# Pricing local emission exposure of road traffic

## An agent-based approach

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# Motivation

# Costs Related to Exhaust Emissions

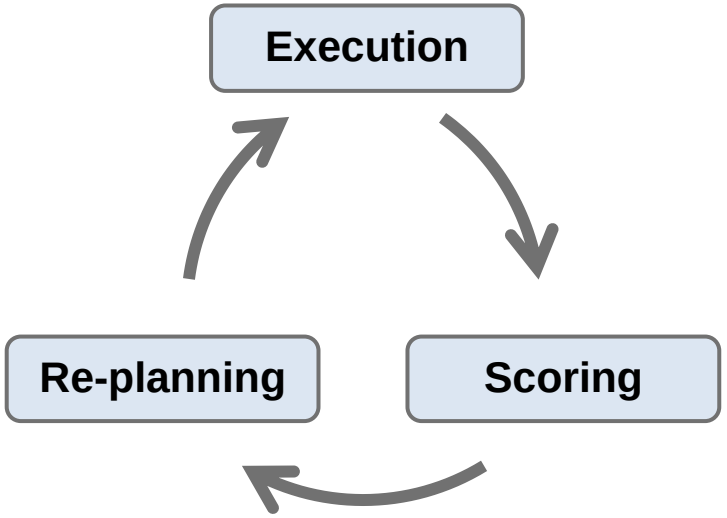
Related to Popuation / Activity Location Density

- Direct damages to human health (increased health costs, mortality, …)
- Indirect impacts on housing market (reduced property values, rents, …)
- Indirect impacts on quality of life, livability of the city

- Direct damages to building structure

- Indirect impacts from global warming (weather extremes)

# Optimal Pricing with MATSim


$$V_p = \sum_{i=1}^{n} V_{perf,i} + \sum_{i=1}^{n} V_{tr,i} = 100utils$$

$$V_p = \sum_{i=1}^{n} V_{perf,i} + \sum_{i=1}^{n} V_{tr,i} = 97utils$$

$$V_p = \sum_{i=1}^{n} V_{perf,i} + \sum_{i=1}^{n} V_{tr,i} = 90utils$$



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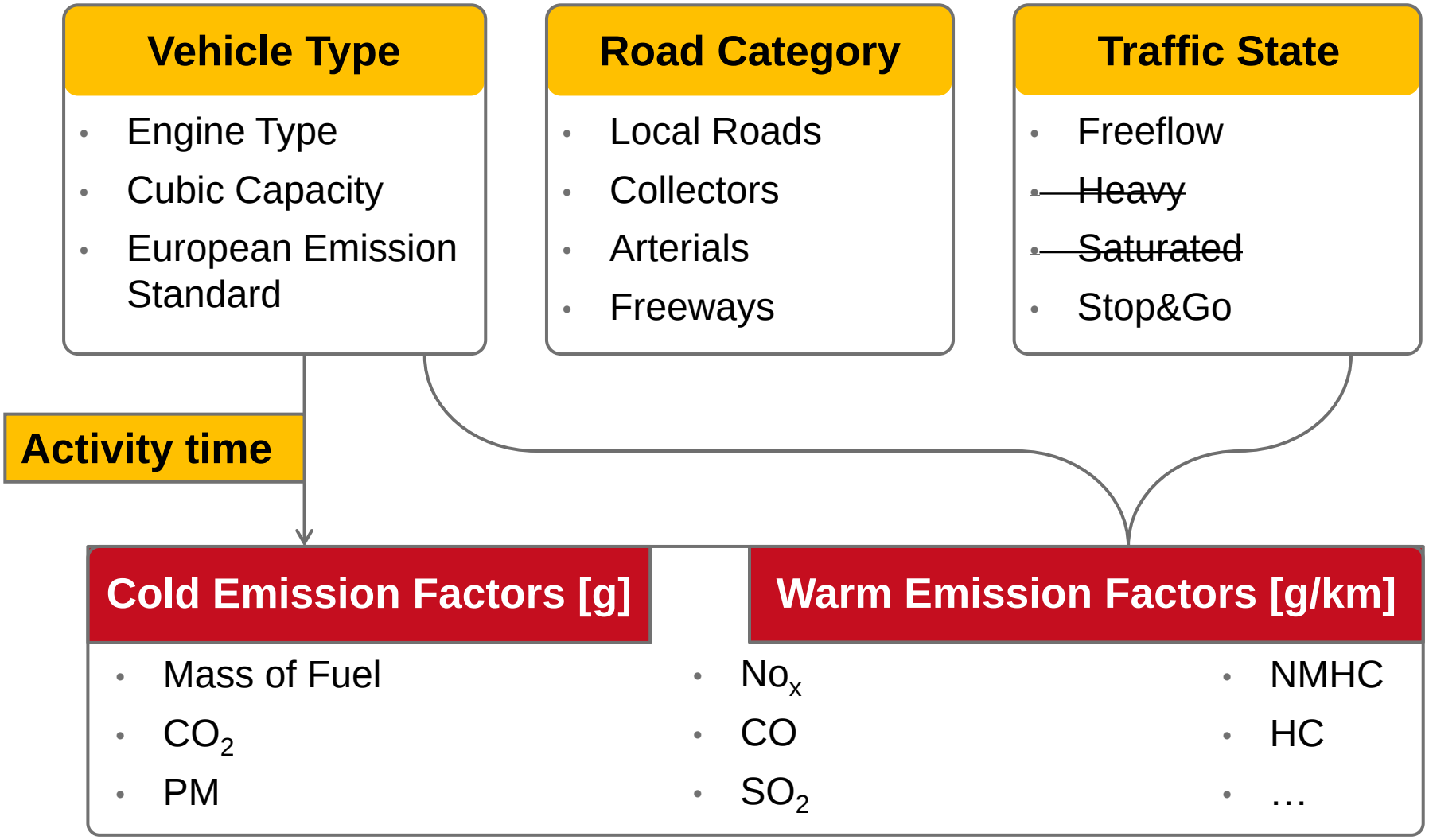
# Deriving Damage Cost Estimates of Exhaust Emissions

1. Modeling emission levels
2. Modeling dispersion and deriving air quality
3. Modeling exposure of individuals to air pollutant concentration
4. Applying concentration-response functions [numbers of cases for mortality, life years lost, hospital admissions, premature mortality, minor restricted activity days, work loss days, etc.]
5. Assigning monetary values to each of these cases

How to determine the “correct” price level iteratively?

