey of 1,790 rail passengers on the Illawarra and ESR rail lines undertaken as part of the CRC study support the use of barrier data since 97% responded that they were travelling within 15 minutes of their ideal time.[9]

Figure 2.2: AM Peak Travel Time Profile



2.3 Model Calibration

The predicted loads were compared with observed loads and a set of calibration factors were developed to bring the model closer into alignment with observed loads.

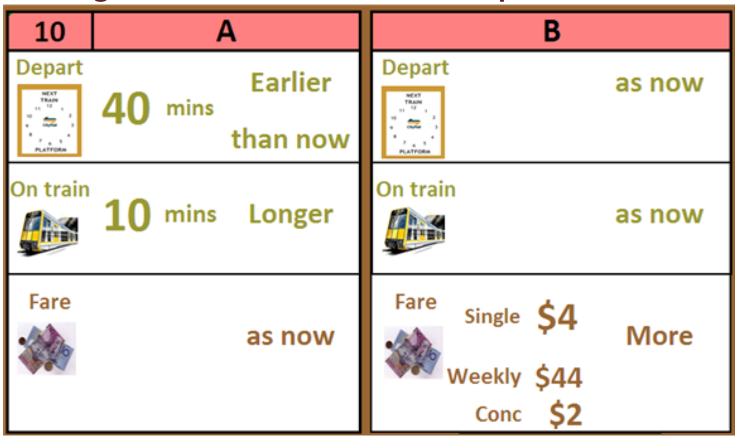
In fact, two calibration factors were calculated. The first factor was an overall factor to match the modelled patronage to the observed count for the full the AM 3.5hr period. The second factor was in fact a set of temporal factors that adjusted the desired travel time profile. The factors were calculated six times. Each successive step used the results of the previous step.

[9] The survey of 1,790 Illawarra and Eastern Suburbs Line passengers found that 80% were travelling at the 'ideal time' and a further 17%, travelling within 15 mins of their ideal time (13% preferring a train earlier and 4% a train later). Thus, 97% were travelling within 15 minutes of their ideal time and only 3% were travelling outside of 15 minutes of their ideal time. The survey is described in Henn L., Douglas N.J. and Sloan K. (2011) *"The Potential for Displacing Sydney Peak Hour Commuters"*, 34th Australian Transport Research Forum, Adelaide 2011.

3. Market Research

The demand parameters used in the train choice model were based on market research undertaken in 2010 across the Sydney suburban rail network. Passengers were presented with a series of paired journey choices and asked by interviewers which of the pair of train services they would use in each situation. An example is shown in Figure 3. In essence, the passenger is being asked whether they would pay $4 more to travel on their current train rather than travel 40 minutes earlier on a train taking 10 minutes longer but at the same fare 'as now'.

Figure 3: Market Research Example Situation



By designing a series of choices that varied the times and costs in a statistically controlled way it was possible to determine how much passengers were willing to pay to avoid having to travel an hour earlier or later than their ideal travel time and how much they were willing to pay to save onboard train time.

In total, fifty choices were designed with passengers completing eight or nine choices each. Half the fifty choices featured travelling earlier than desired. The other half featured travelling later than desired. Embedded in the design was a trade-off between onboard travel time and fare so that a value of travel time could be established.

The fares and travel times were varied around the passenger's current trip. For fares, there were five variations. Three variations featured a surcharge on the current fare and two variations featured a discount. In this way it was possible to test whether passengers were more sensitive, dollar for dollar, to a discount or a surcharge.

In total, 786 Sydney rail passengers travelling on suburban services during the peak period were interviewed. A statistical model was fitted to the data that explained the variation in response of passengers to the fifty questions in terms of the travel time, displacement and fare.

Analysis of the response found passengers to value early displacement at around half that of onboard train time but value late displacement nearly the same as onboard train time. In fact, the values would produce rooftops with similar slopes to those shown in Figure 1. Travelling an hour earlier than desired was valued the same as spending an extra 32 minutes on the train (giving the ratio of 0.53 in Table 3). Travelling an hour later was valued the same as an extra 56 minutes on the train.

The value of onboard travel time depended on the direction of the fare change. Dollar for dollar, passengers were less willing to pay a surcharge than they were willing to accept a discount. This translated into a higher willingness to accept (WTA) than willingness to pay (WTP). On average, passengers were willing to pay a fare surcharge of $13.56 to save an hour of onboard train time but required a discount of $33.80 to be willing to accept an extra hour of travel time.

