

# Traffic Noise Modeling in Agent-Based Land Use/Transport Models

Doctoral Defense, December 1, 2021

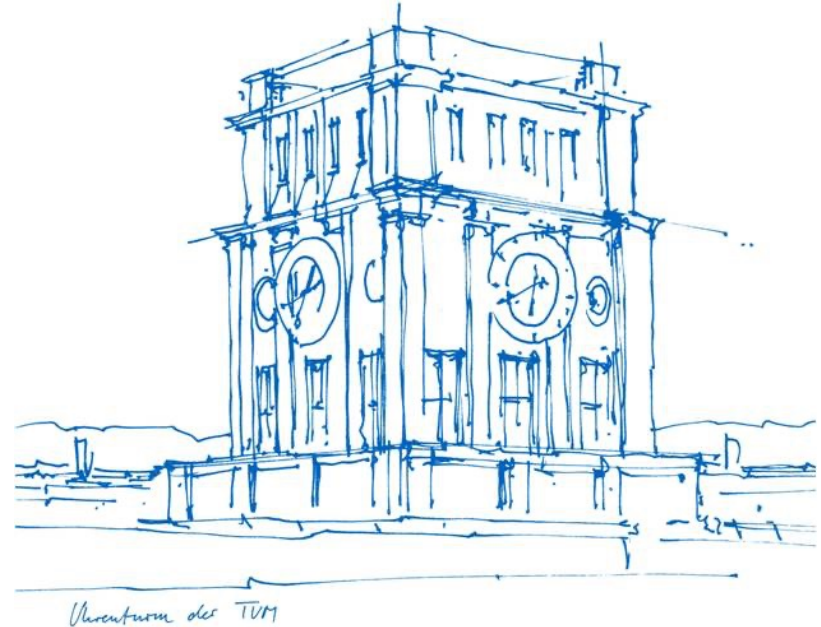
Nico Kuehnel

## Examination Committee

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1. Prof. Dr.-Ing. Rolf Moeckel
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# Introduction



# (Road) Traffic Noise

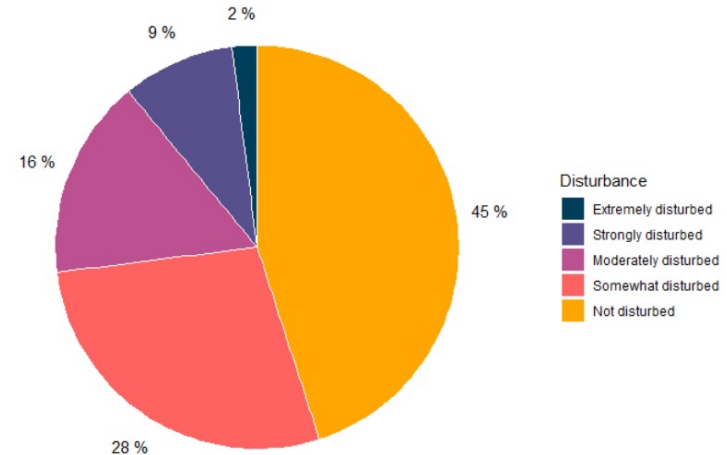
- Caused by:
  1. Propulsion noise
  2. Rolling noise
  3. (Aerodynamic noise, negligible for speeds < ~130km/h)
- Usually described in **dB(A)**

	dB(A)	
Extremely Loud	120	Aircraft at take off
	110	Car horn
	100	Subway
Very Loud	90	Truck, motorcycle
	80	Busy crossroads
	70	Noise level near a motorway
Loud	60	Busy street through open windows
	50	Light traffic
	40	
Moderate	30	Quiet room
	20	
	10	Desert
Faint	0	Hearing threshold

# (Road) Traffic Noise May...

- Impair **health** of exposed residents
  - Reduce **quality of life** and well-being
  - Reduce neighborhood **attractiveness**
  - Decrease **value** of real estate properties
- 
- In addition, traffic noise is inherently a **negative external effect** in which the polluters and those affected can vary widely

Road noise disturbance  
in Germany

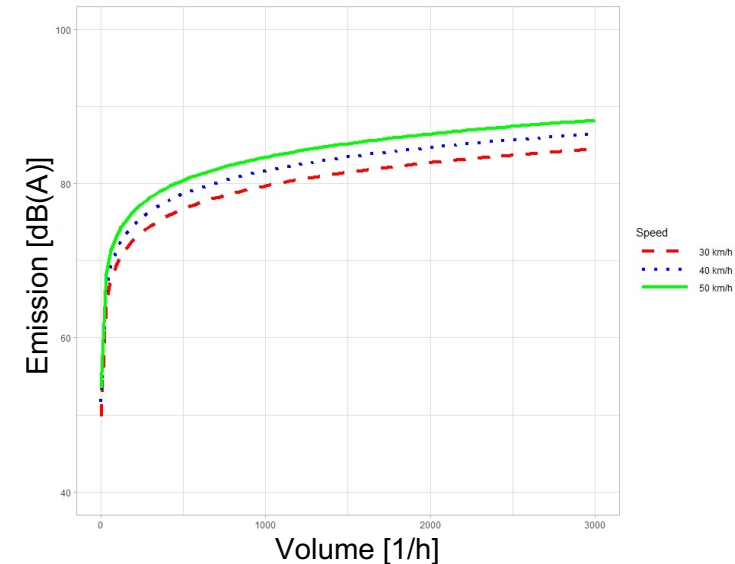


Source: Rückert-John et al. (2013) Umweltbewusstsein in Deutschland

# Noise Models

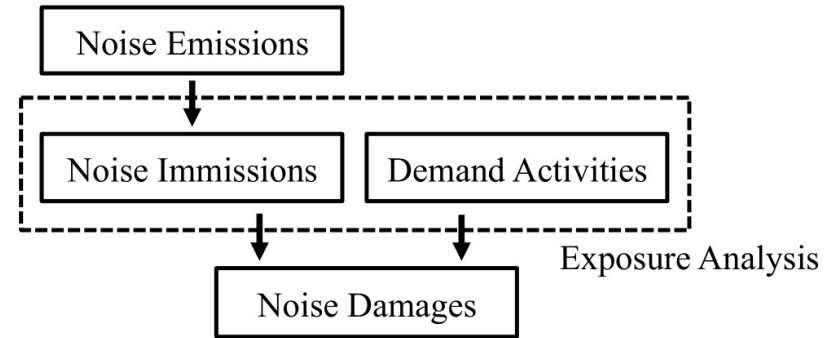
# Noise Models

- **Emissions** are modeled per road segment, taking into account traffic volumes, speeds and other factors
- Noise **immissions** are calculated per **receiver point**, taking into account surrounding emissions and sound attenuation
- Results are often compiled and displayed in strategic **noise maps**
- In Germany: guideline **RLS19** (prev. RLS-90)



