

# Simulation of individual injury risk with an agent-based transport model

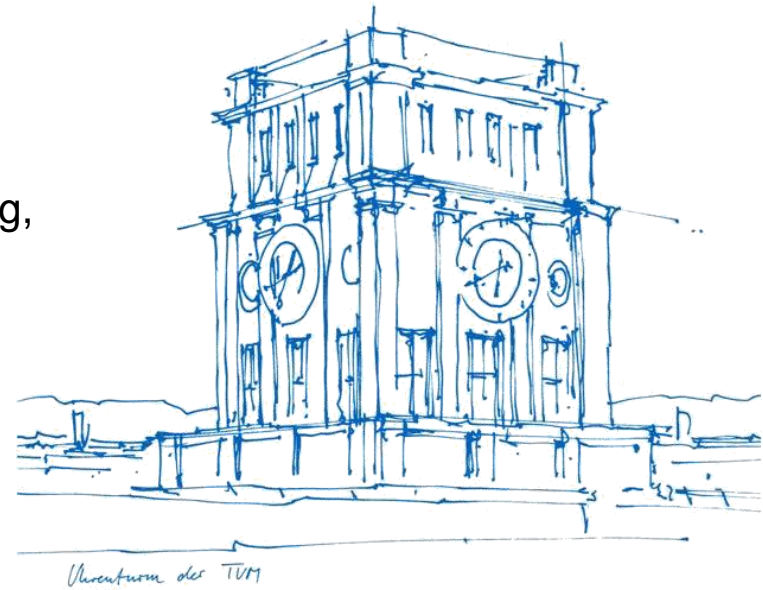
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Modeling Spatial Mobility

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# What is novel?

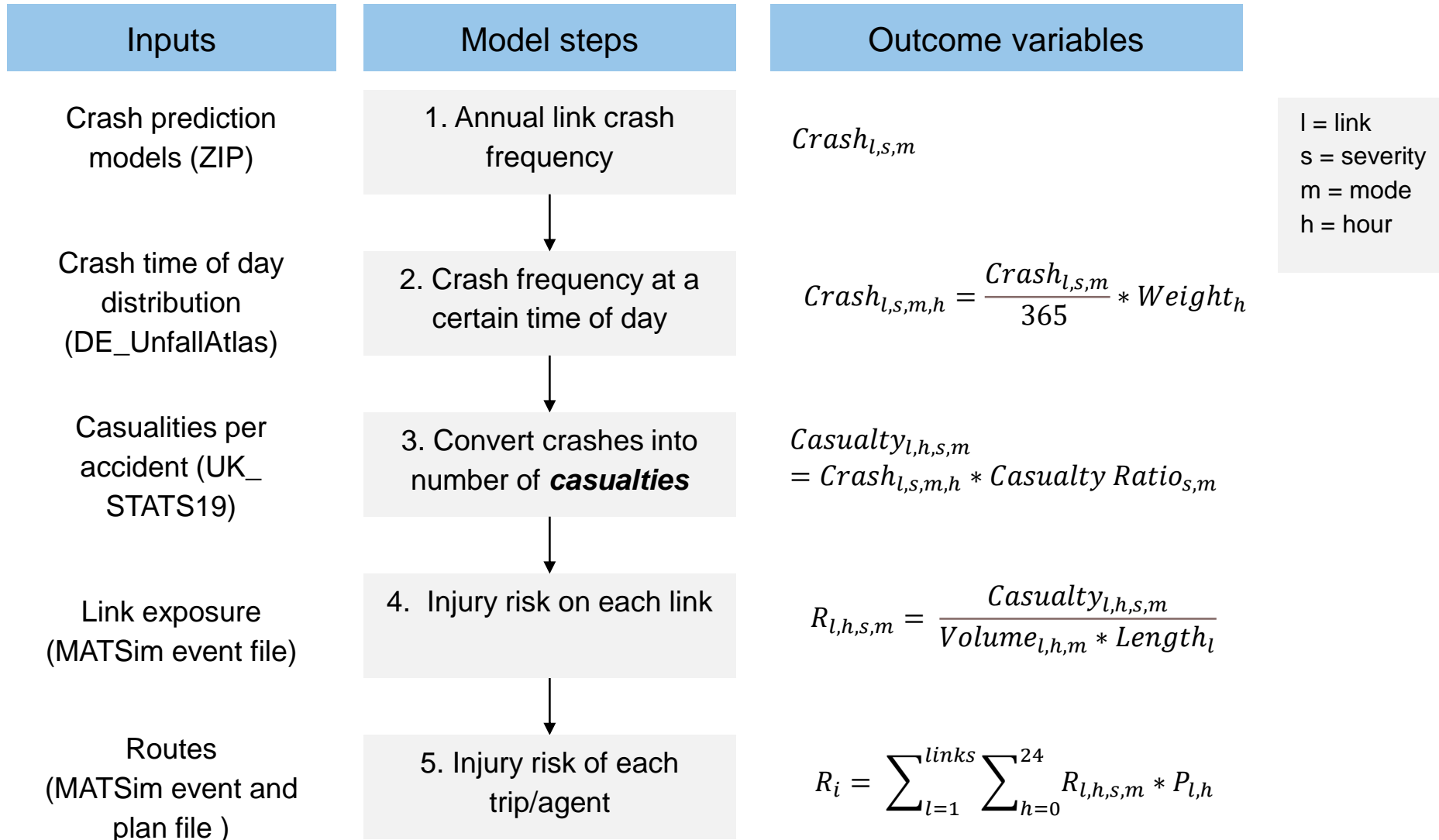
Existing road safety models:

- Calculate **number of crashes of links**
  - Apply models **commonly on a subset of roads** (primarily on main roads)
  - Apply models **mainly for car mode**
- Useful for finding out where the crash occurs, but cannot answer the question who is exposed to the risk of being killed or injured

In this study, a **novel and practical** road safety model is developed:

- Calculate **number of casualties on links**
  - Apply **to the entire network** (including cyclist roads and minor roads for pedestrian)
  - Apply models **for car-occupants, cyclists and pedestrians**
  - Built in **an agent-based environment**
- Can assess the crash injury risk of individual trips and individual agents.

# How we model individual injury risks in MATSim



# Step 1: Annual Crash frequency

Data: UnfallAtlas 2016 - 2018

Statistic models: Zero-Inflated Poisson (ZIP)

Dependent variables: annual number of crash of link l by **severity** by **case (mode)**

| Case   | Truck/PT | Car | Bike | Pedestrian | Victim       |
|--------|----------|-----|------|------------|--------------|
| Case 1 | √        | √   |      |            | Car-occupant |
| Case 2 | √        | √   | √    |            | Cyclist      |
| Case 3 |          |     | √    |            | Cyclist      |
| Case 4 | √        | √   | √    | √          | Pedestrian   |

# Estimation results (Step 1: non-zero model coefficients)

| Variable                       | Case 1 Car-occupant |          | Case 2 Cyclist |          | Case 3 Cyclist only |          | Case 4 Pedestrian |          |
|--------------------------------|---------------------|----------|----------------|----------|---------------------|----------|-------------------|----------|
|                                | Light               | Severe   | Light          | Severe   | Light               | Severe   | Light             | Severe   |
| Intercept                      | -2.68***            | -1.87*** | -4.14***       | -3.13*** | -2.29***            | -1.94*** | -3.50***          | -2.73*** |
| <b>Traffic conditions</b>      |                     |          |                |          |                     |          |                   |          |
| Motor traffic volumes in 1,000 | 0.04***             | 1.72***  | 0.18***        | 0.23*    | -                   | -        | 0.05*             | -        |
| x motorway                     | base                | -        | -              | -        | -                   | -        | -                 | -        |
| x primary road                 | 0.10***             | -        | -              | -        | -                   | -        | -                 | -        |
| x secondary road               | 0.09***             | -        | -              | -        | -                   | -        | -                 | -        |
| x tertiary road                | 0.88***             | -        | -              | -        | -                   | -        | -                 | -        |
| x residential or minor road    | 4.13***             | -        | -              | -        | -                   | -        | -                 | -        |
| Bike flows in 1,000            | -                   | -        | 4.91***        | 6.32***  | 4.74***             | 5.74***  | -                 | -        |
| Pedestrian flows in 1,000      | -                   | -        | -              | -        | -                   | -        | 2.68***           | 2.80***  |
| <b>Roadway function</b>        |                     |          |                |          |                     |          |                   |          |
| is motorway                    | base                | base     | -              | -        | -                   | -        | -                 | -        |
| is primary road                | -0.30***            | -0.33    | -              | -        | -                   | -        | -                 | -        |
| is secondary road              | -0.13***            | -0.33    | 1.03***        | 1.05**   | -                   | -        | -                 | -        |
| is tertiary road               | -1.24***            | -        | 0.90***        | 0.65     | -0.46***            | -        | 0.51***           | -0.37    |
| is residential road            | -2.33***            | -1.61*** | 1.55***        | 1.14**   | 0.19*               | 0.56**   | -                 | -        |
| <b>Roadway geometry</b>        |                     |          |                |          |                     |          |                   |          |
| log(link length)               | 0.36***             | 0.14***  | -              | -        | -                   | -        | -                 | -        |
| Number of intersections        | 0.06***             | -        | -              | -        | -                   | -        | -                 | -        |
| Efron's pseudo R2              | 25.6%               | 17.6%    | 13.9%          | 2.3%     | 7.59%               | 1.6%     | 10.0%             | 4.0%     |
| McFadden's pseudo R2           | 23.9%               | 22.7%    | 13.1%          | 9.3%     | 11.1%               | 8.1%     | 16.6%             | 15.2%    |