# Approach

# Modeling Emission Levels



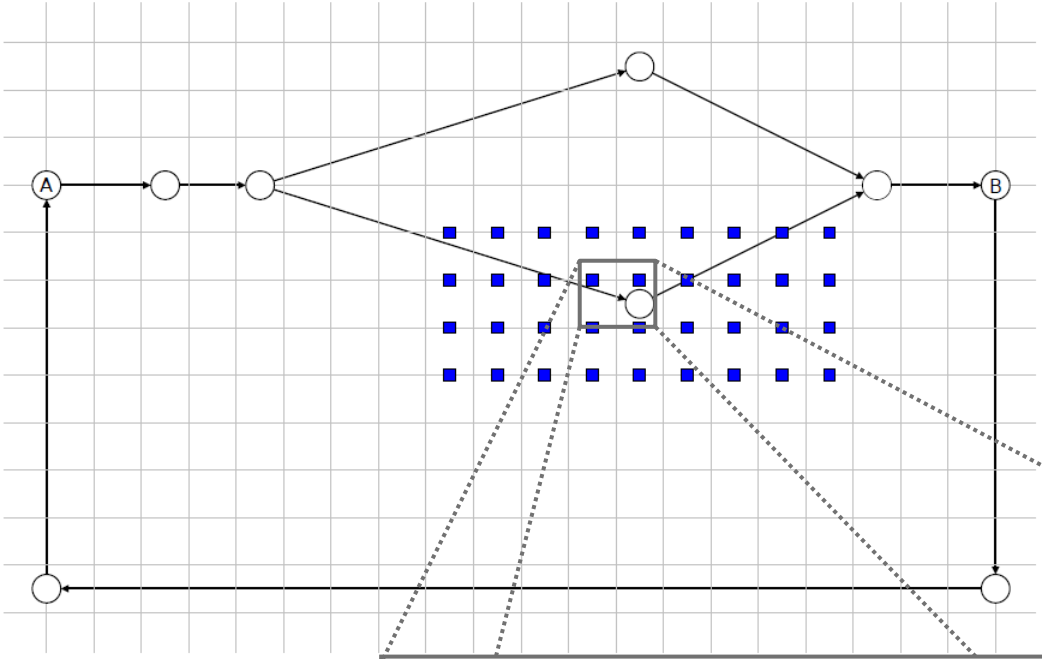

HBEFA: Handbook on Emission Factors for Road Transport (see www.hbefa.net)
This is a non-exhaustive list of differentiations provided by HBEFA 3.1

# Idea 1: Emission Toll (Independent of Exposure)

- Whenever a person leaves a road segment:
  - Calculate emissions (dependent on vehicle, traffic state, …)
  - Calculate emission costs (flat toll per [g])
  - Charge that person with the resulting individual toll

- Differentiated tolls are now part of the individual decision making process of every person

# Idea 2: Exposure Toll (Dependent of Exposure)




$$C_{actual} = C_{average} \cdot \frac{t_{actual}}{t_{average}}$$

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.000 € | 0.000 € | 0.000 € | 0.002 € | 0.000 € | 0.000 € | 0.000 € |
| 0.000 € | 0.000 € | 0.002 € | 0.029 € | 0.002 € | 0.000 € | 0.000 € |
| 0.000 € | 0.002 € | 0.029 € | 0.132 € | 0.029 € | 0.002 € | 0.000 € |
| 0.002 € | 0.029 € | 0.132 € | 0.216 € | 0.132 € | 0.029 € | 0.002 € |
| 0.000 € | 0.002 € | 0.029 € | 0.132 € | 0.029 € | 0.002 € | 0.000 € |
| 0.000 € | 0.000 € | 0.002 € | 0.029 € | 0.002 € | 0.000 € | 0.000 € |
| 0.000 € | 0.000 € | 0.000 € | 0.002 € | 0.000 € | 0.000 € | 0.000 € |

# Results:

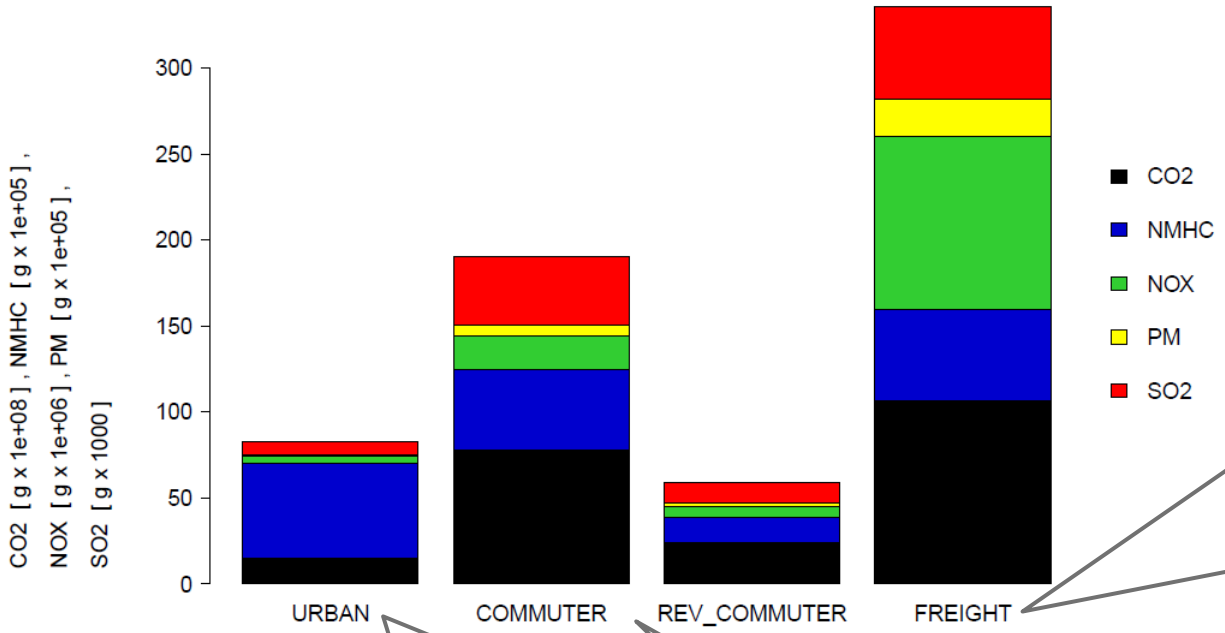
# Munich Metropolitan Area

# Subpopulations and Choice Dimensions

- Subpopulations:
  - Urban travelers
  - Commuters
  - Reverse Commuters
  - Freight

- Choice dimensions:
  - Route choice
  - Mode choice (car vs public transit; other modes fixed)
  - Freight: only route choice

