Estimating the Costs of Over-crowding on Melbourne’s Rail System

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Abstract

Multi-modal demand forecasting models have traditionally ignored the problem of over-crowding on public transport, essentially treating the capacity of public transport (PT) services as infinite.

In recent years PT over-crowding has become a major problem in several of Australia’s cities, and is expected to worsen without major investments in public transport infrastructure. This has created a need for modelling tools which explicitly include the cost of over-crowding, to support the planning of major capacity boosting infrastructure, such as the Melbourne Metro and the Brisbane Inner Rail Solution.

Over the past two years, an innovative approach to the modelling of over-crowding has been developed, overcoming previous key challenges. Traditionally, models have “averaged together” seated and standing passengers and have considered the crowding costs associated with outward and return journeys separately. This new approach addresses these weaknesses by including the creation of an explicit distinction between seated and standing passengers and their respective perceptions of crowding, as well as differentiating between crowding costs for outward and return journeys by jointly modelling the modal choice for both legs simultaneously.

An important finding of work has been that when the crowding model is applied to the Melbourne base year (2011), the model’s predictions of rail demands improve significantly when compared with observed patronage data. This suggests that crowding effects are already materially affecting observed travel patterns on Melbourne’s rail network, and paves the way for a better understanding of the costs of crowding now and into the future.

1. Introduction

In recent years public transport (PT) over-crowding has become a major problem in several Australian cities, and is expected to worsen without major investment in PT infrastructure and services. In the AM Peak (7:00AM to 9:00 AM) in Melbourne, cordon loads at the Central Business District (CBD) Cordon increased by approximately 33 per cent between 2004 and 2008. In the same period rail capacities only increased by 10 per cent (Department of Transport, 2009). This considerable increase in patronage relative to the capacity of the network led to a significant increase in overcrowding on the metropolitan rail network.

Models of transit overcrowding, and behavioural responses to overcrowding, have received less attention in the literature than models of traffic congestion, and transit overcrowding has not been a core feature of transport models in practice (SKM, 2009; Lei and Chen 2004). This may be because transit overcrowding can often be overcome by running more frequent services (a relatively cost effective solution which does not require complex modelling). It may also be due to the very high model run times associated with the modelling of transit overcrowding.
However, in some Australian cities, there is now limited scope to increase peak rail frequencies. In Melbourne, for example, the CBD loop and some critical linkages near the CBD are nearing their maximum hourly train capacity (under current network operations). Solutions, such as major upgrades to signalling systems, restructuring of rail routes, or the construction of new infrastructure (e.g. the proposed Melbourne Metro rail tunnel) are expensive and / or have major consequences for accessibility.

This has created a need for modelling tools which aid planners in quantifying and forecasting the scale and location of overcrowding, and which can adequately evaluate the impact and economic benefit of infrastructure / policies aimed at reducing overcrowding.

Models of transit crowding typically work by including additional generalised cost components which monotonically increase with passenger demands. Viewed within a behavioural / econometric context, these costs are intended to reflect the perceived cost of over-crowding.

The costs of overcrowding can manifest in multiple ways, both in real life and in models.

Key costs of overcrowding are:

- Lack of car parking supply (affecting park and ride trips)
- Delays in reaching / leaving the platform due to over-crowding (e.g. queues at fare gates, escalators, etc.).
- Crowding on platform
- Inability to board a full service (due to lack of capacity), leading to increases in the expected value and variance of wait times
- Increases in travel time and travel time unreliability, due to delays in passenger boarding / alighting
- In-vehicle discomfort due to over-crowding (which might include having to sit next to other passengers, having to stand, or having to stand in highly crowded conditions)

The effect of these costs is to make crowded services / stops less attractive. Within transit assignment models, this can lead to specific changes in travel behaviour, such as switching to alternative transit services / modes / stops. Additional behavioural responses, such as switching to alternative primary modes (e.g. car), alternative destinations, or travelling earlier / later, are typically handled within the broader demand model within which the transit assignment is embedded.

As with traffic congestion, the modelling of transit overcrowding is necessarily iterative, with each iteration converging toward an equilibrium between demand and supply. Iterations are typically implemented within the transit assignment (inner loop), and in the broader demand model (outer loop).

