Chair of Traffic Engineering and Control
TUM School of Engineering and Design
Technical University of Munich

A Cross-City Comparative Study - Athens and Munich: Road Network Quality and Multimodal Perceived Safety

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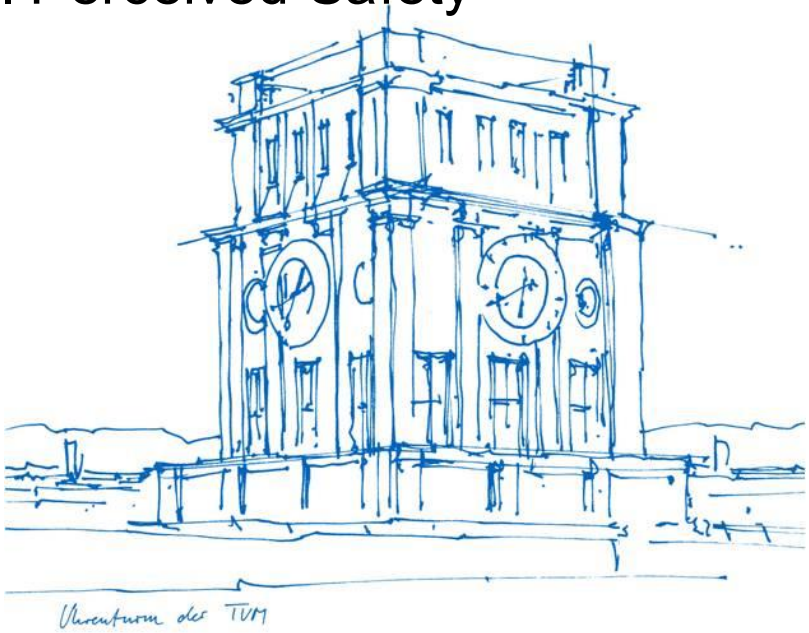


Background

- Traffic system development requires a multimodal perspective
- Micromobility is increasingly promoted as sustainable transport



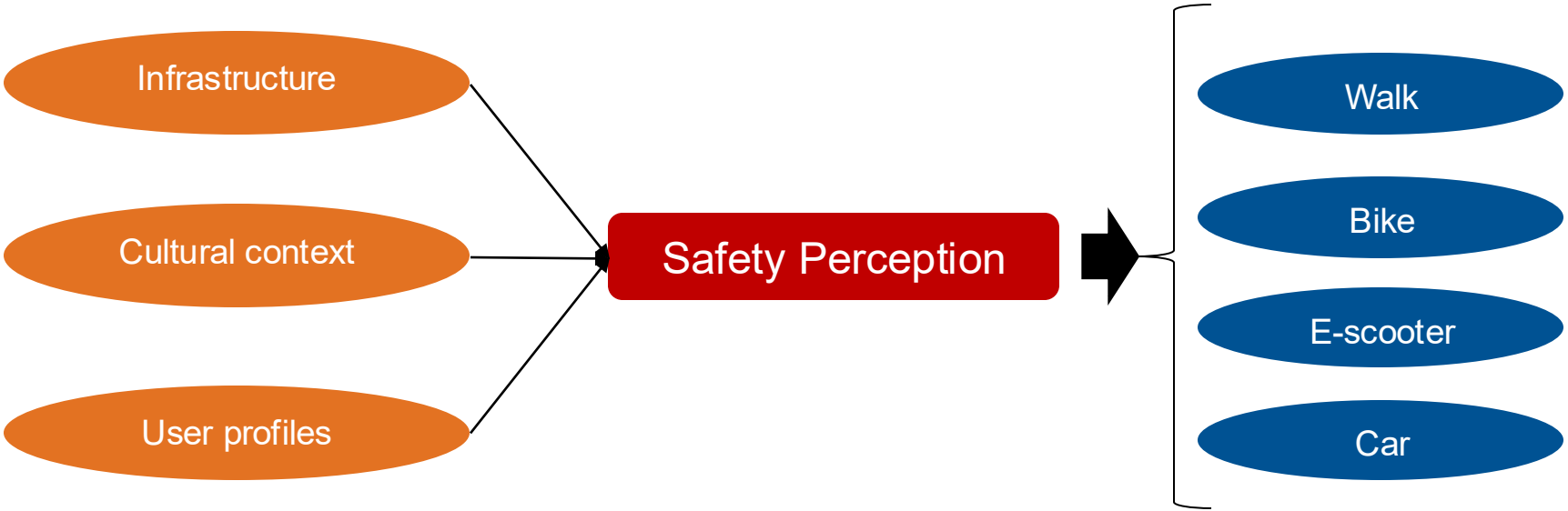
- Complex urban transport environments are also a source of daily stress for users