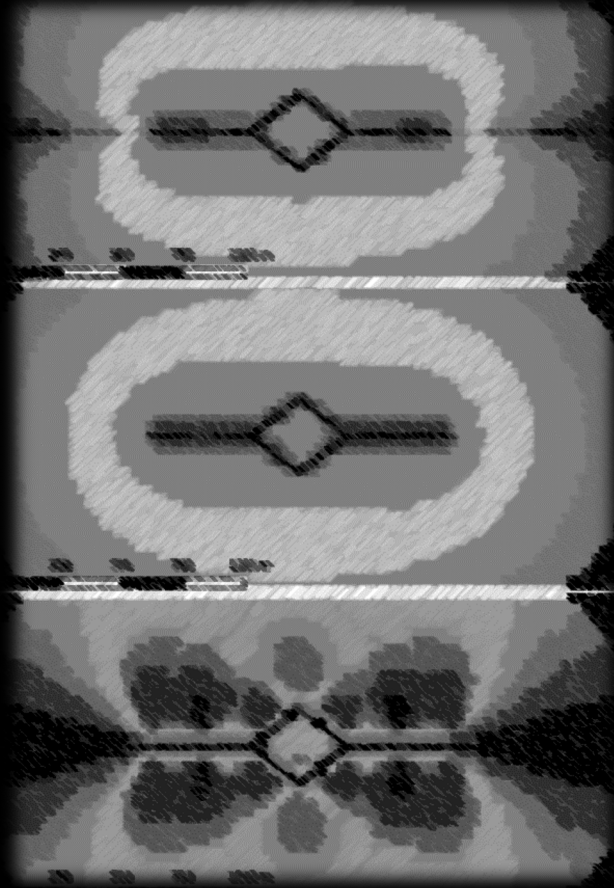
# Noise Model – Transport Model

- Since traffic noise models rely on average speed and aggregated flows, it is a natural step to couple them with **transport models**
- The transport simulation **MATSim** offers individual agents and a mesoscopic traffic flow representation that can be easily aggregated to flows
- A first implementation of the German RLS-90 has been implemented by **Kaddoura et al.** (2017)



Kaddoura, I., Kröger, L., and Nagel, K. (2017). An activity-based and dynamic approach to calculate road traffic noise damages. *Transportation Research Part D: Transport and Environment*, 54:335–347.

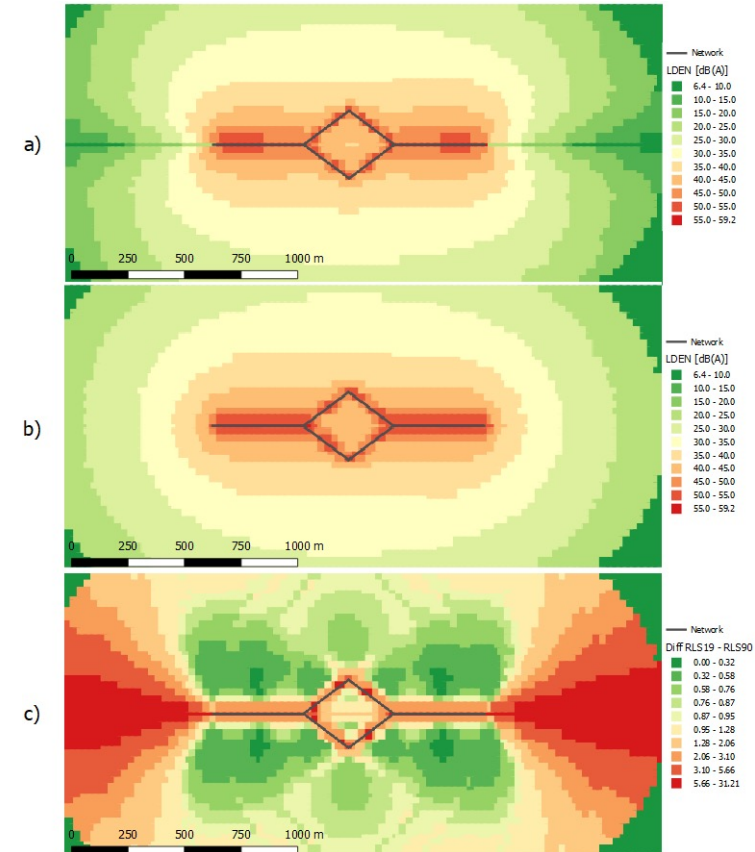
# Noise Model Updates in MATSim



Kuehnel, N., Kaddoura, I., and Moeckel, R. (2019). Noise shielding in an agent-based transport model using volunteered geographic data. In *Procedia Computer Science*, volume 151, pages 808–813. Elsevier.

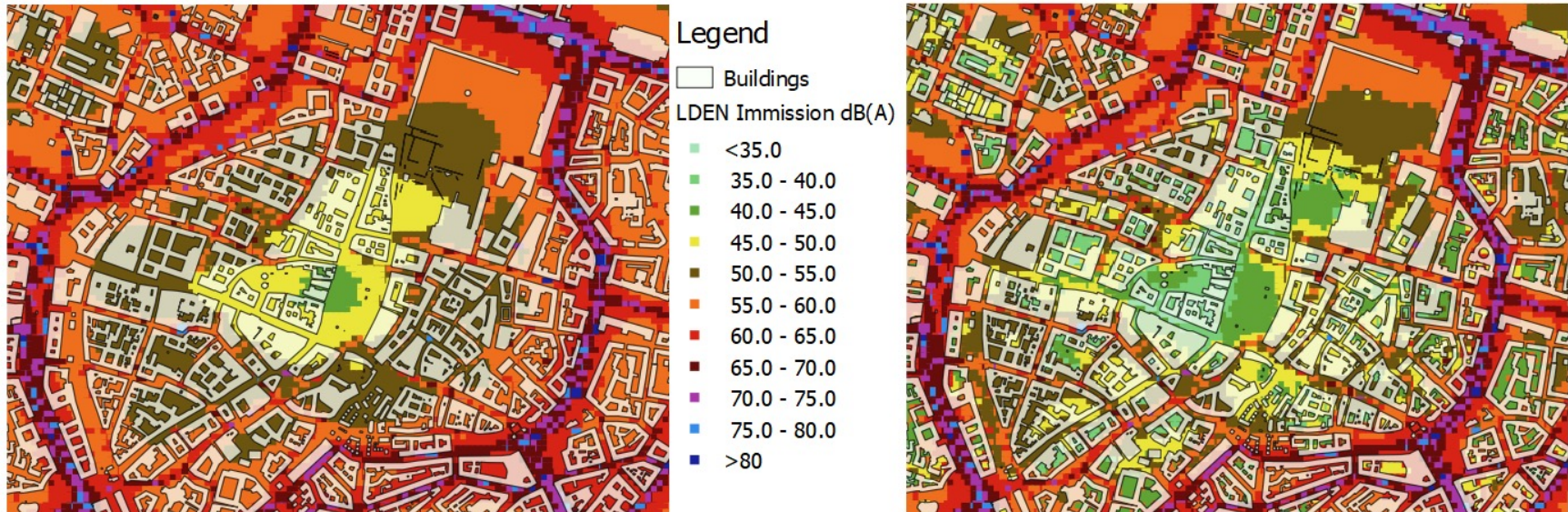
# Noise Model Improvements

- During the course of this dissertation, the old RLS-90 has been updated with the **RLS-19**
- This update has been incorporated in MATSim
- In the process, some existing limitations were removed or reduced (finer segmentation of links, **shielding and reflection effects**, ...)