# Base Case: Absolute Emissions by Subpopulation




7.6% of total population

- Major part of total emissions
- PM and NOX over-proportionally high

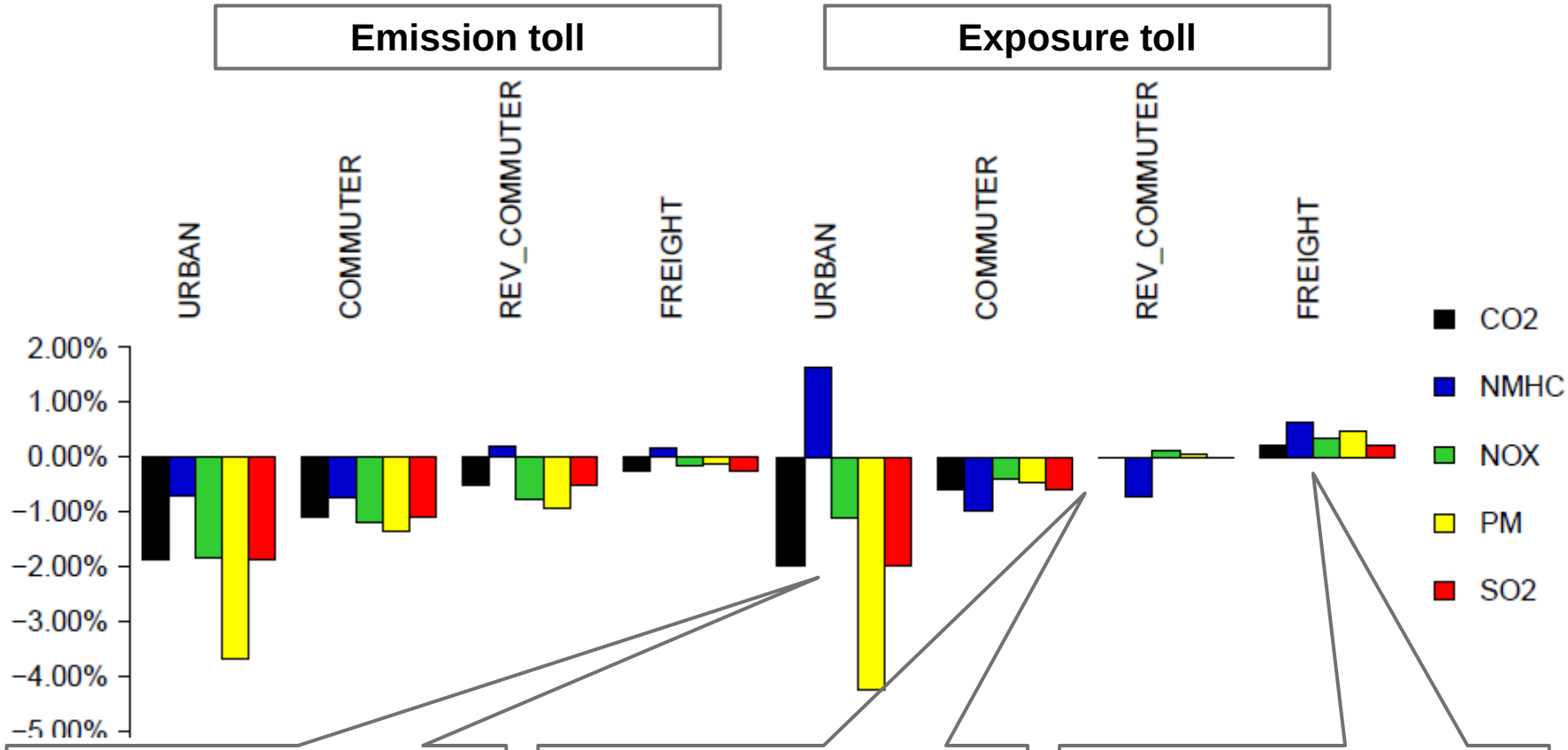
68% of total population

- Relatively small part of total emissions
- NMHC over-proportionally high > cold starts!

14.6% and 9.8% of total population

- Commuters drive longer distances than rev. commuters…
- …and therefore emit more emissions

# Changes in Relative Emissions by Subpopulation




- Similar impact on emission level
- Higher share of short trips with car (NMHC)

- Less emission reduction for commuters and rev. commuters

- Higher emission levels for freight



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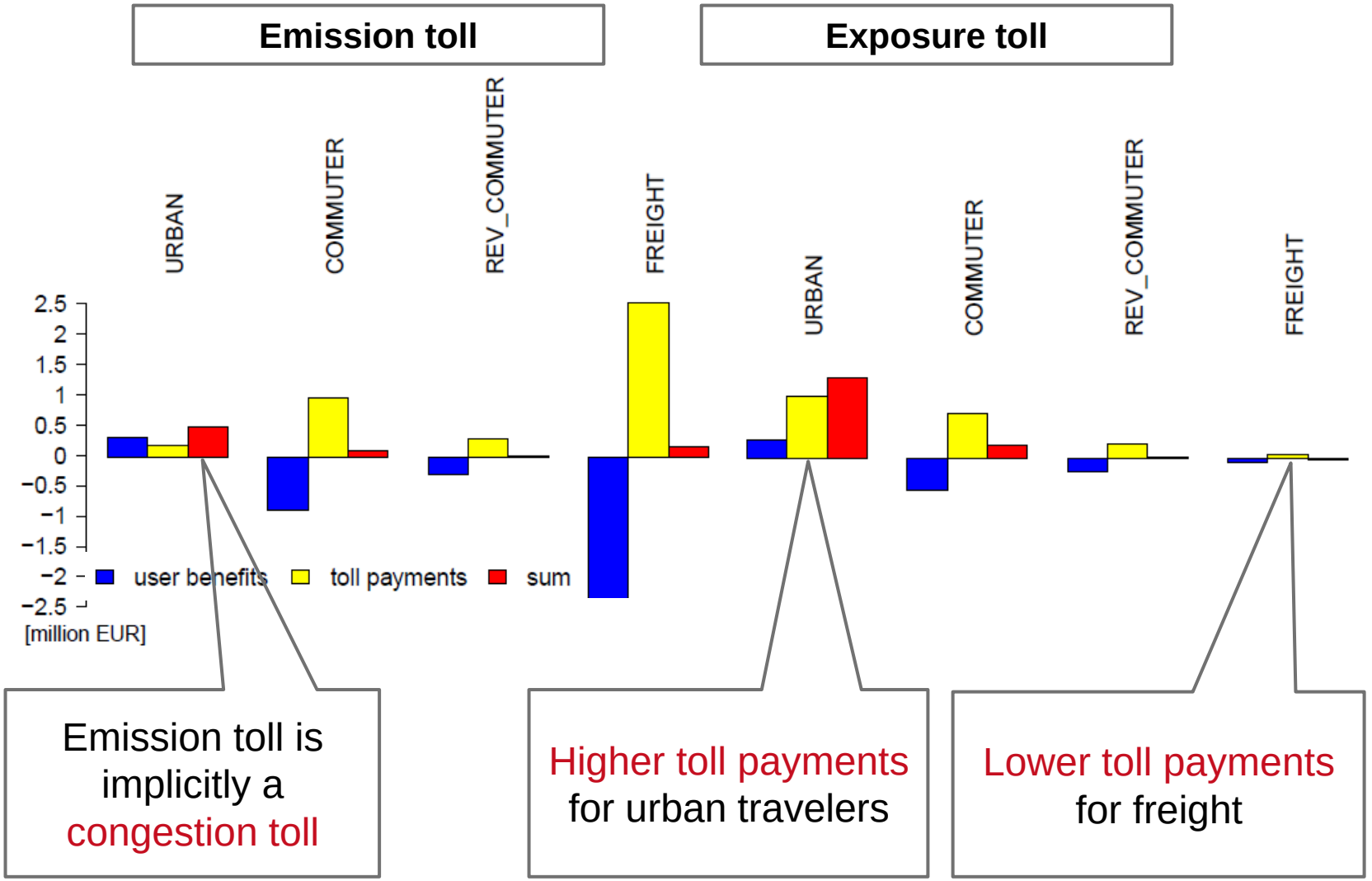
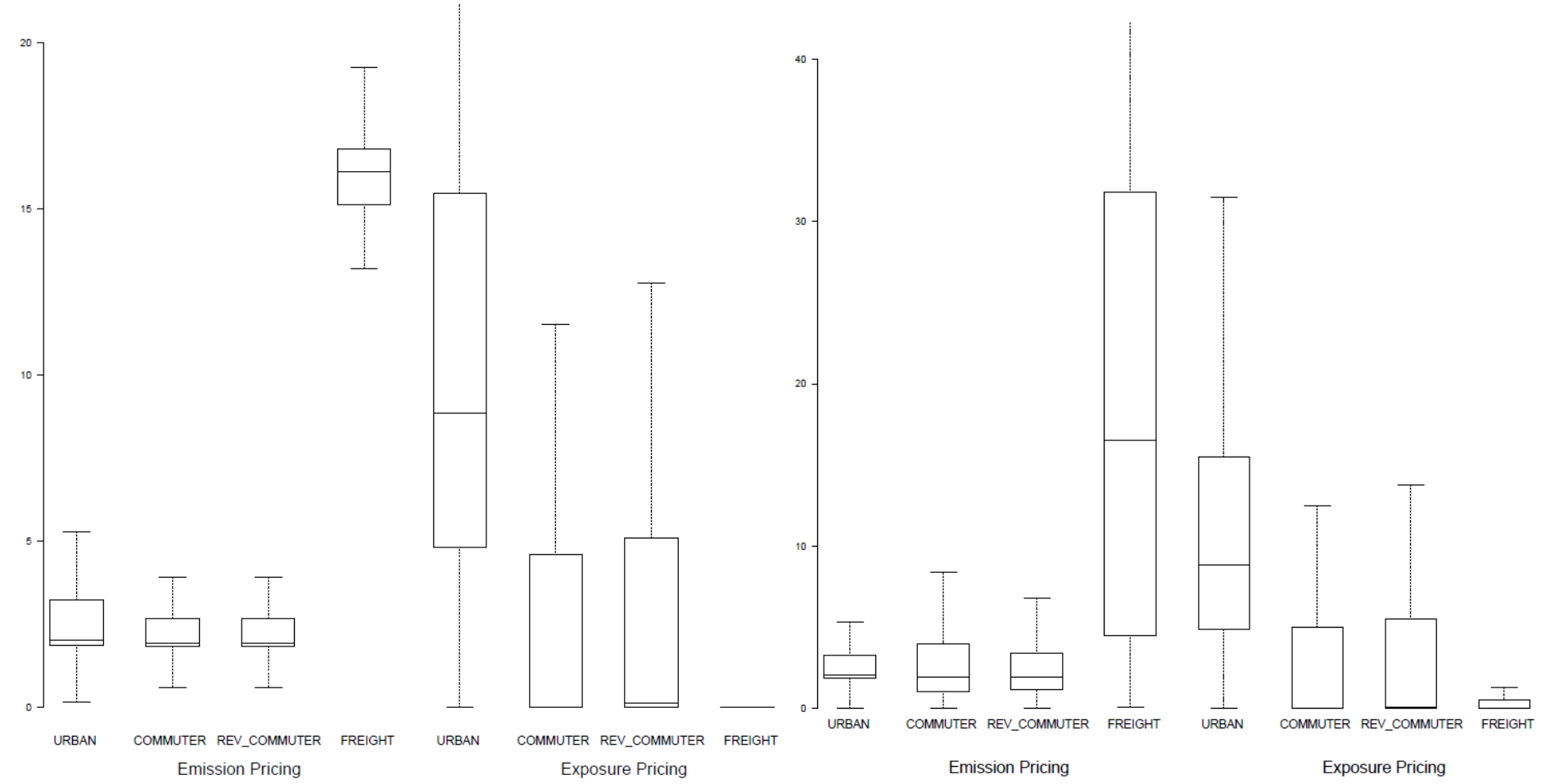
# Absolute Changes in User Benefits by Subpopulation