Hypothesis

Varied factors might affect on Safety Perception

Safety Perception might affect on mode choice



State of art: safety perception/stress research

- Infrastructure-based stress indices
  -> **Subjective safety perception** is missing

- Physiological stress measurement
  -> costly and **hard to scale**
  -> Not clear yet the connection with mode choice

- Single city / single mode focus
  -> **Holistic analysis** is missing

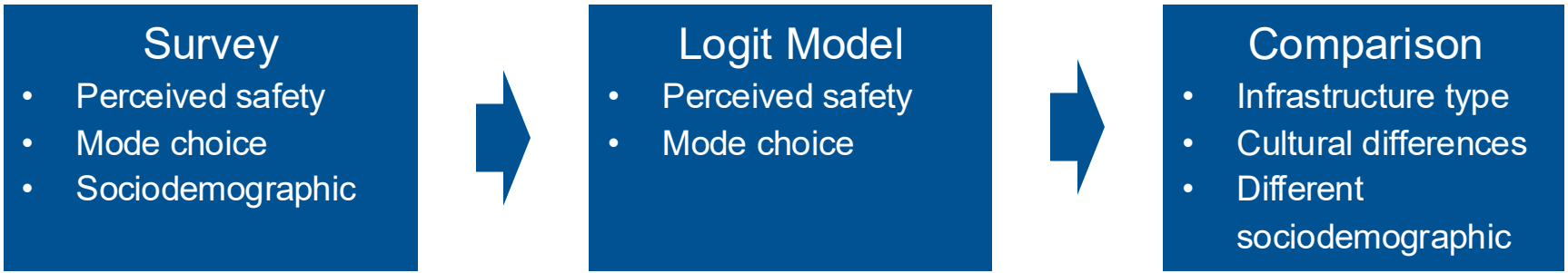
➡ Survey-based:
subjective safety perception

➡ Cross-country comparison

➡ Multimodal analysis:
Walk, Bike, E-scooter, Car

Aim and Approach

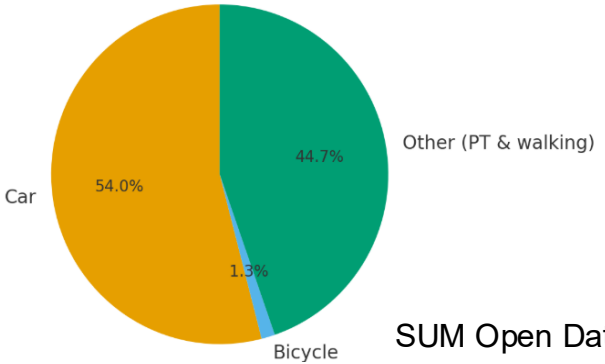
Understand how **infrastructure design** and **cultural context** affect **multimodal safety perception** and **mode choice**.



Study Area

Athens (Tzouras et al. (2024))

- “Car-dominant city”
- Population: 643 thousand (in the centre)
- Car-centric road network, fewer cycle lanes



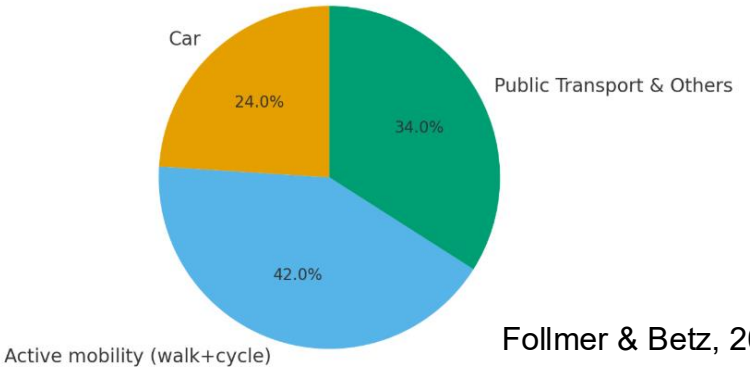
SUM Open Data Platform, 2024



Study Area

Munich

- “Micromobility-friendly”
- Population: 1.6 million
- Over 1200 km cycling network



