Optimal Public Transport Fares for Sydney

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Disclaimer

Much of the work described here was done in my role as a consultant to IPART.

Nevertheless, the views expressed here are my own. They do not necessarily represent the views of IPART.
Overall approach

• Theory is well established, but...
• Measuring externalities is difficult:
  – Congestion dependent on TOD, local geography
  – Modal switching in hypothetical situations
  – Conceptual confusion over accident costs and road pricing
• Marginal cost estimates were also challenging
• Results sensitive to input assumptions
Overall approach

The optimal fare maximises social welfare.

\[ p^r* = c^r + mec^r + \sum_{i \neq r} \left[ c^i - p^i + mec^i \right] \left( \frac{\partial X^i}{\partial X^r} \right) \]

\( p^i \) is the price of mode \( i \);
\( mec \) is the marginal external cost by mode;
\( c \) is the marginal cost by mode;
\( \frac{\partial X^i}{\partial X^r} \) is the marginal rate of modal substitution;
\( X \) is output for each mode in passenger-km units.

First best – second best

\[ p^r * - c^r - mec^r = \sum_{i<>r} [c^i - p^i + mec^i] \left( \frac{\partial X^i}{\partial X^r} \right) \]

First best outcome is for \( p = c + mec \) for all modes.

But if road pricing is too low (i.e., \( p^c - c^c < mec^c \)) and reforming it is infeasible (second-best world), then public transport subsidy becomes optimal (i.e., \( p^{PT} < c^{PT} + mec^{PT} \), where \( mec^{PT} \ll mec^c \)).

Note that \( \frac{\partial X^i}{\partial X^r} < 0 \) where modes are substitutes.
Method

- Traffic simulations: BTS STM
  - Congestion effect
  - Fuel consumption (emissions)
  - Modal substitution rates

- Marginal costs:
  - Relied on cost accounting data
  - Distinguish between capacity and usage costs
  - Actual and efficient costs considered
Which externalities are relevant?

Relevant externalities are costs not borne by person making the mode choice decision. For decision to travel by car:

– Costs borne by non-car occupants
  1. Air pollution and GHG
  2. Pedestrian and cyclist accident victims

– Costs borne by car occupants (caused by occupants of other cars)
  1. Congestion
  2. Accident victims occupying cars
External costs borne by non-car occupants
External costs to car occupants

Area A: external travel time

Line is time taken to travel 1 km as a function of total vehicle journeys travelled in a given time period. This function is a characteristic of a particular road network.

hours/km

Area C

Area B

Δq

vehicle journeys within a defined time period and spatial network
Accident externality

• Two questions are relevant:
  1. Who makes the modal choice decision?
  2. How does this decision impact the accident costs borne by others?

• We need to know the relationship between:
  – Traffic density and cost of ped./cyclist injury
  – Traffic density and cost of car occupant injury
External part of crash costs borne by car occupants depends on slope of $(\text{crash cost}/\text{VKT})$ vs VKT.

Area A: $\text{ext crash cost} = 0$

Area C = 0

Area B

Line is accident rate $(\text{crash cost}/\text{VKT})$ as function of total VKT.

$\Delta q$

$\text{crash cost}/\text{VKT}$

$\text{VKT}$
Incidence of crashes doesn’t increase with traffic density for Sydney

(Syd metro total crashes 2011/Syd mVKT 2012) vs Syd metrop VKT 2012

Crashes / mVKT (2 hourly periods)

Sydney metrop VKT 2012 in a 2 hr time of day slot
Severity of crashes doesn’t increase with traffic density for Sydney

(Syd metro fatal crashes 2011/Syd mVKT 2012) vs Syd metrop VKT 2012

Sydney metrop VKT 2012 in a 2 hr time of day slot
Simulating congestion

- We need to estimate the relationship between \(1/\text{speed}\) and traffic density
- BTS model runs for CityRail study were used for different times of day: AM, IP, PM, EV
- Marginal external congestion cost can be estimated geometrically from the \(1/s \cdot v\) density curve
- Sufficient data could be obtained without simulation modelling, potentially
Generic flow, speed, density relationships