Note:

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1

Not significant variables were not estimated in the final model (-)

## Estimation results (Step 2: Count model coefficients)

| Variable                      | Case 1 Car-occupant |          | Case 2 Cyclist |          | Case 3 Cyclist only |          | Case 4 Pedestrian |          |
|-------------------------------|---------------------|----------|----------------|----------|---------------------|----------|-------------------|----------|
|                               | Light               | Severe   | Light          | Severe   | Light               | Severe   | Light             | Severe   |
| Intercept                     | -1.61***            | -6.81*** | -3.24***       | -5.81*** | -4.88***            | -7.06*** | -4.37***          | -5.99*** |
| Traffic conditions            |                     |          |                |          |                     |          |                   |          |
| Motor traffic volume in 1,000 | 0.01***             | 0.01***  | 0.01***        | 0.01     | 0.01***             | 0.01     | 0.01***           | 0.01     |
| x motorway                    | base                | -        | -              | -        | -                   | -        | -                 | -        |
| x primary road                | -                   | -        | -              | -        | -                   | -        | -                 | -        |
| x secondary road              | 0.04***             | -        | -              | -        | -                   | -        | -                 | -        |
| x tertiary road               | 0.11***             | -        | -              | -        | -                   | -        | -                 | -        |
| x residential or minor road   | 0.18***             | -        | -              | -        | -                   | -        | -                 | -        |
| Bike flows in 1,000           | -                   | -        | 0.08***        | 0.08***  | 0.10***             | 0.10***  | -                 | -        |
| Pedestrian flows in 1,000     | -                   | -        | -              | -        | -                   | -        | 0.10***           | 0.11***  |
| Roadway function              |                     |          |                |          |                     |          |                   |          |
| is motorway                   | base                | base     | -              | -        | -                   | -        | -                 | -        |
| is primary road               | -0.30***            | -0.14**  | base           | base     | base                | base     | base              | base     |
| is secondary road             | -0.68***            | -0.14**  | -0.12*         | -0.21*   | -                   | -        | -                 | -        |
| is tertiary road              | -1.28***            | -0.78*** | -0.12*         | -        | 0.32***             | -        | -                 | -0.22    |
| is residential road           | -2.21***            | -0.93*** | -0.11          | -0.43*** | -                   | -0.22*   | -0.24***          | -0.77*** |
| Roadway geometry              |                     |          |                |          |                     |          |                   |          |
| log(link length)              | 0.35***             | 0.81***  | 0.38***        | 0.45***  | 0.51***             | 0.62***  | 0.46***           | 0.54***  |
| Number of intersections       | 0.03***             | -        | 0.03***        | 0.04***  | 0.01***             | -        | -                 | -        |
| Efron's pseudo R2             | 25.6%               | 17.6%    | 13.9%          | 2.3%     | 7.59%               | 1.6%     | 10.0%             | 4.0%     |
| McFadden's pseudo R2          | 23.9%               | 22.7%    | 13.1%          | 9.3%     | 11.1%               | 8.1%     | 16.6%             | 15.2%    |