Follmer & Betz, 2018



Survey Contents

1. Perceived Safety

- *"How safe do you feel on this road?"* (1–7 scale)
- Follow-up (Munich only): reasons for feeling unsafe
  e.g., traffic, no crossings, bad pavement

2. Mode Choice

- *"Which mode would you choose?"* (Car, Bike, E-scooter, Walk)

3. Personal Information

- Age, gender, education, income,
- Vehicle ownership, license
- Frequency of using each mode

How safe do you feel on this road? Rate each case from 1 (not at all safe) to 7 (very safe).



Mark only one oval per row.

	1(not at all safe)	2	3	4	5	6	7(very safe)
Driving a car	◯	◯	◯	◯	◯	◯	◯
Using a shared electric bike	◯	◯	◯	◯	◯	◯	◯
Using a shared electric scooter	◯	◯	◯	◯	◯	◯	◯
Walking	◯	◯	◯	◯	◯	◯	◯

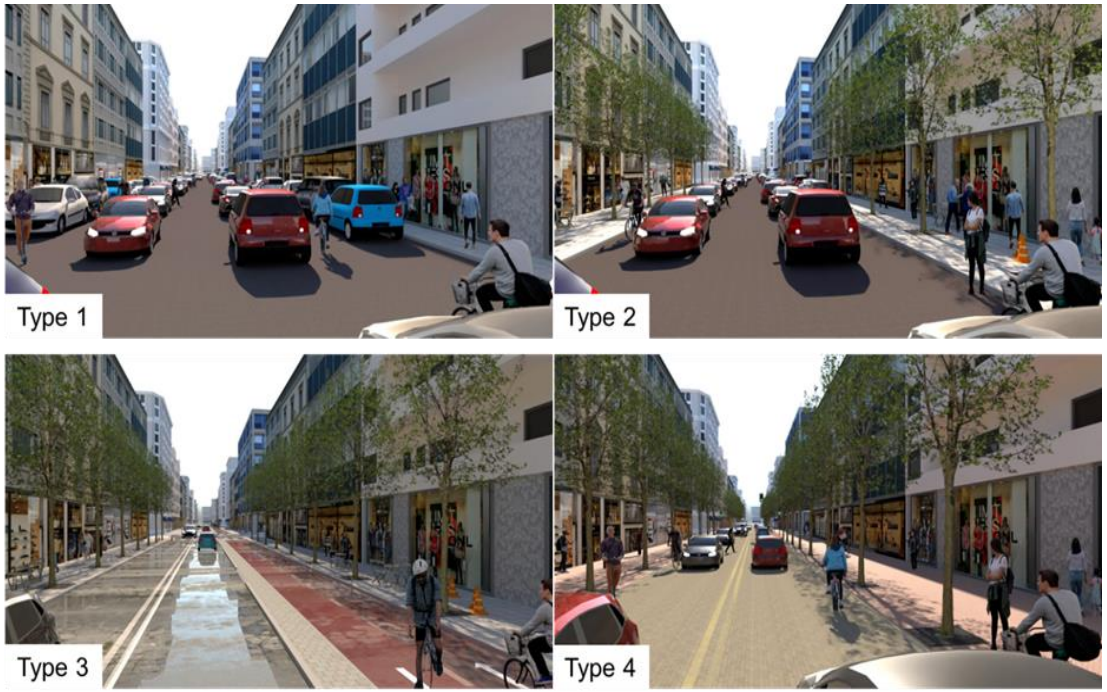
Four infrastructure types (Tzouras et al. (2024))

