Fachhochschule Nordwestschweiz
Hochschule für Architektur, Bau und Geomatik

Modelling Pedestrian Traffic in and Around Swiss Railways Stations

13th Symposium of the European Association for Research in Transportation (hEART), TU Munich, 12 June 2025

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OVERVIEW

Background

Methodology & data

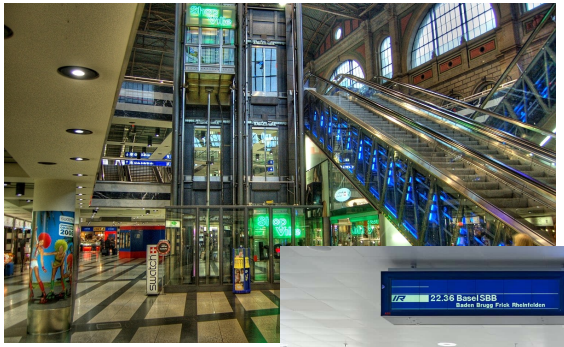
Results

Case study application

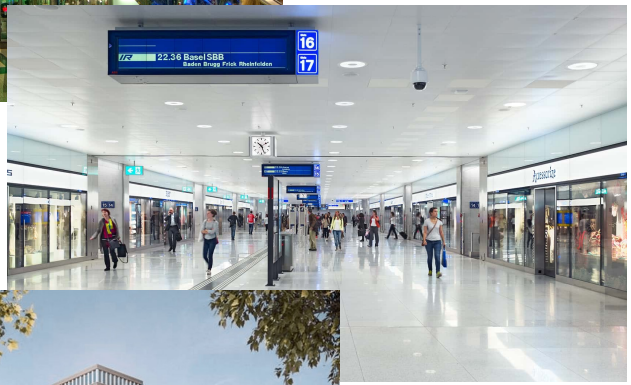
Discussion

MAIN RAILWAYS STATION ARE PART OF THE URBAN FABRIC

- Railway stations and its surroundings are **destinations** for various pedestrian activities.
- Limited understanding of the **number and type of those pedestrian activities** and its spatial interactions.
- **No evidence-based method to evaluate design scenarios** to better integrate railway stations with its surroundings.



Zurich Main Station
ShopVille 1990



New underpass 2014

Europaallee
2014

MORE PASSENGERS, MORE INTEGRATED RAILWAY STATIONS, MORE PLANNING CHALLENGES

Around **20% - 35% more rail passengers** expected in Switzerland until 2035.

Transfers and walking duration are highly negatively perceived and represent a substantial component of generalised costs.

Decentralised “**Mobility Hubs**” (Verkehrsdrehscheiben)

- Efficient transfers between all modes of transport
- Attractive places as destinations
- Integration with urban development

New planning questions:

- Where to place additional underpasses?
- Where to improve sidewalks and crossings?
- Where to place which commercial ground floor usage?
- Where to invest in street furniture and sojourning facilities?

Genève-Aux-Vives
2019

Visualisation of the Mobility Hub concept

RESEARCH QUESTIONS

1. At what level of accuracy and detail can **pedestrian flow in and around Swiss railroad stations** be described?
2. How do such models differ **between different types of railway stations**?

Development and comparison of pedestrian volume models in two different railway stations

3. How can such a model be applied to **evaluate design scenarios?**

→ Applicaton in a case study

TWO DIFFERENT TYPES OF RAILWAY STATIONS

Lucerne

Center of Central Switzerland

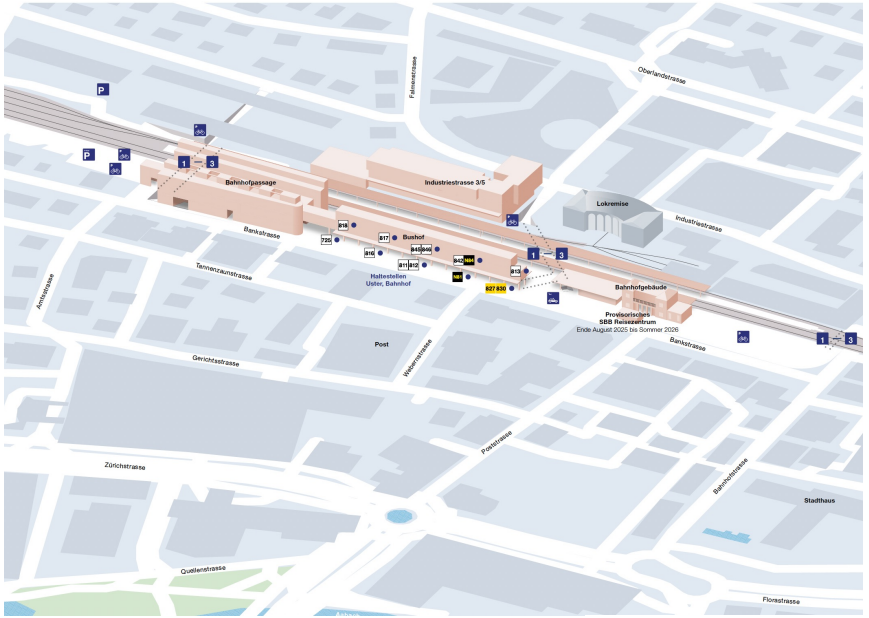
Population

- 83k residents
- 83k jobs

Railway station

- 110k pax/day
- 66 shops and services

Uster



Regional Center in Zurich Area

Population

- 37k residents
- 18k jobs

Railway station

- 28k pax/day
- 22 shops & services

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HOW TO MODEL PEDESTRIAN FLOW?

Direct Demand Models:
Statistical regression to model pedestrian flow, focusing on two interrelated dimensions:

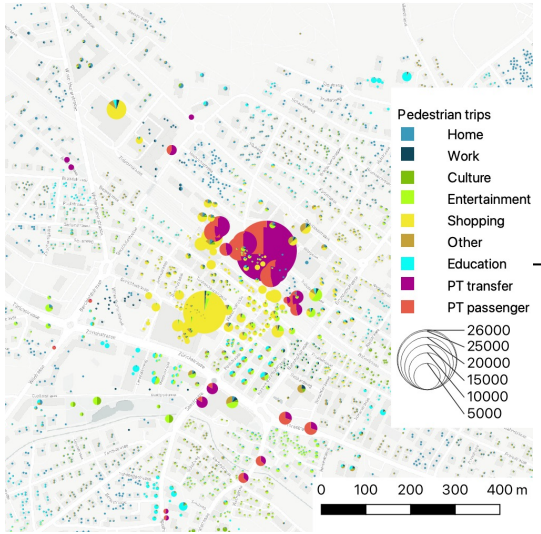
- **Trip Generation & Attraction**:
  Boarding and alighting passengers, attraction potential and visibility of commercial establishments and detailed land use data (Cooper et al., 2019; Van Eggermond et al., 2022)

- **Betweeness Centrality:**
  - **Distance Measures**: Metric or angular distances such as the cumulative changes in direction, e.g., Space Syntax (Bafna, 2003).
  - **Beyond Distance**: Consider turns and environmental qualities in addition to distance (Sevtsuk & Basu, 2022).
  - **Comprehensive Network Analysis**: Multiple building levels to account for horizontal, vertical, and angular variations in multi-level environments like stations (Cooper et al., 2019; Van Eggermond et al., 2022).

