Yarra Trams – Monash Research Selection

Prof Graham Currie
Public Transport Research Group
Monash Institute of Transport Studies
Monash University
A Movement and Place Framework for Trams

Street Types for London’ – Transport for London’s Movement & Place Matrix

A Movement and Place Framework for Trams

**Movement Classification**

- M1 (No Separation): 57%
- M2 (Peak-Hour Lane): 2.4%
- M3 (Pedestrianised Space): 0.6%
- M4 (Visible Separation): 15.4%
- M5 (Physical Separation): 24.8%

**Place Classification**

- P1 (Local): 23.3%
- P2 (Neighbourhood): 31.3%
- P3 (Municipal): 53.3%
- P4 (Regional): 3.6%
- P5 (State): 3.4%

**Weakest Separation Type**

- M1 – No Separation
  - Mixed traffic operations
  - Vuchic (2005) ROW Category ‘C’

- M2 – Peak Hour Lane
  - Mixed traffic operations, with a tram lane during peak hours only
  - Vuchic (2005) ROW Category ‘C’

- M3 – Pedestrianised Space
  - Transpedestrian mall operating environment, in some cases shared with cyclists, delivery and emergency vehicles.
  - Vuchic (2005) ROW Category ‘B’

- M4 – Visible Separation
  - Mixed traffic operations with a full-time lane exclusive to trams outlined with painted lines or mountable plastic kerbing
  - Mixture of Vuchic (2005) ROW Categories ‘B’ & ‘C’

- M5 – Physical Separation
  - Exclusive ROW, longitudinally-separated ROW, and tram lanes separated by hard kerbing
  - Mixture of Vuchic (2005) ROW Categories ‘A’ & ‘B’

**Strongest Separation Type**

**Smallest Attraction Radius**

- P1. Local
- P2. Neighbourhood
- P3. Municipal
- P4. Regional
- P5. State

**Largest Attraction Radius**
Movement Classification

[Map showing different movement categories with labels M1, M2, M3, M4, and M5, indicating various types of separation and lane usage.]
Place Classification
Movement Place Framework for Tram Development Actions
Relationship Between TOD Score and Distance from the CBD
TOD score and Location
17-05635: Streetcar safety from the tram driver perspective

Farhana Naznin, Graham Currie and David Logan

Public Transport Research Group
Institute of Transport Studies
Monash University
Research Method

**Approach:** Tram driver focus groups

**Focus groups format:**

- 5 focus groups (1 hour each) at 3 tram depots (Kew, Southbank and Preston) involving 30 tram drivers
- Most of the groups had 6-7 participants
- 26 male and 4 female tram drivers
- Participants age 29~63 years, with an average age of 47.6 years (Stdv 10.1 years)
- Participants age tram driving experience 1.17~31 years, with an average experience of 12.5 years (Stdv 10.2 years)
- Predefined discussion guide
- Audio-recorded
Results

Key outcomes from tram driver focus groups:

1. **Key challenges** in tram driving

2. Key factors affecting safe tram driving (Road user behavior)

3. **Tram driver safety perception** for different
   a) Tram lane configurations
   b) Signal settings
   c) Stop configurations

4. **Suggestions** to improve tram road safety
Results - 1. Key challenges in tram driving

1. Safety
   - Passengers safety
   - Pedestrians & cyclists safety
   - Motorists safety

2. On-time running Pressure
   - Main criteria to evaluate driving performance
   - Mostly come from managers after privatisation
   - Increase risk taking attitudes among drivers

3. Keeping constant concentration
   - Tram drivers require high level of concentration while driving
   - Passengers distract driver's concentration
   - Mostly due to sudden emergency brake
   - At the time to avoid an on-road crash

4. Passenger falls on tram

5. Anticipating other road user behavior
   - Reduce the chance of crash risks
   - This quality develops with experience

6. Tram operational constraints
   - No flexibility in lateral direction
   - Only reaction is brake
   - Long Braking distance
   - Inconsistent shift works
   - Long working works
   - Difficult to balance work and social life
   - Recent increment in passenger demand
   - On-board ticket validation system
   - Non user friendly equipments

7. Fatigue workload
   - Others
Results - 2. Key challenges in safely driving trams

- Rule violation:
  - Make U turns and right turns over tram tracks without giving way to trams
  - Cross stationary trams at stop
  - Become impetuous to overtake trams

- Road users behaviour:
  - Lack of awareness:
    - Use of mobile phone and earphone while walking
    - Cross unprotected traffic lane to get on a tram
    - Passengers get off the tram and walk in front of tram
  - Poor understanding of road rules:
    - Unfamiliar Interstate and international visitors
    - Often perform wrong manoeuvre around trams
a) Safety perceptions on alternative tram route sections:

- ‘There is no safe route section’; Tram drivers do not perceive any route section as safe.