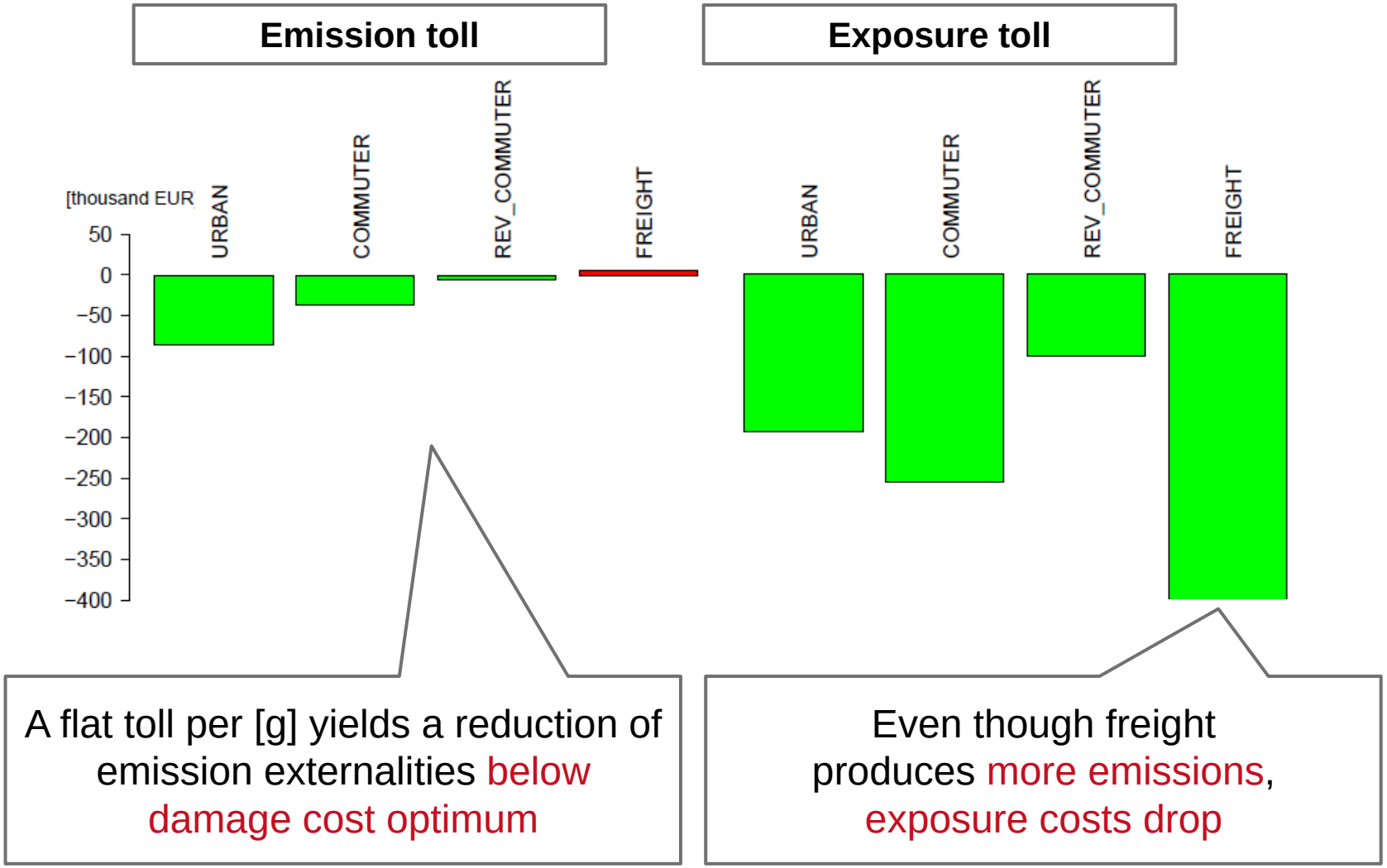
# Resulting Emission Cost Factors (Link-Based)