Apply and test different approaches for two Swiss railway stations

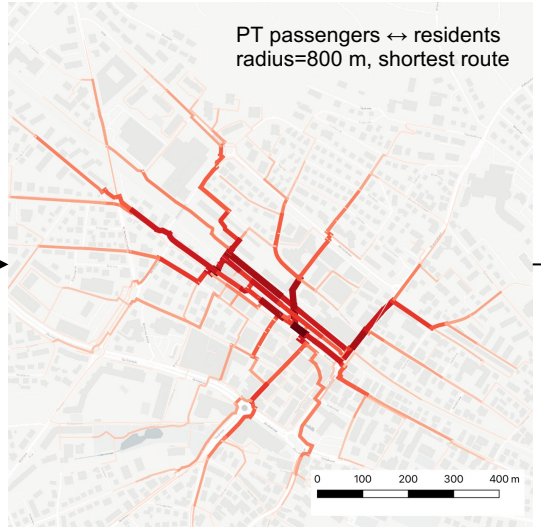
MODELLING APPROACH

Trip generation and attraction
Activity density



- Boarding and alighting passengers
- Land use data (residents and jobs)
- Commercial establishments and its visibility)

Betweenness
Independent variables



- Different distance measures: metric, angular, vertical and combinations
- Consideration of environmental qualities
- Different distance bands (donuts)
- Different activity segments

Pedestrian volume on a weekday
Dependent variable

- Manual counts
- Automatic counts

RIDGE REGRESSION

Pedestrian counts **Network measures**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \varepsilon$$

$$L_{OLS}(\hat{\beta}) = \sum_{i=1}^{n} (y_i - x_i' \hat{\beta})^2 = ||y - X\hat{\beta}||^2$$

$$L_{ridge}(\hat{\beta}) = \sum_{i=1}^{n} (y_i - x_i' \hat{\beta})^2 + \lambda \sum_{j=1}^{m} \hat{\beta}_j^2 = ||y - X\hat{\beta}||^2 + \lambda ||\hat{\beta}||^2.$$

Describe **link-based pedestrian volume** based on various **link-specific variables**, e.g. betweenness residents <-> public transport passengers within 200m

Ordinary least square with issues if predictors are correlated

Ridge regression with λ-parameter to deal with a set of correlated variables and many predictors

Weighted regression with lower weights for high volume observations. Goodness-of-fit and literature suggests this is a valid approach (see Cooper et al., 2021).

λ-parameter impacts distribution of predictors, therefore t-test values cannot be computed.

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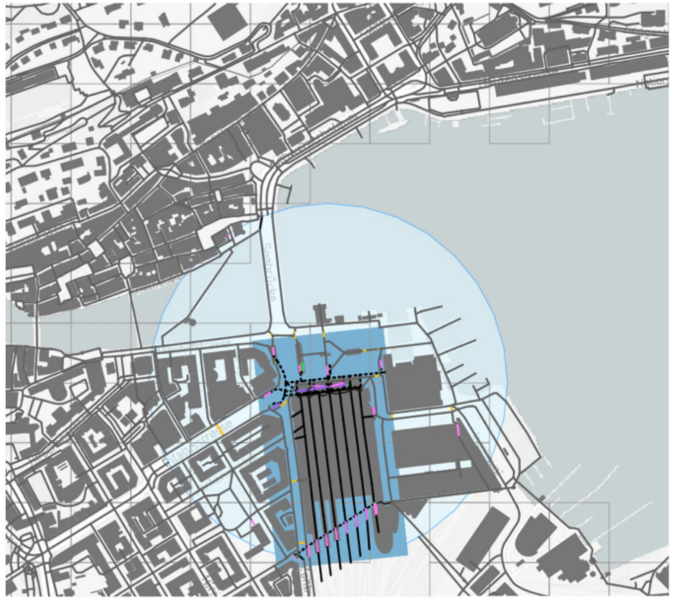
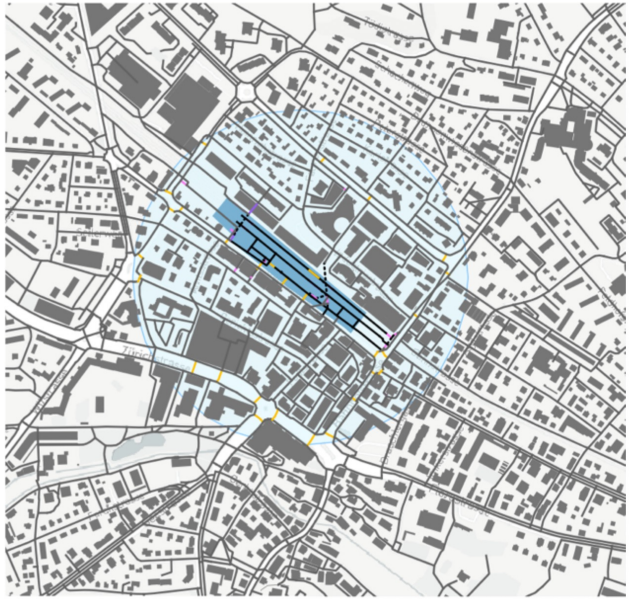
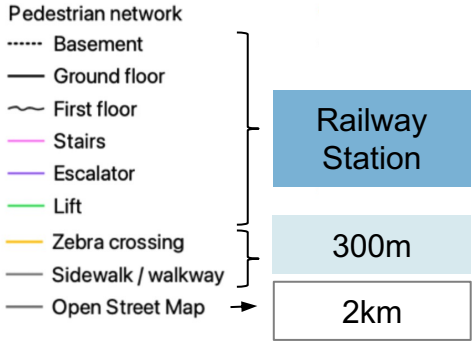
PEDESTRIAN NETWORK

Lucerne



Uster





TRIP ATTRACTION AND GENERATION

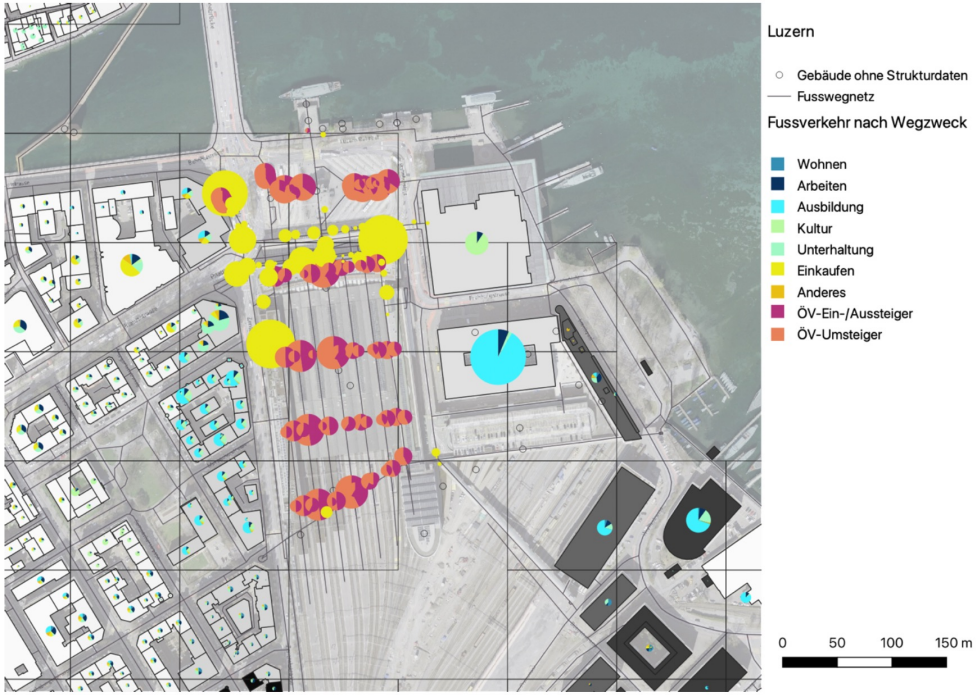
Within Railway station

- **Boarding and alighting passengers** based on agent-based transport simulation (SIMBA MOBi)
- **Sales transactions**
- **Empirically observed visitor-to-sale factors**, e.g. 4.6 for clothing stores; 1.1 for supermarkets

