Background on the Tube

- The first Tube lines were built in 1863 (Metropolitan, Circle)
- Since 1863, the population of London has increased almost three-fold
- Renovation and maintenance on the tube is common
  - Four Lines Modernization, Victoria Line Improvements
  - Revamp of Victoria Station, Bank/Monument Maintenance
- Delays cause hundreds of thousands of hours in lost productivity for passengers
Tube Delays due to Overcrowding, Hours/Year

Source: Smith, 2017

*Originally located on previous slide, moved for clarity due to no animations
Passenger Flow

- Passenger flow is the act of and measurement of passengers moving through a particular area
  - Three kinds of measurements:
    - Directional: Direction that a person is travelling. (Used in corridors, escalators)
    - Spatial: Amount of people in a given area. (Passenger density on platforms)
    - Temporal: Time at which passenger flow occurs
- Passenger flow is an oft-studied topic, and we have many conclusions to base our findings on
<table>
<thead>
<tr>
<th>LOS</th>
<th>Average pedestrian space (ft²/p)</th>
<th>Average inter-person space (ft)</th>
<th>Description</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≥ 13</td>
<td>≥ 4.0</td>
<td>Standing and free circulation through the queuing area possible without disturbing others within the queue.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
<tr>
<td>B</td>
<td>10-13</td>
<td>3.5-4.0</td>
<td>Standing and partially restricted circulation to avoid disturbing others within the queue is possible.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
<tr>
<td>C</td>
<td>7-10</td>
<td>3.0-3.5</td>
<td>Standing and restricted circulation through the queuing area by disturbing others is possible; this density is within the range of personal comfort.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
<tr>
<td>D</td>
<td>7-10</td>
<td>2.0-3.0</td>
<td>Standing without touching is impossible; circulation is severely restricted within the queue, and forward movement is possible only as a group; long-term waiting at this density is discomforting.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
<tr>
<td>E</td>
<td>3-7</td>
<td>&lt;2.0</td>
<td>Standing in physical contact with others is unavoidable; circulation within the queue is not possible; queuing at this density can be sustained only for a short period without serious discomfort.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
<tr>
<td>F</td>
<td>&lt; 2</td>
<td>Variable</td>
<td>Virtually all people within the queue are standing in direct physical contact with others; this density is extremely discomforting; no movement is possible within the queue; the potential for pushing and panic exists.</td>
<td><img src="image" alt="Illustration" /></td>
</tr>
</tbody>
</table>

*Originally located on previous slide, moved for clarity due to no animations*
Methodology Overview

● Station Selection
  ○ Determine the most important stations to focus on

● Employee Interviews
  ○ Find the problem areas in the stations

● CCTV Observation
  ○ Collect raw data about congestion at peak times

● Passenger Survey Analysis
  ○ Determine correlations between congestion and passenger satisfaction based on intranet data within TfL

● Refine Solutions
  ○ Focus group with CSM to improve on suggested solutions for issues
Station Selection Criteria

- Station selection was a multi-step process
  - Receive recommendations for stations from sponsors
  - Create matrix comparing stations
<table>
<thead>
<tr>
<th></th>
<th>Interchange station</th>
<th>Construction</th>
<th>Severe Congestion</th>
<th>CCTV</th>
<th>Accessible</th>
<th>Network Rail Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank/Monument</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Embankment</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Euston</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Liverpool Street</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Oxford Circus</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Paddington</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Victoria</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Waterloo</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

*Originally located on previous slide, moved for clarity due to no animations*
Employee Interviews

- Euston
  - 6 employees
  - Peaks: Fri. (0700-0900, 1730-1900) and weekend (0930-1200, 1730-1900)
  - Customers had problems with wayfinding
  - Identified problem areas
Packed Escalators (6,7,8)
Employee Interviews

- Liverpool Street
  - 10 employees
  - Peaks: Tue. and Wed. (0630-0930, 1630-1930), weekend (0930-1230)
  - Customers had problems with wayfinding
  - Identified problem areas
Ticket Hall B & C
CCTV Observation

- British Transport Police laptop
- Capture image every minute, on the minute
- 180 captures taken for each 3-hour set
- Count passengers in frame
- Repeat for different views
On-Peak vs. Off-Peak Example:
Liverpool Street Ticket Hall B, Tuesday 6/6
Data - Liverpool Street, Common Occurrences
Level of Service Values - Liverpool Street