In the remainder of this paper, the cost of on-board crowding is the primary focus. On board crowding has particular characteristics, some of which pose major modelling challenges:

- The cost of crowding varies along the length of a service, as passengers board / alight the service,
- The perceived cost of crowding varies between passengers, with seated passengers incurring a lower cost of crowding than standing passengers. This may lead to
particular behaviours which maximise the probability of obtaining a seat, such as boarding at an earlier stop. To model this, seated and standing costs must be separately calculated (which has challenges in software implementation)

- The perceived cost of crowding may vary considerably between the two directions of a return journey. In the morning, passengers living at the end of a line will generally be guaranteed a seat (low cost of crowding), but when returning home in the afternoon, these same passengers may have to stand for much of their journey (high cost of crowding). Modal choice decisions (such as public transport versus car) for outward and return trips are generally made jointly, based on the combined cost of the return journey. This poses a challenge for trip based models which do not link outward and return journeys.

Over the past two years, a transit assignment model that includes the cost of on board crowding and accounts for the particular characteristics identified above has been developed.

The remainder of this paper will outline the overcrowding methodology and will include validation of the model against 2011 passenger counts. The validation is benchmarked against previous model validation results (not including overcrowding), which provides encouraging support for the new model, and which provides an interesting insight into the impact over-crowding is already having on Melbourne’s rail network. Finally, an attempt is made to quantify the current aggregate cost of crowding in Melbourne.

2. The Zenith Transit Assignment Model

2.1 Overview

The Zenith Transit Assignment model has been extended to include capacity constraints on transit passenger demands. The model has been tested and successfully applied for the state of Victoria in Australia.

Key features of the model are:

- Inclusion of costs to reflect “in-vehicle discomfort due to overcrowding”
- Explicit disaggregation of seated and standing costs
- An iterative “volume averaging” algorithm which converges to a stable equilibrium
- The ability to output disaggregate cost skims (including crowding costs)
- Integration within the broader Zenith demand model, which links outward and return journeys into tours

2.2 Measures of Service Capacity

A key input required by any capacity constrained transit assignment model is measures of capacity for each transit service.

In this study, capacity was reflected through the combined use of two variables:

- Number of seats
- Crush capacity (maximum reasonable load)
Quantification of seating capacity is vital in separately modelling the costs of seated and standing passengers.

As part of developing a Victorian implementation, both measures were defined for all services in the Greater Melbourne transit network.

Key assumptions included:

- Tram routes were assigned a seated and crush capacity according to the average tram servicing each route
- Trains were assigned a seated and crush capacity based on the number of carriages
- Buses were assumed to all be the same size

Trains within the model were assumed to have 500 seats and a crush capacity of 1250 within the model. The remainder of this paper will focus primarily on rail network crowding.

2.2 Crowding Cost Function

As part of this study, the Zenith Transit Assignment model was extended to include costs related to in-vehicle discomfort due to overcrowding.

This was implemented through a “crowding cost function”, which adjusts the value of time perceived by passengers under varying crowding levels. Value of time adjustment factors are calculated per route segment (i.e. separately for each segment of each route), and separately for seated and standing passengers.

The crowding cost function was derived from the Australian Transport Council (ATC) guidelines (2006a), which were in turn derived from a review of Australian and International literature and guidelines. The ATC suggest separate seated and standing values, as shown in Table 1. Our function was entirely consistent with the ATC guidelines up to “crush capacity” loadings. A value of 0.1 in the table indicates that perceived value of time should be increased by 10 per cent.

<table>
<thead>
<tr>
<th>Load Factor (passengers)</th>
<th>Seated Valuation</th>
<th>Standing Valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>0.0</td>
<td>N/A</td>
</tr>
<tr>
<td>100% (seats)</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Crush capacity</td>
<td>0.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Beyond crush capacity, it is assumed that the crowding cost will continue to increase. While loads in excess of crush capacity may seem to contradict the definition of crush capacity, such situations must be allowed for within the modelling (and have also been observed in over-crowding surveys). Rather than applying a “hard limit” on capacity, the crowding function progressively increases the perceived cost of crowding to avoid (or minimise) over capacity situations. This is consistent with the way in which road traffic is modelled in strategic models.