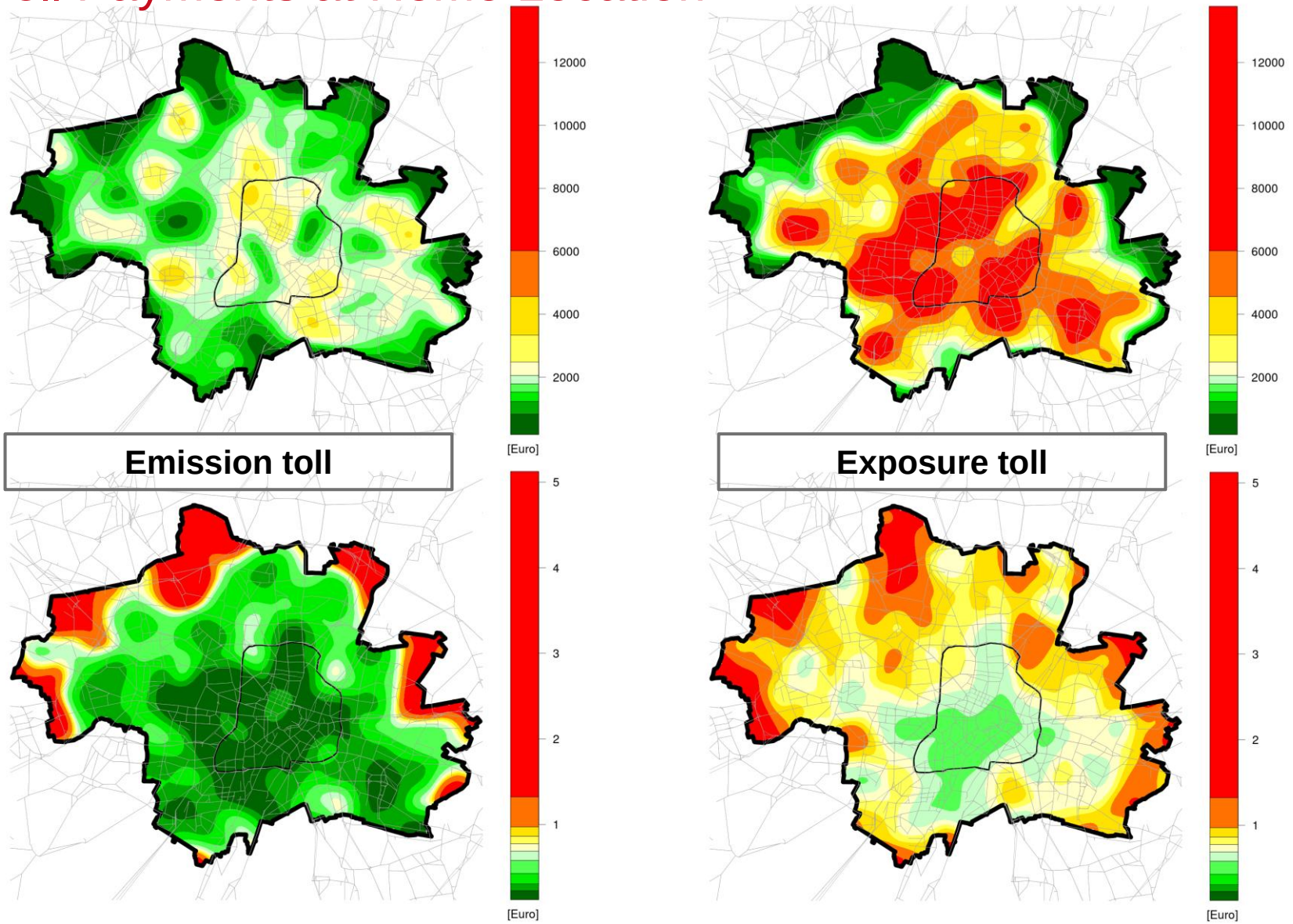

**Overall**

**City Area**

# Absolute Changes in Exposure Costs by Subpopulation



# Toll Payments at Home Location



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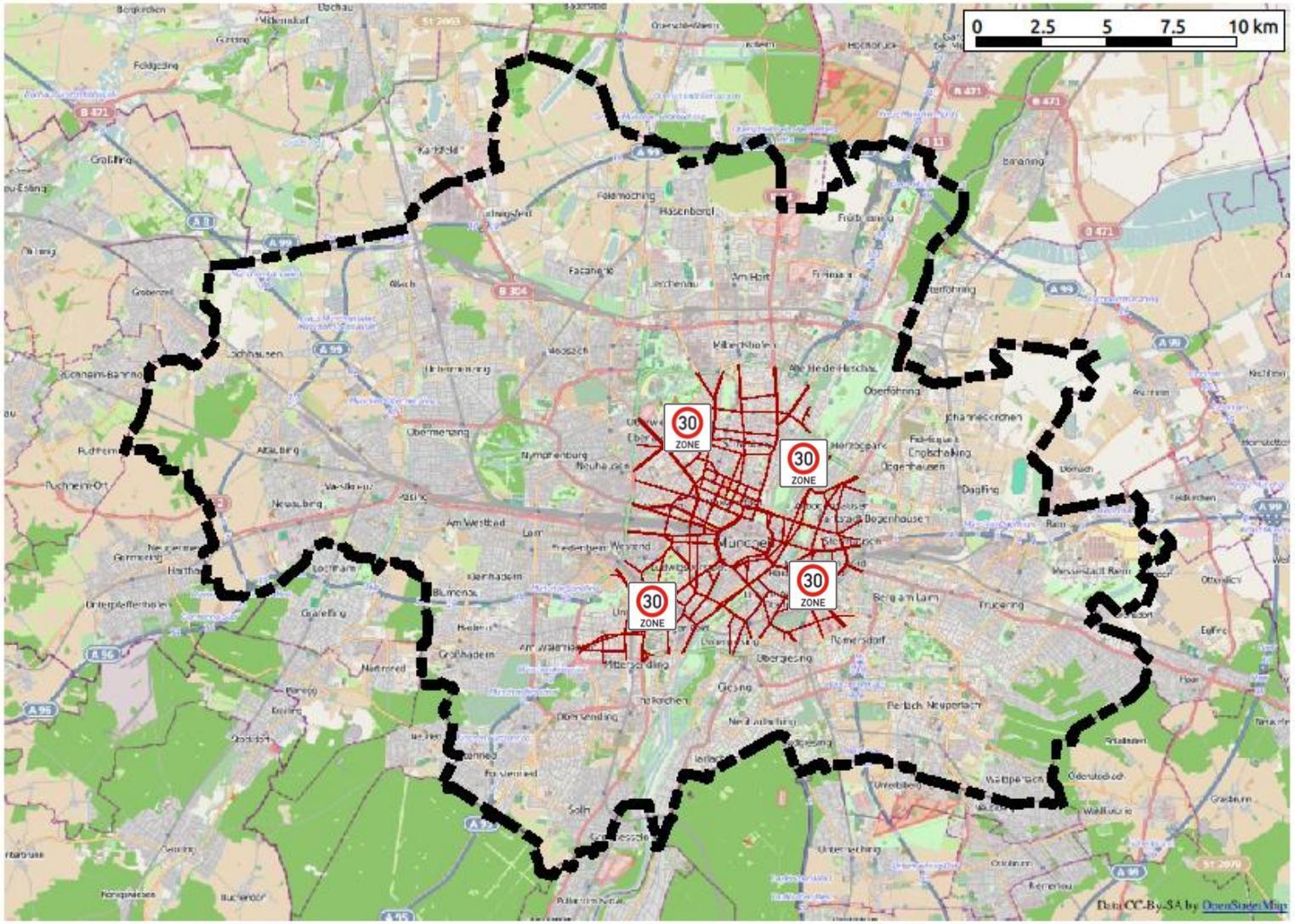
# Summary