Table 3: Estimated Values of Displacement & Travel Time

Valuation	Mean	Std Error	Low	High
Early Displacement/Onboard Time	0.53	0.06	0.41	0.65
Late Displacement/Onboard Time	0.93	0.08	0.77	1.09
Value of Onboard Time/Surcharge (WTP) $/hr	13.56	1.47	10.68	16.44
Value of Onboard Time/Discount (WTA) $/hr	33.80	12.52	9.26	58.34

Notes: WTP (Willing to Pay) WTA Willing to Accept (WTA)

In combination, the survey produced four values of displacement. A discount of $18 would be required to get passengers to travel an hour earlier (53% of 33.80) and a $31 discount to travel an hour later (93% of 33.80). Alternatively, a surcharge of $6 (53% of 13.56) would be required to get passengers to travel an hour earlier and $11 (93% of 13.56) to travel an hour later. Therefore dollar per dollar, surcharges were estimated to be three times more effective than discounts in getting passengers to shift their time of travel.

Table 3 also presents the statistical variability (denoted Std Error) in the mean (or average) estimate derived from the sample of passengers surveyed. The statistical variability reflects the fact that different passengers had different preferences regarding travel time and fare. Some responded strongly to a high fare and others did not. As only a sample of passengers was interviewed rather than a full census, if the survey was repeated a different mean estimate would result. The standard error provides a measure of the range in the mean estimate that could result.

As can be seen, the displacement values were estimated with reasonable precision. Early displacement ranged between 0.41 and 0.65 and late displacement between 0.77 and 1.09.[10]

At $13.85 per hour, the surcharge value of time was similar to the peak value of time of $12.85 reported in the CityRail Compendium.[11] The estimate was also relatively precise with a survey error range from $10.68 to $16.44 per hour.

By contrast, the discount value of time of $33.80 per hour was far less precisely estimated and had a wide range of $9.26 to $58.34 per hour. The response to the fare discounts across the respondents was much more varied than to the surcharge, dollar per dollar. A much larger sample would be required to reduce the range in the mean estimate to that for the fare surcharge. Given the lack of precision and the relatively high value, a lower discount value of time of $20 per hour was used in the rooftops model for the central case forecasts.

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[10] The low and high values are the 95% confidence lower and upper values calculated at ± 1.96 the standard error. If the survey was repeated with a different sample of passengers interviewed, there is a 95% chance that the value would lie within this range.

[11] The value given in the CityRail Compendium 2010 (page 68) was estimated using similar Stated Preference research undertaken in 2004 by Douglas Economics and RailCorp. RailCorp has updated the values using economic indicators.

4. Case Study of the Illawarra Line

The Illawarra line including South Coast intercity services was used as a case study. The Illawarra suburban line carries 46,000 passengers in the AM 3.5 hour peak.[12] The total compares with 317,000 trips made on the CityRail network as a whole. Thus, the Illawarra line accounts for 15% of trips.

Figure 4.1: Illawarra Rail Line

In the AM Peak, 70% of Illawarra trips originate at an Illawarra station and 30% originate on another rail line and travel to an Illawarra line station.

Of originating trips, 60% exit at a CBD station, 20% travel within the Illawarra line and 5% travel on past Martin Place station to the remaining stations on the Eastern Suburbs Railway.[13] The remaining 15% transfer onto another rail line with the North Shore the most popular transfer destination.

South Coast intercity services operate from Bomaderry, Port Kembla and Wollongong and carry just over 5,000 passengers in the AM 3.5 hour peak. Intercity services carry around 10% of Illawarra suburban services. Of the total of 5,000 South Coast trips, two thirds originate at a South Coast station and one third travel to another South Coast station.

Intercity trains stop at larger 'suburban' stations such as Hurstville, which required the services to be included in the rooftops model.[14] Of passengers originating at a South Coast station, 40% travel to CBD stations, 35% travelling to other south coast intercity stations and 12% travel to suburban Illawarra stations. The remaining 13% transfer onto another rail line.

The Illawarra line obtains high AM passenger load factors (passengers as a percentage of seat capacity) in the AM peak. Indeed, in March 2010, Illawarra suburban services obtained the highest average passenger loadings of all lines. Table 4.1 presents the observed RailCorp loadings for the

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12 The patronage figures are taken from the Origin – Destination matrix (AM peak 3.5 hours) presented on page 50 of the "*Compendium of CityRail Travel Statistics Seventh Edition*", June 2010. The 'West' is the biggest rail line with around 50,000 using services in the AM peak.

13 The Eastern Suburbs and Illawarra are physically one and the same. For public timetable reasons, the two services are separated. Central station is the dividing station.

14 Passenger boarding Intercity services north of Thirroul are included in the suburban Illawarra figure.

Illawarra line.[15] Thus, in terms of the study, the Illawarra line offers a prime candidate for spreading passenger loads by introduction of fare discounts / surcharges.