The choice between curves beyond crush capacity involves a trade off between:

- Model convergence – a flatter curve results in better model convergence
- Prevention of over capacity situations – a steeper curve will act as a greater deterrent to over capacity situations
The selected curve was deemed to provide the best balance between these competing objectives (shown in Figure 1). The output of the crowding function (the value of time adjustment factor), is expressed in terms of “minutes of crowding penalty, per minute of in-vehicle travel time”, and increases as the crowding level increases. Two curves are included, one for passengers who are seated (red), and one for passengers who must stand (in blue).

For example, at crush capacity, 10 minutes spent sitting would incur a 3 minute penalty. 10 minutes spent standing would incur a 10 minute penalty.

![Figure 1: Crowding functions](image)

### 2.3 Linking of Outward and Return Journeys

The Zenith Transit Assignment model is embedded within the Zenith demand model. The demand model links outward and return trips into a single journey (a simplistic form of tour), when calculating destination and modal choices.

The outcome is that crowding costs for both the outward and return journey are taken into account in mode choice decisions. This is particularly important in the context of crowding, which is often directional asymmetric. For example, in the morning peak, passengers living at the end of a train line will generally be guaranteed a seat (low cost of crowding), but when returning home in the afternoon, these same passengers may have to stand for much of their journey (high cost of crowding).

A model which doesn't link outward and return journeys could potentially suffer from inconsistent inbound / outbound demands passenger demands. The model may also not be appropriately responsive to infrastructure / policies aimed at reducing crowding. Linking of journeys in the Zenith model is seen as an important feature.
3. Model Calibration and Validation

3.1 Calibration

The introduction of crowding costs within the model had the effect of increasing public transport generalised costs, resulting in reduced public transport mode share. Given that the model had already been calibrated and validated to observed transit passenger counts (without crowding), the introduction of crowding costs caused the model to under-estimate demands.

As a result, a short calibration exercise was required to increase aggregate transit demands back to their original level. This was achieved through the modification of global transit access penalties, which vary by each combination of access / transit mode. Access / egress penalties were reduced by approximately 4 minutes for transit each mode.

3.2 Effect on Patronage

Figure 2 displays an example of the impact of the capacity constrained transit assignment in comparison to the unconstrained transit assignment process for a highly overcrowded line (the South Morang in 2046). It is evident that the constraining process does reduce loads to a level closer to crush capacity, but in this case the loads still exceed crush capacity. The model does not treat crush capacity as a hard limit on demand.

It is also evident that passenger loads reduce along most of the route, not just in the section where loads exceed crush capacity. As a result, the point at which crush capacity is reached has shifted from Bell station towards the CBD.

Within the broader Zenith Four Step model, the displaced passengers will have been assigned to alternative travel options, including:

- Switching to alternative transit modes, especially if they are under-capacity (e.g. from rail to tram)
- Switching to alternative lines / routes (e.g. switching from the Epping Line to the Upfield line)
- Switching modes (e.g. travelling by car)
- Within a line, passengers may also redistribute amongst services, with passengers switching from over-crowded express routes to less crowded all-stopping services.
- Switching to alternative destinations.
3.3 Validation

The transit assignment model (including crowding costs) was validated against observed transit passenger counts for tram, bus and train. This section focuses on train validation.

Figure 3 shows the impact of including crowding costs on CBD cordon loads by individual rail lines. The x-axis shows counted demands, with modelled demands on the y-axis. The blue series shows modelled demands excluding crowding costs. The red series shows modelled demands including crowding costs. It is evident that the red series (including crowding costs) is significantly more correlated with observed counts (the R-Squared increases from 0.88 to 0.97).

The raw data (with crowding costs) is presented in Table 2.
**Table 2: Load at CBD Cordon by Line (AM Peak Only)**