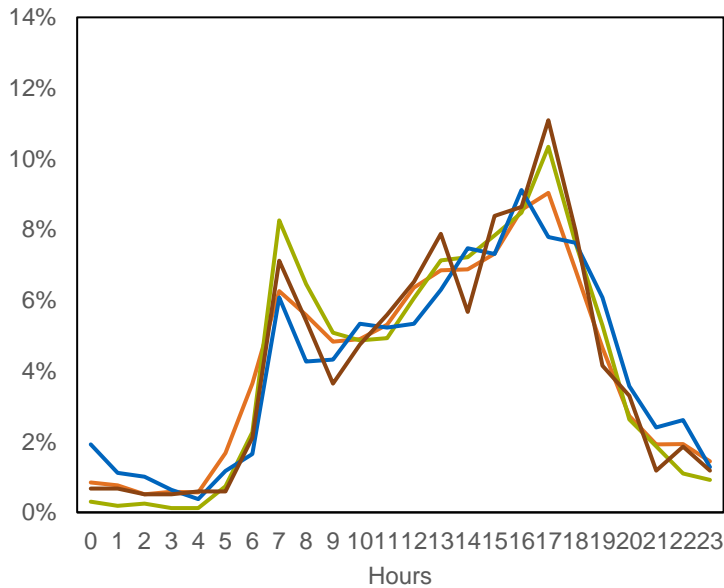
Note:

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1

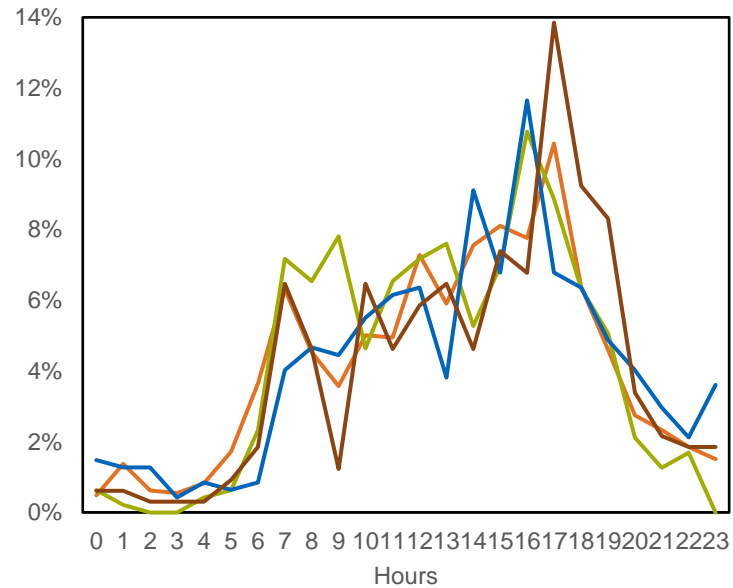
Not significant variables were not estimated in the final model (-)

# Step 2: Crash distribution over time of day

### Light injured crash



### Severe injured crash



- Case 1 Vehicle-vehicle crash
- Case 2 Bike-Vehicle crash
- Case 3 Bike-Bike crash
- Case 4 Pedestrian-x crash

# Step 3: Convert into casualties

Average number of casualties by severity for different travel modes extracted from UK STATS19

|        | Light accident |         |            | Severe accident |         |            |                            |         |            |
|--------|----------------|---------|------------|-----------------|---------|------------|----------------------------|---------|------------|
|        | Light injured  |         |            | Light injured   |         |            | Killed or severely injured |         |            |
|        | Car            | Cyclist | Pedestrian | Car             | Cyclist | Pedestrian | Car                        | Cyclist | Pedestrian |
| Case 1 | 1.23           | 0.00    | 0.00       | 0.29            | 0.00    | 0.00       | 1.01                       | 0.00    | 0.00       |
| Case 2 | 0.01           | 0.99    | 0.00       | 0.01            | 0.01    | 0.00       | 0.01                       | 0.99    | 0.00       |
| Case 3 | 0.00           | 1.05    | 0.00       | 0.00            | 0.00    | 0.00       | 0.00                       | 1.00    | 0.00       |
| Case 4 | 0.02           | 0.01    | 1.03       | 0.01            | 0.00    | 0.05       | 0.02                       | 0.01    | 1.00       |