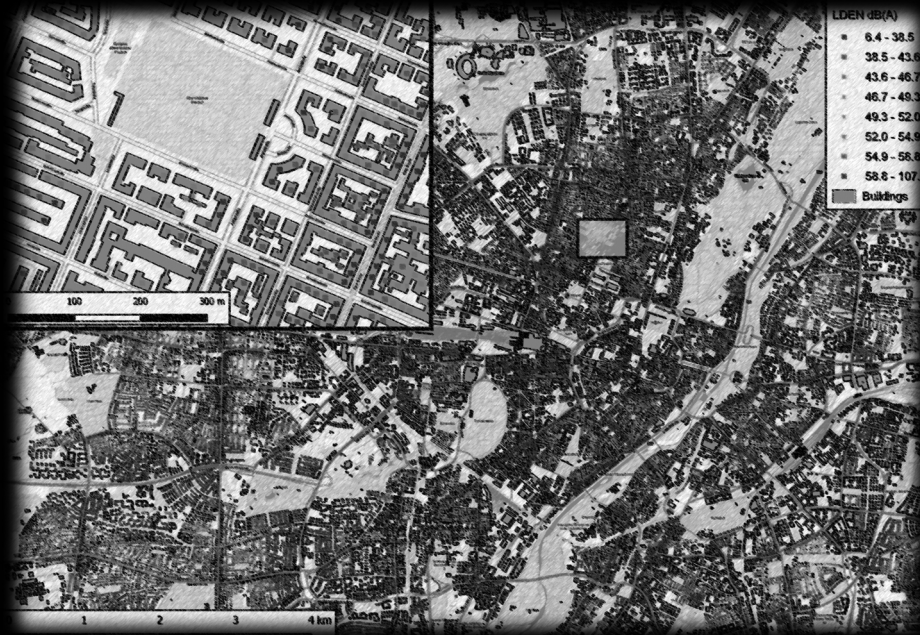
# Shielding Impact of Buildings

- In an application for Munich, the amount of external costs of noise resulted in a rough **decrease of 20%** compared to the initial implementation that ignores the shielding impacts





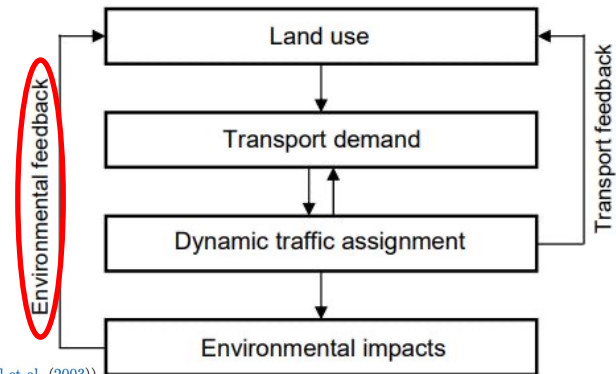
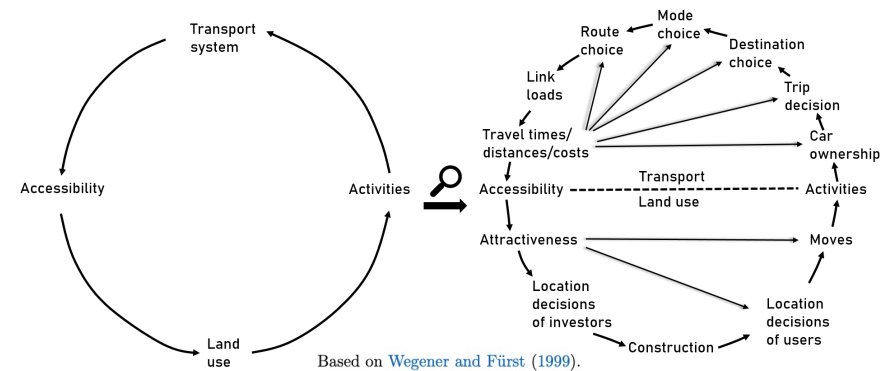
# Integrated Land Use/Transport/Environment Model



Kuehnel, N., Ziemke, D., and Moeckel, R. (2021b). Traffic noise feedback in agent-based Integrated Land-Use/Transport Models. *Journal of Transport and Land Use*, 14(1):325–344–325–344.

# Integrated Land Use/Transport/Environment Model

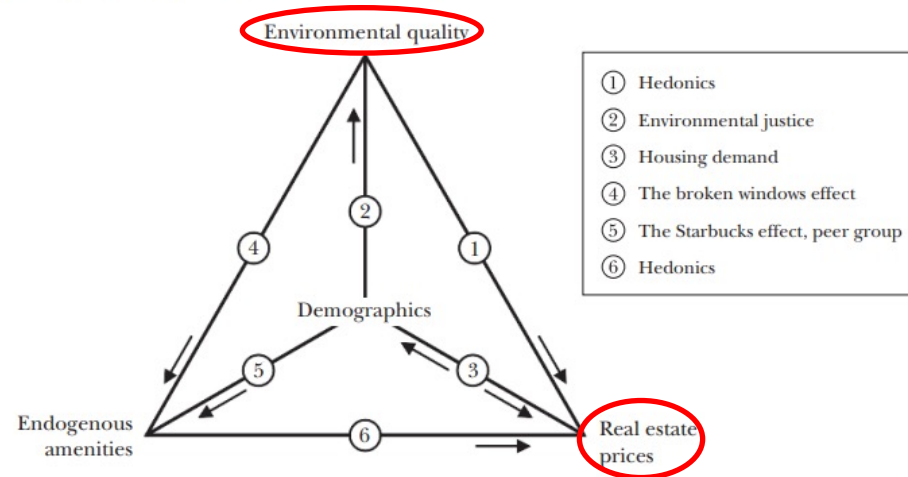
- Lately, **MATSim** has been coupled with the land use model **SILO**, which captures demographic and housing updates over multiple years (**ILUT model**)
- Recent studies point out the lack of **environmental considerations** in ILUT models (Acheampong et al. 2015, Gu et al. 2015)
- Land Use/Transport/Environment (**LTE**) aim to capture the complex interactions between these components



# Integrated Land Use/Transport/Environment Model

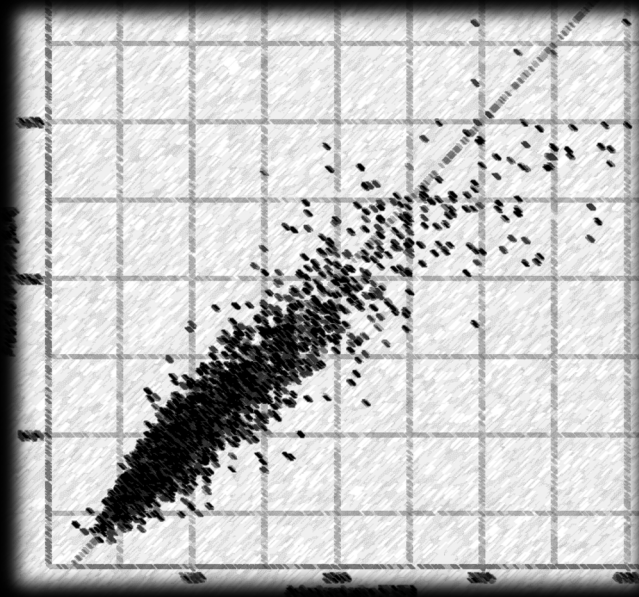
- Traffic noise as a component which is known to interact with land use (i.e., neighborhood degradation and subsequent price decreases)
- Idea: add **environmental feedback** of traffic noise to the existing ILUT model of SILO and MATSim
- **Prerequisite: identify reactions to traffic noise**

Pyramid of Environmental Gentrification



Source: Banzhaf and McCormick (2012).