Table 4.1: Average Loads on Morning Peak Illawarra Trains to Sydney CBD
RailCorp Loading Surveys March 2010

Line		One Hour Peak 0800-0859 (Central Time)				3.5 hr Peak 0600-0930 (Sydenham Time)			
(Survey Station)	Service	Trains	Seats	Pax	LF	Trains	Seats	Pax	LF
Illawarra	Cronulla	4	3,520	5,120	145%	12	10,586	11,590	110%
(Sydenham)	Waterfall/Thirroul/S'land	6	5,088	7,355	145%	13	11,086	12,490	115%
	Hurstville/Mortdale	4	3,546	4,050	115%	12	10,344	7,425	70%
	Suburban Total	14	12,154	16,525	135%	37	32,016	31,505	100%
Line		One Hour Peak 0729-0828 (Central Time)				3.5 hr Pk 0530-0900 (Helensburgh Time)			
(Survey Station)	Service	Trains	Seats	Pax	LF	Trains	Seats	Pax	LF
South Coast	Kiama/Dapto/P. Kembla	3	2,560	1,410	55%	9	5,520	3,240	60%
(Helensburgh)	Thirroul - Bondi Junction	2	1,704	50	5%	3	2,516	60	0%
	South Coast Total	5	4,264	1,460	35%	12	8,036	3,300	40%

For March 2010, RailCorp loading surveys estimated an average passenger loading of 135% for the fourteen peak hour Illawarra Suburban services measured at Sydenham. The average load factor varied by service group. For the four services commencing at Cronulla, the average passenger load reached 145% with 5,120 passengers compared to 3,520 seats. Thus at least 1,600 passengers were standing at Sydenham.[16] For the six Waterfall/Thirroul/Sutherland starters, a similar load factor of 145% was obtained with 7,355 passengers and 5,088 seats. However the four 'local' or 'all stop' Hurstville and Mortdale starters had a lower load factor of 115% at Sydenham.

Compared to other suburban services, Cronulla and Waterfall/Thirroul/Sutherland starters had the highest observed peak hour passenger loads at 145%. The next highest average load was for South services via Granville at 135% followed by Northern services with an average of 130%.

South Coast intercity services were also included in the model because the stopping pattern overlaps that of the suburban Illawarra services. All intercity services stop at Hurstville for example. Thus Hurstville passengers have the full range of suburban and also intercity services to choose from. In addition, setting different fares on intercity services compared to suburban services would also affect loadings.[17] Unfortunately, RailCorp does not survey passenger loads for South Coast intercity services at the same point as for suburban services. Instead of Sydenham, South Coast services are measured further out at Helensburgh at the end of suburban services; this makes comparison of loadings difficult since loadings will be lower than at Sydenham. In fact, in March 2010, the average loading for the 5 peak hour intercity services was only 35% at Helensburgh.

15 The loading figures are taken from page 38 of the 2010 Compendium. A full tabulation of all CityRail lines is given in section 5.1 of the Compendium.

16 Some seats will have been empty (often middle seats in three seat rows) thus the number standing will have exceeded 1,600.

17 In New Zealand, a minimum fare is set on longer distance express commuter services out of Wellington to discourage passengers who could use local services.

5. Forecast Impact on Patronage & Revenue

5.1 Fare Incentives Modelled

The model was used to predict the ability of fare discounts and fare surcharges to spread Illawarra passenger loads across the AM peak . In section 6, the results are generalised to other rail lines of interest. Nine incentives were modelled:

1. Free Travel on Trains Arriving Central before 7am
2. Free Travel on Trains Arriving Central before 7.30am
3. Free Travel on Trains Arriving Central before 8am
4. 50% Discount on Trains before 0715 & after 0915
5. 25% Discount on Trains arriving Central before 8am and after 9am
6. 25% Surcharge on trains arriving Central between 8 and 9am
7. 10% Surcharge on trains arriving Central between 8 and 9am and a 10% discount on trains arriving before 8am and after 9am
8. 10% Surcharge on trains arriving Central between 8 and 9am and a 30% discount on trains arriving before 8am and after 9am
9. 25% Surcharge on trains arriving Central before 8 and 9am and a 25% discount on trains arriving before 8am and after 9am

Tests 1 and 4 were similar to actual fares introduced in Melbourne and Sydney and Test 5 is similar to a discount fare introduced on a rail line in Wellington. These three tests allow the model forecasts to be compared with observed patronage response to actual fare initiatives. The three examples are discussed in sections 5.2 to 5.4.

A key assumption that was made in the modelling work is that the total volume of rail patronage remained unaffected. That is the discount or surcharge only affected the choice of train and did not generate or suppress any rail trips.

5.2 Melbourne Early Bird Ticket

The Early Bird ticket was trialled on two rail lines in October 2007 and rolled out onto all 15 rail lines in March 2008 and is still available as of April 2012. The Early Bird is a multi-trip pack of ten tickets offering passengers free rail travel if trips are completed before 7 a.m. Passengers are required to validate their ticket when exiting CBD station barriers.

