Investigating the effects of RTCI (real-time crowding information) in urban public transport under different demand conditions

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5th International Workshop and Symposium
TRANSIT DATA 2019 – Paris, France
8th – 10th July 2019
Background

• Public transport (PT) overcrowding – major (and recurrent) challenge for modern-day urban transport systems
  • Growing emphasis on ‘soft’ travel demand management solutions – so as to maximise PT network efficiency
• ITS-fed data could allow passengers to make more informed choices – and thus improve journey experience

• potential consequences…?
• proper system architecture / design…?
• means of achieving effectiveness…?

⇒ simulation tools
RTCI – real-time crowding information

• utilise ITS data to provide real-time advice on current (predicted?) passenger flows
• RTCI – in early research and implementation stages
• increasingly feasible – abundant data sources:
  • automated passenger counts (APC)
  • fare-ticketing systems (AFC, smart-card data…)
  • WiFi, Bluetooth, video cameras…
BusMezzo (Cats, 2011):

• simulation-based PT assignment model

• dynamic decision-making model – path utility recurrently updated at each action (choice)
  • e.g. may decide to re-route in response to ATIS updates

• proposed algorithm – inclusion of instantaneous RTCI in path choice model:
  • generate the RTCI based on the latest run (departure) only
  • update the RTCI disseminated to passengers
  • utilise the RTCI in decision process
Methodology – RTCI algorithm

From ITS to path choice model - assumptions:

<table>
<thead>
<tr>
<th>RTCI level</th>
<th>in-vehicle occupancy level</th>
<th>crowding penalty $\beta_{RTCI}^{e,s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>&lt; 80% seat cap.</td>
<td>1.0</td>
</tr>
<tr>
<td>-</td>
<td>&lt; 100% seat cap.</td>
<td>1.2</td>
</tr>
<tr>
<td>-</td>
<td>&lt; 80% total cap.</td>
<td>1.5*</td>
</tr>
<tr>
<td>-</td>
<td>&lt; 100% total cap.</td>
<td>1.8*</td>
</tr>
</tbody>
</table>

* 1.2 if seated

$\beta_{RTCI}^{e,s}$ included as an in-vehicle time multiplier in the utility function

$\nu_i = \sum_{s \in i} \beta_{s,t}^{CL} \cdot IVT_s + \sum_{s \in i} \beta_{s}^{WT} \cdot WT_s + \sum_{s \in i} \beta_{s}^{WKT} \cdot WKT_s + \sum_{s \in i} \beta_{s}^{NTR} \cdot NTR_s + \varepsilon_i$

(Yap, Cats, van Arem, 2018)
- RP valuations
Research objectives

• simulation of urban PT system performance (PM peak) – within-day effects

• effects of ‘raw’ instantaneous RTCI in various demand conditions?
  • RTCI penetration rate [%]
  • choice sensitivity (probabilistic vs. deterministic choices)
  • network saturation rate

→ could it help expose (and efficiently utilise) the available PT system capacity?

→ RTCI effectiveness with system-wide response?
  • could it potentially ‘backfire’ in certain conditions?

sample results on toy network
→ excessive choice sensitivity
  + 100% penetration rate
  = detrimental impact on travel experience

(extended Spiess-Florian (1989))
Case study – Krakow PT system

Kraków (Poland) - urban PT system model in BusMezzo:

- population: 750k (metro area 1.5m)
- PM peak: ~75k [passengers/hr]
  - OD data from HTS and at-stop surveys
- 110 zones, 15m OD paths
- 130 lines, 525 stops – GTFS data
  - mainly bus / tram services
Results – RTCl impact in PM peak

- **increase** in no. of seated passengers
- **reduction** in excessive overcrowding

[pass.] flows – comparison vs. [no RTCl] case
Results – RTCI impact in PM peak

Impact upon passengers’ journey experience (welfare):

<table>
<thead>
<tr>
<th>travel time components</th>
<th>no RTCI</th>
<th>100% RTCI relative change [Δ %]</th>
</tr>
</thead>
<tbody>
<tr>
<td>walking time</td>
<td>18%</td>
<td>- 1%</td>
</tr>
<tr>
<td>waiting time</td>
<td>25%</td>
<td>- 1%</td>
</tr>
<tr>
<td>in-vehicle time</td>
<td>44%</td>
<td>- 3%</td>
</tr>
<tr>
<td>transfer penalty</td>
<td>13%</td>
<td>- 3%</td>
</tr>
<tr>
<td>waiting time – denied boarding</td>
<td>2%</td>
<td>- 19%</td>
</tr>
</tbody>
</table>

