Investigating the effects of in-car passenger volume and its distribution on train dwell time

Konstantina Argyropoulou (University College London), Howard Wong & Dr. Taku Fujiyama
Background

Factors affecting dwell time

<table>
<thead>
<tr>
<th>Passenger mobility &amp; relevant time factors</th>
<th>Platform design</th>
<th>Vehicle design</th>
<th>Crowding effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>-within a coach</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-among train</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>coaches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-at different</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>times of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>day</td>
</tr>
</tbody>
</table>

Does an already crowded train require a longer dwell time?

Does an evenly distributed passengers’ mean a shorter dwell time?
Objective

Investigating the effects of in-car passenger volume and its distribution on train dwell time

-Better users’ management strategy
-More even crowd distribution

Optimise:
-train capacity
-operation
-performance
-reliability
-dwell time

• Hammersmith & City Line of London Underground
  • 7-stock trains with a weight measurement system

• Loadweigh data
  • "Live total load (in kg)/coach" = Passengers/coach
  • "Average population weight" = Passengers/coach
  • Data from September 2016 (2,740 records)
  • For AM peak period
Research contents

- Analysis of total train loading effect on dwell time
- Analysis of highest loaded coach effect on dwell time
- Distribution unevenness effect on dwell time – Train Unevenness Index (TUI) development
Descriptive analysis (1/3)

Percentage of loading per coach

- Percentage (%) of loading distribution per coach compared with the average one (ROY-PAD link)
- Percentage (%) of loading distribution per coach compared with the average one (BAR-MGT link)

Different links
Different hours

TRANSIT DATA 2019
5th International Workshop & Symposium
Paris

8-9-10 July 2019
Descriptive analysis (2/3)

Are the two highest loaded coaches always adjacent?

<table>
<thead>
<tr>
<th>Difference</th>
<th>Number of coaches</th>
<th>Percentage (%) out of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1622</td>
<td>59.20%</td>
</tr>
<tr>
<td>2</td>
<td>403</td>
<td>14.71%</td>
</tr>
<tr>
<td>3</td>
<td>378</td>
<td>13.80%</td>
</tr>
<tr>
<td>4</td>
<td>276</td>
<td>10.07%</td>
</tr>
<tr>
<td>5</td>
<td>57</td>
<td>2.08%</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>0.15%</td>
</tr>
<tr>
<td>Total</td>
<td>2740</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

- Calculate the location difference of two highest loaded coaches
- In more than half of total trains the two highest loaded coaches are adjacent

Is the maximum loaded coach predictable?

- Find the location of highest loaded coach per link

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Train ID: 395/396 departing HMS @ 7:52:13 am
Train ID: 345/346 departing HMS @ 9:16:23 am
Train ID 447/448 departing HMS @ 8:11:25
Descriptive analysis (3/3)
Determination of loading unevenness

- Method of categorising coaches based on the ratio volume/capacity to: even, uneven or very uneven and count each category’s coaches
- Categorisation based on the most and least crowded coach

<table>
<thead>
<tr>
<th>Least crowded coach (v/c)</th>
<th>Most crowded coach (v/c)</th>
<th>Characterisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Even</td>
</tr>
<tr>
<td>Low</td>
<td>Medium</td>
<td>Uneven</td>
</tr>
<tr>
<td>Low</td>
<td>High</td>
<td>Very uneven</td>
</tr>
<tr>
<td>Medium</td>
<td>Low</td>
<td>Uneven</td>
</tr>
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<td>Medium</td>
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</tr>
<tr>
<td>High</td>
<td>High</td>
<td>Even</td>
</tr>
</tbody>
</table>

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Analysis 1 (1/5)
Unevenness investigation

- Need of one number to represent the uneven passengers’ distribution on trains
- Render trains’ distribution unevenness easily comparable

Index

1. Measure unevenness
2. Be able to differentiate front loaded/end loaded
3. Represent the magnitude of unevenness
Analysis 1 (2/5)
Definition of Train Unevenness Index (TUI)

- Based on the concept of Gini coefficient → the most commonly used measurement of inequality in wealth and income.

\[
TUI = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} (x_i - x_j)}{n(n-1)x} \quad [\text{n: number of coaches, } x: \text{coach loadweigh}] \\
1 \leq TUI \leq +1
\]

- Values closer to 0: more even train
- Values closer to ±1: more uneven distribution of passengers
- Zero values: uniform distribution, symmetrical to the middle
Analysis 1 (3/5)

TUI evaluation

- Comparison with the basic unevenness measure

\[ \% \text{ unevenness} = \frac{(\text{Half front - load}) - (\text{Half rear - load})}{\text{total train load}} \% \]

- ↑ % distribution unevenness → |TUI| ↑

- High performance of index
Analysis 1
(4/5)
TUI evaluation
Analysis 1 (5/5)

**TUI evaluation**

Average TUI values for all links at AM peak period
Analysis 2 (1/2)

Loading effect on dwell time

- Slight observed trend
- Higher loading → higher dwell time

Loading: 0-20000kg
No clear trend

Loading: 20000-40000kg
No clear trend

Loading: 40000-60000kg
Slight upward trend

Loading: 60000-80000kg
Lack of data
Analysis 2 (2/2)

Distribution unevenness effect on dwell time

- No clear unevenness effect on dwell time
- **Critical coach** (usually the highest loaded) mainly determines dwell time.

BUT… per link

Low loading → high unevenness
Low loading → low dwell time

↑unevenness, dwell time ↓
Main contributions

- Development of a single index, to describe train distribution, which is clear, simple and independent of train load
- Identification of the strong relationship between loadweigh data & dwell time especially of the maximum loaded coach
- Failure to identify a clear trend between dwell time and TUI value of a train, which corresponds to its unevenness.
Recommendations for future work

• Information provision and Operations Plans
• Combine index with load data and other station-specific characteristics (e.g. stations layouts etc.)
• Appropriate maintenance guidance for coaches with high loading
• Apply innovative solutions for decrowding metro stations, manage counterflows on platforms etc.
• Upgrade existing dwell time formulas
Thank you

Any questions?

Konstantina Argyropoulou  konst.argyropoulou@gmail.com