- Exposure should be accounted for; bottleneck is the air pollution concentration model > simplified approach
- Calculation of vehicle-specific, time-dependent tolls is possible for large-scale real-world scenarios
- Both, emission toll and exposure toll can be used as benchmark for evaluating real-world policies
- Emission toll (flat value per [g]) leads to only a small reduction in exposure costs
- Exposure toll will lead to less exposure costs, but can lead to more emissions [potential conflict: CO2 vs local pollutants]
- MATSim allows for in-depth analysis (e.g. identifying areas with “environmentally friendly” vs “polluting” life styles

Thank you.

# Evaluating a Speed Limitation in the Inner City

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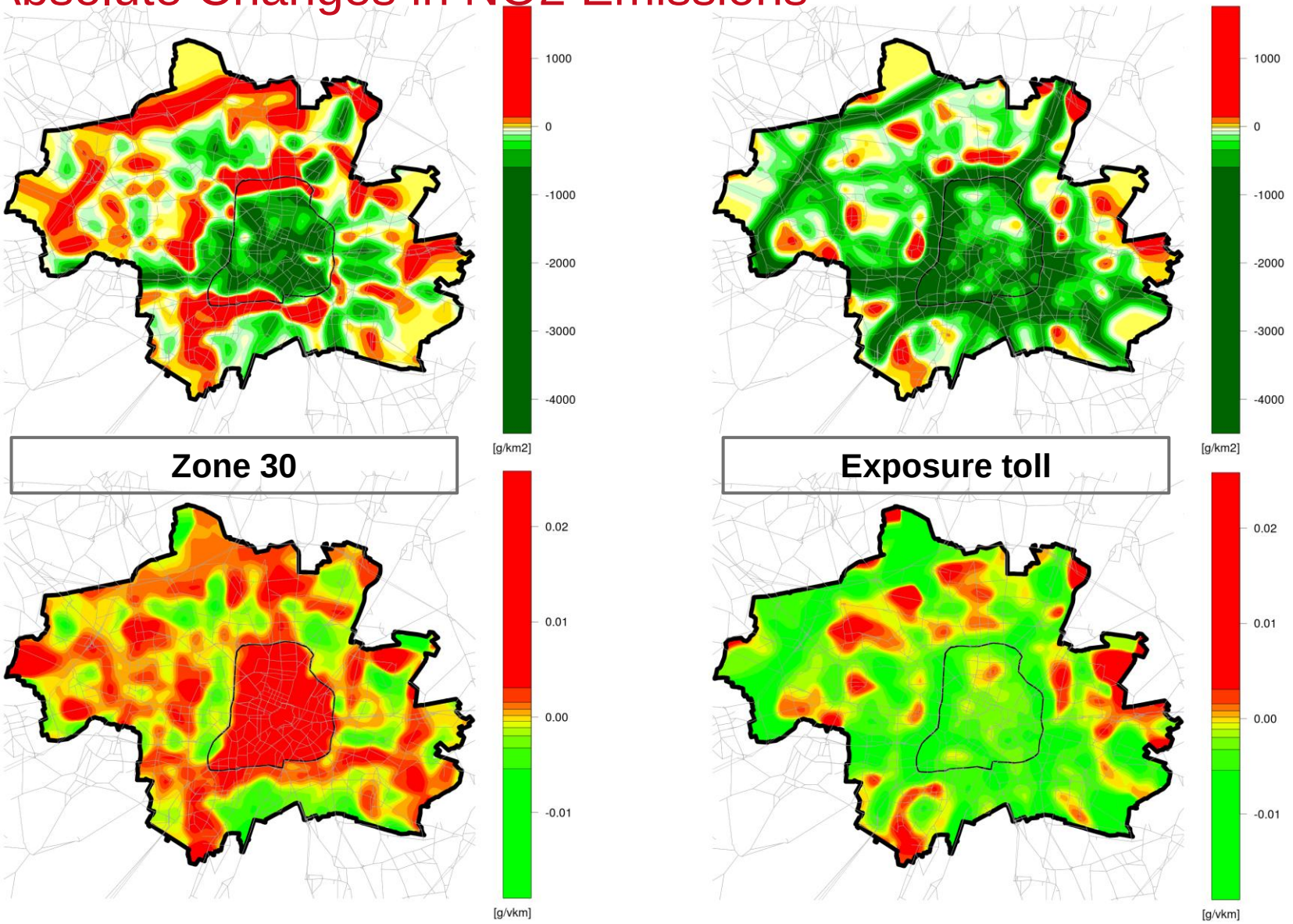
# Absolute Changes in NO2 Emissions



