Service Reliability Measurement using Oyster Data
- A Framework for the London Underground

David L. Uniman
MIT – TfL
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• **Research Objective**

To develop a framework for quantifying reliability from the perspective of passengers using Oyster data that is useful for improving service quality on the Underground.

• **How reliable is the Underground?**
  - how do we *think* about reliability?
  - how do we *quantify* it?
  - how do we *understand* its causes?
  - how do we *improve* it?
Reliability means the degree of predictability of the service attributes including comfort, safety, and especially travel times.

- Passengers are concerned with average travel times, but also with certainty of on-time arrival.
Framework - Reliability Buffer Time Metric

• Criteria for Reliability Measure
  • Representative of passenger experience
  • Straightforward to estimate and interpret
  • Usefulness and applicability – compatible with JTM

• Propose the following measure: **Reliability Buffer Time (RBT) Metric**

  “The amount of time above the typical duration of a journey required to arrive on-time at one’s destination with 95% certainty”

\[
RBT = (95^{\text{th}} \text{ percentile} - 50^{\text{th}} \text{ percentile})_{O-D, \ AM\ Peak, \ LUL\ Period} \quad \text{sample size} \geq 20
\]

![Graph showing the 50th and 95th percentiles with RBT calculation.](image)
Framework – Separating Causes of Unreliability

- **Two** types of factors that influence reliability and affect the applicability & usefulness of the measure:

1. Chan (2007) found evidence for the effects of **service characteristics** on travel time variability – impact on aggregation (e.g. Line Level measure)

2. In this study, observed that reliability was sensitive to the performance of a few (3-4) days each Period, which showed large and non-recurring delays (believe Incident-related)
Propose to classify performance into two categories along two dimensions – degree of recurrence and magnitude of delays

- Relate to reliability factors and strategies to address them

<table>
<thead>
<tr>
<th>Recurrent Reliability</th>
<th>Incident-Related Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-to-day (systematic) performance</td>
<td>Unpredictable or Random (unsystematic) delays</td>
</tr>
<tr>
<td>Includes the effects of service characteristics and other repeatable factors (e.g. demand)</td>
<td>Unreliability caused by severe disruptions, additional to inherent levels of travel time variation</td>
</tr>
<tr>
<td>Can be considered as the Underground’s potential reliability under “typical” conditions</td>
<td>Together with performance under “typical” conditions, makes up the actual passenger experience</td>
</tr>
</tbody>
</table>

Methodology – use a classification approach based on a Stepwise Regression to automate process
- **Bakerloo Line Example:** Waterloo to Piccadilly Circus – AM Peak, Feb. 2007

\[
\text{T.T. Actual} = P[\text{No Disruption}] \times \text{T.T. Recurrent} + P[\text{Disruption}] \times \text{T.T. Incident-related}
\]

\begin{align*}
\text{T.T. Actual} & = 4\text{-min} \\
\text{T.T. Recurrent} & = 3\text{-min} \\
\text{T.T. Incident-related} & = 10\text{-min} \\
P[\text{No Disruption}] & = 17/20 \text{ days} = 85\% \\
P[\text{Disruption}] & = 3/20 \text{ days} = 15\%
\end{align*}
Framework – Validation with Incident Log data

- Validation of **non-recurrent** performance with Incident Log data (from NACHs system) confirmed Incident-related disruptions as the primary cause.

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### Brixton to Oxford Circus (Victoria NB) - February 7, AM Peak

*Graph showing travel time vs departure time.*

### Brixton to Oxford Circus (Victoria NB) - February 14 - AM Peak

*Graph showing travel time vs departure time.*

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<table>
<thead>
<tr>
<th>Date</th>
<th>Cause Code</th>
<th>Result</th>
<th>Indicative NAX’s</th>
<th>Incident Start</th>
<th>Incident End</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 7</td>
<td>Fleet</td>
<td>Train Withdrawal</td>
<td>2.6124</td>
<td>7:02am</td>
<td>8:20am</td>
</tr>
<tr>
<td>February 7</td>
<td>Customer - PEA</td>
<td>Train Delay</td>
<td>3.5756</td>
<td>9:16am</td>
<td>9:19am</td>
</tr>
<tr>
<td>February 14</td>
<td>Customer - PEA</td>
<td>Train Delay</td>
<td>9.8803</td>
<td>8:03am</td>
<td>8:06am</td>
</tr>
<tr>
<td>February 14</td>
<td>Signals</td>
<td>Train Delay</td>
<td>47.8043</td>
<td>9:05am</td>
<td>9:16am</td>
</tr>
<tr>
<td>February 14</td>
<td>Signals</td>
<td>Partial Line Suspension</td>
<td>45.4703</td>
<td>9:57am</td>
<td>11:19am</td>
</tr>
</tbody>
</table>
Excess Reliability Buffer Time Metric

• Using these 2 performance categories, we can extend our reliability measure by comparing the actual performance with a baseline value.

