SBB-Beirat Technologie, Methoden und Prozesse

Analysis and modeling of pedestrian flows in railway stations

Flurin Hänseler, Transport and Mobility Lab, EPFL

December 4, 2013
Pedestrian flows in train stations
The PedFlux Project

Collaborative EPFL/CFF research project:
Development of a comprehensive modeling framework for pedestrian demand estimation in railway stations.

1) extensive data analysis of exemplary train station → Gare de Lausanne

2a) development of demand estimation methodology → dynamic origin-destination demand

2b) development of traffic assignment model → accessory to demand estimation → level-of-service assessment

3) application of combined framework to case study
Pedestrian underpasses of Gare de Lausanne
Coverage of tracking sensors

**Monitored area** in PIO (above) and PIE (below):

Figure adapted from VisioSafe
Tracking algorithm

Sensor topology:

Figure adapted from VisioSafe
(1) Detection
Tracking algorithm

(1) Detection – (2) Tracklet generation

Figure adapted from VisioSafe
Tracking algorithm

(1) Detection – (2) Tracklet generation – (3) Association

Figure adapted from VisioSafe
Sample trajectory

- ‘tracked’ vs. interpolated periods
- microscopic vs. macroscopic fidelity
Sample trajectory

- corresponding \((v,t)\)-map
Pedestrian movements on January 16, 2013

Animation: http://youtu.be/HHMXTJ1Q1kY
Visualization of pedestrian demand

- pedestrian underpasses, Gare de Lausanne
- busiest 15-min period
- extracted from tracking data

Figure: Nicholas Molyneaux, EPFL
Gare de Lausanne
07:37 – 7:52
10-day average
Periodic flow patterns

Daily pattern (January 16, 2013)

pedestrian demand (#/h)

06:00 12:00 18:00 24:00

0.3 0.6 0.9 1.2

\(10^4\)
### Heat map of PUs, January 22, 2013

#### Table: Pedestrian walkway LoS density threshold values according to NCHRP

<table>
<thead>
<tr>
<th>LOS</th>
<th>Pedestrian density</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 0.179 [ped/m²]</td>
</tr>
<tr>
<td>B</td>
<td>&lt; 0.270</td>
</tr>
<tr>
<td>C</td>
<td>&lt; 0.455</td>
</tr>
<tr>
<td>D</td>
<td>&lt; 0.714</td>
</tr>
<tr>
<td>E</td>
<td>&lt; 1.333</td>
</tr>
<tr>
<td>F</td>
<td>≥ 1.333</td>
</tr>
</tbody>
</table>

* density as indicator for:*
  - comfort
  - performance
  - safety

Ref: [Hig00], Exhibit 18-3
Heat map of PUs, January 22, 2013

Figure: SBB-I-AT-BZU-PFL
Heat map of PUs, January 22, 2013

Figure: SBB-I-AT-BZU-PFL
Heat map of PUs, January 22, 2013

SBB Bahnhof Bern
Visualisierung Qualitätsstufen

Bahnhofhalle

LoS C 0.37 P/qm

Figure: SBB-I-AT-BZU-PFL
Heat map of PUs, January 22, 2013
Heat map of PUs, January 22, 2013

LoS E 1.12 P/qm

Figure: SBB-I-AT-BZU-PFL
Heat map of PUs, January 22, 2013

aggregation: $\Delta t = 60 \text{ s}, A = 7.29 \text{ m}^2$

7:40–7:41: Low occupation, no train arrivals
Heat map of PUs, January 22, 2013

aggregation: $\Delta t = 60 \text{ s}, \ A = 7.29 \text{ m}^2$

Heat map of PUs, January 22, 2013

aggregation: $\Delta t = 60 \text{ s}, A = 7.29 \text{ m}^2$

7:42–7:43: Arrival of train IR 706 at 7:41:24 on platform 5/6
Heat map of PUs, January 22, 2013

aggregation: $\Delta t = 60 \text{ s}, \ A = 7.29 \text{ m}^2$

7:43–7:44: Arrival of train IR 1407 at 7:42:20 on platform 3/4
aggregation: $\Delta t = 60$ s, $A = 7.29$ m$^2$

7:44–7:45: Gradual decrease in pedestrian occupation
Voronoi-based spatial tessellation

• finite set of points $p_1, p_2, \ldots$ in space
• Voronoi cell of point $p_i$ defined as

$$V(p_i) = \{ p \mid \|p - p_i\| \leq \|p - p_j\|, i \neq j \}$$

• each point represents a pedestrian
Empirical fundamental diagram
Framework for pedestrian flow estimation

- Train timetable, travel surveys
- Spatio-temporal observations
- Layout of walking facilities