- However, any traffic measure that separates trams from general traffic was considered as safer
  - *Raised tram tracks*
  - *Tramways with raised yellow kerbing beside tracks*
Results - 3. Tram driver safety perception of different tram lane, signal and stop priority features

- **Light rail tracks** were perceived as safe. However, perceived as unsafe mostly at night due to low light as well as when passengers cross the tracks.

- **Full-time and part-time tram lanes** were not believed to have any road safety benefit due to lack of road rules compliance by road users.
b) Safety concerns at intersections:

- Most tram drivers stated the positive road safety benefits of 'hook turns'; some were found to be concerned about unfamiliar motorists which are unsafe.
- Tram drivers appreciated the presence of 'T' light for trams, as it improves tram travel time, but could not see any road safety benefits.
- ‘No right turn’ signs were perceived to be ignored by motorists.
Results

c) Road safety issues at tram stop:

- ‘Platform tram stops’ were clearly identified as the safest type of tram stop for passengers by almost all tram drivers.
- Tram drivers perceived ‘Easy access stop’ as the most dangerous type of stop.
- Tram drivers perceived the risk of passengers being hit by cars while boarding and alighting at ‘kerbside stops’.
- ‘Safety zone stops’ are perceived to have risk of passengers being struck by trams at the narrow waiting area.
4. Suggestions to improve road safety

- More safety campaigns
- More safety education
- Law enforcement
- How to drive with trams
- Limitations of trams
- Need to educate school students about road rules
- Impose fines and penalties for breaking road rules
- More authorized person on tram network to warn road users

- Advertisement on radio, television and billboards
- Through customer service staff
- More Rhino show off
- Can act to increase safety awareness
Eco-driving for Melbourne Trams: a Preliminary Study using Yarra Trams E-Class Tram Driving Simulator

Graham Currie
Long Truong

Public Transport Research Group
Monash Institute of Transport Studies
Monash University, Australia
Eco-driving

- Eco-driving is driving that minimises energy use and contributes to emission reduction
  - while not compromising safety (and on-time performance for PT)
- Eco-driving initiatives
  - Eco-driving training/ assistance devices
  - Vehicle maintenance
  - Eco-routing

![Eco-driving flowchart](image-url)

We advise you to drive without haste keeping an eye on your environment to always judge your situation correctly.

- **Start/Acceleration**
  - Depress accelerator soft for shorter time
  - Use light foot
  - Keep pace with traffic

- **Driving at constant speed**
  - Maintain constant speed
  - As such, save on fuel

- **Free-wheeling**
  - Release the accelerator as early as possible
  - Keep engine running

- **Stop killing**
  - Stop the engine

![Eco-Driver](image-url)

Vehicle Maintenance  | Driving Style  | Crash Avoidance
---|---|---
Well-maintained vehicles are more efficient.  | Smart driving choices improve fuel economy.  | Eco-driving is safe driving.

Eco-Driving

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Eco-driving effectiveness

- Reported reductions in fuel consumption and CO2 emissions range from 5% to 40% across various jurisdictions and initiatives (Alam & McNabola 2014)

- In Australia
  - Car: 11% fuel saving (simulated experiment – Qian & Chung 2011)
  - Truck: 27% fuel saving (field experiment – Symmons & Rose 2009)

- PT vehicles
  - Bus: 2% to 10% fuel saving (Xu et al 2016)
  - Train: 5% to 10% energy saving (Gonzalez-Gil et al 2014)

- Other potential effects?
  - Reduced intersection capacity (increased fuel consumption at the network level)
  - Crash risks (distractions associated with assistance devices)
Eco-driving for Trams

- Limited research has been conducted
  - 3% energy saving in Leipzig and Brno (ACTUATE 2015), but unclear if regenerative braking is utilised
- Substantial cost savings given energy represents 15 to 20% of the operation expenditures of a light rail network (http://www.uitp.org/)

5 GOLDEN RULES FOR SAFE ECO-DRIVING OF CLEAN VEHICLES:

1. Acceleration should be quick
2. The “steady state” on the throttle/accelerator should be avoided
3. The rolling ratio should be as high as possible, while ensuring compliance with the schedule
4. Unnecessary braking should be avoided and usage of wear-free electric brakes for energy recuperation should be optimised
5. Conscious use of the heating, air conditioning and ventilation system