Classical flow (q) vs density (k) and avg speed relations

- q
- 1/k

[Graph showing the relationship between flow (q), density (k), and average speed (avg)]
Simulated speed-density relationship for Sydney EV IP

Congestion effect, Sydney metropolitan area

\[ y = 2 \times 10^{-4} x^2 - 3 \times 10^{-6} x + 0.0222 \]

\[ R^2 = 0.9598 \]
mecc = VOTT * avg trip length (y₀ – y_int)
The Y-intercept of the tangent line is only necessary information about the functional form.
Time of Day-sensitive marginal costs

Literature on the peak-load pricing problem (see Crew, Fernando and Kleindorfer (1995)) notes that if two conditions are satisfied:

• only one type of production technology is in use in all time periods; and
• no (or minimal) peak-shifting in response to price signals,

then the welfare-optimal price is equal to:
1. $b$ in the off-peak period; and
2. $b + \beta$ in the peak period.

$b$ is operating cost per unit per period, and
$\beta$ is the per-day cost of providing a unit of capacity.
CityRail capacity vs usage costs
(suggested classification)

Usage

• Rollingstock maintenance
• Train operations and crewing
• Revenue collection
• Overhead and marketing

Capacity

• Infrastructure maintenance
• Customer interface (including station staffing)
CityRail marginal cost example

<table>
<thead>
<tr>
<th>Description</th>
<th>2011/12 figures from IPART (2008), table 6.2, p. 53</th>
<th>$2011/12</th>
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</thead>
<tbody>
<tr>
<td>actual usage cost ($m nominal)</td>
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<td>1,233.00</td>
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<td>efficient usage cost ($m nominal)</td>
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<td>894.00</td>
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<td>PJ (m)</td>
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<td>actual usage rate ($/PJ)</td>
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<td>efficient usage rate ($/PJ)</td>
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<tr>
<td>actual capacity cost ($m nominal)</td>
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<td>1,421.00</td>
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<td>efficient capacity cost ($m nominal)</td>
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<tr>
<td>peak PJ (m)</td>
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<tr>
<td>actual capacity rate ($/peak PJ)</td>
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<td>efficient capacity rate ($/peak PJ)</td>
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<td>6.37</td>
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**Actual marginal costs of RailCorp**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>offpeak $/PJ</td>
<td>4.00</td>
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<tr>
<td>peak $/PJ</td>
<td>11.14</td>
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**Efficient marginal costs of RailCorp**

<table>
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<tr>
<th>Description</th>
<th>Value</th>
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<tr>
<td>offpeak $/PJ</td>
<td>2.90</td>
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<td>peak $/PJ</td>
<td>9.28</td>
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</table>
Who should bear the cost of inefficient PT provision?

PT passenger (*fare reflects actual mc*)?
- No ability to influence PT provider
- PT provider insensitive to loss of farebox
- Likely switch to modes with high external cost

Government (*fare reflects efficient mc*)?
- Capable of directing PT provider to reform
- Subject to fiscal pressure to reduce subsidies
Results sensitive to usage – capacity split of costs
Sensitivity to usage – capacity cost split (2)
Sensitivity to VOTT
(base: $25/hr peak, $10/hr offpeak)

Optimal rail prices

VOTT multiplier

$/PJ

AM
IP
PM
EV
How much do buses contribute to road congestion?

Optimal bus prices

$\$/PJ

BJ / VJ ratio for congestion causation
Sensitivity to deadweight loss of taxation

Optimal rail prices

$/PJ vs. lambda

AM
IP
PM
EV
Related developments

• Opal card replaced all periodic tickets for trains, ferries and most buses on 1 September 2014, improving scope for time-of-day pricing.

• IPART released issues paper on 26 August 2014: *Estimating the external benefits of public transport*
  
Selected references