Type 1 – Car-Dominated
- Narrow sidewalk (<1.5 m) + No vegetation
- No bike lane

Type 2 – Wider Sidewalk
- Broader sidewalks with vegetation
- No bike lane

Type 3 – Cycle-Friendly
- Two-way bike lane with buffer
- No parking space

Type 4 – Shared Space
- All modes share the street
- Speed limit reduced (30 km/h)



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Perceived Safety Level Calculation

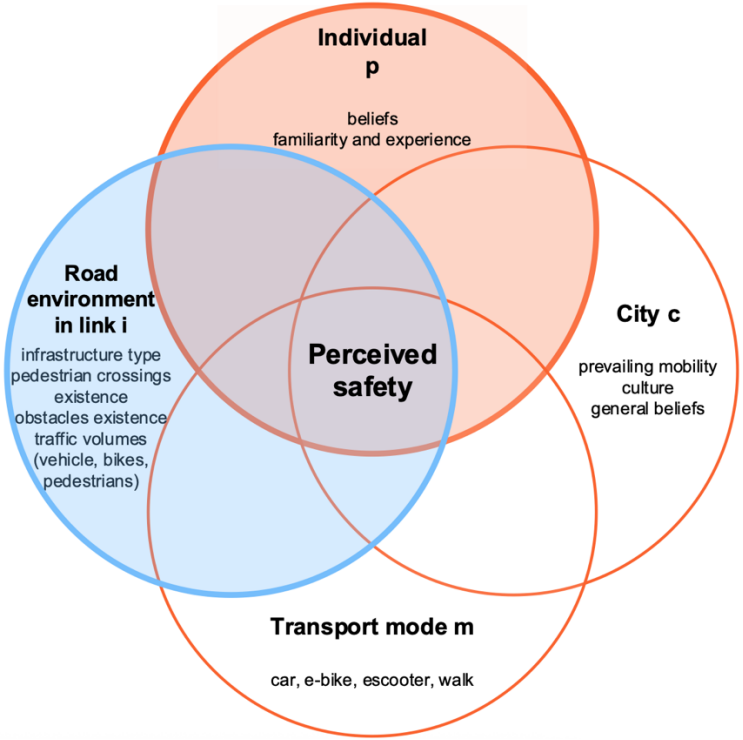
(Tzouras et al. (2024))

$psafe *_{p,i,m,c} =$

$$\left(\sum_{t=1}^{T} \beta_{soc(t)_m} \times soc(t)_i + \sum_{t=1}^{T} \beta_{beh(t)_m} \times beh(t)_i\right)$$

$$+\beta_{type_{,m}} \times type_s \quad \text{(Type 1-4)}$$
$$+\beta_{pav_m} \times pav_s \quad \text{(Good or Bad)}$$
$$+\beta_{obs_m} \times obs_s \quad \text{(Present or not)}$$
$$+\beta_{cross_m} \times cross_s \quad \text{(Zebra, signalized, or no crossing)}$$

$$+\beta_{veh_m} \times veh_s + \beta_{bike_m} \times bike_s + \beta_{ped_m} \times ped_s$$



β: Calculated by Maximum likelihood estimation based on survey responses

Mode Choice Calculation

(Tzouras et al. (2024))