The patronage effects of the Early Bird ticket were reviewed by Currie.[18] He estimated that in 2010, 8,000 to 9,000 passengers used the ticket each weekday. Of these passengers, 23% had shifted their time of travel (2,000–2,600 passengers) by an average of 42 min. The shift reduced demand during peak hour (8-9am) between 1.2% and 1.5% from previous levels which was considered equivalent to a maximum of five average train loads. The program cost was estimated to have cost $6 million in lost fare revenue.

[18] Currie G. (2009) *"Exploring the Impact of the 'Free Before 7' Campaign on Reducing Overcrowding on Melbourne Trains"* Paper presented at the 32nd Australasian Transport Research Forum Auckland, New Zealand 29th September 2009.

Currie considered that demand growth far outweighed this effect so that overloading had increased after the early bird program had been introduced. Its effect was to reduce the scale of increased overloading. Overall, it is unclear to what degree the early bird ticket program has acted to reduce overloading. Peak travel during the less critical 7:00 to 8:00 a.m. peak time has been reduced; however, its effect during the critical 8:00 to 9:00 a.m. peak time is low.

5.3 Sydney Smart Saver

The Smart Saver was introduced as trial on the West, Carlingford and Richmond rail lines in August 2008. The trial lasted for ten weeks.

The Smart Saver was valid on trains scheduled to arrive at Central between 4 am – 7:15 am or between 9:15 am and 10:15 am departing from Central anytime before 4 pm and after 6:30 pm.

Research by TNS[19] summarized by Henn[20] estimated that the Smart saver had led to 2% per cent reduction in peak hour rail patronage on the rail lines with the broad travel time exclusions (including those in the pm peak) being identified as a major inhibitor of ticket take-up.

5.4 Wellington Peace Monthly

A fare discount of 25% was offered on the standard monthly for travel on the Johnsonville line in Wellington during the 2000s. The discounted monthly fare was called the Peace Monthly and was available on all trains except the busiest two inbound trains (arriving 08:07 and 8:20) in the AM peak.

The Johnsonville line is a short 11km rail line which operates to a 15-20 timetable during the peak period. Tickets are inspected on trains by guards. The Peace Monthly was introduced to encourage people off the busiest two trains which suffered from overloading. The ticket was considered to have reduced patronage on the two trains by 20%.[21]

5.5 Forecast Patronage and Revenue Impacts

The impact on patronage was measured in terms of the passenger load of trains at Sydenham. Trains were aggregated according to their arrival time at Central. Three groups were defined: early peak (trains arriving between 6 and 8am), peak hour (trains arriving between 8 and 9am) and late peak (trains arriving between 9 and 9.30). The change in train load was expressed as a percentage of the base load.

The revenue impact was calculated assuming a base average adult fare of $3.30 per trip ($1.65 was assumed for school children who account for 9% of trips). The fare incentive was applied to all trips

[19] TNS Social Research 2008, *"SmartSaver trial evaluation report of findings September – October 2008"*, report to RailCorp, Sydney.

20 Henn, Karpouzis and Sloan (2010) *"A review of policy and economic instruments for peak demand management in commuter rail", paper presented at the* 33rd Australasian Transport Research Forum Conference held in Canberra, on 29 September - 1 October, 2010.

[21] The estimate was provided by Graham Mowday Marketing Manager of Tranz Metro up until mid 2011.

on affected AM peak trains not just the passengers travelling on trains at Sydenham. The forecast impact of the incentives on passenger loads and revenue is presented in Table 5.5.

Table 5.5: Predicted Patronage and Revenue Impact

Illawarra & South Coast Services

	Fare Incentive	Peak Train Load at Sydenham Early Peak Before 0800	Peak Hour 0800-0900	Late Peak 0900-1000	Revenue Change %
1	Free Travel before 7am	3%	-2%	-1%	-11%
2	Free Travel before 7.30am	9%	-6%	-3%	-22%
3	Free Travel before 8am	19%	-11%	-6%	-37%
4	50% Discount before 0715 & after 0915	1%	-4%	7%	-15%
5	25% Discount before 8am & after 9am	4%	-4%	4%	-14%
6	25% Surcharge 8-9am	5%	-6%	6%	10%
7	10% Surcharge 8-9am & 10% Discount Before/After	4%	-4%	4%	-1%
8	10% Surcharge 8-9am & 30% Discount Before/After	6%	-8%	7%	-13%
9	25% Surcharge 8-9am & 25% Discount Before/After	9%	-11%	9%	-5%

Free travel on trains arriving Central before 7am was forecast to reduce peak hour patronage by 2%. The low response results from a combination of the average fare $3.30, a 'discount' value of time of $20 per hour and the need to travel an hour earlier. With a value of time of $20 per hour, saving $3.30 would be worth only ten minutes of onboard travel time. However, to qualify for this saving passengers would need to travel an hour earlier, which for the average customer would be equivalent to around 30 minutes of onboard train time. Nevertheless, for a minority of customers (with lower values of time) this would be worthwhile, and at 2%, the forecast peak hour reduction was of a similar magnitude, albeit slightly greater, than the 1.2-1.5% reduction estimated to have resulted from the Melbourne Early Bird ticket. In terms of ticket revenue, the model forecast a reduction of 11% which reflects the patronage share of early peak trains.