Outside railway station

- **Resident and workplace statistics** on 100m raster
- **Trip generation factors**
  - For residents based on **national travel diary data**
  - For workplaces based on **common sense assumptions**, e.g. 80 trips per FTE for shops; 10 trips for travel agency
- **Distribution within raster cells** to individual buildings based on building footprint

Lucerne: Trip generation and attraction



PEDESTRIAN COUNTS

Manual counting

- About 45 counting stations within a 300 m radius of the railway station
- 5 to 8 counting station at trip generators
- Tuesday or Thursday afternoon in May 2023
- 12 minutes interval
- 3 to 4 repetitions at each counting station

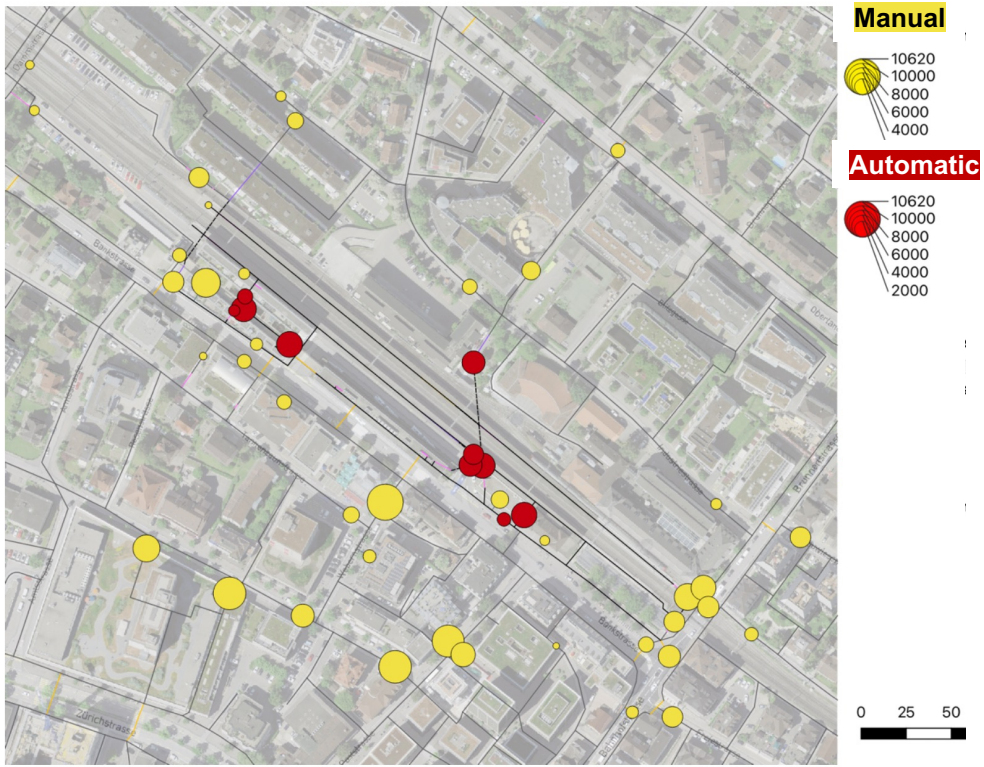
Automatic counting

- 28 counting stations in Lucerne; 10 in Uster
- 5 minutes intervals
- 24h / 365d

Aggregation / Scaling

- Average daily traffic
- Scaling to derive average yearly volume

Counting data in Uster



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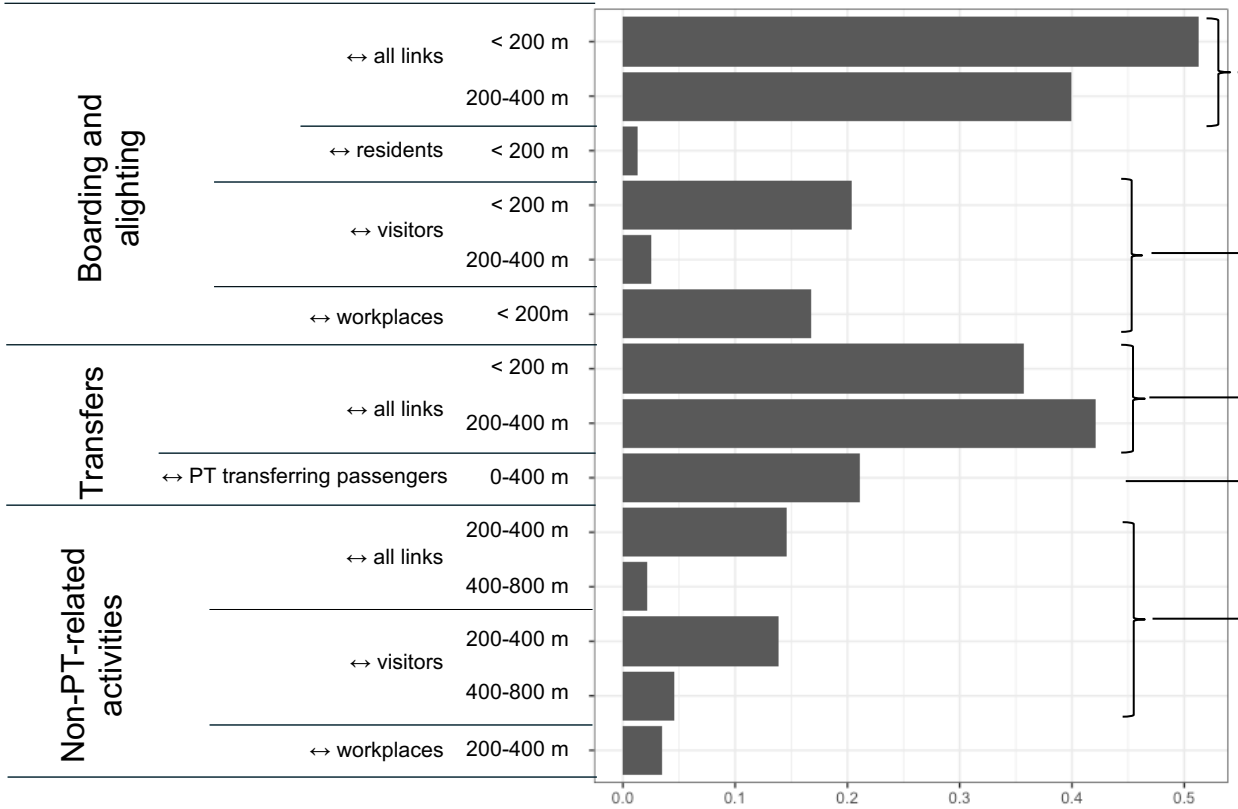
LUCERNE