Case 1: vehicle-vehicle accident

Case 2: bike-vehicle accident

Case 3: bike-bike accident

Case 4: pedestrian-x accident



# Application

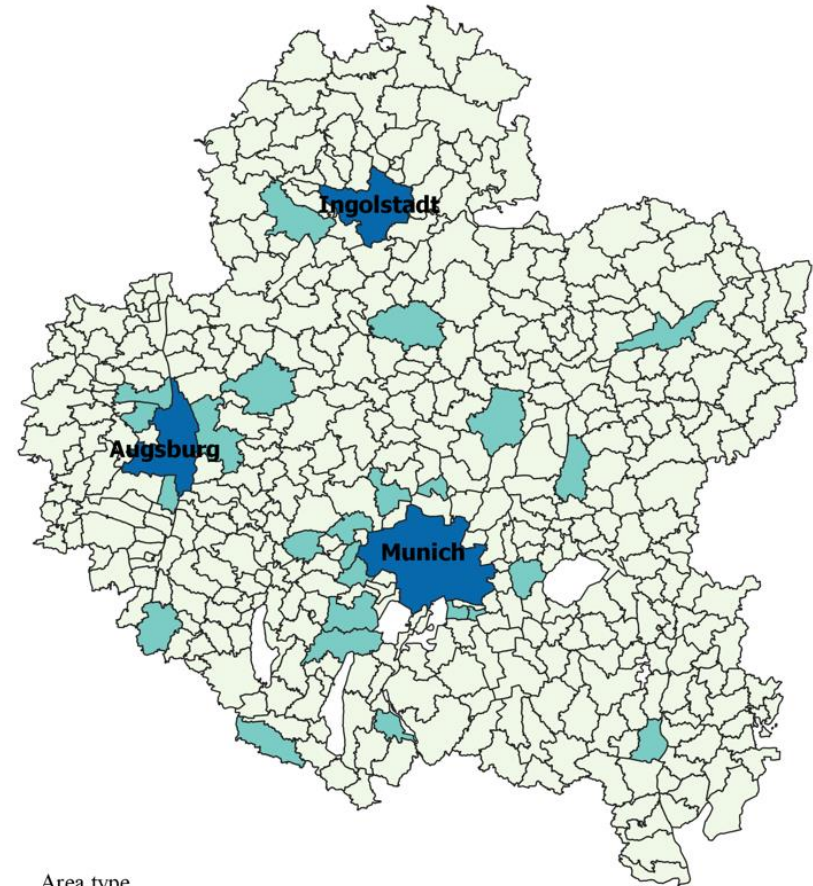
8 million synthetic trips generated from in-house agent-based land use and transport model (SILO and MITO):

... 44% car trips

... 13% cycling trips

... 18% pedestrian trips.

