ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

TRANSP-OR

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

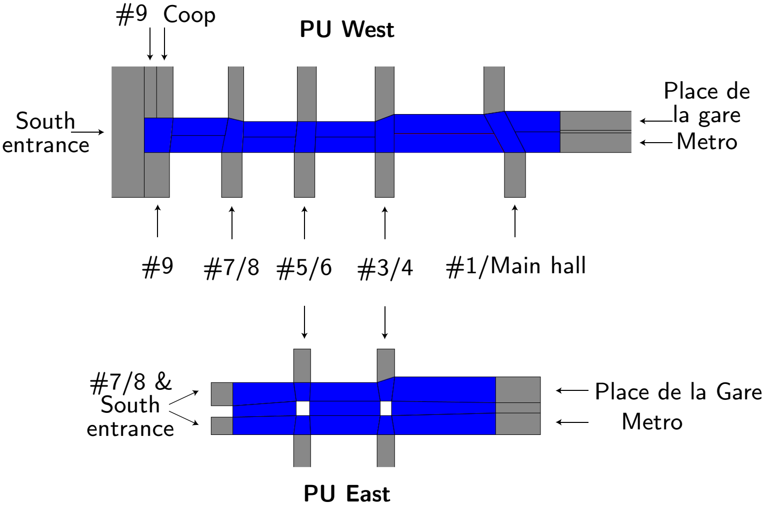
Pedestrian flows in train stations

The PedFlux Project

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

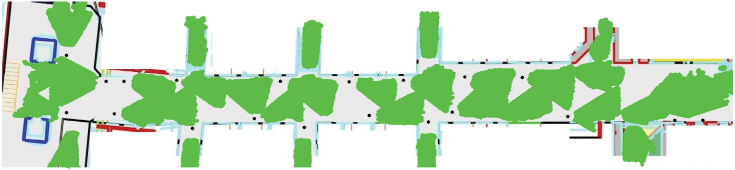
1) extensive data analysis of exemplary train station
   → Gare de Lausanne
2a) development of demand estimation methodology
   → dynamic origin-destination demand
2b) development of traffic assignment model
   → accessory to demand estimation
   → level-of-service assessment
3) application of combined framework to case study

Pedestrian underpasses of Gare de Lausanne



Coverage of tracking sensors

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



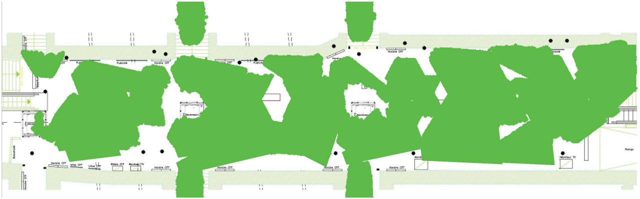
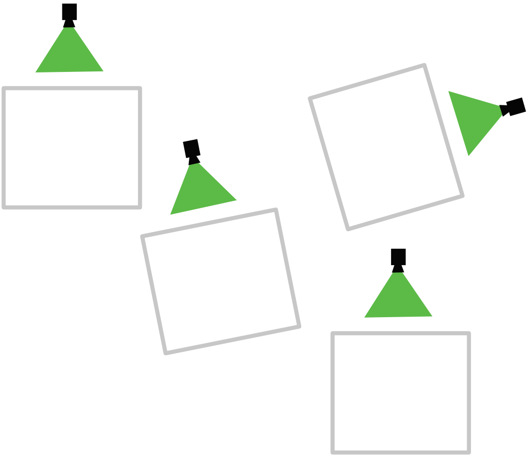


Figure adapted from VisioSafe

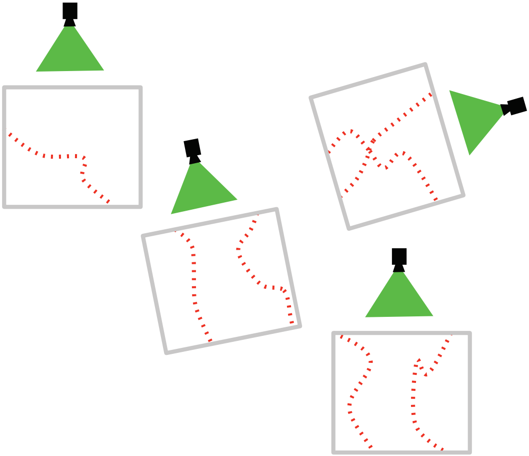
Tracking algorithm

Sensor topology:



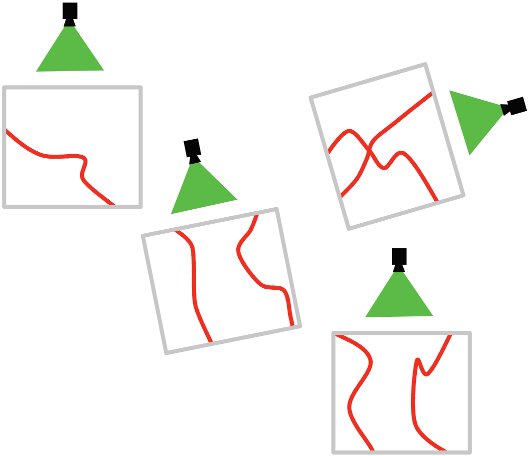
Tracking algorithm

(1) Detection



Tracking algorithm

(1) Detection – (2) Tracklet generation



Tracking algorithm

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

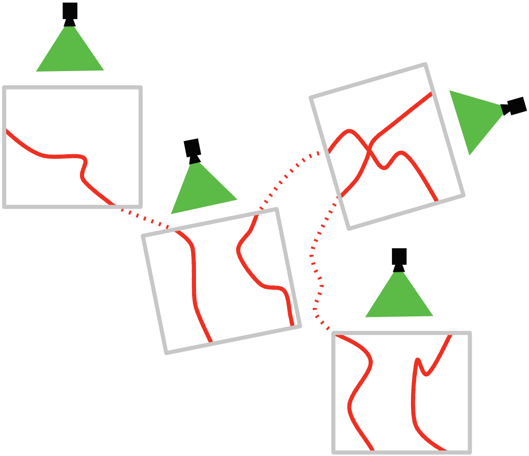
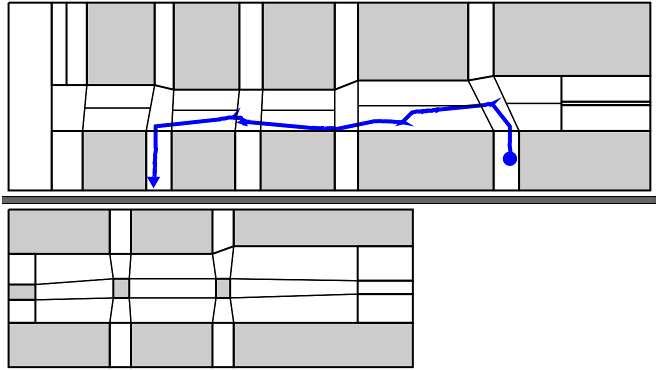