Most important access- and egress predictors are independent of trip generation and attraction

Access- and egress from public transport to shops and jobs

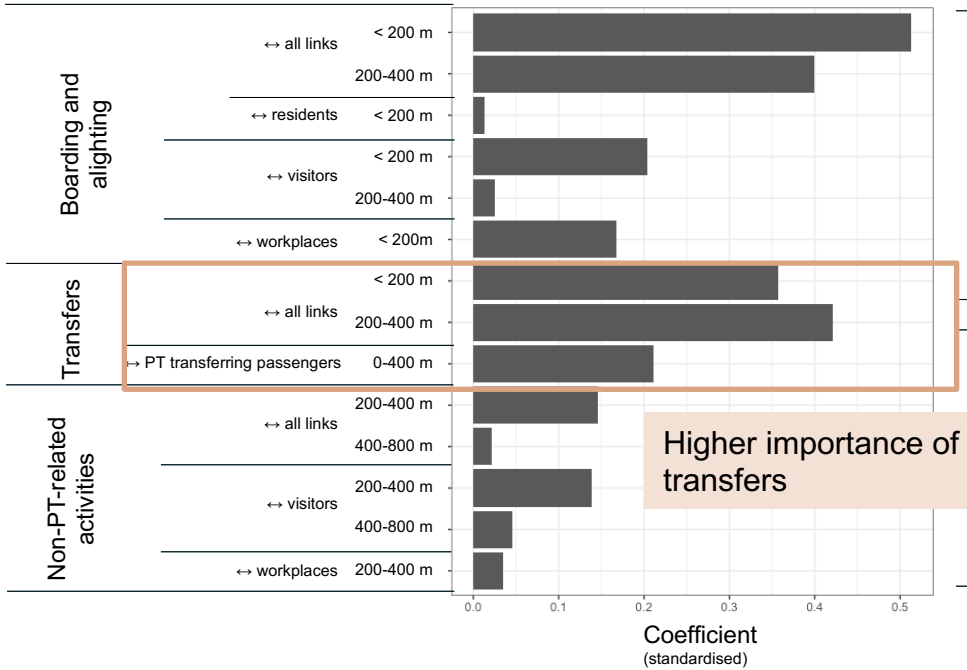
Pedestrian volumes on all surrounding links!

Less direct impact on volume between platforms

Distance decay: decreasing importance with longer distances.

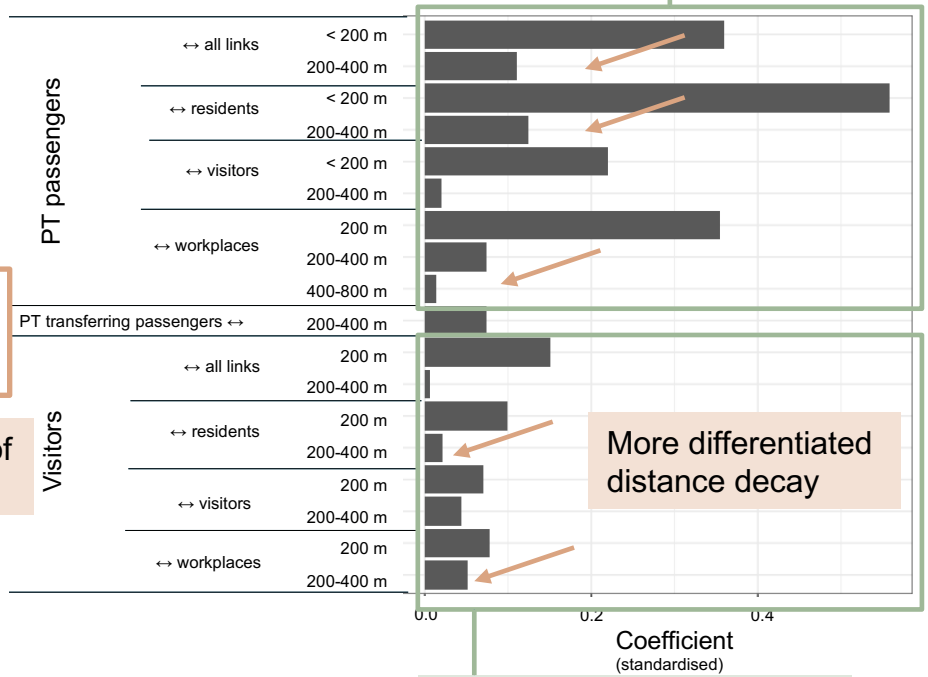
COMPARISON OF MODEL PARAMETERS

Lucerne



Higher importance of transfers

Uster



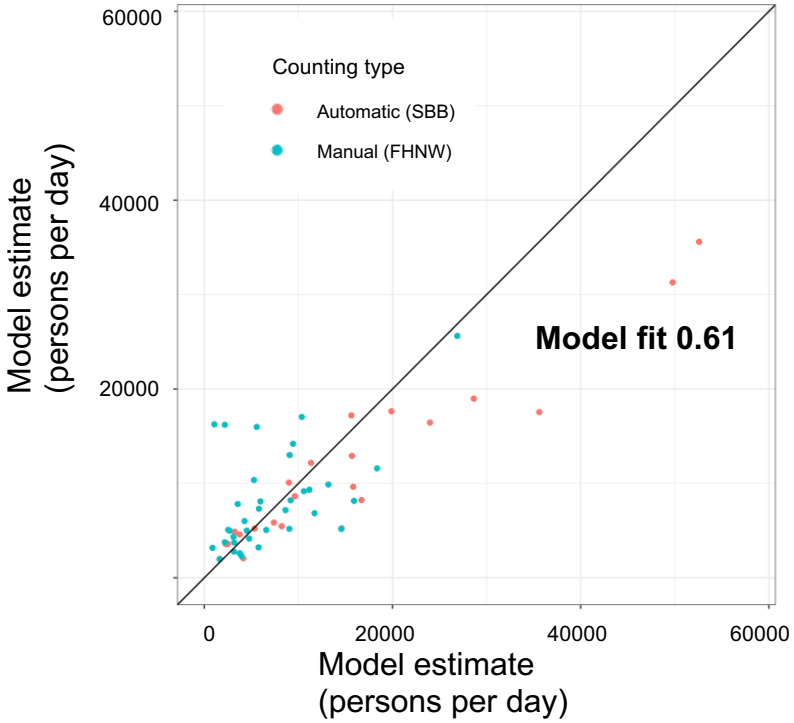
Access and egress as most important drivers of pedestrian link volume