Extending free travel half an hour to trains arriving at Central up to 7.30am increased the shift out of the peak hour threefold. Peak hour loads fell 6% with early peak loads increasing by 9%. At 22%, the loss in AM peak revenue was forecast to be significant.

Offering free travel up to 8am increased the shift out of the peak hour to 11% but with a marked reduction in revenue of 37%. This fare structure could also be practically difficult to implement, as it could create large customer build up behind CBD turnstiles shortly before 8am. The remaining scenarios therefore adopt a more focussed approach to fare incentives with a lesser level of discount.

Test 4, a 50% fare discount on trains before 0715 and after 0915, matches the fare conditions of the Sydney Smart Saver. The model forecast peak hour passenger loads to reduce 4% which is double the 2% reported for the Smart Saver during its ten week trial. Revenue was forecast to reduce by 15%.

Test 5, a 25% discount on trains before 8am and after 9am produced a 4% reduction in peak hour patronage. This is much lower than the 20% reduction reported for the Peace Monthly ticket in Wellington. The Wellington ticket was less restrictive however being available on all but two peak trains arriving in a thirty minute window.

The model forecast a bigger response to a 25% fare surcharge in test 6. Peak hour passenger loads fell by 6% which was 50% greater than the 25% discount on early and late peak trains. The higher demand response reflected the lower 'surcharge' value of time estimated by the market research. The revenue impact was positive, increasing by 10% although it should be remembered that total rail demand was assumed to remain unchanged.

A 10% surcharge on peak hour trains combined with a 10% discount on early and late trains produced a more modest 4% reduction in peak hour patronage but had a near neutral revenue impact (-1%).

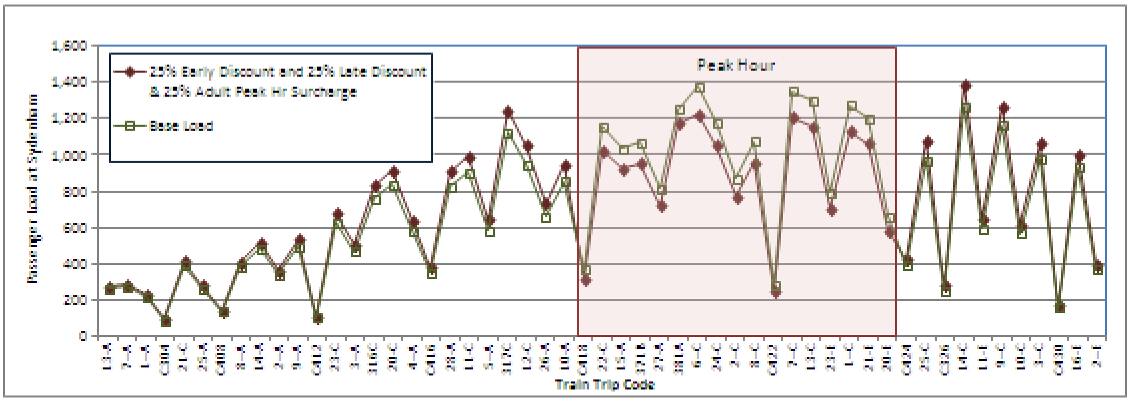
A 10% surcharge on peak hour trains combined with a 30% discount on early and late trains produced an 8% reduction in peak hour patronage but had a more substantial revenue impact of minus 13%.

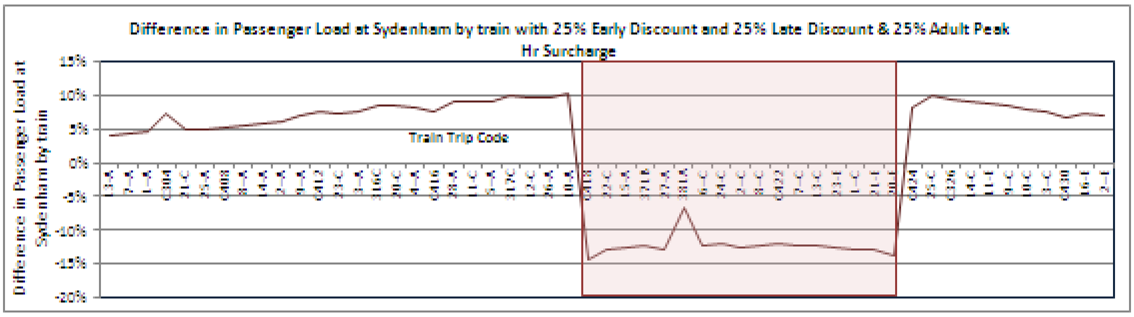
Increasing the fare difference to 25% produced the largest patronage shift out of the peak. Peak hour train loads fell 11% for a relatively small revenue loss of 5%. Figure 5.5 shows the effect of the fare policy on individual train loads (presented in chronological order).