Figure adapted from VisioSafe

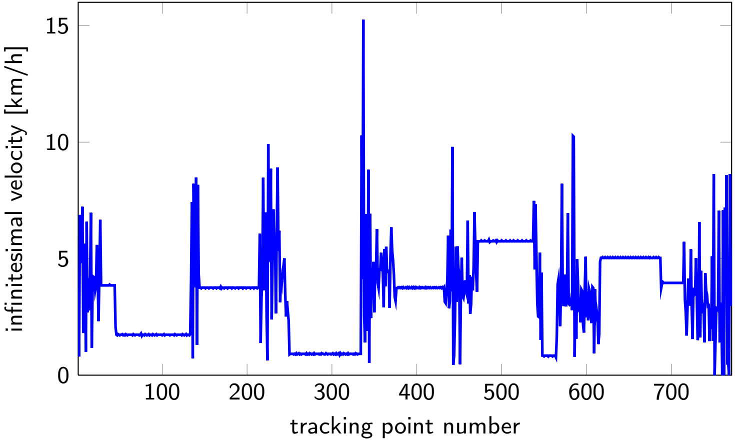
Sample trajectory

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



Sample trajectory

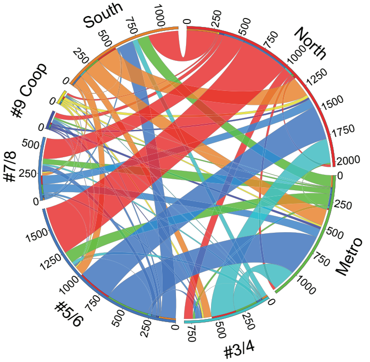
- corresponding (v,t)-map



Pedestrian movements on January 16, 2013

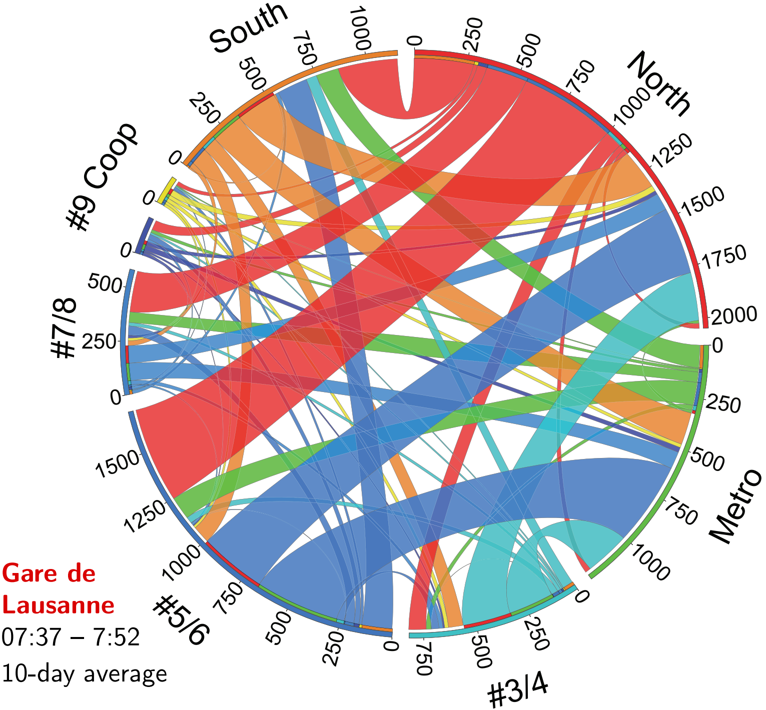
Animation: http://youtu.be/HHMXTJ1Q1kY

Visualization of pedestrian demand

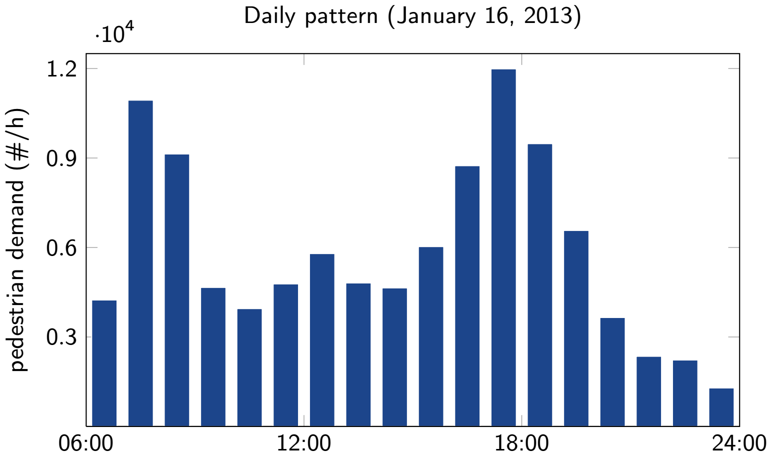


- pedestrian underpasses, Gare de Lausanne
- busiest 15-min period
- extracted from tracking data

Figure: Nicholas Molyneaux, EPFL


South
North
#9 Coop
#7/8
#5/6
#3/4
Metro
Gare de Lausanne
07:37 – 7:52
10-day average

Periodic flow patterns



Heat map of PUs, January 22, 2013

	LOS	Pedestrian density
(blue)	A	< 0.179 [ped/m^2]
(cyan)	B	< 0.270
(green)	C	< 0.455
(yellow)	D	< 0.714
(orange)	E	< 1.333
(red)	F	≥ 1.333

Table: Pedestrian walkway LoS density threshold values according to NCHRP

density as indicator for:

- comfort
- performance
- safety

Heat map of PUs, January 22, 2013

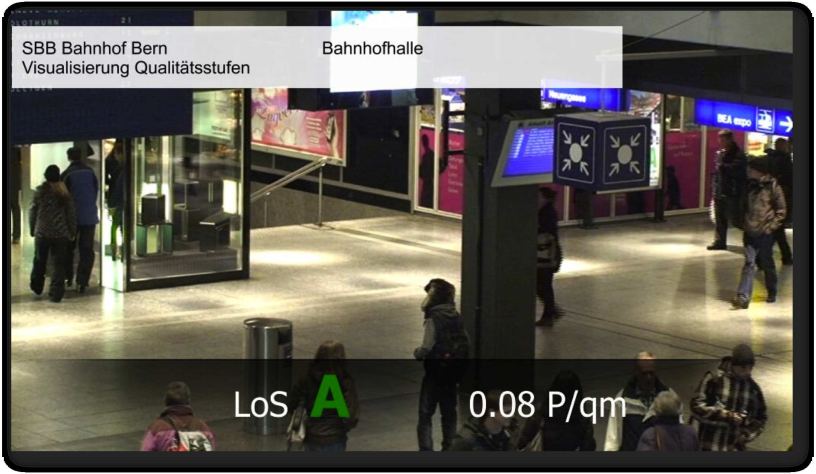


Figure: SBB-I-AT-BZU-PFL

Heat map of PUs, January 22, 2013

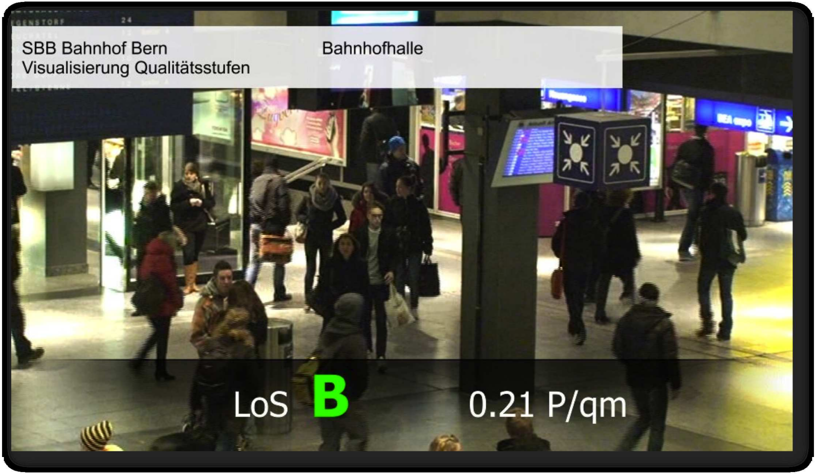
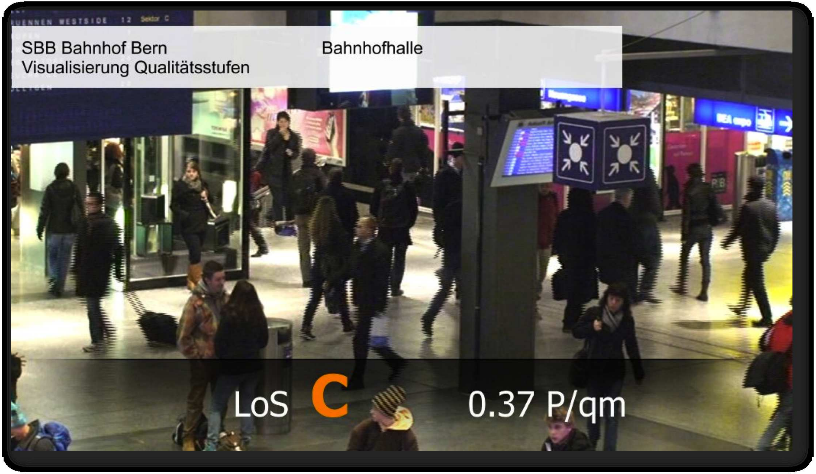