<table>
<thead>
<tr>
<th>Line Groups</th>
<th>Observed</th>
<th>Constrained Model</th>
<th>Difference</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Northern Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williamstown</td>
<td>2,727</td>
<td>3,351</td>
<td>624</td>
<td>22.9%</td>
</tr>
<tr>
<td>Werribee</td>
<td>11,129</td>
<td>12,023</td>
<td>894</td>
<td>8.0%</td>
</tr>
<tr>
<td>Sydenham</td>
<td>10,303</td>
<td>12,135</td>
<td>1,832</td>
<td>17.8%</td>
</tr>
<tr>
<td>Craigieburn</td>
<td>12,279</td>
<td>11,473</td>
<td>-807</td>
<td>-6.6%</td>
</tr>
<tr>
<td>Upfield</td>
<td>3,547</td>
<td>3,623</td>
<td>76</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Clifton Hill Group</strong></td>
<td>17,281</td>
<td>18,122</td>
<td>841</td>
<td>4.9%</td>
</tr>
<tr>
<td>Epping</td>
<td>6,935</td>
<td>8,347</td>
<td>1,412</td>
<td>20.4%</td>
</tr>
<tr>
<td>Hurstbridge</td>
<td>10,346</td>
<td>9,775</td>
<td>-571</td>
<td>-5.5%</td>
</tr>
<tr>
<td><strong>Burnley Group</strong></td>
<td>30,540</td>
<td>29,308</td>
<td>-1,232</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Camberwell</td>
<td>22,752</td>
<td>23,134</td>
<td>382</td>
<td>1.7%</td>
</tr>
<tr>
<td>Glen Waverley</td>
<td>7,788</td>
<td>6,174</td>
<td>-1,614</td>
<td>-20.7%</td>
</tr>
<tr>
<td><strong>Caulfield Group</strong></td>
<td>38,150</td>
<td>38,799</td>
<td>649</td>
<td>1.7%</td>
</tr>
<tr>
<td>Dandenong</td>
<td>16,471</td>
<td>16,399</td>
<td>-72</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Frankston</td>
<td>13,559</td>
<td>13,892</td>
<td>332</td>
<td>2.5%</td>
</tr>
<tr>
<td>Sandringham</td>
<td>8,120</td>
<td>8,508</td>
<td>389</td>
<td>4.8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>125,956</td>
<td>128,834</td>
<td>2,877</td>
<td>2.3%</td>
</tr>
</tbody>
</table>
Comparing this data with data from the previously calibrated model without crowding a number of improvements are seen. This data is presented in Table 3 which shows the difference between modelled and observed cordon line loads.

- **Table 3: Comparison of Load at CBD Cordon by Line (AM Peak Only)**

<table>
<thead>
<tr>
<th>Rail Line</th>
<th>Unconstrained Diff.</th>
<th>Constrained Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williamstown</td>
<td>-15%</td>
<td>+23%</td>
</tr>
<tr>
<td>Werribee</td>
<td>+16%</td>
<td>+8%</td>
</tr>
<tr>
<td>Sydenham</td>
<td>+35%</td>
<td>+18%</td>
</tr>
<tr>
<td>Craigieburn</td>
<td>-19%</td>
<td>-7%</td>
</tr>
<tr>
<td>Upfield</td>
<td>-27%</td>
<td>+2%</td>
</tr>
<tr>
<td>Epping</td>
<td>+18%</td>
<td>+20%</td>
</tr>
<tr>
<td>Hurstbridge</td>
<td>-13%</td>
<td>-6%</td>
</tr>
<tr>
<td>Camberwell</td>
<td>-4%</td>
<td>+2%</td>
</tr>
<tr>
<td>Glen Waverley</td>
<td>-48%</td>
<td>-21%</td>
</tr>
<tr>
<td>Dandenong</td>
<td>+5%</td>
<td>0%</td>
</tr>
<tr>
<td>Frankston</td>
<td>+11%</td>
<td>+2%</td>
</tr>
<tr>
<td>Sandringham</td>
<td>-33%</td>
<td>+5%</td>
</tr>
</tbody>
</table>

Key improvements occur on the shorter train lines; Upfield, Glen Waverley and Sandringham. This is due to the availability and attractiveness of the empty, shorter running trains. These lines all see significant increases in patronage and as such are more closely matched to observed data.

Figure 4 shows the AM Peak train load changes in the between the validated un-constrained model run, and the validated capacity constrained model run.

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**Figure 4: Change in AM Peak Load for the purposes of validation**
3.4 Using the Model to Estimate the Cost of Crowding

In order to estimate the costs of overcrowding on Melbourne’s metropolitan rail network the over-crowding model was disabled and all other model inputs and parameters were maintained. This model is different to that discussed in Section 3. It includes the global access penalties that were implemented following the calibration and validation process. As such it does replicate observed 2011 rail demand levels and instead represents a hypothetical situation of infinite capacity. The model was given five demand cycles to converge under these uncrowded conditions.