More differentiated distance decay

Non-PT-related activities of secondary importance

MODEL FIT

Lucerne



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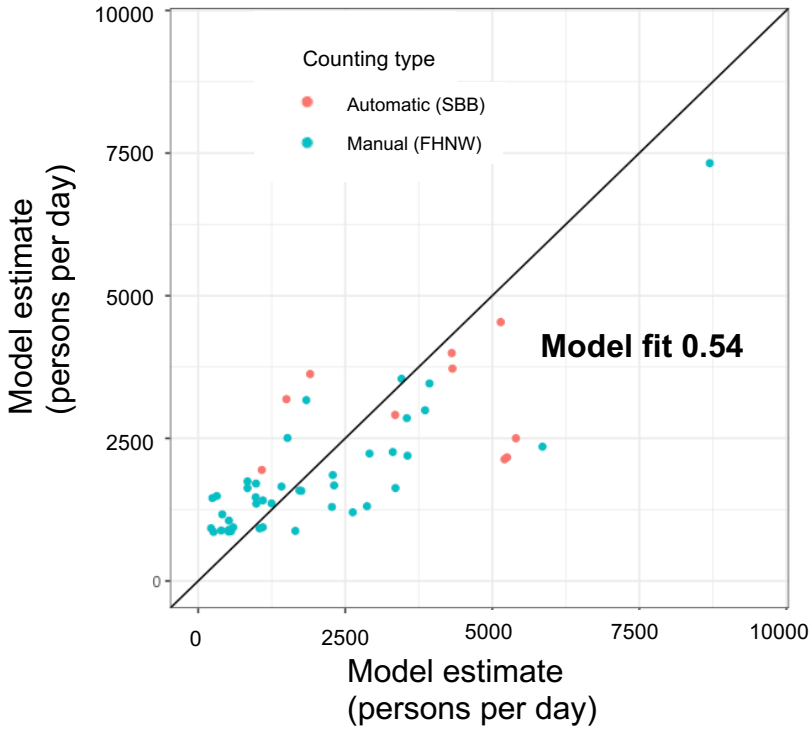
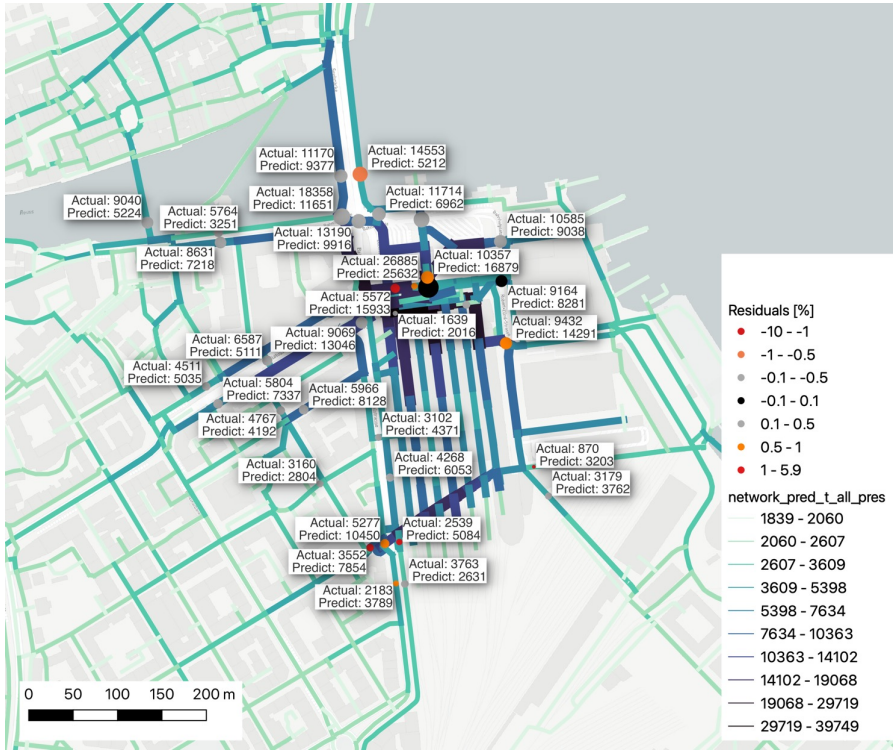


NETWORK VOLUMES

Lucerne



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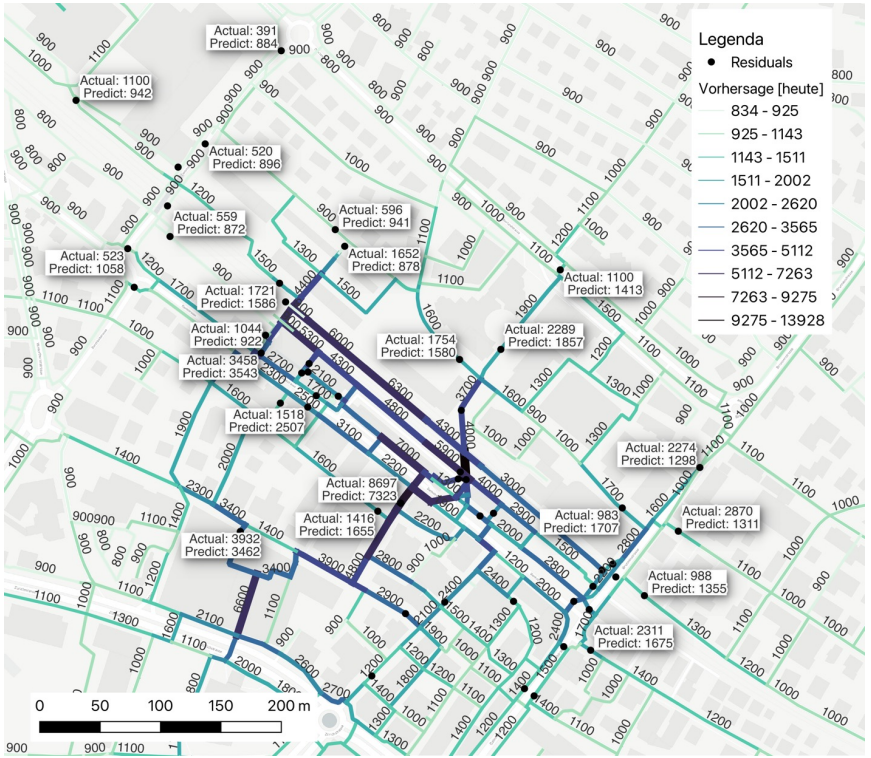