Utility function

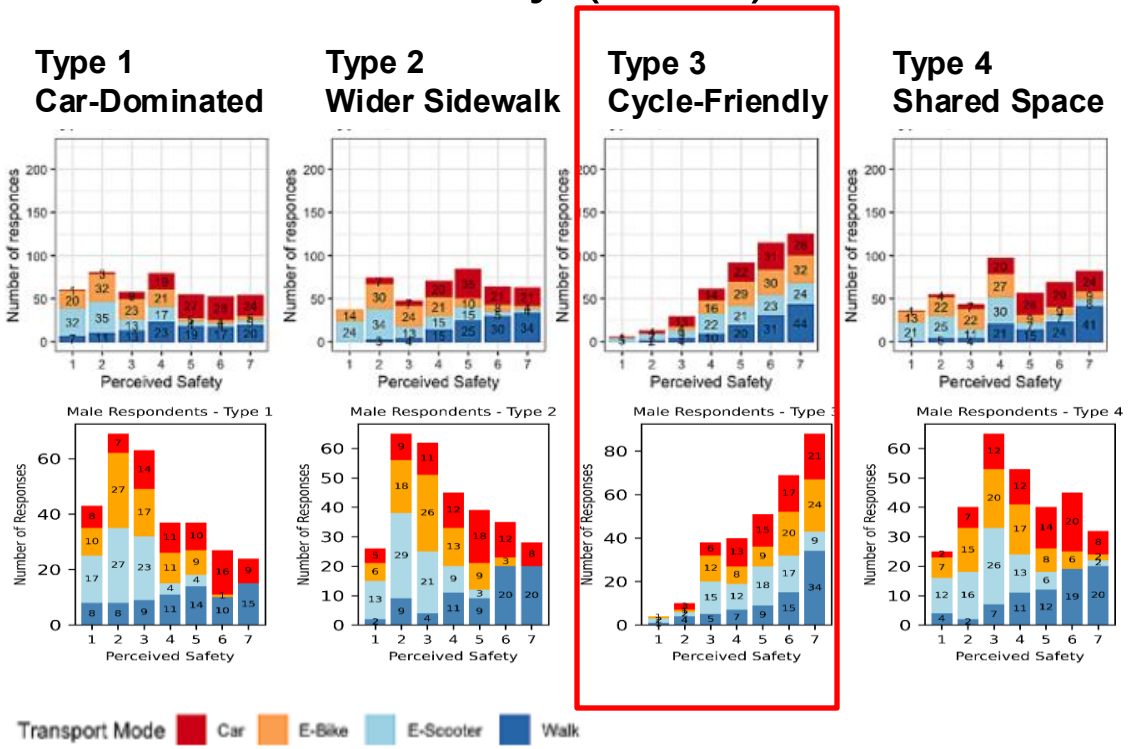
$$U_{i,m,s} = \beta_{0,m} + \beta_{time_m} \times time_{m,s} + \beta_{cost_m} \times cost_{m,s} + \beta_{psafe_m} \times \left(psafe_{i,m,s} - 4\right) + \epsilon_{i,m,s}$$

Travel time of mode m

Travel cost of mode m

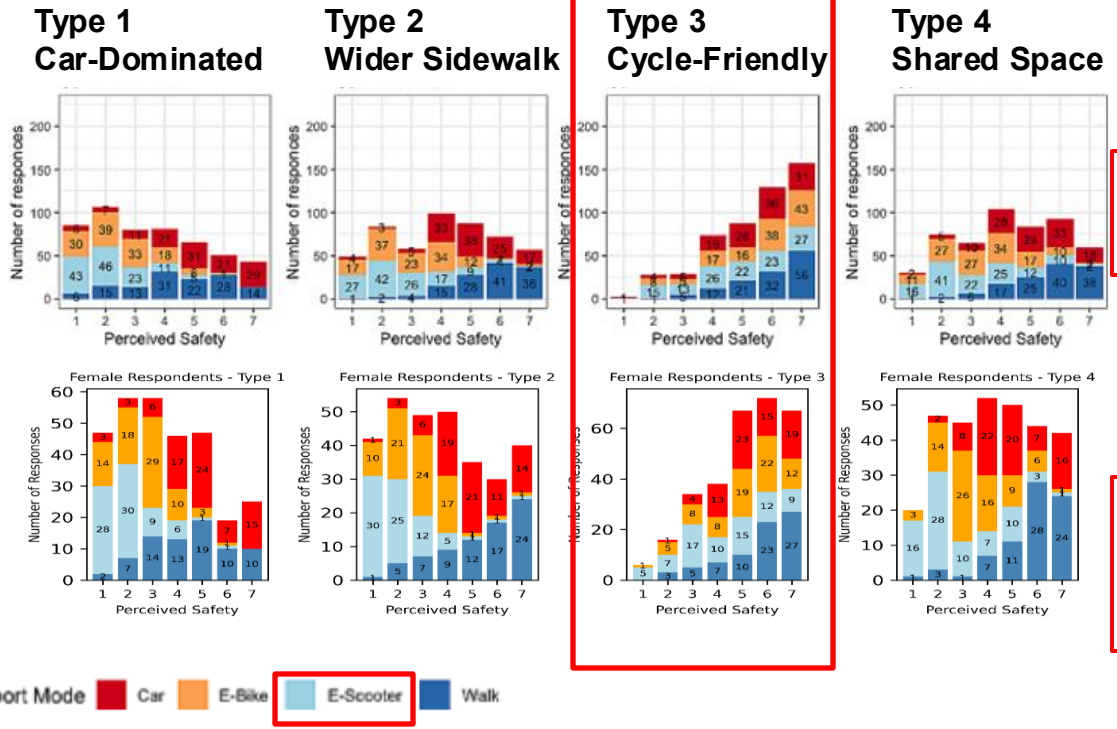
Perceived safety level (Perceived safety levels below 4 increase the disutility of mode m)