# Road Traffic Noise and Rent Prices: A Hedonic Pricing Study



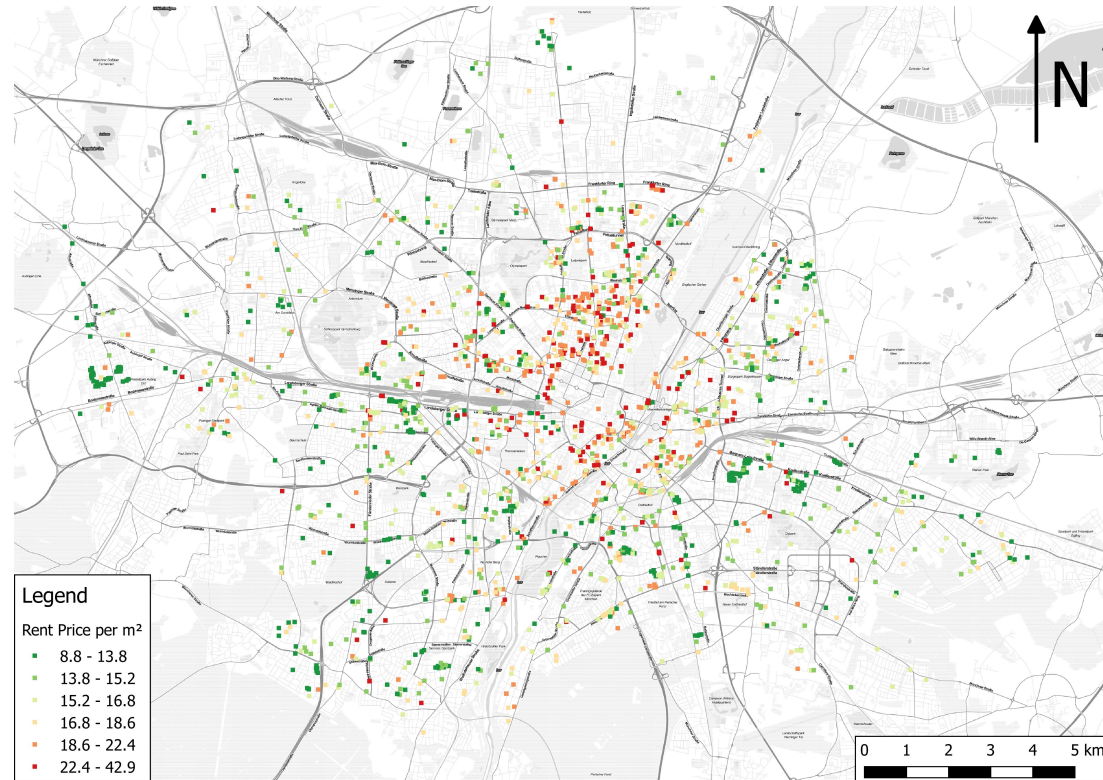
Kuehnel, N. and Moeckel, R. (2020). Impact of simulation-based traffic noise on rent prices. *Transportation Research Part D: Transport and Environment*, 78:102191.

# The price of quietness

- Noise sensitivity depreciation index:

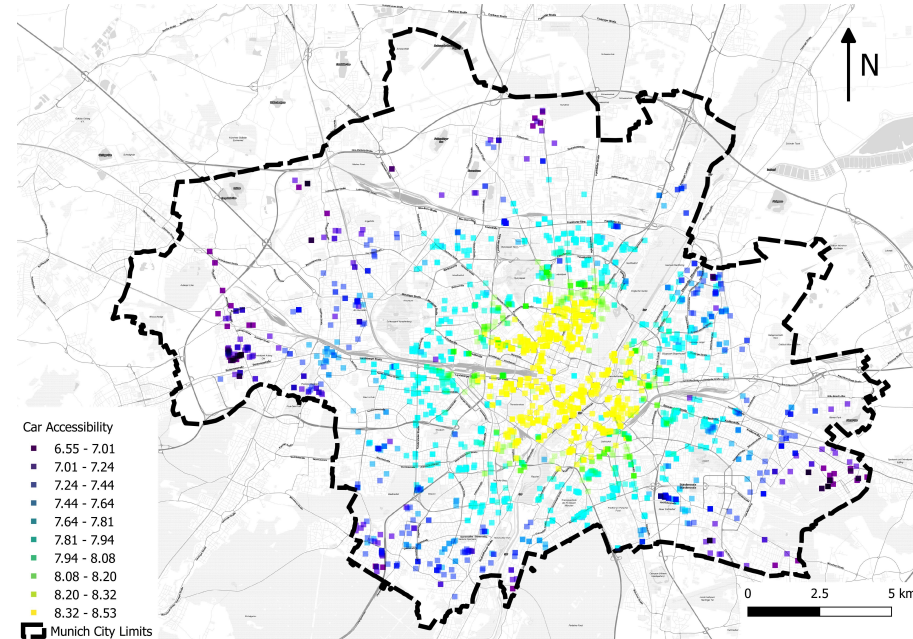
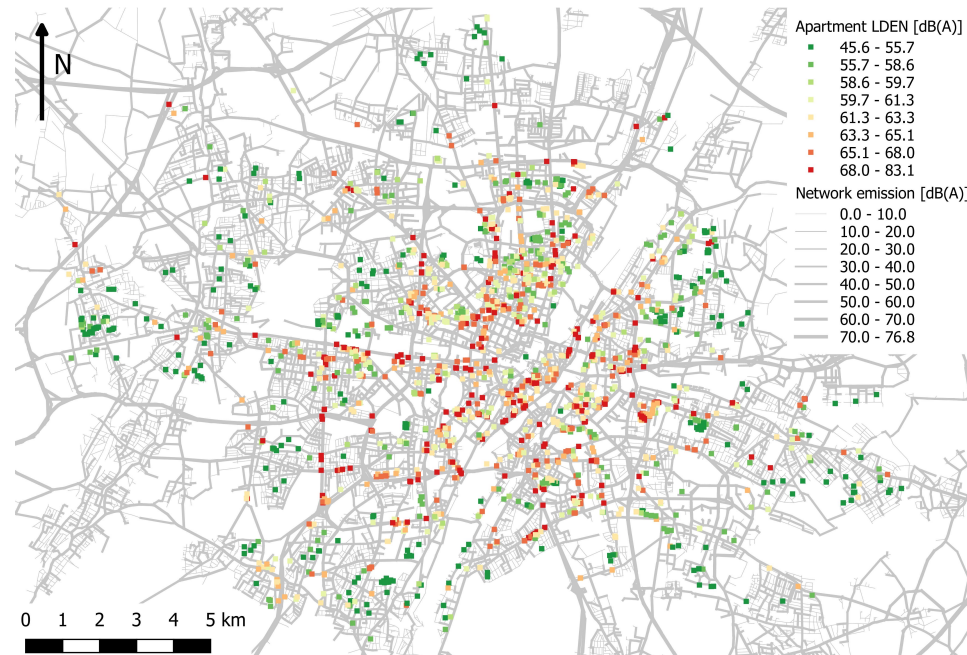
$$\text{NSDI} = \frac{\text{percentage change of housing price}}{\text{increase of noise}}$$