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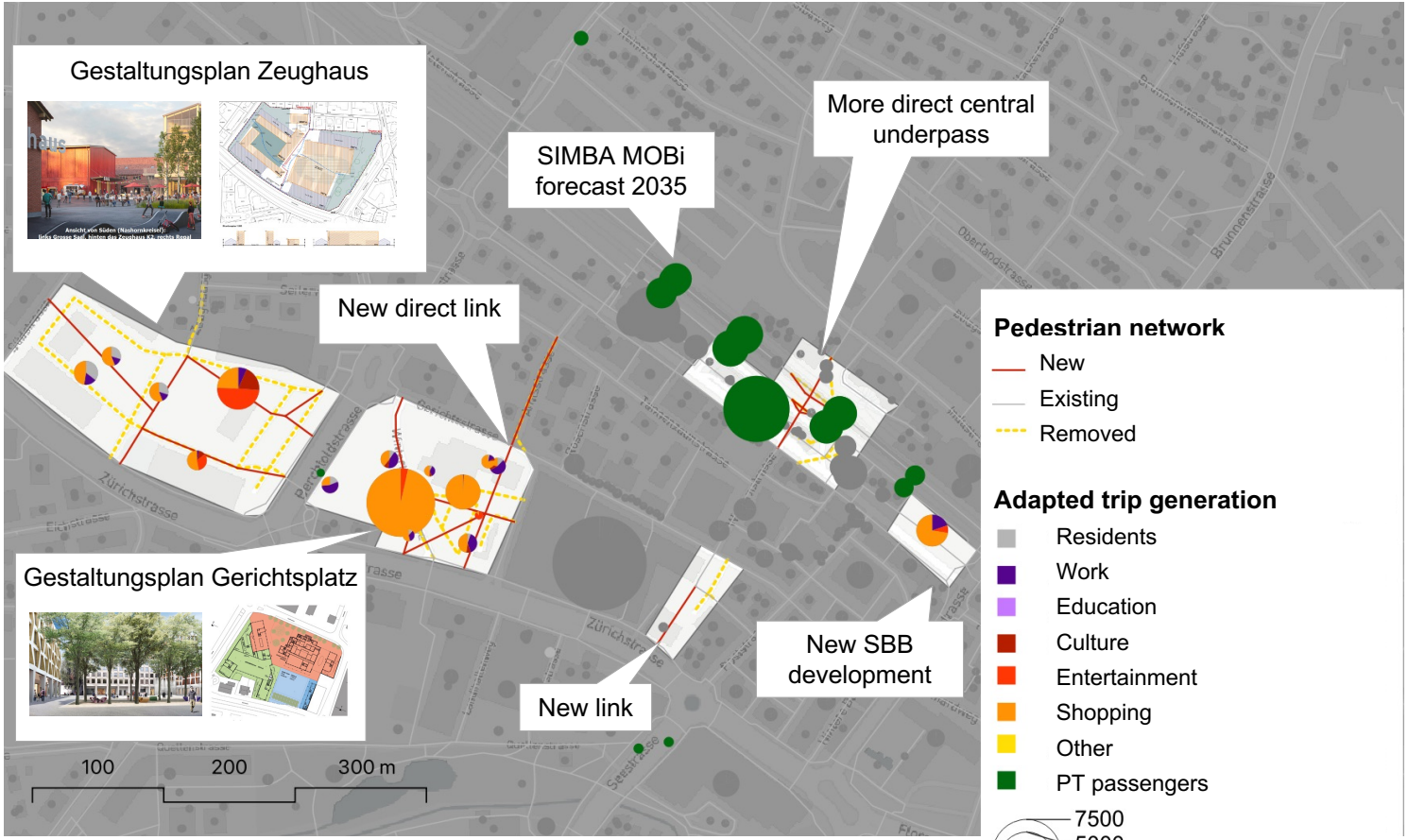
MODELLING PEDESTRIAN FLOWS WITH PLANNED DEVELOPMENTS



IMPACT OF NEW DEVELOPMENTS AND NETWORK CHANGES ON PEDESTRIAN VOLUME

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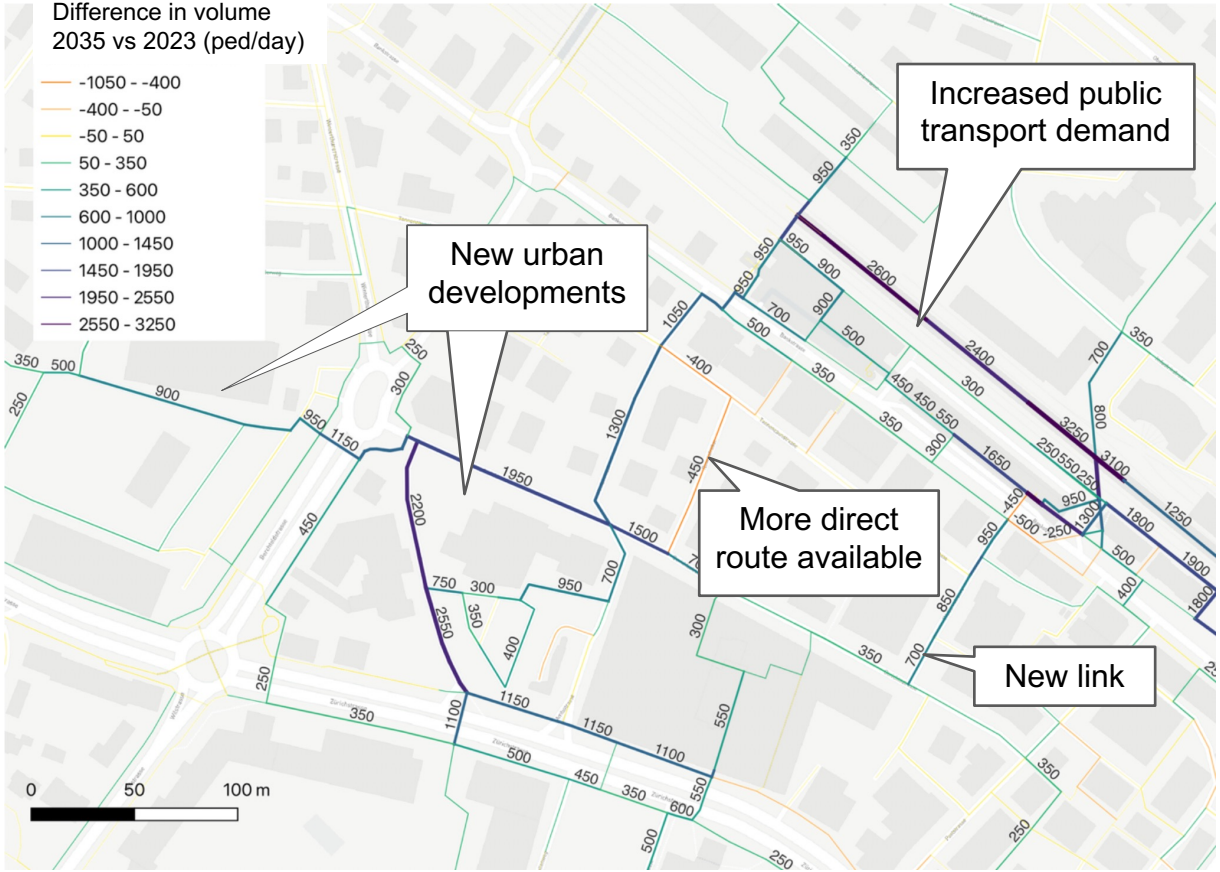
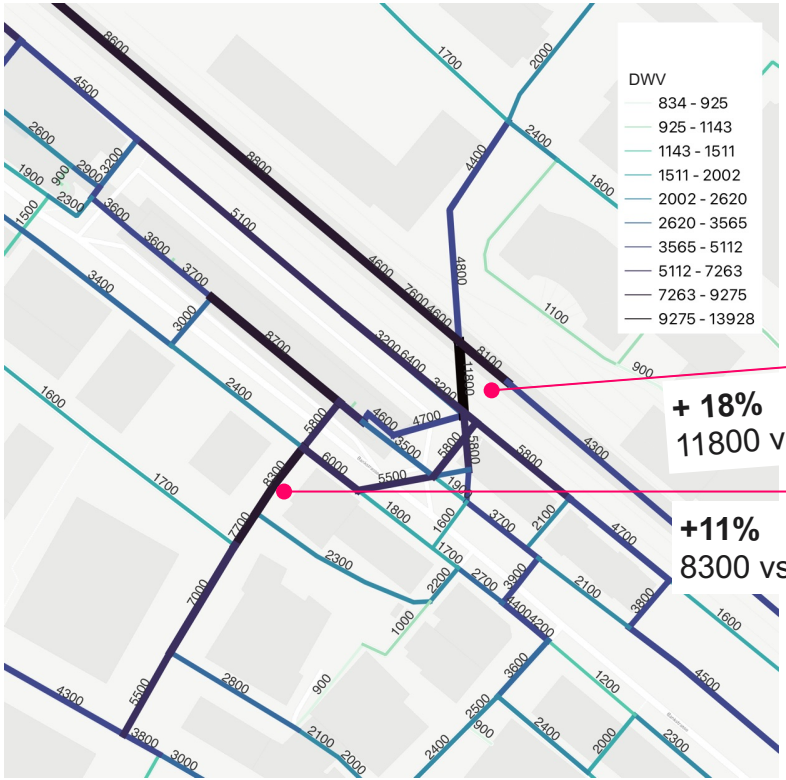