Figure: SBB-I-AT-BZU-PFL

Heat map of PUs, January 22, 2013



Heat map of PUs, January 22, 2013

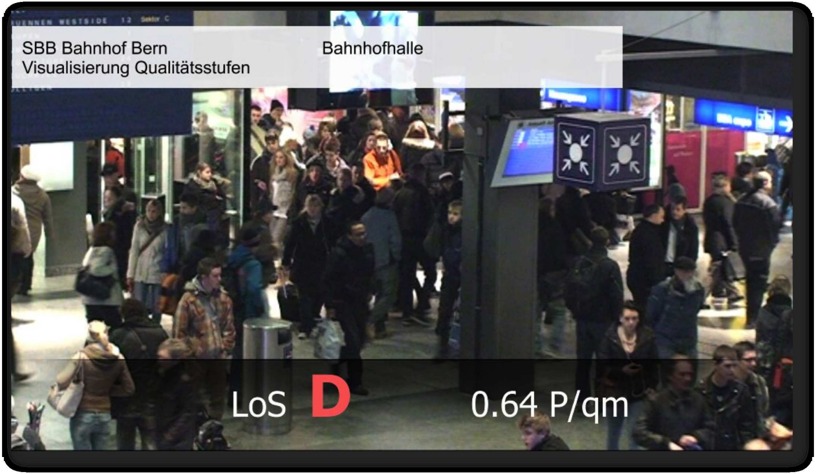


Figure: SBB-I-AT-BZU-PFL

Heat map of PUs, January 22, 2013

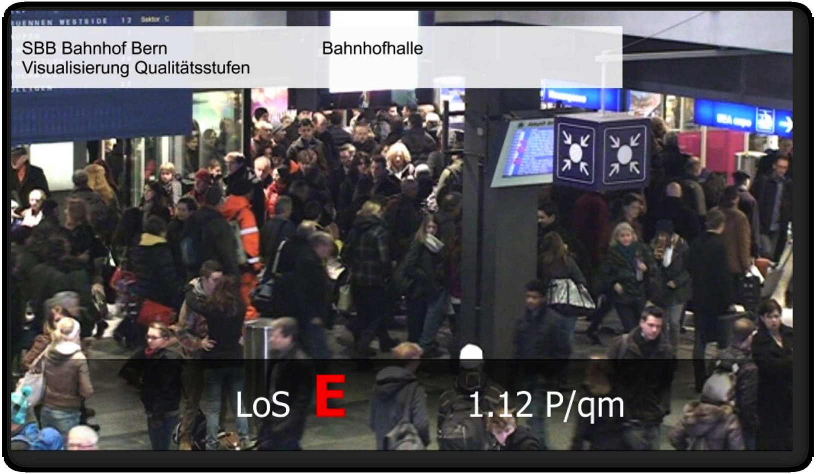
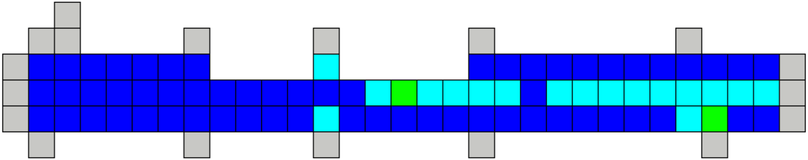


Figure: SBB-I-AT-BZU-PFL

Heat map of PUs, January 22, 2013

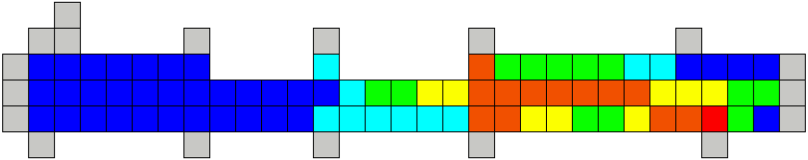
aggregation: $\Delta t = 60$ s, $A = 7.29$ m^2



7:40–7:41: Low occupation, no train arrivals

Heat map of PUs, January 22, 2013

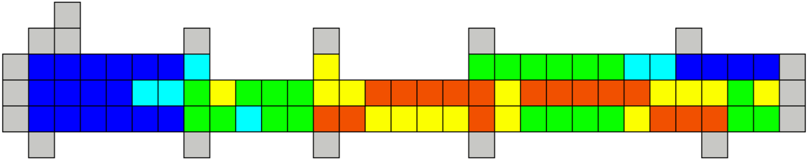
aggregation: $\Delta t = 60$ s, $A = 7.29$ m^2



7:41–7:42: Arrival of train IR 1606 at 7:40:20 on platform 3/4

Heat map of PUs, January 22, 2013

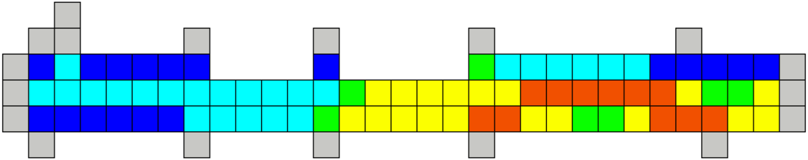
aggregation: $\Delta t = 60$ s, $A = 7.29$ m^2