- Hedonic pricing study by regression analysis for rent prices in Munich
- Data taken from [immobilienscout24.de](https://www.immobilienscout24.de)
- In total 3,144 geo-coded apartments (mean rent ~18€/m<sup>2</sup>)



# Traffic Noise and Car Accessibility

- Accessibility as a confounding variable to account for positive impacts of road infrastructure





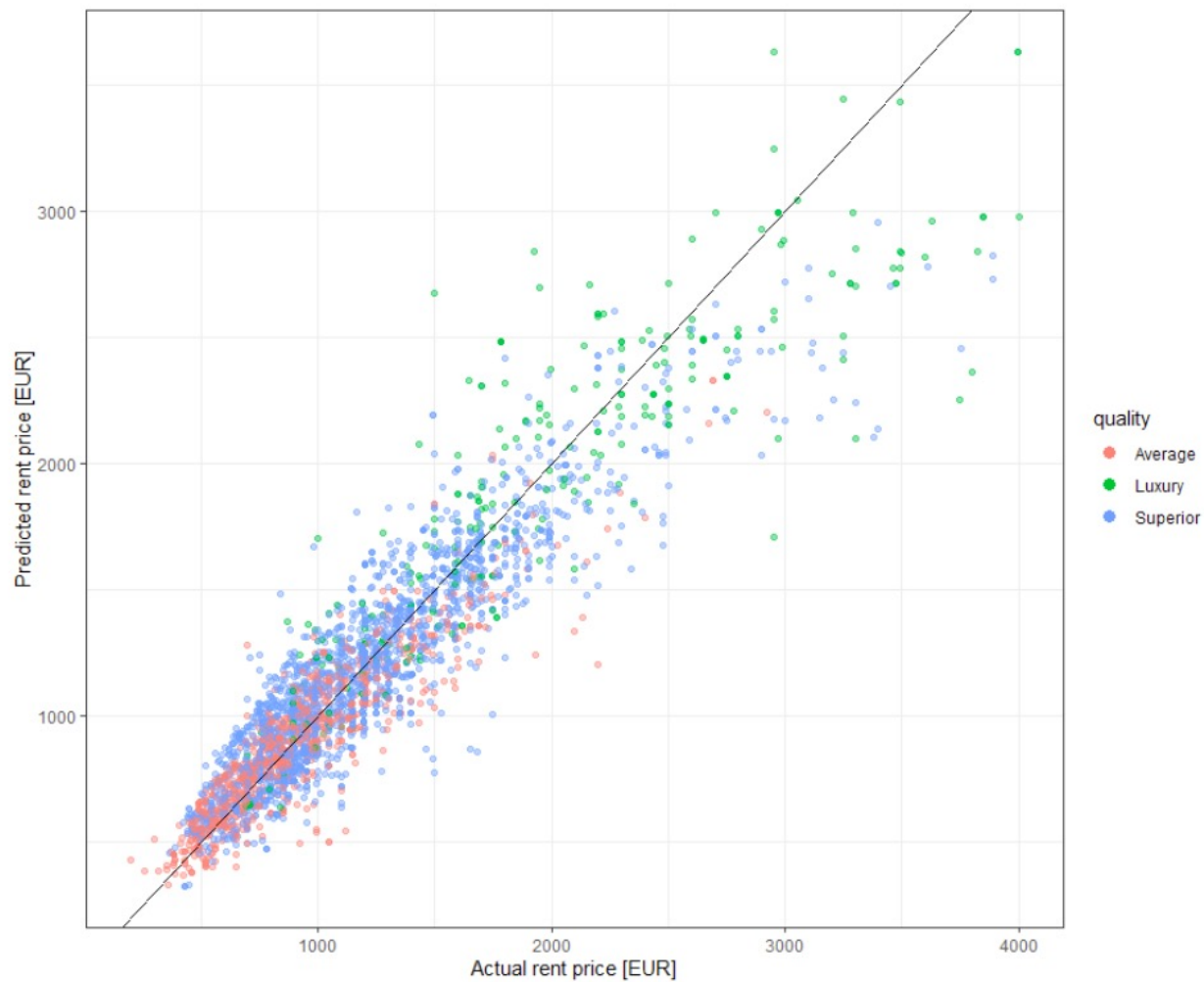
# Results

- Highly significant negative impacts of noise
- **Resulting NSDI: -0.46 %/dB(A)**
- Categorical noise variable model for non-linear relationship and thresholds
- Up to **10% price discount** for very loud apartments

		Dependent variable:	
		log(rent)	
		Model (1)	Model (2)
	log(area)	0.7705*** (0.0077)	0.7706*** (0.0077)
	noise	-0.0046*** (0.0006)	
	low noise		0 (Base)
	moderate noise		-0.0360*** (0.0103)
	loud noise		-0.0583*** (0.0127)
	very loud noise		-0.1005*** (0.0243)
	microscopic car accessibilities	0.2272*** (0.0091)	0.2165*** (0.0091)
	Parking available	0.0183 ** (0.0070)	0.0180** (0.0070)
	Quality: Luxury	0.1666*** (0.0114)	0.1678*** (0.0114)
	Quality: Superior	0 (Base)	0 (Base)
	Quality: Average	-0.1433*** (0.0082)	-0.1430*** (0.0083)
	State: First time use	0 (Base)	0 (Base)
	State: New Building	-0.0340*** (0.0096)	-0.0298** (0.0097)
	State: First time use after restoration	-0.0817*** (0.0122)	-0.0815*** (0.0124)
	State: Restored	-0.1021*** (0.0214)	-0.1020*** (0.0215)
	State: Modernized	-0.1179*** (0.0151)	-0.1171*** (0.0152)
	State: Well-kept	-0.1589*** (0.0106)	-0.1580*** (0.0108)
	State: Renovated	-0.1694*** (0.0114)	-0.1697*** (0.0115)
	constant	2.4031*** (0.0753)	2.2390*** (0.0798)
	Observations	3,145	3,145
	R2	0.8597	0.8552
	Adjusted R2	0.8591	0.8545
	Residual Std. Error	0.1783	0.1757
	F Statistic	1,213	1,124