The results of this test also give insight into the amount of latent demand for public transport travel that might currently exist in within Melbourne, which may be suppressed by current crowding levels. This unconstrained model run was treated as the ‘base case’, and all impacts of public transport overcrowding have been made through comparisons to this base case scenario. The results of this model run were analysed in three ways – network wide statistics, rail network changes and economic analysis – and are presented below.

3.4.1. Network Wide Statistics

One way that the impact of over-crowding can be analysed is by looking at the network wide impacts on public transport demand. Table 4 shows several key performance indicators.
Table 4: Network performance indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Time of day</th>
<th>No capacity constraints</th>
<th>With Capacity constraints</th>
<th>Perc. Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM Peak</td>
<td>1,468,896</td>
<td>1,484,737</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td>Inter Peak</td>
<td>4,824,268</td>
<td>4,828,323</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>PM Peak</td>
<td>1,588,261</td>
<td>1,603,351</td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>2,251,506</td>
<td>2,254,533</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10,132,931</td>
<td>10,170,944</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>Car KMs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>19,034,964</td>
<td>19,283,120</td>
<td>1.3%</td>
<td></td>
</tr>
<tr>
<td>Inter Peak</td>
<td>57,355,695</td>
<td>57,437,846</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>20,969,741</td>
<td>21,202,007</td>
<td>1.1%</td>
<td></td>
</tr>
<tr>
<td>Off-Peak</td>
<td>33,595,871</td>
<td>33,633,279</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>130,956,272</td>
<td>131,556,252</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>Total PT Trips</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM Peak</td>
<td>340,918</td>
<td>318,315</td>
<td>-6.6%</td>
<td></td>
</tr>
<tr>
<td>Inter Peak</td>
<td>565,394</td>
<td>556,222</td>
<td>-1.6%</td>
<td></td>
</tr>
<tr>
<td>PM Peak</td>
<td>293,476</td>
<td>274,139</td>
<td>-6.6%</td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>264,990</td>
<td>258,646</td>
<td>-2.4%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1,464,777</td>
<td>1,407,321</td>
<td>-3.9%</td>
<td></td>
</tr>
<tr>
<td>PT In Vehicle Passenger Kms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM Peak</td>
<td>5,836,574</td>
<td>5,252,708</td>
<td>-10.0%</td>
<td></td>
</tr>
<tr>
<td>Inter Peak</td>
<td>7,421,724</td>
<td>7,207,443</td>
<td>-2.9%</td>
<td></td>
</tr>
<tr>
<td>PM Peak</td>
<td>5,215,895</td>
<td>4,753,247</td>
<td>-8.9%</td>
<td></td>
</tr>
<tr>
<td>Off Peak</td>
<td>4,043,415</td>
<td>3,913,770</td>
<td>-3.2%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22,517,608</td>
<td>21,127,168</td>
<td>-6.2%</td>
<td></td>
</tr>
</tbody>
</table>

Overall public transport trips are reduced quite significantly, by 3.9 per cent, when public transport capacity constraints are implemented. It can also be seen that the peaks, both morning (6.6 per cent) and evening (6.6 per cent), are impacted more than the inter-peak (1.6 per cent) and off-peak time (2.4 per cent) periods. This is due to the concentration of significant overcrowding during the peaks. It can also be seen that the impact on PT in-vehicle public transport kilometres, 6.2 per cent across the day, is greater than that on public transport trips. This suggests that those on longer trips, being affected by a larger penalty due to more time spent in-vehicle, are leaving public transport for other modes.

Note also that the reductions in non-peak periods may not just be related to crowding in those periods, but also due to the linking of outward and return journeys. For example, a commuting journey made to work in the AM peak, and returning home in the off peak, will be affected mostly by crowding in the AM peak. However, with the mode choice decision being made jointly over the outward and return periods, both periods see a reduction in demand.

