STRC 2015

Modeling pedestrian flows in train stations: The example of Lausanne railway station

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Monte Verità, April 16, 2015
Pedestrian flows in train stations
Pedestrian demand and supply

- train timetable, frequentation data
- historical information
- network layout

Demand estimation

- OD demand
- traffic conditions

Network loading

- link flow counts
- trajectory recordings
Outline

1. Lausanne railway station
2. Data analysis
3. Origin-destination demand estimation
4. Network loading model
5. Conclusions
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1. Lausanne railway station
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Lausanne railway station: Aerial view
Lausanne railway station: Walking areas

- Pedestrian walking network
- Entrance: centroid with historical information
- Platform: centroid without historical information
- Link with a priori flow estimate based on timetable
- Link equipped with directed flow counter
- Area covered by pedestrian tracking system
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Pedestrian demand and supply: Data analysis

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Demand estimation

Network loading

link flow counts

trajectory recordings

demand

traffic conditions
Pedestrian movements on January 16, 2013

Animation: https://youtu.be/HHMXTJlQ1kY
Hourly pedestrian demand over a day

Figure: 10-day reference set, 2013
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Pedestrian demand and supply: Demand Estimation

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Demand estimation

- Demand
- Network loading
- Traffic conditions

- Link flow counts
- Trajectory recordings
OD demand estimation: Overview

• estimation of demand in walking facilities based on
  – train timetable
  – pedestrian counts
  – historical data (travel surveys, sales data)
  – trajectories (validation only)

• demand-inelastic network loading
  – walking speed $v \sim \mathcal{N}(1.34 \text{ m/s}, 0.34 \text{ m/s})$ [Wei92]
  – unique route per OD pair

• case study: morning peak period, Lausanne railway station
  – busiest 30-min period of the day (07:30 – 08:00)
  – 25 arriving and departing trains
Train-induced flows

boarding/disembarkation flows
platform exit flows
platform access flows
Platform exit flows: Model

Figure: Continuous-time, piecewise linear model
Platform exit flows: Simulation

Figure: April 10, 2013, platform #5/6, Lausanne railway station
Total demand in Lausanne railway station

Figure: 10-day reference set, 2013
Average OD demand in Lausanne railway station

- pedestrian walking network
- peak period: 7:30 – 8:00
- origin of streams
  - train platforms
  - city/metro/bus
  - shops
Lausanne railway station
07:30 – 08:00
Year 2013
Flow map of Lausanne railway station (2013)

Figure: 7:40–7:41

- 10 ped/min
- 100 ped/min

0 25 50 75 ≥ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:41–7:42

- 10 ped/min
- 100 ped/min

Legend:

- 0
- 25
- 50
- 75
- ≥ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:42–7:43

- 10 ped/min
- 100 ped/min

Legend:

- 0
- 25
- 50
- 75
- ≥ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:43–7:44

○ 10 ped/min ○ 100 ped/min

0 25 50 75 ≥ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:44–7:45

0 25 50 75 ≥ 100 ped/min

10 ped/min 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:45–7:46

- 10 ped/min
- 100 ped/min

0 25 50 75 ≥ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:46–7:47

0 25 50 75 ≥ 100 ped/min

○ 10 ped/min ○ 100 ped/min
Flow map of Lausanne railway station (2013)

Figure: 7:47–7:48

- 10 ped/min
- 100 ped/min

0 25 50 75 ≥ 100 ped/min
Outline

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Pedestrian demand and supply: Network loading

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Demand estimation

Network loading

traffic conditions

link flow counts

trajectory recordings
Network loading model: Overview

Requirements:

- accurate prediction of travel time and density
- low computational cost, ‘easy’ calibration
- aggregate model (input and output at aggregate level)

Input:

- demand
- network topology
Pedestrian network loading: Space representation

- walkable area
- entry/exit points
- route
  - sequence of areas
Pedestrian network loading: Space representation

- **walkable area**
- **entry/exit points**
- **route** – sequence of areas
- **path** – sequence of cells
Pedestrian network loading: Propagation model

pedestrian fundamental diagram \cite{Wei92}

\[ v_f = 1.34 \]

\[ k_{jam} = 5.4 \]
Pedestrian network loading: Propagation model

Pedestrian fundamental diagram [Wei92]

speed (m/s)

$\nu_f = 1.34$

flow (#/ms)

$q_{opt} = 1.22$

density (#/m$^2$)

$k_{opt} = 1.75$

$k_{jam} = 5.4$
Level-of-service assessment

<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>

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

density as indicator for:
- comfort
- performance
- safety

Ref: [Hig00], Exhibit 18-3
Level-of-service assessment
Level-of-service assessment
Level-of-service assessment

Figure: SBB-I-AT-BZU-PFL
Level-of-service assessment
Level-of-service assessment

Figure: SBB-I-AT-BZU-PFL
Pedestrian network loading: PU West, Lausanne

Figure: Pedestrian Underpass West, Lausanne railway station
Pedestrian network loading: PU West, Lausanne

- simulated pedestrian density map
- prediction of travel times, flows and densities
- January 22, 2013, 07:40 – 07:46

<table>
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Animation: [http://youtu.be/16_MkoF70Hc](http://youtu.be/16_MkoF70Hc)
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Conclusions

• explorative analysis of several pedestrian data sets related to Lausanne railway station

• development of schedule-based origin-destination demand estimator for pedestrian flows in railway stations

• development of pedestrian network loading model for level-of-service assessment in pedestrian facilities in railway stations
Thank you

STRC 2015:
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Support by SBB-I-AT-BZU-PFL and EPFL-TraCE is gratefully acknowledged.

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