Result: Perceived Safety (male)



Median safety:
Athens = 5, Munich = 4

Result: Perceived Safety (female)



Munich Female feels lower safety in Type 3

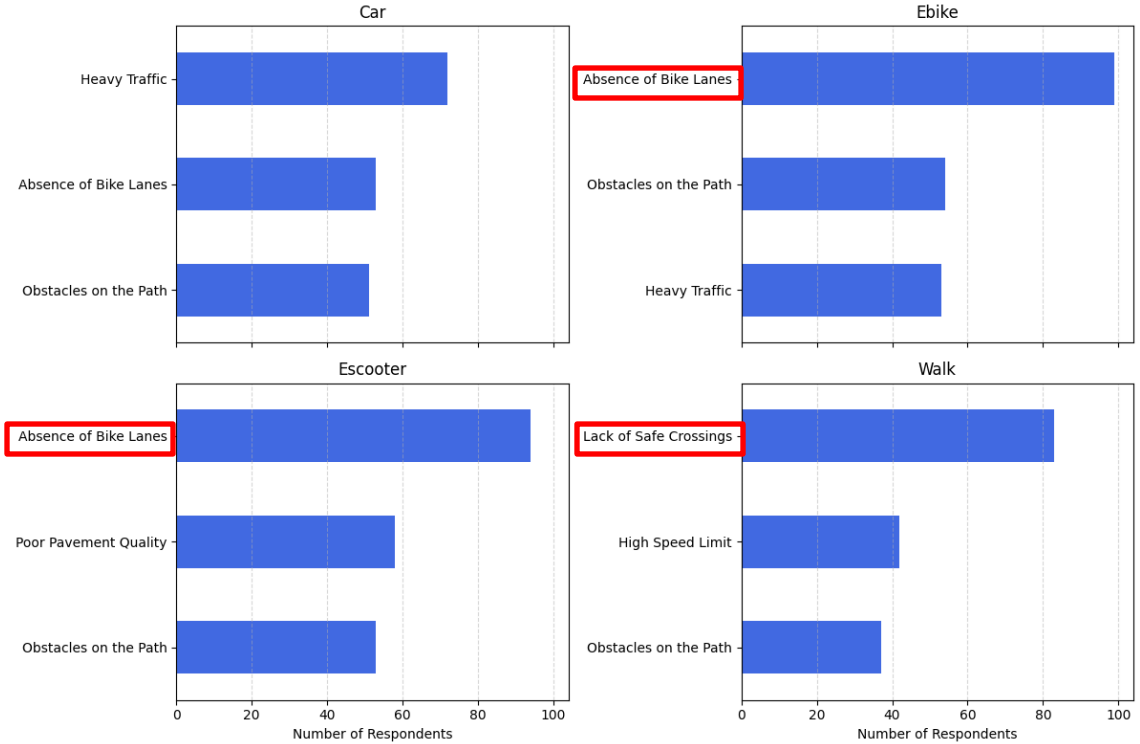
E-scooters consistently lowest rated (unsafe in both cities).