Note: Signif. codes: '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1 robust SE in (brackets)

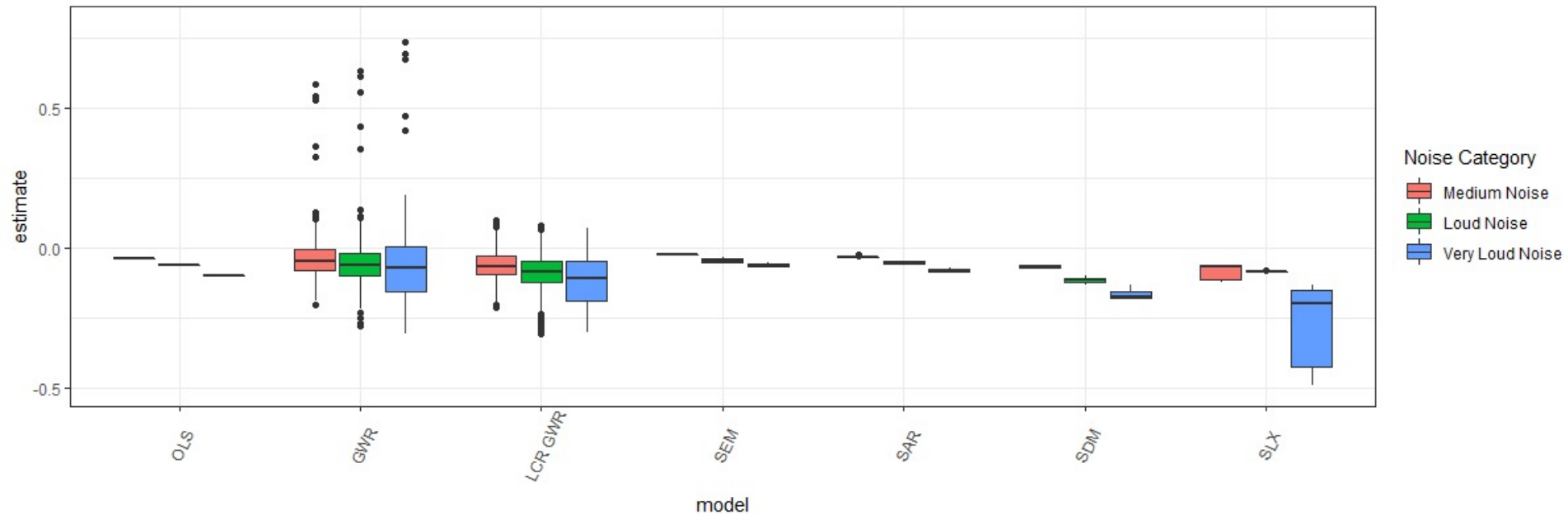
# Results





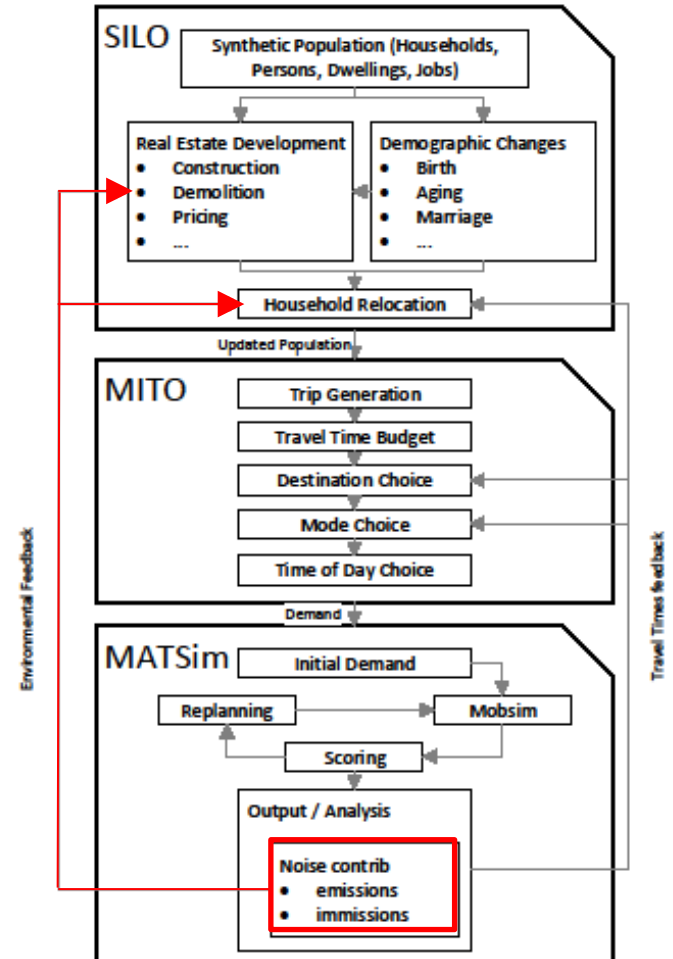
# Results

- Results stay stable also with spatial regression models



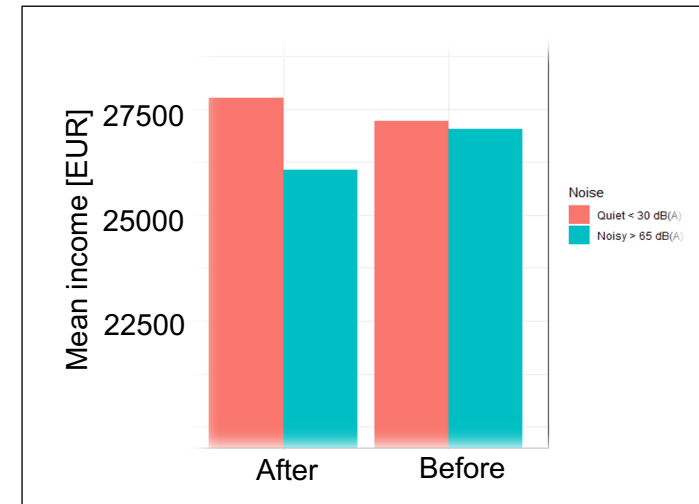
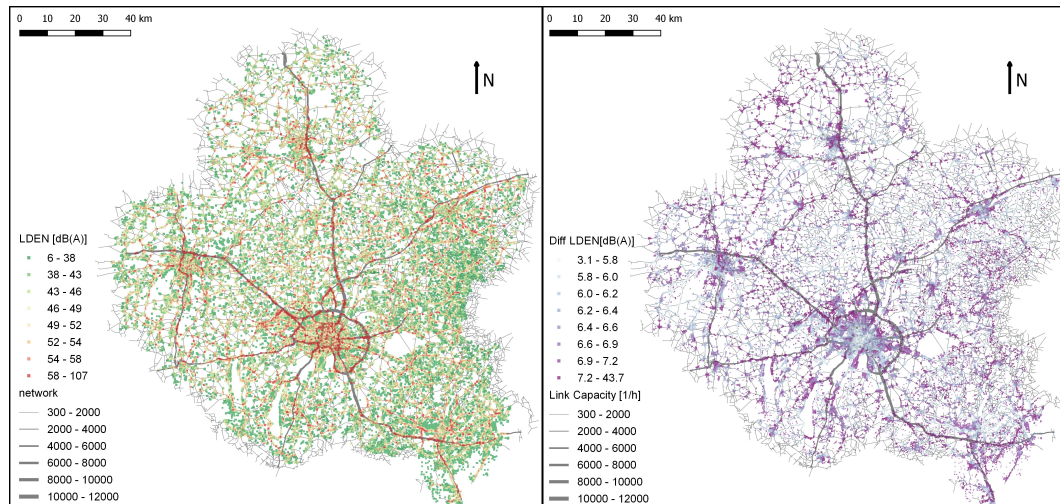
# LTE Model