Change of pedestrian volume plotted on current network

IMPACT OF A MORE DIRECT CENTRAL UNDERPASS

Current network with demand for year 2035



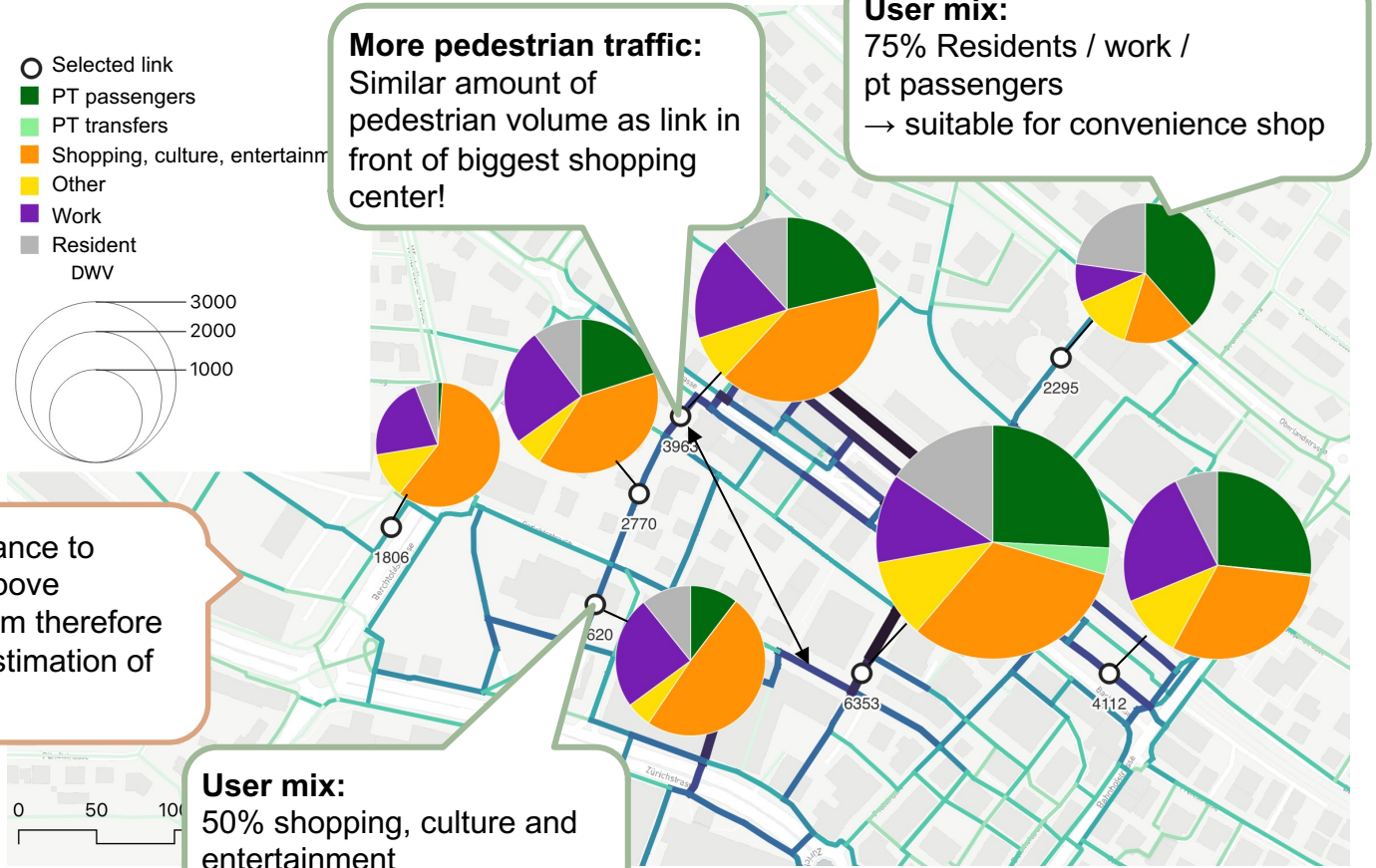
Adapted network with demand for year 2035

+ 18%
11800 vs. 13900 P/d (DWV)

+11%
8300 vs. 9200 P/d (DWV)

The more direct underpass leads to a **concentration of foot traffic** due to route choice effects.

CHARACTERISATION OF PEDESTRIAN TRAFFIC



More pedestrian traffic:
Similar amount of pedestrian volume as link in front of biggest shopping center!

User mix:
75% Residents / work / pt passengers
→ suitable for convenience shop

Limitation: Distance to railway station above threshold of 400 m therefore potential underestimation of expected flow

User mix:
50% shopping, culture and entertainment
→ suitable for coffee shop

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LIMITATIONS

Transferability of models:

- **Similar model structure** and **importance of variables**
- **Differences** with regards to **differentiation of individual variables**

Spatial context

- In Uster: **manual adjustments to trip generation factors for supermarkets** (city vs. residential neighborhood) increased model fit.
- **Visibility and accessibility as additional factors** to explain trip generation and attraction

Daily averages:

- Pedestrian flows are currently modelled as **undirected daily averages** during a workday.
- Pedestrian flows and its composition vary considerable over the time of the day. Therefore, also **daytime specific parameters** would need to be estimated (see e.g. Sevtsuk et al. 2021)

Direct demand model

- Pedestrian volumes are estimated based **solely on betweenness indicators**.
- Flows are **not necessarily consistent with trip attraction / generation**.

FUTURE RESEARCH

Validation of models: Application in other railway stations of similar spatial context.

Regression of pedestrian trip attraction: Differentiate for spatial context and pedestrian accessibility.

More detail: Define pedestrian flow models that differentiated between directions and times of the day.