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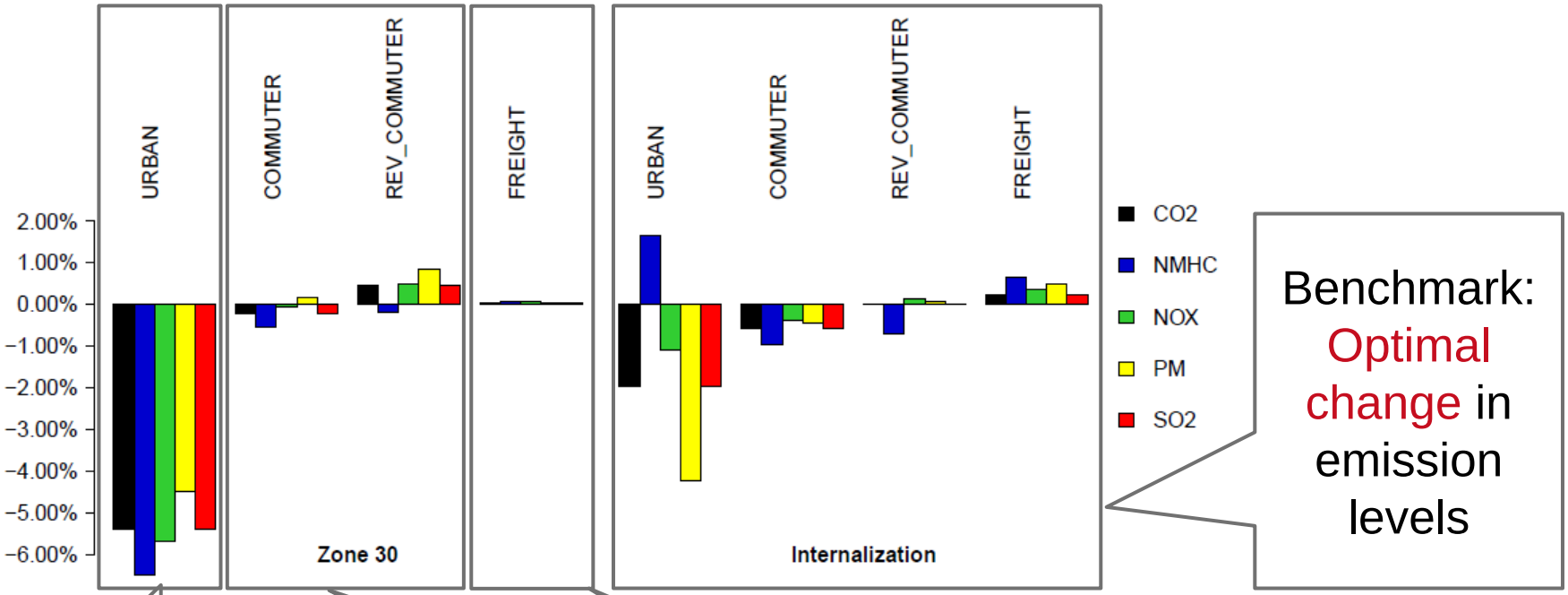
# Changes in Relative Emissions by Subpopulation




Benchmark: Optimal change in emission levels

Mode choice effect: Emission levels below the economic optimum

Re-route effect: Emission levels above the economic optimum

Re-route effect: Emission level still below the economic optimum



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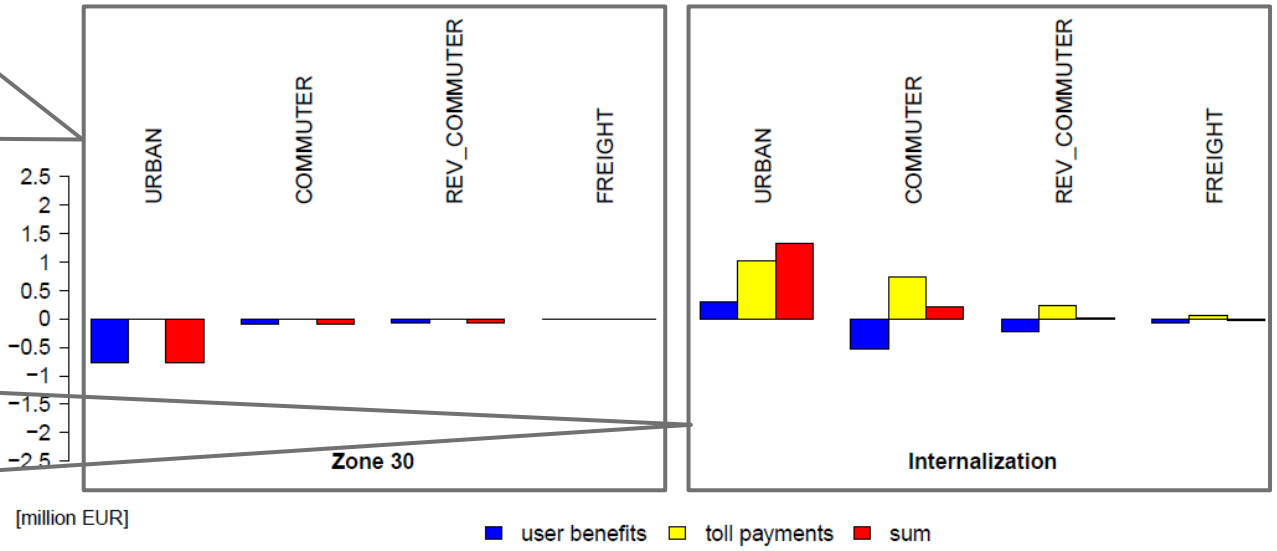
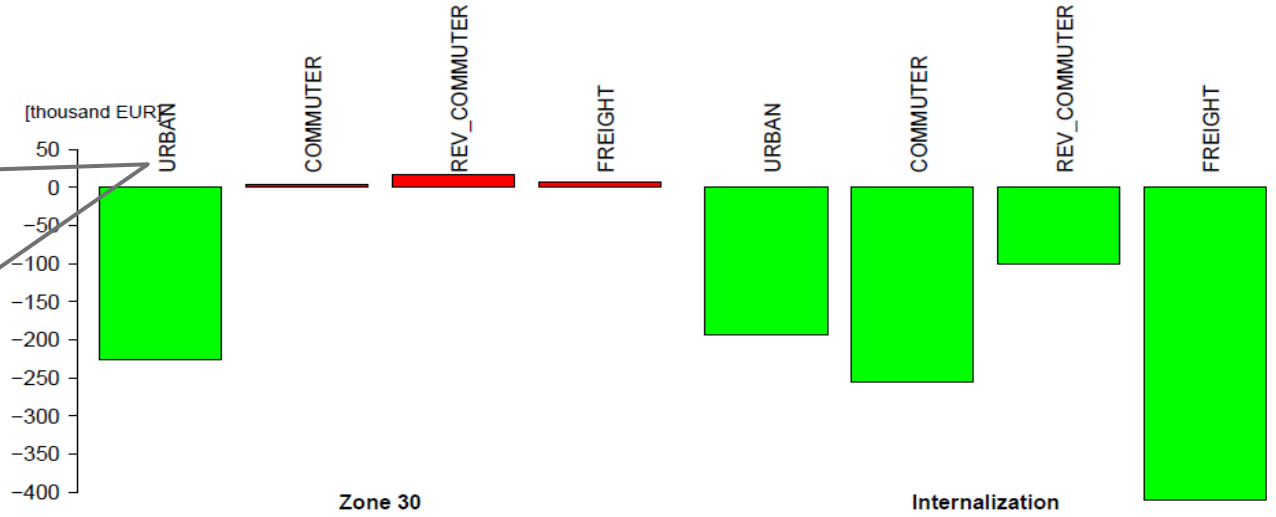
# Absolute Changes in Benefits by Subpopulation

Loss in user benefit for all subpopulations

Net welfare gains: Emission toll is implicitly a congestion toll

Exposure costs: Zone 30 is an effective strategy for urban travelers, ineffective for other subpopulations