The graphs shows passengers tend to shift to the trains closest to the peak hour that offer a fare advantage whereas within the peak hour, the shift is greatest towards the start and finish rather than at the peak of the peak.

Figure 5.5: Impact of a 25% Surcharge on Pk Hr & 25% Discount on Early & Late Pk Trains

Passenger Loads on Illawarra & South Coast Trains measured at Sydenham





5.6 Sensitivity Analysis

The parameters used in the model to measure passenger response to fare discounts and surcharges were based on market research questionnaire surveys of passengers.

To test the effect on patronage and revenue, four sensitivity tests were undertaken that varied the parameter values. The parameter values are summarised in Table 5.6.1.

Table 5.6.1: Sensitivity Tests

Valuation	Central Case	A Survey WTA	Central Case ± 20% B Low -20%	C High +20%	D CityRail VOT
Early Displacement/Onboard Time	0.53	0.53	0.42	0.64	0.53
Late Displacement/Onboard Time	0.93	0.93	0.74	1.12	0.93
Value of Onboard Time/Surcharge (WTP) $/hr	13.56	13.56	10.85	16.27	12.85
Value of Onboard Time/Discount (WTA) $/hr	20	33.80	16	24	12.85

The sensitivity analysis was undertaken for a 25% surcharge on trains arriving Central between 8-9am and a 25% discount on trains arriving before 8am and after 9am.

Table 5.6.2: Sensitivity Test Results

Predicted Patronage & Revenue Impact on Illawarra & South Coast Services

Response to a 25% fare surcharge on peak hour and 25% discount on early and late peak services

	Sensitivity Test	Early Peak Before 0800	Peak Hour 0800-0900	Late Peak 0900-1000	Revenue Change %
9	Central Case	9%	-11%	9%	-5%
9A	Survey Discount VOT of $33.80/hr	7%	-9%	7%	-5%
9B	Low Values of Displacement & Travel Time (-20%)	14%	-15%	13%	-6%
9C	High Values of Displacement & Travel Time (+20%)	6%	-8%	6%	-4%
9D	CityRail Compendium Peak Value of Time ($12.85/hr)	11%	-14%	12%	-5%

Using the survey mean estimate for the discount value of time of $33.80 per hour (test 9A) instead of the $20 per hour assumed (whilst keeping all the other parameters the same) reduced the patronage shift out of the peak hour from 11% to 9%.

Reducing the parameter values by 20% (test 9B) increased the shift out of the peak hour to 15% whereas increasing the values by 20% (9C) lowered the shift to 8%.

The final test replaced the discount and the surcharge values of time with a single value of time of $12.85 per hour as given in the CityRail Compendium for peak travel. With this value of time, the shift out of the peak increased to 14%.There was less impact on revenue with a reduction of 4% to 6% compared to 5% in the central case.

In conclusion, the value of time evidence suggests a greater likelihood for lower values of time and especially so for fare discounts. Accepting this suggest implies greater upside potential for peak spreading than downside.

6. Applying the Forecasts to Other Rail Lines

6.1 Indirect Approach

The model forecasts presented in section 5 are applied to Illawarra, Main West, North Shore and all rail lines. The forecasts are used to determine the reduction in peak hour trips to the CBD and the revenue impact of the seven fare incentives. It should be remembered that the model was developed and calibrated to the Illawarra and South Coast rail lines and although the behavioural parameters used in the model were based on market research undertaken across the suburban network, the patronage and timetable data was necessarily specific to the Illawarra and South Coast rail lines. Thus given that 'rooftop' models have not been developed for the other rail lines, the forecasts can only be indicative.

Factors likely to influence the extent of peak spreading include the average trip length from the CBD, the frequency of peak and shoulder peak services and the fare structure. In terms of shoulder peak services, if services are timetabled close to peak hour services, passengers would need to displace fewer minutes to take advantage of a fare incentive than if there was a wider service gap.

6.2 Peak Hour Patronage Reduction

The forecasts were based on patronage figures given in the 2010 CityRail Compendium. The Compendium tabulates the number of trips made to and from each rail line for the AM peak 3.5 hour period.[22] It was assumed that the fare discounts and surcharges would only apply to trips made to CBD stations. Of a total of 317,000 AM peak trips the Compendium gives a figure of 149,000 (just under one half) made to CBD stations.

The Compendium estimates that 55% of AM peak trips to the CBD are made in the peak hour. Thus the total of peak hour CBD trips is 82,000. By line, 12,700 are made on the Illawarra, 10,700 on West and 8,000 on North Shore services. These estimates are shown on the bottom line of Table 6.2.