7:42–7:43: Arrival of train IR 706 at 7:41:24 on platform 5/6

Heat map of PUs, January 22, 2013

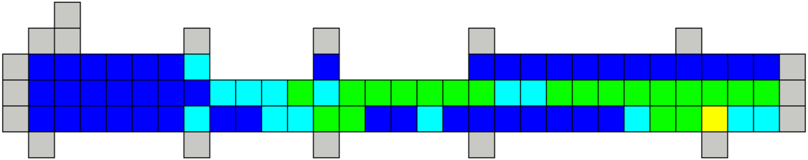
aggregation: $\Delta t = 60$ s, $A = 7.29$ m^2



7:43–7:44: Arrival of train IR 1407 at 7:42:20 on platform 3/4

Heat map of PUs, January 22, 2013

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



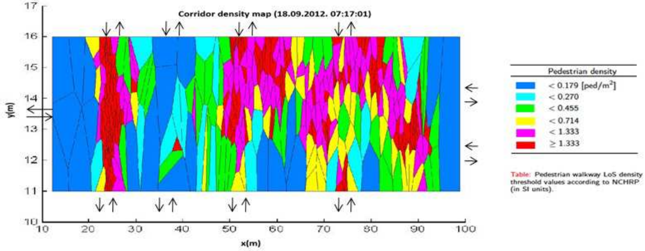
7:44–7:45: Gradual decrease in pedestrian occupation

Voronoi-based spatial tessellation

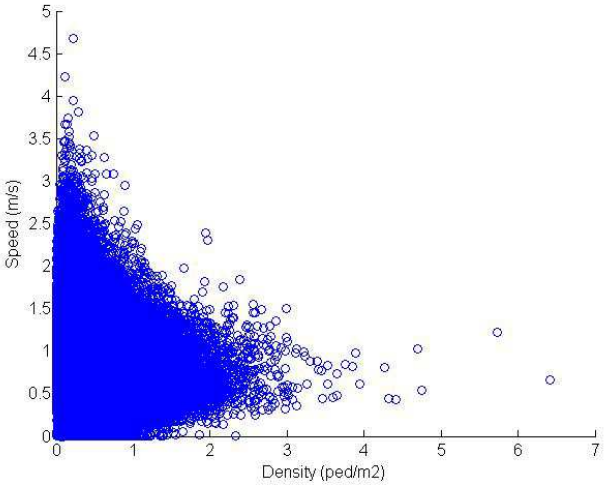
- finite set of points $p_1, p_2, \ldots$ in space
- Voronoi cell of point p_i defined as