3.4.2. Rail Network Changes

Within the rail network, the impact of over-crowding varies by line. This is due to the varying demand for travel as distance from the CBD increases. For travellers that live in area covered by 2 rail lines, one of which is shorter than the other such e.g. people living in the area between the Sandringham Line and the Frankston Line. The Shorter of the two lines will be a more attractive in a constrained network as they are more likely to still have available seats and vehicles with less crowded conditions. Figure 5 shows the change in rail load resulting from the modelling of constrained capacities. This shows that when rail capacity is constrained the longer rail lines: Dandenong, Frankston, Ringwood have reduced AM peak rail loads. Shorter lines such as Sandringham and Glen Waverly show slight increases in patronage for the same period.
3.4.3. Economic analysis

The model can be used to understand the impacts of different schemes, such as an infrastructure change, a transit service improvement, a change in land use or demographic patterns, or a change in travel behaviour, as well as to calculate economic benefits or disbenefits associated with each scheme. This is done by comparing a base case scenario, which is used to represent “business as usual”, (ATC2006a), with a project case, which contains certain changes.

User benefits and disbenefits are calculated by estimating the change in consumers’ surplus for all users of the transport system. Consumers’ surplus is defined by the ATC as “the surplus of consumers’ willingness-to-pay over and above what they actually pay for a given quantity of a good or service,” (ATC 2006b). Given this definition, user benefits are equal to the total change in consumers’ surplus.

By treating our unconstrained model run as a ‘Do Nothing’ base case and the capacity constrained model run as a ‘Project Case’ we can analyse the cost of capacity constraint using the consumer surplus outputs.

Table 5 shows the economic outputs from the model split by cost component type.
Table 5: Daily and annualised disbenefits from crowding

<table>
<thead>
<tr>
<th>Component</th>
<th>Daily Disbenefits (hours)</th>
<th>VOT</th>
<th>Annual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowding</td>
<td>-56,461</td>
<td>$14.40</td>
<td>$231,715,000</td>
</tr>
<tr>
<td>Other PT</td>
<td>-3,503</td>
<td>$14.40</td>
<td>$14,376,000</td>
</tr>
<tr>
<td>Private Vehicle</td>
<td>-7,834</td>
<td>$12.69</td>
<td>$28,334,000</td>
</tr>
<tr>
<td>Commercial Vehicle</td>
<td>-461</td>
<td>$38.13</td>
<td>$5,008,000</td>
</tr>
<tr>
<td>Total</td>
<td>-68,259</td>
<td>N/A</td>
<td>$279,433,000</td>
</tr>
</tbody>
</table>

This shows that the estimated total costs in Melbourne due to public transport over-crowding are approximately $280 million per year. It is worth noting that this includes some minor costs due to over-crowding on trams and buses however these will be relatively small compared to that of the metropolitan trains.

The above analysis also includes $28 million (10%) related to increased road congestion impacts on private vehicle travel, and $5 million (1.7%) related to increased road congestion impacts on commercial vehicles. These costs are caused by travellers switching from public transport to car, as a result of transit over-crowding.

4. Conclusions

This paper has detailed the implementation of a public transport capacity constraint module within a four-step strategic model. The model applies factors to sections of a public transport route based on volume and capacity. These factors have an impact on route choice within the public transport assignment and an impact on overall public transport cost. These costs are then used as an input for mode choice which allows the model to forecast shifts from public transport to car, walking and cycling as a result of over-crowding. The model has also taken into account both the outward and return journeys when choosing between car and public transport and as such the potential to be standing on a train in the evening can have an impact on decisions to take car or public transport in the morning.

The inclusion of capacity constraints in public transport modelling has also been found to improve the base year model validation (2011), especially on shorter train lines that offer seats, and less crowded conditions than longer routes. This has allowed the model to provide insight into the latent demand in base year and future modelling scenarios.

By removing the capacity constraint module, the model was able to quantify the economic costs associated with crowding on metropolitan trains in 2011. This was shown to be approximately $280 million per year.

It is worth noting that the methodology used does not include the impact of over-crowding on reliability or social-exclusion elements. These broader effects of crowding are recommended for future research.

It is also noted that there are additional “costs of overcrowding” which are not captured by this model, including increased travel times, decreases in service reliability, increased waiting times as a result of not being able to board a full service, inability to find a car park at train stations, crowding on platform, and delays in reaching / departing platforms. As such, the estimated cost of overcrowding on Melbourne’s rail network is likely to be an underestimate. Further work to include these costs would be lead to more accurate estimates.
References


Australian Transport Council (2006b), “Volume 5: Background material”, ATC, Canberra, Australia.

Department of Transport (2009), “Validation Model Data - Estimated Average Weekday Entries, Exits”, Department of Transport, Melbourne.