Result: Perceived Safety Factors

P value for Perceived Safety model parameters (95% confidence interval for the variable)

	Car		Bike		E-scooter		Walk	
City	**Athens**	**Munich**	**Athens**	**Munich**	**Athens**	**Munich**	**Athens**	**Munich**
Age	0.005*	No	0.001*	0.036*	0.003*	<0.001*	No	0.037*
License Ownership	<0.001*	<0.001*	No	No	No	<0.001*	<0.001*	No
Zebra Crossing	<0.001*	0.021*	0.001*	0.023*	< 0.001*	0.024*	<0.001*	<0.001*
Crossing w/signals	No	0.005*	No	0.003*	No	0.013*	No	<0.001*
Pavement	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.028*	0.002*
Obstacles	0.040*	No	<0.001*	<0.001*	<0.001*	No	<0.001*	No
Vehicle density	No	No	0.017*	No	No	No	No	No
Bike density	No	No	No	No	No	No	0.050*	No
Pedestrian density	No	No	No	No	No	No	No	No
Type1	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Type2	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.027*
Type4	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.002*	No

Result: Reasons for Unsafe Feeling (Munich)



Lack of infrastructure (bike lanes, crossings) affects on VRU unsafe feelings

Result: Mode Choice

Binary Logit Model results (P value: 95% confidence interval for the variable)

	Car		Bike		E-scooter		Walk	
	Athens	**Munich**	**Athens**	**Munich**	**Athens**	**Munich**	**Athens**	**Munich**
Travel Costs	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	0.004*		
Travel Time	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*	0.001*	< 0.001*	0.001*
Perceived Safety	< 0.001*	No	< 0.001*	< 0.001*	< 0.001*	0.001*	< 0.001*	No

Perceived safety influences micro-mobility choice

Perceived safety influences other mode choice only in Athens

Conclusion

- **Infrastructure design** affects perceived safety
  - Especially **the presence of crossings, bike lanes,** and **pavement quality** have a strong influence
  - Influence is different in **different traffic modes**

- There might be differences according to **cultural context**
  - The **presence of obstacles** affects on perceived safety of the Athens people but not Munich people
  - Munich people generally have a lower safety perception

- Perceived stress did not significantly vary across socio-demographic groups in this study

- Results provide input for **fair, user-oriented transport policy**

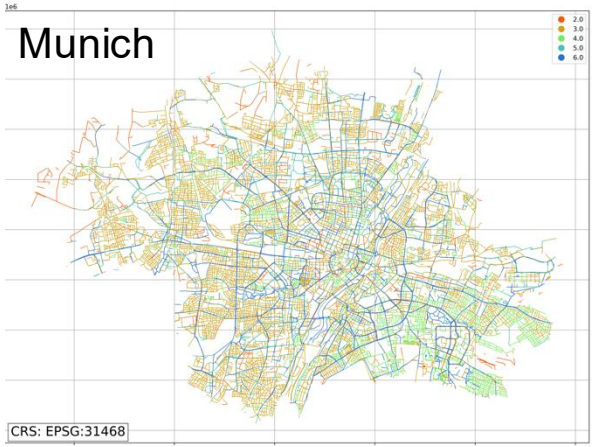
Limitation/ Future applications

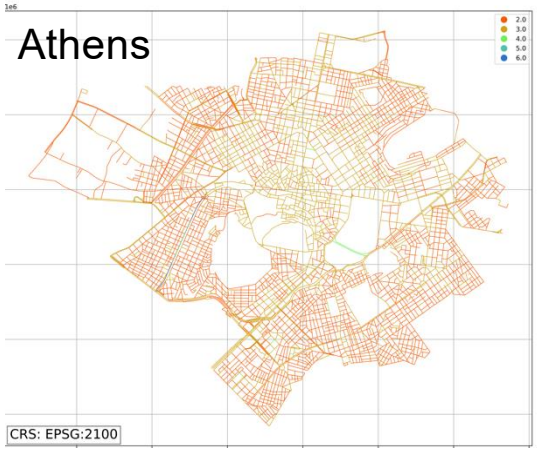
Limitation

- Sample bias: Munich survey (n=50) mostly young and educated students.
- Survey images cannot capture all real-world complexities.

Future application

- **Subjective vs Objective:** Comparison of infrastructure type influence on perceived safety and physiologically detected stress
- **Cultural influence:** Perceived safety of Athens from Munich people, and vice versa (to be published)
- **Digital twin:** visualizing perceived stress of different modes





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