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

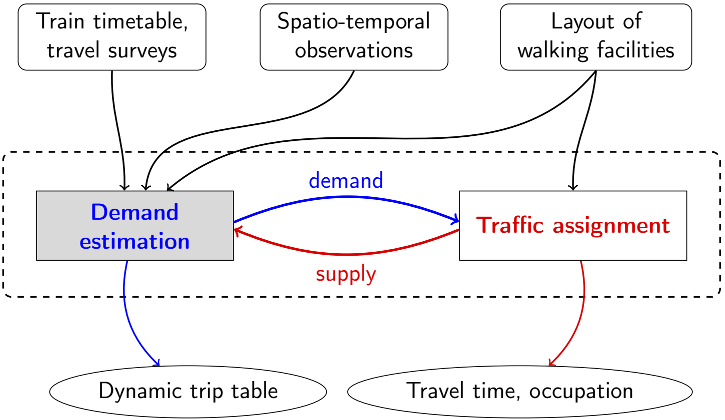
- each point represents a pedestrian



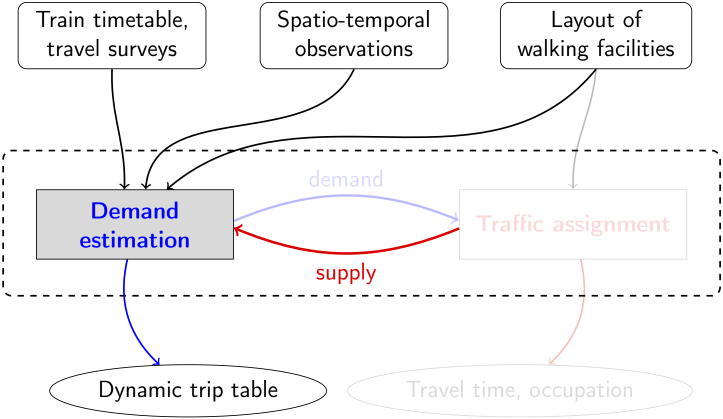
Empirical fundamental diagram



Framework for pedestrian flow estimation

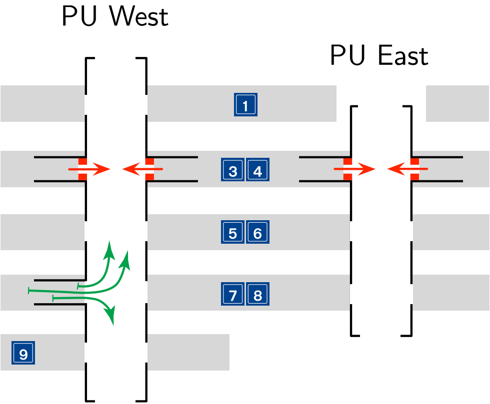


Pedestrian demand estimation



Pedestrian demand estimation: Train timetable

→ flows into pedestrian underpasses
→ sample pedestrian trajectories



Pedestrian demand estimation: Train timetable

- correlation between train schedule and pedestrian flows

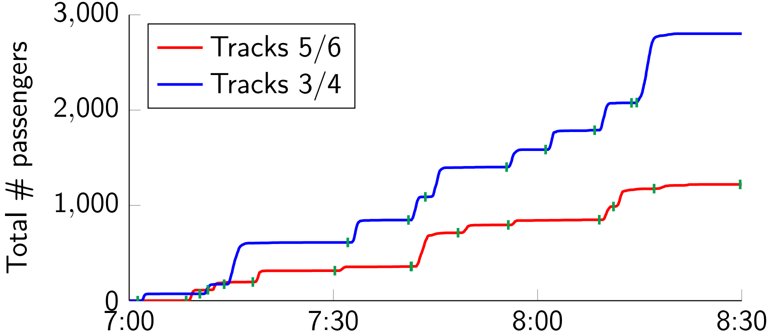
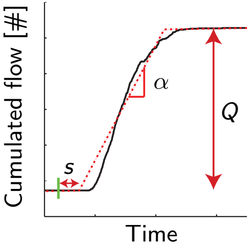


Figure: Train unloading flow and train arrivals, April 9, 2013

Pedestrian demand estimation: Train timetable

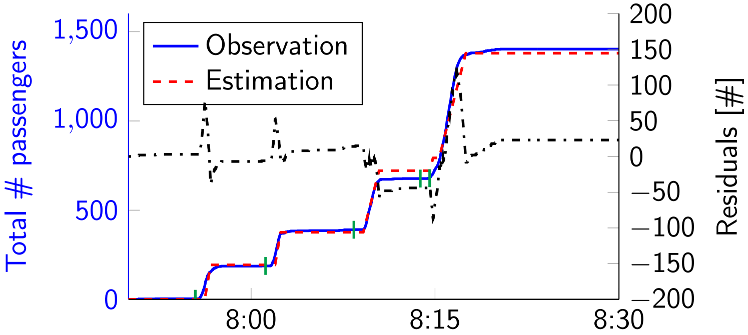
- correlation between train schedule and pedestrian flows
- ‘unloading flow’ as superposition of train-induced events



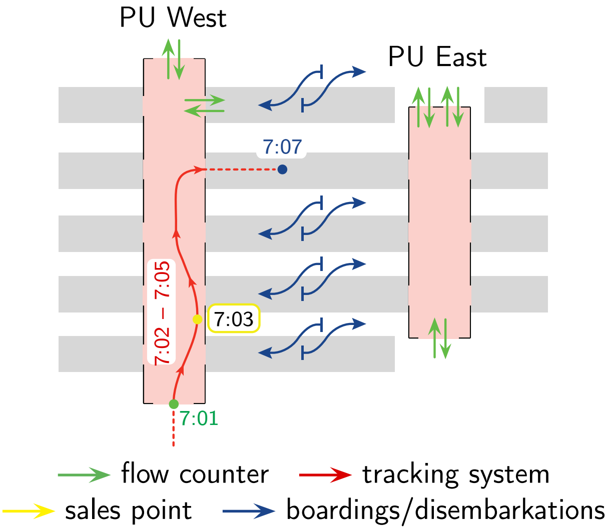
- inflow after train arrival
- dead time: $s \approx 46.3$ s
- flow rate:
  $\alpha_{long} = 6.8 \pm 1$ #/s
  $\alpha_{short} = 4.5 \pm 1$ #/s
- disembarkations per train:
  $Q = 80 \ldots 500$