(ACTUATE 2015)

Luijt et al 2017
Eco-driving with Yarra Trams E-Class Tram Driving Simulator

- How the Yarra Trams E-Class Tram Driving Simulator can be used to monitor eco-driving for trams?
  - Drive cycles can be extracted from the simulator’s performance data outputs.
  - Drive cycles would be improved by eco-driving principles
  - Energy consumption can be estimated from drive cycles
    - a new energy estimation model is developed
Energy estimation model using drive cycles

- Train tram dynamics
  - Tractive force $F_{tr}$
  - Track resistance $F_{res}$
  - Force due to track gradient $F_{grad}$
- Instantaneous electrical power requirement is determined from the tractive power
  - Regenerative breaking is considered
- Energy consumption is then determined from power requirement

\[ F_{tr} - F_{res} - F_{grad} = M_{train}^e a = F_a \]
Excel VBA tool for energy estimation (1)

- Inputs:
  - Drive cycle (driving record file from the simulator can be read directly)
  - Model parameters: tare mass, payload, number of axels, track gradient, max force, max traction power, efficiency etc
    - These parameters can be calibrated specifically for E-Class trams
- Outputs:
  - Power requirement
  - Energy consumption
Excel VBA tool for energy estimation (2)

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<tr>
<th>A</th>
<th>B</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>C:1\Users\Long\Downloads\R\PRE\R1.idr</td>
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<tr>
<td>3</td>
<td>Driver Name</td>
</tr>
<tr>
<td>4</td>
<td>Session date</td>
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<tr>
<td>5</td>
<td>Scenario</td>
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<table>
<thead>
<tr>
<th>5</th>
<th>Energy consumption (kWh/km)</th>
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<tbody>
<tr>
<td>6</td>
<td>without regenerative braking</td>
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<tr>
<td>7</td>
<td>regenerative braking utilised 100%</td>
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</table>

<table>
<thead>
<tr>
<th>9</th>
<th>Model parameters</th>
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<tbody>
<tr>
<td>10</td>
<td>Tare mass (kg)</td>
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<tr>
<td>11</td>
<td>Payload (kg)</td>
</tr>
<tr>
<td>12</td>
<td>Energy storage system mass (kg)</td>
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<tr>
<td>13</td>
<td>Number of axles</td>
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<tr>
<td>14</td>
<td>Track gradient in %</td>
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<tr>
<td>15</td>
<td>Max force (KN)</td>
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<tr>
<td>16</td>
<td>Max traction power (kW)</td>
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<td>17</td>
<td>Efficiency</td>
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**Graphs:***
- **Breaking Power:** The graph shows the breaking power over time.
- **Regenerative Breaking Power:** The graph illustrates the regenerative breaking power over time.

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**Notes:**
- The Excel VBA tool is used for energy estimation.
- The data includes parameters such as energy consumption, payload, and traction power.
- The graphs display the performance of the system over time, highlighting the energy consumption and regenerative braking.
Tram Driving Simulator Experiments (as part of a Final Year Project)

- 6 Participants (including 2 controls)
- 1 Scenario (Light Rail Only)
- 4 Stages
  - Training (10-15 minutes)
  - Pre eco-driving training (3 runs)
  - Eco-driving training (for 4 participants)
  - Post eco-driving training (3 runs)
<table>
<thead>
<tr>
<th>Participant No.</th>
<th>Average Pre-Eco (kWh/km)</th>
<th>Average Post-Eco (kWh/km)</th>
<th>Change in Energy (%)</th>
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<tbody>
<tr>
<td>P1</td>
<td>3.735</td>
<td>3.917</td>
<td>4.87</td>
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<tr>
<td>P2</td>
<td>4.532</td>
<td>3.966</td>
<td>-12.49</td>
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<td>P3</td>
<td>4.284</td>
<td>3.730</td>
<td>-12.93</td>
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<td>4.306</td>
<td>4.188</td>
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<td>3.083</td>
<td>2.790</td>
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<td>P6</td>
<td>3.479</td>
<td>3.997</td>
<td>14.89</td>
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<td>(P1-P4)</td>
<td>4.21</td>
<td>3.95</td>
<td>-6.27</td>
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<tr>
<td>(P5-P6 - Controls)</td>
<td>3.28</td>
<td>3.39</td>
<td>3.42</td>
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Potential energy savings of around 6%
CONNECTING CITIES

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