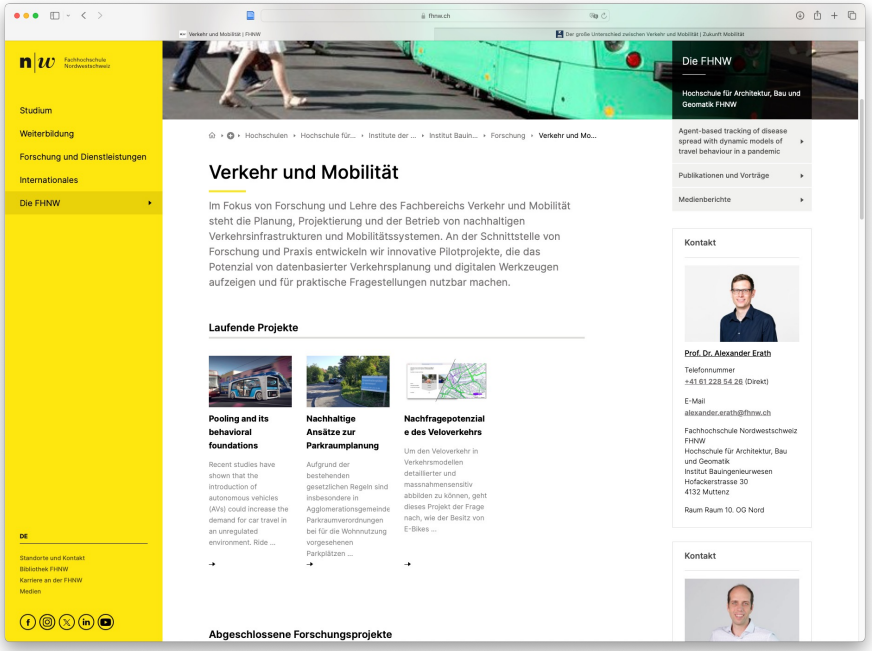
New Method: Application of **trip distribution model and OD-matrix estimation** based with trip specific distance decay function and replace betweenness measures

THANK YOU

🙏 Funding from SBB Research Funds

🙏 Whole project team, in particular Michael van Eggermond

🙏 Your attention and contribution to the discussion



https://www.fhnw.ch/verkehr-und-mobilitaet

APPENDIX

LITERATURE

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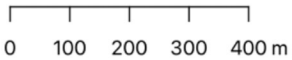
TRIP GENERATION / ATTRACTION FACTORS

	Trips per day	Source
Residents	1.73 per resident	MZMV 2015, «Kernstadt» only
Employment «general»	1.21 per FTE	MZMV 2015, «Kernstadt» only
Employment «shop»	25 – 100 per (FTE)	Own analysis
Employment «education»	40 per FTE	Bubenhofer (2022)
Employment «culture»	24 per FTE	Bubenhofer (2022)
Employment «entertainment»	46 per FTE	Bubenhofer (2022)
Public parc	700 per ha	Own analysis

TRIP ATTRACTION AND GENERATION

Lucerne



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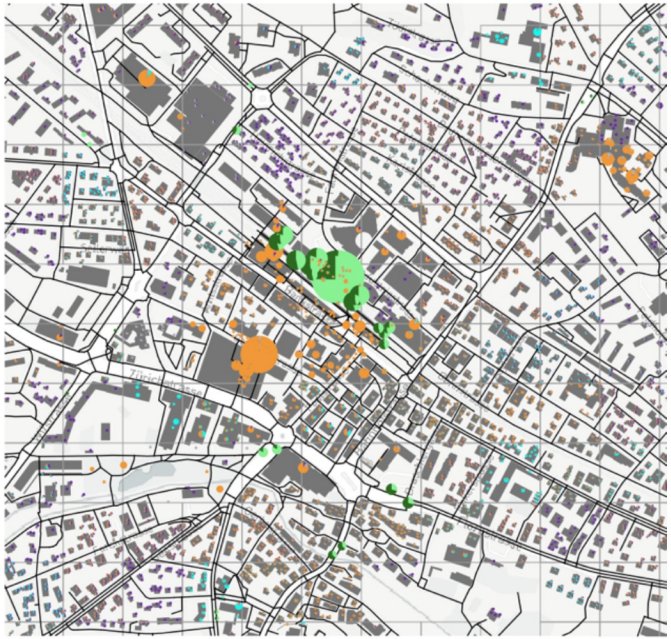
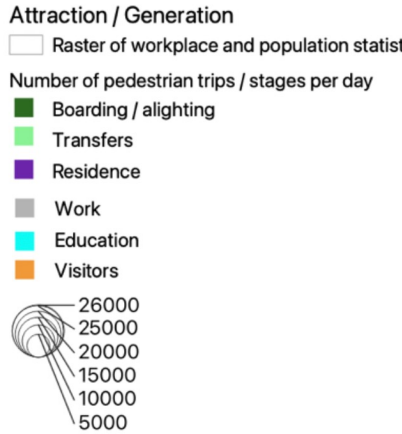
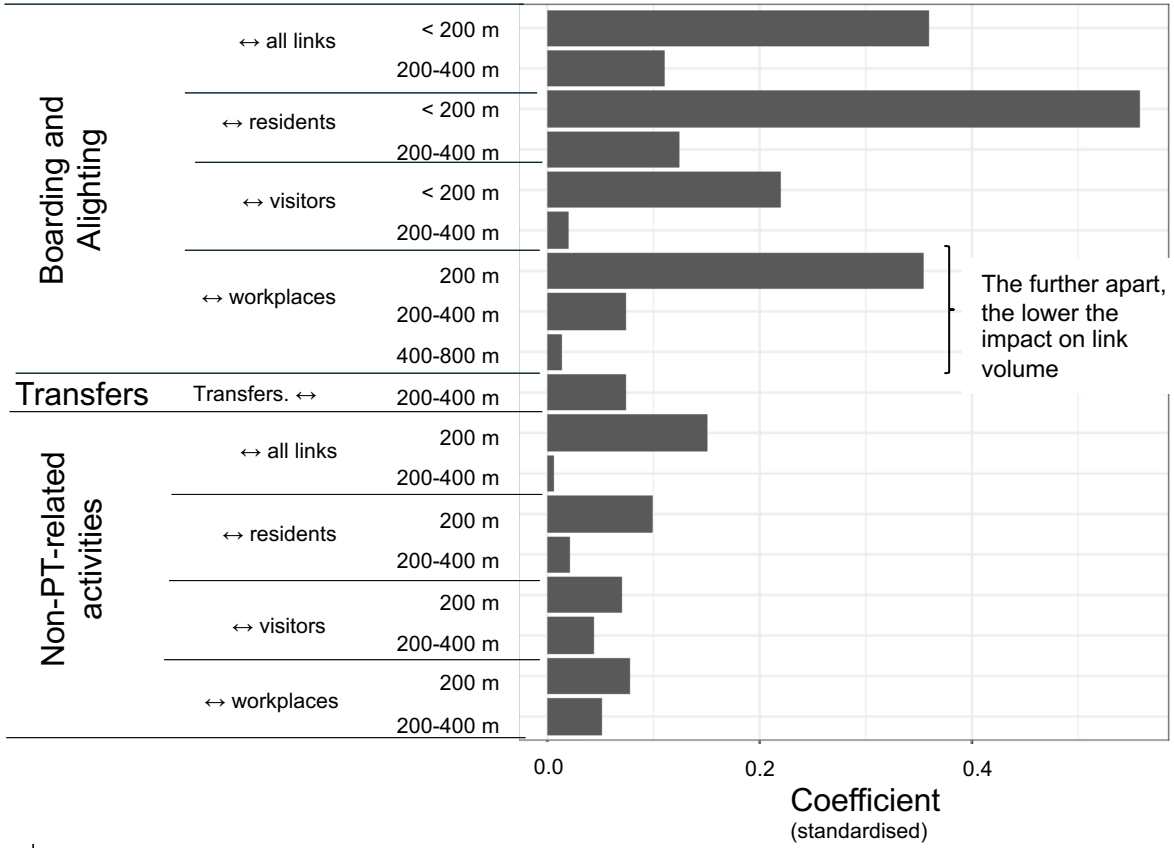




USTER: RESULTS OF LASSO REGRESSION



The further apart, the lower the impact on link volume

Public transport as most important driver of pedestrian link volume

Estimates of pedestrian activities (visitors) as second important driver of pedestrian link volume