Pedestrian demand estimation: Train timetable

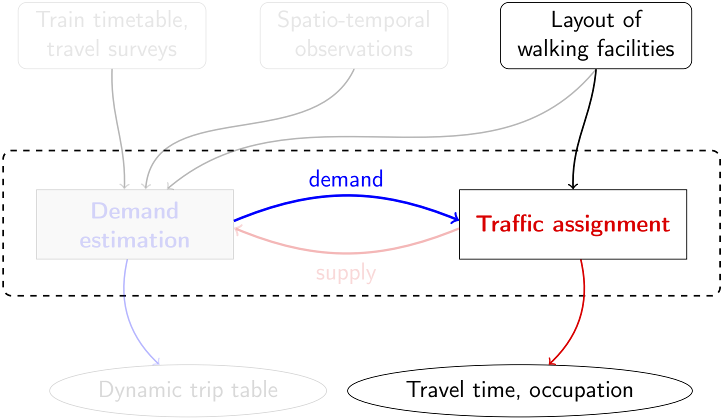
- correlation between train schedule and pedestrian flows
- ‘unloading flow’ as superposition of train-induced events
- sample prediction (April 9, 2013, based on HOP data)



Pedestrian demand estimation: Methodology



Pedestrian traffic assignment

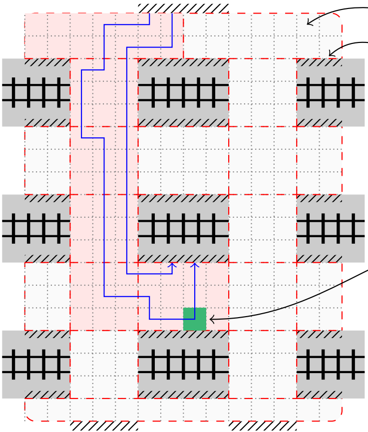


Pedestrian traffic assignment: Desired properties

- 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

$\rightarrow$ mesoscopic pedestrian flow model

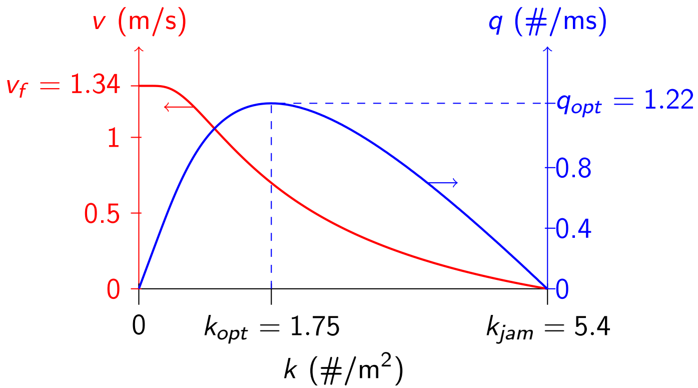
Pedestrian traffic assignment: Space representation



- walkable area
- entry/exit points
- route
  - sequence of areas
- path
  - sequence of cells

Pedestrian traffic assignment: Propagation model

pedestrian fundamental diagram [Wei93]



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

	LOS	[#/m^2]
(blue)	A	< 0.179
(cyan)	B	< 0.270
(green)	C	< 0.455
(yellow)	D	< 0.714
(orange)	E	< 1.333
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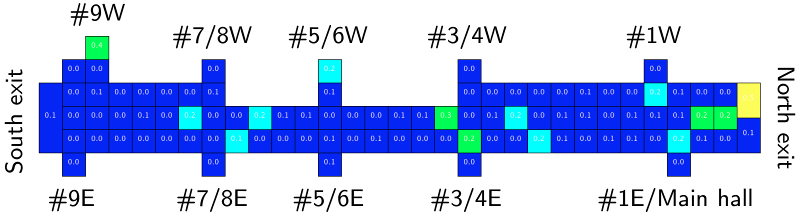

Concluding remarks and next steps

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

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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.

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