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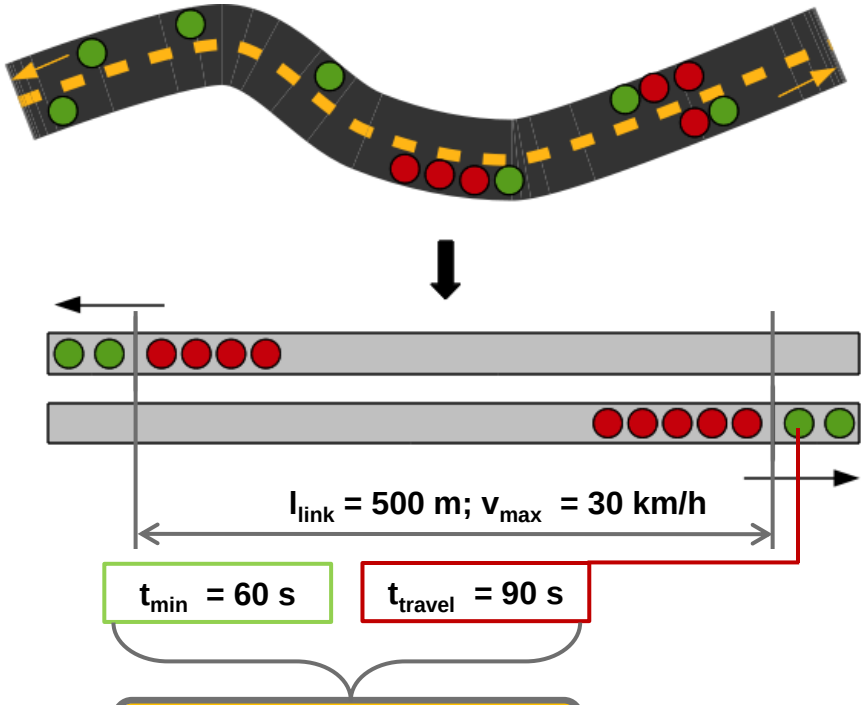
# Backup

# Emission Modeling Tool: Warm Emission Events



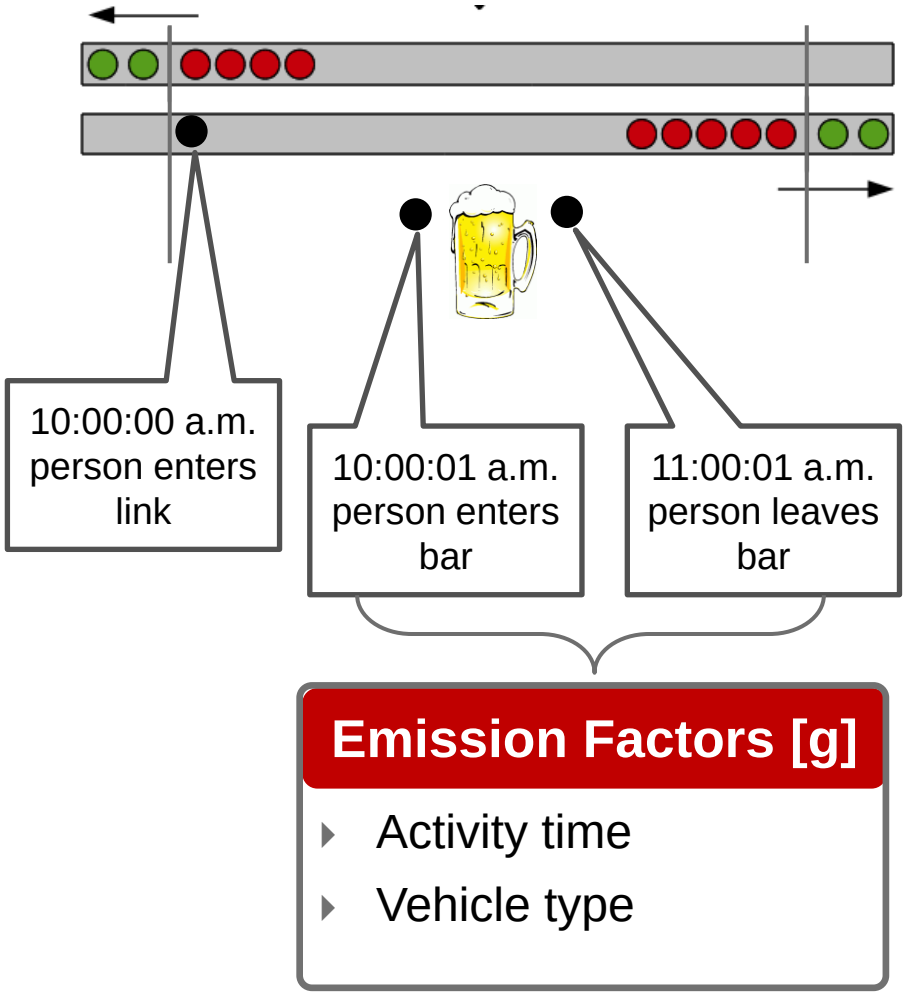

**Traffic State**

- Freeflow (60 s)
- ~~Heavy~~
- ~~Saturated~~
- Stop&Go (30 s)

$$x_{freeFlow} = l_{link} - x_{stopGo}$$

$$x_{stopGo} = (l_{link} \cdot v_{stopGo} \cdot (v_{max} - v_{avg})) / (v_{avg} \cdot (v_{max} - v_{stopGo}))$$

# Emission Modeling Tool: Cold Emission Events



# Behavioral Parameters

**Table 5.1.:** Estimated and adjusted utility parameters; resulting VTTS.

(a) Tirachini et al. (2014)

| | | |
|---|---|---|
| $\hat{\beta}_{tr,car}$ | $-0.96$ | $[\frac{utils}{h}]$ |
| $\hat{\beta}_{tr,pt}$ | $-1.14$ | $[\frac{utils}{h}]$ |
| $\hat{\beta}_{c}$ | $-0.062$ | $[\frac{utils}{AUD}]$ |
| $\hat{\beta}_{perf}$ | $N/A$ | $[\frac{utils}{h}]$ |
| $VTTS_{car}$ | $+15.48$ | $[\frac{AUD}{h}]$ |
| $VTTS_{pt}$ | $+18.39$ | $[\frac{AUD}{h}]$ |

(b) MATSim

| | | |
|---|---|---|
| $\beta_{tr,car}$ | $-0.00$ | $[\frac{utils}{h}]$ |
| $\beta_{tr,pt}$ | $-0.18$ | $[\frac{utils}{h}]$ |
| $\beta_{c}$ | $-0.07949$ | $[\frac{utils}{EUR}]$ |
| $\beta_{perf}$ | $+0.96$ | $[\frac{utils}{h}]$ |
| $VTTS_{car}$ | $+12.08$ | $[\frac{EUR}{h}]$ |
| $VTTS_{pt}$ | $+14.34$ | $[\frac{EUR}{h}]$ |

# Emission Cost Factors

Table 5.2.: Emission cost factors by emission type. Source: Maibach et al. (2008).

| Emission type | Cost factor $[EUR/ton]$ |
|---|---|
| $CO_2$ | 70 |
| $NMHC$ | 1'700 |
| $NO_x$ | 9'600 |
| $PM$ | 384'500 |
| $SO_2$ | 11'000 |