The forecast impact of each fare incentive was determined by multiplying the number of trips by the predicted peak hour percentage reduction in Table 5.5.

Offering free travel on trains arriving Central before 7am is forecast to reduce CBD trips by 300 on Illawarra line and by 200 on both West and North Shore services. If offered on all services, a reduction of 1,600 CBD trips in the peak hour is forecast.

Three times the reduction is forecast if free travel is extended to 7.30am with 4,900 CBD trips shifted out of the peak hour if offered on all rail lines. If free fares are extended up to 8am the reduction in peak hour demand is forecast to increase to 9,000 passengers.

The same patronage shift as offering free fares on trains up to 8am is forecast with a 25% surcharge on peak hour trains in combination with a 25% discount on trains arriving before 8am and after 9am (test 9). In total, 9,000 peak hour CBD trips are forecast to shift out of the peak hour. By line, 1,400 trips are diverted from Illawarra services, 1,200 from West and 900 from North Shore services.

[22] Page 51 of the 2010 CityRail Compendium.

If the discount and surcharge is lowered to 10%, the patronage shift reduces by two thirds to 3,300 trips across all lines (test 7).

Table 6.2: Predicted Peak Hour Patronage Reduction

Predicted Reduction in Peak Hour Patronage to Sydney CBD Stations

		Peak Hour	AM Peak Hour Reduction (Trips)			
	Incentive	Reduction %	Illawarra	West	N. Shore	ALL CBD
1	Free Travel before 7am	-2%	-300	-200	-200	-1,600
2	Free Travel before 7.30am	-6%	-800	-600	-500	-4,900
3	Free Travel before 8am	-11%	-1,400	-1,200	-900	-9,000
4	50% Discount before 0715 & after 0915	-4%	-500	-400	-300	-3,300
5	25% Discount before 8am & after 9am	-4%	-500	-400	-300	-3,300
6	25% Surcharge 8-9am	-6%	-800	-600	-500	-4,900
7	10% Surcharge 8-9am & 10% Discount Before/After	-4%	-500	-400	-300	-3,300
8	10% Surcharge 8-9am & 30% Discount Before/After	-8%	-1,000	-900	-600	-6,600
9	25% Surcharge 8-9am & 25% Discount Before/After	-11%	-1,400	-1,200	-900	-9,000
	Total AM Peak 1 Hour Patronage	na	12,700	10,700	8,000	82,000

6.3 Revenue Impact

A crude assessment of the impact on ticket revenue was made by multiplying the forecast percentage revenue reduction (Table 5.5) with annual AM peak (3.5 hrs) revenue.[23] Revenue was estimated assuming an average fare of $3.16 per trip.[24] For all trips to the CBD, annual AM peak revenue was estimated at $118 million and is shown in the bottom row of Table 6.3.

Table 6.3: Predicted Revenue Impact of Fare Incentives

		Revenue	Annual Revenue Change $m			
	Incentive	Change %	Illawarra	West	N. Shore	ALL CBD
1	Free Travel before 7am	-11%	-2.0	-1.7	-1.3	-13
2	Free Travel before 7.30am	-22%	-4.0	-3.4	-2.5	-26
3	Free Travel before 8am	-37%	-6.8	-5.7	-4.2	-44
4	50% Discount before 0715 & after 0915	-15%	-2.7	-2.3	-1.7	-18
5	25% Discount before 8am & after 9am	-14%	-2.6	-2.2	-1.6	-17
6	25% Surcharge 8-9am	10%	1.8	1.5	1.1	12
7	10% Surcharge 8-9am & 10% Discount Before/After	-1%	-0.2	-0.2	-0.1	-1
8	10% Surcharge 8-9am & 30% Discount Before/After	-13%	-2.4	-2.0	-1.5	-15
9	25% Surcharge 8-9am & 25% Discount Before/After	-5%	-0.9	-0.8	-0.6	-6
	Annual AM Peak 3.5hr Ticket Revenue $m	na	18	15	11	118

23 The model only models the AM peak 3.5 hr period. It is noted that CityRail already offers an off-peak return for travel after 0930. The implications of lengthening the period of analysis to, for example, midday have not been explored.

24 The average fare of $3.30 used in the rooftops model was adjusted downwards to $3.16 to allow for school children. The figure compares with an average revenue per trip of $2.81 calculated from annual ticket data in the 2010 Compendium. To calculate annual patronage, AM peak 3.5 hour patronage was multiplied by 250.

Offering free travel to passengers travelling to the CBD on trains arriving Central before 7am was estimated to cost $13 million per year. This is slightly more than double the $6 million loss in revenue estimated for the Melbourne Early Bird ticket.

Extending free travel to 7.30am doubled the revenue loss to $26 million a year and to $44 million if extended to 8 am.