- Implemented a feedback from MATSim to SILO to provide noise values for each dwelling (~2.5 million)
  - Price discount** for noisy dwellings (hedonic pricing model)
  - Noise sensitivity** of relocating agents (stated preference study of Hunt et al 2010)
- Run from 2011 (base year) until 2030 to
  - Confirm sensitivity
  - Assess changes in noise exposure

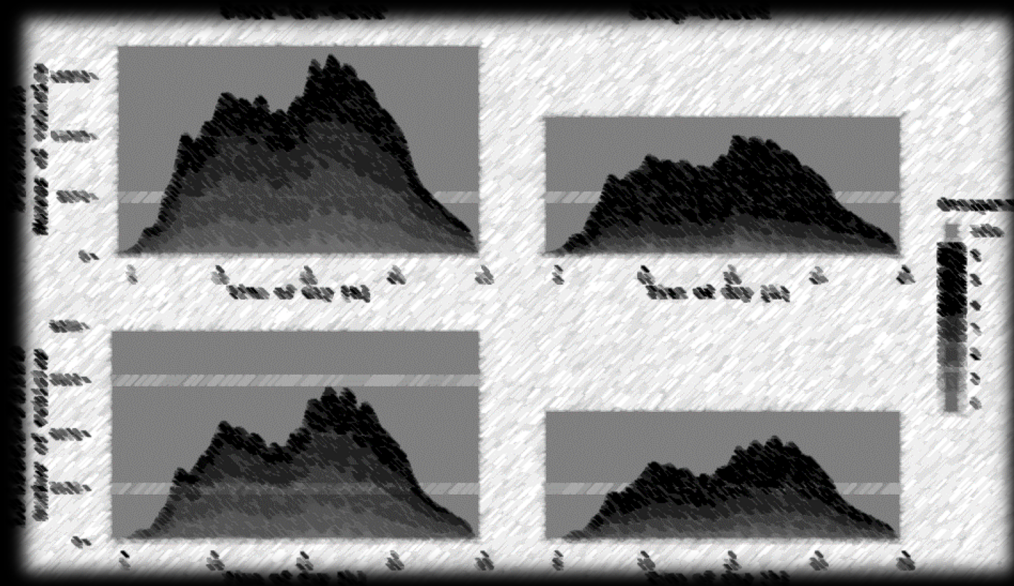


# LTE Model

- **Proof of concept** for an agent-based integrated LTE model on a microscopic scale



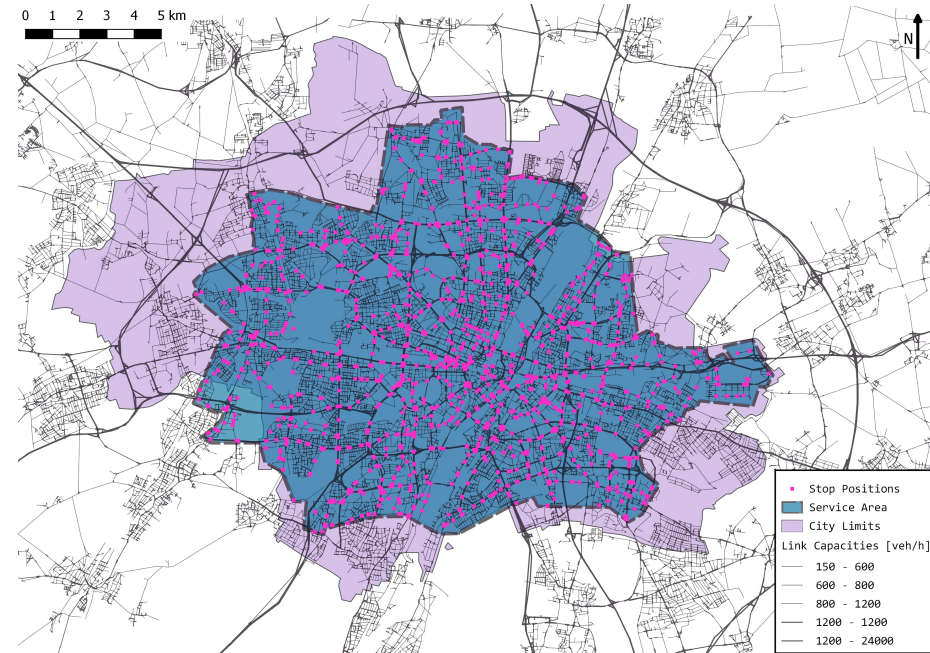
# Electric Ride-pooling and the Impact on Traffic Noise



Zwicky, F., Kuehnel, N., Moeckel, R., and Axhausen, K. W. (2021). Agent-based simulation of city-wide autonomous ride-pooling and the impact on traffic noise. *Transportation Research Part D: Transport and Environment*, 90:102673.

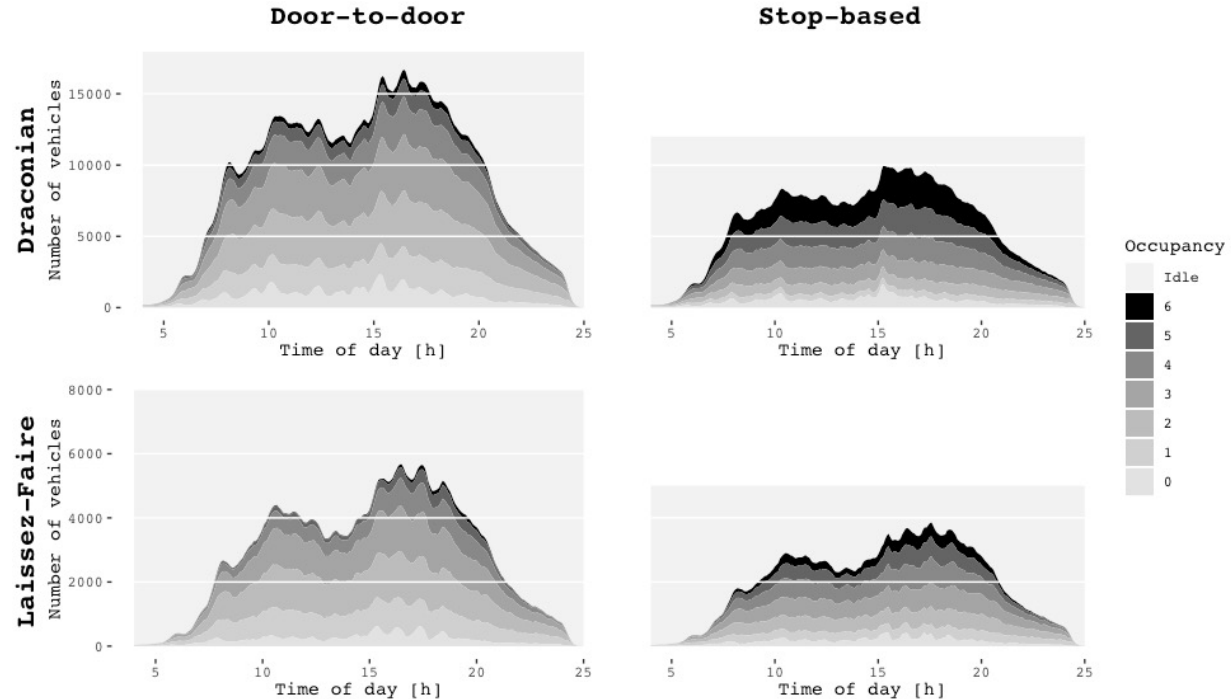
# Electric Ride-pooling and the impact on Traffic Noise