- reduced risk of worst crowding experience:
  - 28% less excessive overcrowding [pass-hours]
  - 19% lower delay due to boarding denial

- limited but network-wide welfare improvements

<table>
<thead>
<tr>
<th>on-board experience - share of [pass-hrs]</th>
<th>RTCI penetration rate</th>
<th>relative change [Δ %]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>○○○○ ○○○○ ○○○○ ○○○○○</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td>○○○○ ○○○○ ○○○○ ○○○○○</td>
<td>22%</td>
</tr>
<tr>
<td></td>
<td>○○○○ ○○○○ ○○○○ ○○○○○</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pass. welfare</th>
<th>RTCI penetration rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>
Results – what if PT demand increases?

- PM peak demand increased by ca. 65%
- RTCI can still be advantageous – and help mitigate worst overcrowding experience

<table>
<thead>
<tr>
<th>travel time components</th>
<th>100% RTCI - relative change [Δ %]</th>
</tr>
</thead>
<tbody>
<tr>
<td>walking time</td>
<td>- 1%</td>
</tr>
<tr>
<td>waiting time</td>
<td>- 9%</td>
</tr>
<tr>
<td>in-vehicle time</td>
<td>- 5%</td>
</tr>
<tr>
<td>transfer penalty</td>
<td>- 4%</td>
</tr>
<tr>
<td>waiting time – denied boarding</td>
<td>- 35%</td>
</tr>
<tr>
<td>welfare</td>
<td>+4.6%</td>
</tr>
</tbody>
</table>

Reduction in excessive overcrowding

[pass.] flows – comparison vs. [no RTCI] case
Results – RTCl and choice sensitivity

What if choice sensitivity would change – other things being equal…?

- minor impact of RTCl for low (probabilistic) choice sensitivity
  - and higher network demand (saturation)

- travel experience not necessarily worse with higher % of passengers responding to RTCl…

- … yet – instantaneous RTCl could become counterproductive in high (deterministic) sensitivity
### Results – RTCI accuracy

<table>
<thead>
<tr>
<th>RTCI accuracy</th>
<th>RTCI penetration rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>‘typical’ PM demand</td>
</tr>
<tr>
<td>accurate</td>
<td>61%</td>
</tr>
<tr>
<td>overestimated</td>
<td>11%</td>
</tr>
<tr>
<td>underestimated</td>
<td>28%</td>
</tr>
<tr>
<td>expected a seat, had to stand</td>
<td>18%</td>
</tr>
</tbody>
</table>

- simplified accuracy measure
  - decisions preceding passengers’ boarding actions
- apparently, not much impact of RTCI penetration rate or choice sensitivity

→ on the other hand:
- instantaneous RTCI especially prone to inaccuracies with rising network saturation in time:
Results – RTCI accuracy

Spatial RTCI (in)accuracy – possible risks in case of:

- low-frequency bus services, inadequate PT supply
- no alternative paths, boarding denial
- bus vs. train on a busy suburban route - contrasting capacities

<table>
<thead>
<tr>
<th>RTCI underestimation probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10%</td>
</tr>
<tr>
<td>10 - 30%</td>
</tr>
<tr>
<td>30 - 50%</td>
</tr>
<tr>
<td>&gt; 50%</td>
</tr>
</tbody>
</table>
Results – OD welfare

Welfare changes with RTCI - assuming uniform OD demand behaviour:

• no specific ‘winners’ or ‘losers’ – e.g. ambiguous spatial variability

• certain gains for RTCI users
  • up to 5-7% higher welfare
  • improved on-board comfort
  • though higher inaccuracy risk
Conclusions

• real-time crowding information (RTCI) could help travellers recognise the available PT system capacity
  • worst overcrowding experience – less common
• however, RTCI based on instantaneous data is prone to major inaccuracies
  • even for little (or zero) % RTCI penetration rate
  • underestimation risk – especially valid when crowding arises in the PT network
  • and may not be beneficial with ‘exaggerated’ passenger choices

• would such system be actually trusted?

→ combine instantaneous RTCI with historical data (APC, AFC…)
→ shift towards anticipatory information (prediction)
Further research

• non-uniform demand response to RTCI
  • spatial variability / disruptions / user groups / ...
• actual perceptions of crowding information
• day-to-day impact on travel behaviour
• feedback between passenger choices and crowding prediction
  • feasibility of crowding prediction? - information already accounting for passengers’ reactions to that information

➔ practical recommendations and analytical support for future RTCI systems
Thank you very much for your attention!

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