Introducing a ticket similar to the 2008 Sydney Smart Saver trial offering a 50% discount on trains arriving before 7.15am and after 9.15am was estimated to cost $18 million a year.

Combining a 10% discount on early and late peak trains with a 10% surcharge during the peak hour was close to revenue neutral costing $1 million a year. A 25% discount/surcharge was estimated to cost $6 million a year. By contrast, offering a larger discount of 30% on early and late peak trains with a 10% surcharge during the peak hour would cost $15 million a year in lost revenue.

The estimated revenue losses from the discounted fare options are based on assuming passengers with non CBD destinations (45% of AM peak trips) would not receive the discount. In practice although the Airport Rail Line provides a precedent for differential station fares, there could be resistance to pricing CBD rail station fares differently to non CBD stations. Clearly, if the discounts were extended to non CBD customers, the revenue loss would be exacerabated for lesser proportional reductions in train and station crowding. Similarly, extending the discounts to cover the return evening trip would also increase the revenue loss. On the other hand, a revised peak pricing structure would probably replace the current CityRail off-peak ticket product, which may provide an offsetting revenue improvement.

7. Concluding Remarks

The rooftops approach lends itself to modelling the ability of fare to spread peak loads. The model was developed as a 'proof of concept'. Several simplifications were made in the treatment of fare and the description of passenger journeys. Further work could review and improve on these simplifications.

The model was developed for the Illawarra line. The accuracy by which the results can be generalised to other rail lines depends on the similarity of the timetables, demand and fare profiles. Ideally, individual models tailored to each rail line should be built.

The model was used to forecast the patronage and revenue effects of a range of fare incentives. The model predicted that peak hour fare surcharges, dollar for dollar, would be more effective in shifting passengers out of the peak hour than early and late peak discounts. This result reflected the behavioural parameters in the model which were based on the stated response of passengers to hypothetical situations. In general, the market research was successful in estimating values of reasonable magnitude and precision. However, the implied 'discount' value of time was considered to be too high and was replaced by a lower value in the forecasting model. Further market research could be undertaken to improve the accuracy of the 'discount' value of time.

Knowing the profile of when passengers want to travel is a key modelling requirement. The model used a profile based on CBD barrier exits. The model was then calibrated to actual loadings observed on the Illawarra line. It was also possible to validate the model predictions against the actual response to three fare discounts although no examples of introducing fare surcharges were able to be found. More work could be undertaken on understanding the factors that determine when passengers want to travel.

The model was based on travel in the AM peak and did not consider the PM peak. Further work could aim to develop an integrated AM/PM model.

The model has only been used to evaluate fare initiatives. The approach could be extended to evaluate the effect of timetable changes on train passenger loads. Changes that could be modelled include express services in the shoulder peak or an increased number of shoulder peak train services.

Finally, further work could measure the degree of displacement of peak hour passengers who shift into the early and late peak periods. If a reasonably large percentage of passengers displace, there could be opportunities to get a bigger peak reduction by introducing additional shoulder peak trains, subject to the operational feasibility of such scheduling.

8. References

Ashley D. and McPherson C., (2004) *"Estimating Passenger Demand for Fast Rail Services with the Rooftop Model"*, ATRF Adelaide, 2004.

Currie G. (2009) *"Exploring the Impact of the 'Free Before 7' Campaign on Reducing Overcrowding on Melbourne Trains"* Paper presented at the 32nd Australasian Transport Research Forum Auckland, New Zealand 29th September 2009.

Douglas Economics & Trainbrain (2009) *"Modelling Passenger Loads and the Impact of Changes to the CityRail Timetable"*, Report to the Independent Transport Safety and Reliability Regulator NSW, April 2009.

Douglas N.J., Henn L. and Sloan K (2011) *"Modelling the ability of fare to spread AM peak passenger loads using rooftops"* Paper presented at Australasian Transport Research Forum 2011 Proceedings 28 - 30 September 2011, Adelaide, Australia.

Henn L., Douglas N.J. and Sloan K. (2011) *"The Potential for Displacing Sydney Peak Hour Commuters"*, 34th Australian Transport Research Forum, Adelaide 2011.

Henn L., Karpouzis G. and Sloan K. (2010) *"A review of policy and economic instruments for peak demand management in commuter rail"*, paper presented at the 33rd Australasian Transport Research Forum Conference held in Canberra, on 29 September - 1 October, 2010.

Hotelling H., (1929) *"Stability in Competition"*, The Economic Journal, 39, 1929: 41-57.

RailCorp (2008) *"A Compendium of CityRail Travel Statistics"* Seventh Edition June 2010.

TNS Social Research 2008, "SmartSaver trial evaluation report of findings September – October 2008", report to RailCorp, Sydney.

Tyler J. and Hassard R., (1973) *"Gravity/Elasticity Models for the Planning of the Inter-Urban Rail Passenger Business*, PTRC Annual Meeting University of Sussex.