- Ride-pooling services as an emerging transport mode aim to reduce traffic volumes and may thus decrease traffic noise
- Agent-based models suitable to study ride-pooling scenarios
- **Radical** and **Laissez-faire** scenario
- **Stop-based** vs **door-to-door** service



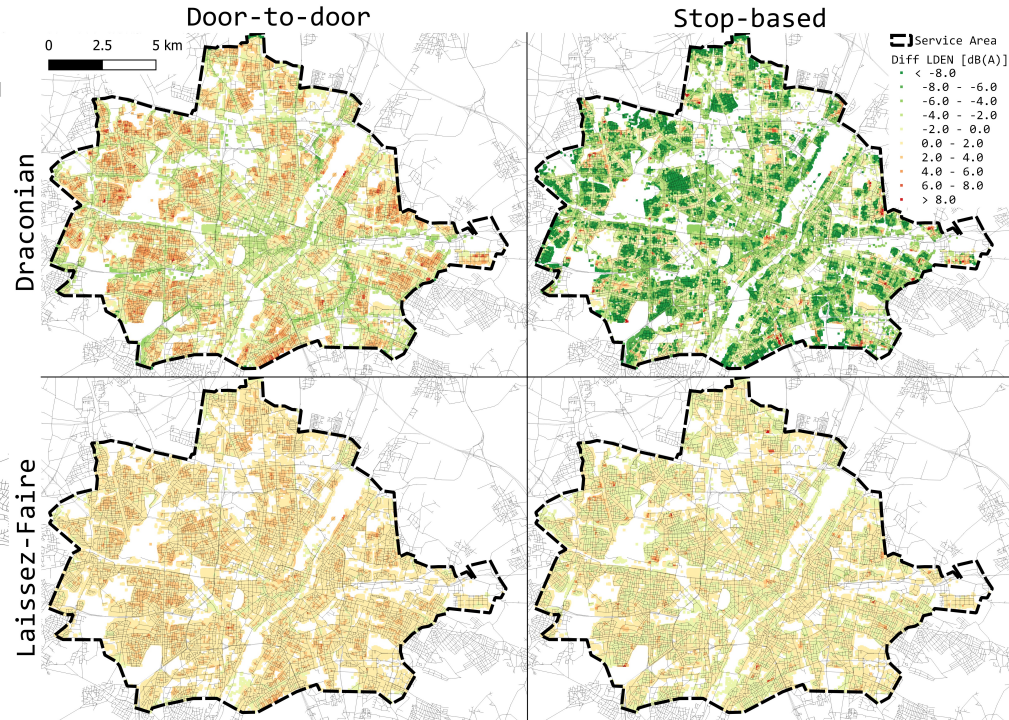
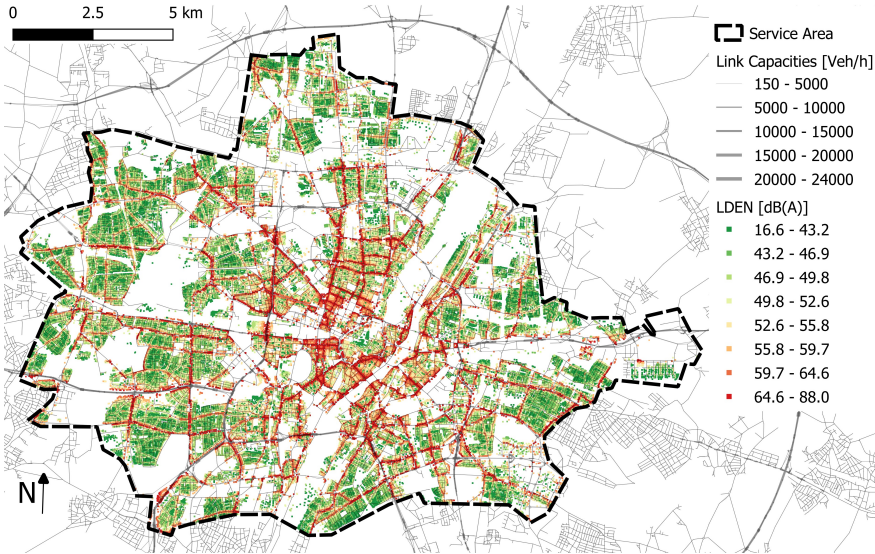
# Electric Ride-pooling and the impact on Traffic Noise

- A comparably small amount of vehicles is required to serve all previous inner-city car trips
- **Stop-based service more efficient** than door-to-door service





# Results




# Conclusions



# Conclusions

Contribution	Limitation
<ul style="list-style-type: none"> <li>Updated and improved open-source noise model for MATSim</li> </ul>	<ul style="list-style-type: none"> <li>Second order reflection</li> <li>Limited building height data</li> <li>Road traffic only</li> </ul>
<ul style="list-style-type: none"> <li>Significant relationship between modeled noise values and rent price</li> </ul>	<ul style="list-style-type: none"> <li>Single municipality only</li> <li>Rent prices only</li> </ul>
<ul style="list-style-type: none"> <li>Proof of concept for a microscopic integrated land use/transport/environment model</li> </ul>	<ul style="list-style-type: none"> <li>Complex, requires more data and research</li> </ul>
<ul style="list-style-type: none"> <li>Novel approach for equity analyses in agent-based models using external costs as proxy</li> </ul>	<ul style="list-style-type: none"> <li>Lacks inclusion of sociodemographic attributes</li> </ul>
<ul style="list-style-type: none"> <li>(electric) ride-pooling services may reduce noise in efficient settings</li> </ul>	<ul style="list-style-type: none"> <li>So far only synthetic demand</li> <li>Combine with accompanying policies</li> </ul>

An aerial photograph of a city, likely Amsterdam, with a color-coded overlay representing noise levels. The map shows a dense network of streets and buildings. A central area is highlighted with a white box containing the text "Thanks for your attention!". A legend in the bottom right corner explains the color coding for LDEN [dB(A)].

Thanks for your  
attention!