- Level of Service
  - Measurement devised in the 1970s
  - Determines how well a system flows based on density

<table>
<thead>
<tr>
<th>LOS Rating</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>density (p/m²)</td>
<td>0.3</td>
<td>0.3&lt;d&lt;0.43</td>
<td>0.43&lt;d&lt;0.718</td>
<td>0.718&lt;d&lt;1.08</td>
<td>1.08&lt;d&lt;2.15</td>
<td>2.15&lt;d</td>
</tr>
</tbody>
</table>
Liverpool Street Ticket Hall B Tue 6/6 Morning Peak LOS

*Originally located on previous slide, moved for clarity due to no animations*
Liverpool Street Ticket Office C Tue 6/6 Morning Peak LOS

Liverpool Street Escalators 4,5,6 Tue 6/6 Morning Peak LOS

Liverpool Street Bridge Tue 6/6 Morning Peak LOS

Liverpool Street Escalators 7,8,9 Tue 6/6 Morning Peak LOS

*Originally located on slide 17, moved for clarity due to no animations*
Euston Ticket Hall On Peak vs. Off Peak

- Euston Ticket Hall On Peak vs. Off Peak

- Euston Ticket Hall Friday 19/5 Morning Peak

- Euston Ticket Hall Saturday 20/5 Morning
Liverpool Street Ticket Hall B LOS
Passenger Survey Analysis - Euston

● Northern Line
  ○ The Northern Line has customers who are satisfied overall with the line
  ○ Signage and information on delays are good, but still have room for improvement
  ○ Train service is a major issue on the Northern Line and a big point of concern
  ○ Platforms tend to be crowded and navigating through stations is a hassle for customers

● Victoria Line
  ○ Customers overall satisfaction with the Victoria Line is above average
  ○ Signage concerns make up a significant portion of the issues with the Victoria Line
  ○ Stations are harder to navigate than average and platforms are too crowded
Passenger Survey Analysis - Liverpool St

- **Central Line:**
  - Overall, passenger satisfaction has gone down recently (85 Q4 15/16, 83 Q1 16/17)
  - Passenger satisfaction on the Central Line is below average for the Tube
  - Train crowding is rated a paltry 69 out of 100, well below average
  - 6% of passengers experience a delay

- **Circle, Metropolitan, Hammersmith and City:**
  - Circle & Hammersmith have overall passenger satisfaction well below that of the Tube
  - Signage and information for these lines are significantly below average (up to 24 points)
  - Circle & Hammersmith need major revamps to stations and the trains themselves
  - Metropolitan line has no significant strengths or weaknesses in terms of satisfaction
Preliminary Solutions:

Overall:

- Increase quality of CCTV cameras to allow better data collection
- Allow passengers to swipe out and back in for no charge within a small time period (<10 min) to allow alternative routes within stations
- Allow cleaning staff to swipe themselves in/out
- Make Help Points more visible from a distance
- Install fail-safe escalators at every set of bidirectional escalators
- Lines on the ground for navigation
Preliminary Solutions:

Euston:

● Increase width of all major passageways
● Remove or replace confusing signage
● Move maps away from choke points
● Split the Northern line to reduce confusion
● Consider a station revamp/rebuild to account for Crossrail 2/High-Speed 2 traffic
Unclear Signage
Northern line via Bank
Platforms 3 and 6
Victoria line
Platforms 4 and 5

Northern line via Charing Cross
← Platforms 1 and 2

*Originally located on previous slide, moved for clarity due to no animations*
Map Location
Preliminary Solutions:

Liverpool St:

- Add more Ticket booths to Ticket Hall C
- Add another bridge across the tracks near Ticket Hall A
- Expand the platforms, or
- Implement platform doors to improve safety on congested platforms
- Add lifts from street to platform for more handicapped accessibility
- Brighter signage and platforms
Unclear Signage
Refining Solutions

- Review sessions with senior TfL staff
  - Covered Overall and station-specific suggestions
- Overall, suggestions aligned with current issue lists
- Some suggestions already being considered
- Review sessions helped to improve and clarify solutions
Special Thanks

We would like to thank Dr. Taku Fujiyama, the staff at Euston and Liverpool Street, especially Sadiq Parker, Mike Donnithorne, and Cassius Powell, and our sponsor, Steve Walling. We couldn't have done it without them.
Euston Layout
Liverpool Street Layout