• Propose the following: **Excess Reliability Buffer Time (ERBT) Metric**

  “The amount of buffer time that passengers need to allow for to arrive on-time with 95% certainty, in excess of what it would have been under disruption-free conditions.”

\[
\text{ERBT} = (\text{RBT}_{\text{Actual}} - \text{RBT}_{\text{Recurrent}})_{\text{O-D, AM Peak, LUL Period}}
\]

sample size ≥ 20, cumulative baseline
Application # 1 – JTM Reliability Addition

- Use measure for routine monitoring and evaluation of service quality – propose to include it within JTM as an additional component.

  - RBT form is compatible with JTM – units (min, pax-min), aggregation (Period, AM Peak, O-D), estimation (Actual, Scheduled, Excess & Weighted)

  TPT | AEI | PWT | IVTT | C&I | RBT

- Apply RBT measure to Victoria Line – AM Peak, Feb. & Nov. 2007

![Graph showing travel times for February and November with median travel time of 16.71 minutes.](image-url)
Application # 1 – JTM Reliability Addition

- Actual weighted RBT value estimation
  - Contribution to Service Quality (i.e. Perceived Performance)

- Compare contribution of RBT to other JTM components through VOT – FEB. 2007

![Comparison of Actual Reliability Buffer Time and Median Journey Time: Victoria Line, AM Peak, Feb/Nov 2007](image)

**Unweighted (VOT\textsubscript{RBT} = 1.0)**

- 50th Perc.
- RBT

**Unweighted, JTM Proportions* (VOT\textsubscript{RBT} = 1.0)**

- AEI
- PWT
- OTT
- CLRS
- RBT

**Weighted, JTM Proportions (VOT\textsubscript{RBT} = 0.6)**

- AEI
- PWT
- OTT
- CLRS
- B\textsubscript{RBT}
- E\textsubscript{RBT}

* total 101% due to rounding
Application # 2 – Journey Planner Reliability Addition

• Better information reduces uncertainty by closing the gap between expectations and reality – improve reliability of service

➢ Propose more COMPLETE information through Journey Planner

SIMPLE EXAMPLE: David’s morning commute – Bow Road to St. James’ Park

![Map of London showing travel times and reliability data.](image)

<table>
<thead>
<tr>
<th>Route</th>
<th>Depart</th>
<th>Arrive</th>
<th>Duration</th>
<th>Interchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>08:31</td>
<td>08:55</td>
<td>00:24</td>
<td><img src="image" alt="View" /></td>
</tr>
<tr>
<td>2</td>
<td>08:36</td>
<td>09:00</td>
<td>00:24</td>
<td><img src="image" alt="View" /></td>
</tr>
</tbody>
</table>

Courtesy of Transport for London. Used with permission.
Application # 2 – Journey Planner Reliability Addition

- **Assessment**: Journey Planner information is INCOMPLETE in 2 ways:
  1. Journey Planner consistently underpredicts Oyster journey times - possibly AET & PWT – leaves around 30-50% of journey to chance
  2. Expected journey times not helpful for passengers concerned with on-time arrival (e.g. commuters)
Application # 2 – Journey Planner Reliability Addition

- Possible representation of new journey information:

**SIMPLE EXAMPLE:** David’s morning commute – **Bow Road** to **St. James’ Park**

<table>
<thead>
<tr>
<th>Route</th>
<th>Depart</th>
<th>Arrive</th>
<th>Duration</th>
<th>Interchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>08:27</td>
<td>08:52</td>
<td>00:25</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>08:31</td>
<td>08:56</td>
<td>00:25</td>
<td></td>
</tr>
</tbody>
</table>

**Journey Summary**
- **Departing:** Wednesday 14 January 2009 at 08:30
- **From:** Bow Road
- **To:** St. James’s Park
- **Restrictions:**

**Chose to:**

- **Depart at… →**
- **Arrive by… →**

<table>
<thead>
<tr>
<th>Route</th>
<th>Depart</th>
<th>Expected Arrival</th>
<th>Latest Arrival</th>
<th>Duration (up to)</th>
<th>Interchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>08:27</td>
<td>08:57</td>
<td>09:11</td>
<td>00:30 (00:41)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>08:19</td>
<td>08:49</td>
<td>09:00</td>
<td>00:30 (00:41)</td>
<td></td>
</tr>
</tbody>
</table>

Courtesy of Transport for London. Used with permission.
Conclusions & Recommendations

1. Reliability is an important part of service quality, relative to average performance, and should be accounted for explicitly.
   ✓ Monitor and evaluate reliability through JTM Extension

2. Incidents have a large impact on service quality through unreliability, which may be underestimated through focus on average performance.
   ✓ Use Oyster and Reliability Framework to improve monitoring and understanding through NACHs (measurement vs. estimate)

3. The impacts of unreliability on passengers can be mitigated through better information.
   ✓ Update travel information and include reliability alternative in Journey Planner
Conclusions & Recommendations

4. In order to manage performance, we need to be able to measure it first.

✓ Framework contributes to making this possible, and sheds light on some of the broader questions...

• How reliable is the Underground?
  - how do we think about reliability?
  - how do we quantify it?
  - how do we understand its causes?
  - how do we improve it?
Thank You

- Special thanks to people at TfL and LUL that made this research possible and a memorable experience