Demand estimation

- Dynamic trip table
- Travel time, occupation

Traffic assignment

Demand

Supply

Dynamic trip table
Travel time, occupation
Pedestrian demand estimation

Train timetable, travel surveys

Spatio-temporal observations

Layout of walking facilities

Demand estimation

Dynamic trip table

Traffic assignment

Travel time, occupation
Pedestrian demand estimation: Train timetable

flows into pedestrian underpasses
sample pedestrian trajectories

PU West

PU East
Pedestrian demand estimation: Train timetable

- correlation between train schedule and pedestrian flows

Figure: Train unloading flow and train arrivals, April 9, 2013

Ref: [MHB13]
Pedestrian demand estimation: Train timetable

- correlation between train schedule and pedestrian flows
- ‘unloading flow’ as superposition of train-induced events

- inflow after train arrival
- dead time: \( s \approx 46.3 \, \text{s} \)
- flow rate:
  \[ \alpha_{\text{long}} = 6.8 \pm 1 \, \text{#/s} \]
  \[ \alpha_{\text{short}} = 4.5 \pm 1 \, \text{#/s} \]
- disembarkations per train:
  \[ Q = 80 \ldots 500 \]

Ref: [MHB13]
Pedestrian demand estimation: Train timetable

- correlation between train schedule and pedestrian flows
- ‘unloading flow’ as superposition of train-induced events
- sample prediction (April 9, 2013, based on HOP data)

Ref: [MHB13]
Pedestrian demand estimation: Methodology

PU West

7:02 – 7:05

7:01

PU East

7:07

7:03

flow counter
tracking system
sales point
boardings/disembarkations
Pedestrian traffic assignment

- Train timetable, travel surveys
- Spatio-temporal observations
- Layout of walking facilities

Demand estimation

Dynamic trip table

Traffic assignment

Travel time, occupation

Demand supply
Pedestrian traffic assignment: Desired properties

- accurate prediction of travel times given demand
  - calibration with trajectory data

- customizable I/O interface
  - coupling with demand estimation framework

- high computational performance
  - several times faster than real-time

→ mesoscopic pedestrian flow model
Pedestrian traffic assignment: Space representation

- walkable area
- entry/exit points
- route
  - sequence of areas
- path
  - sequence of cells
Pedestrian traffic assignment: Propagation model

pedestrian fundamental diagram [Wei93]

\[ v_f = 1.34 \]

\[ q_{opt} = 1.22 \]

\[ k_{opt} = 1.75 \]

\[ k_{jam} = 5.4 \]
Pedestrian traffic assignment: PU West, Lausanne

Figure: Pedestrian Underpass West, Lausanne railway station
Pedestrian traffic assignment: PU West, Lausanne

- pedestrian demand extracted from tracking data
- prediction of travel times, flows and densities
- January 22, 2013, 07:40 – 07:46

<table>
<thead>
<tr>
<th>LOS</th>
<th>[#/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 0.179</td>
</tr>
<tr>
<td>B</td>
<td>&lt; 0.270</td>
</tr>
<tr>
<td>C</td>
<td>&lt; 0.455</td>
</tr>
<tr>
<td>D</td>
<td>&lt; 0.714</td>
</tr>
<tr>
<td>E</td>
<td>&lt; 1.333</td>
</tr>
<tr>
<td>F</td>
<td>≥ 1.333</td>
</tr>
</tbody>
</table>

Animation: [http://youtu.be/16_MkoF70Hc](http://youtu.be/16_MkoF70Hc)
Concluding remarks and next steps

1. extensive data analysis for Gare de Lausanne

2. framework for pedestrian flow modeling
   2a) demand estimation methodology (primary aim)
   2b) traffic assignment model (accessory)

3. application of combined framework to case study
   – prototype tool for integrated demand/supply estimation

* operationalization of research findings with third party – tbd
  – apply knowledge/methodology to further train stations
  – develop decision-aid tools for practitioners

Ref: [HMTB13]
Thank you

SBB-Beirat Technologie, Methoden und Prozesse: Analysis and modeling of pedestrian flows in railway stations
Flurin Hänseler, Transport and Mobility Lab, EPFL

Many results shown in this presentation are due to Nicolas Anken, Nicholas Molyneaux and Thomas Mühlematter.

Support by SBB-I-AT-BZU-PFL, EPFL-TraCE and VisioSafe is gratefully acknowledged. Picture on slide 2 ©Michael Buholzer, Reuters.

– flurin.haenseler@epfl.ch
Highway Capacity Manual.
*Transportation Research Board.*

Pedestrian strategies within railway stations: Analysis and modeling of pedestrian flows (PedFlux Mid-Term Report).

Nicholas Molyneaux, F.S. Hänseler, and M. Bierlaire.
PedFlux Analysis Report: Train-induced loading and unloading flows in platform access ways.
U. Weidmann.  
*Transporttechnik der Fussgänger.*  
Institute for Transport Planning and Systems, ETH Zürich, 1993.