MATSim ran with a subsample of 5% of all trips for trip assignment



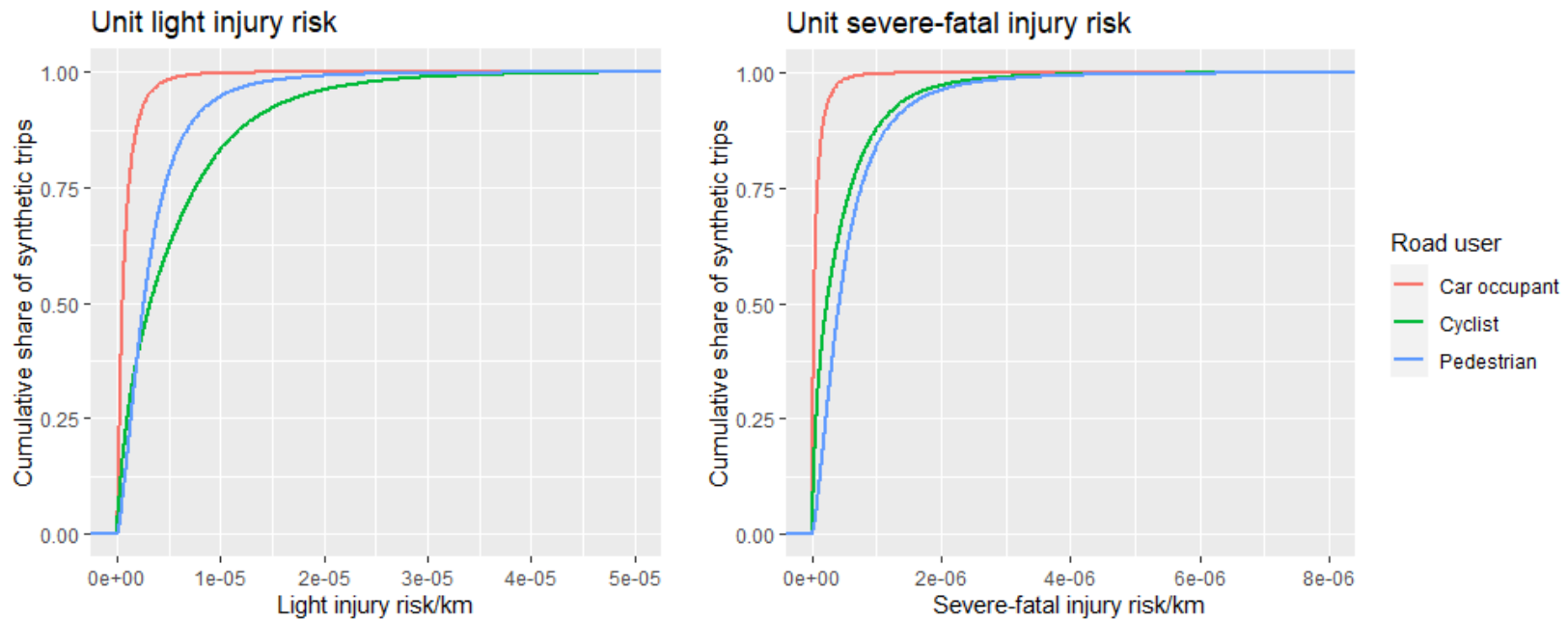
Area type

Urban area: core cities

Urban area: medium-size cities

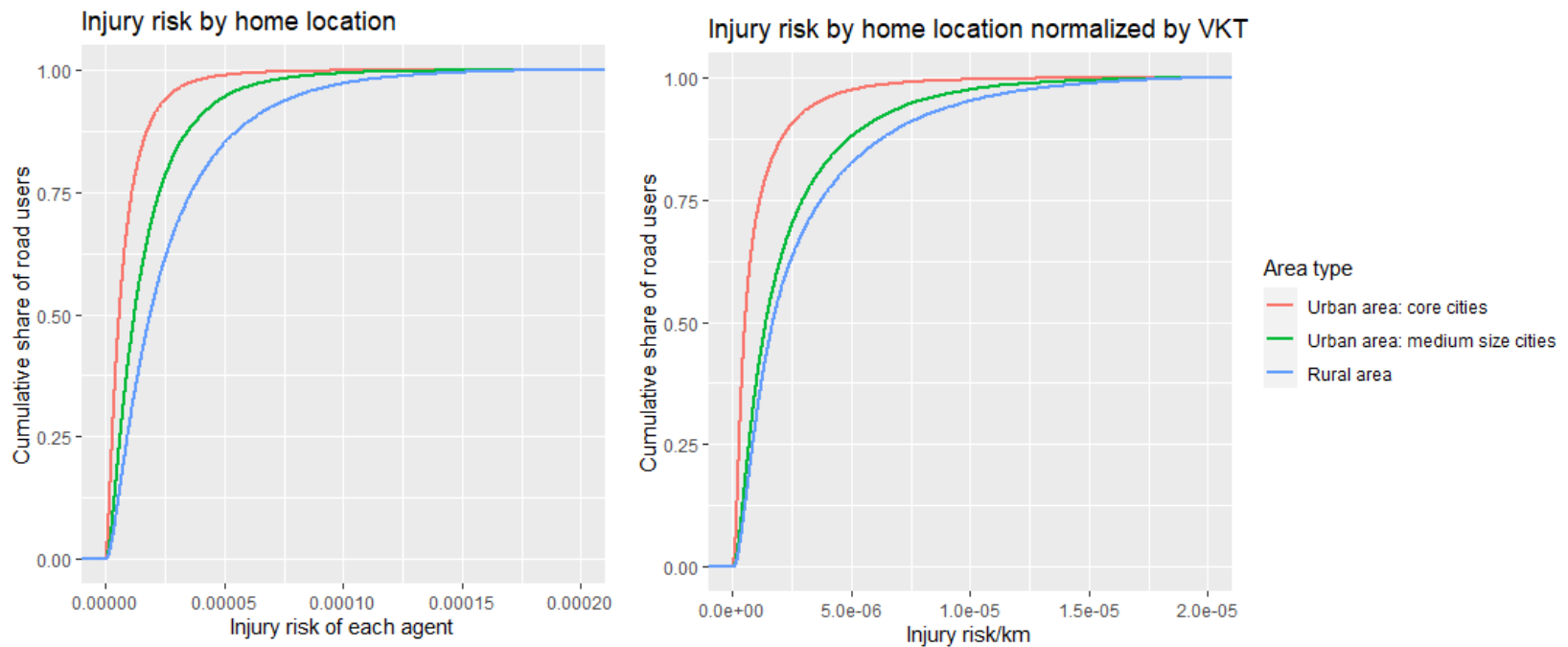
Rural area

# Who are the most vulnerable road users?

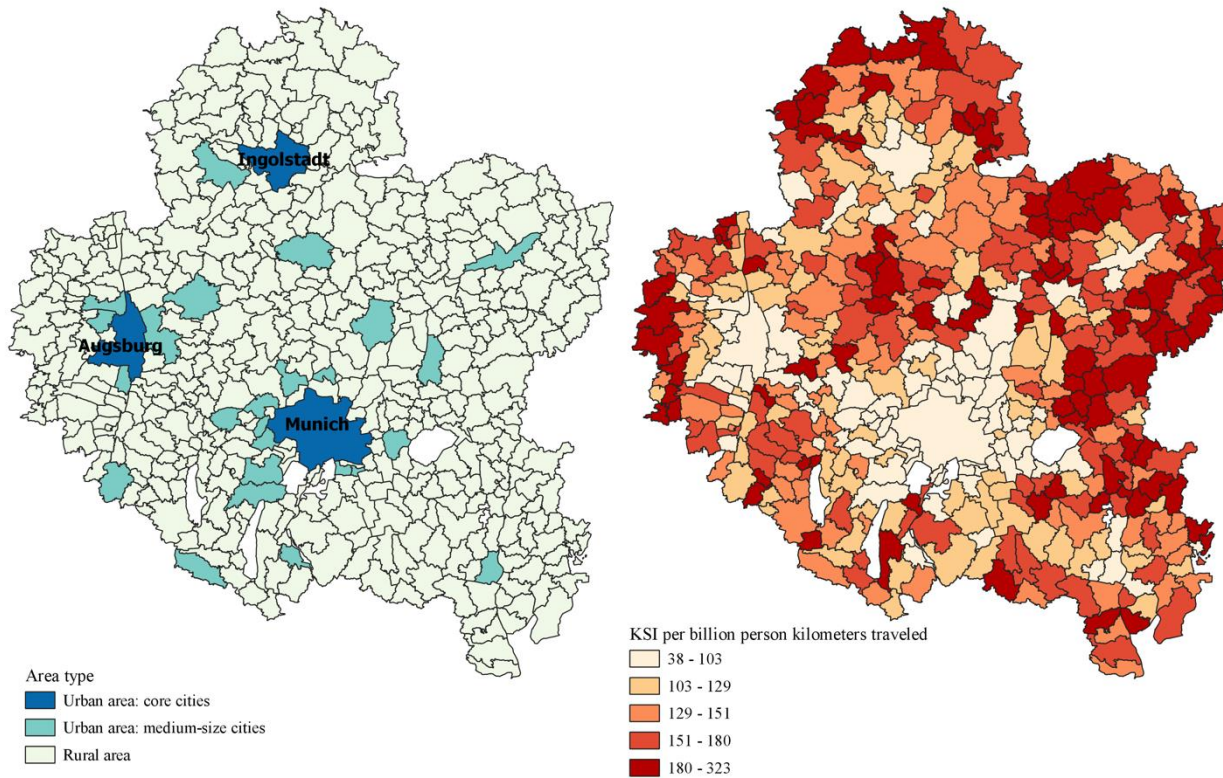


# Road safety inequity?

Distribution of **severe injuries risk** of by the **area type of home location**



# Road safety inequity?



Left: classification of area types for the Munich region

Right: KSI risk per billion person kilometers traveled of each municipality

# Runner in MATSim

```
public void run() {
    com.google.inject.Injector injector = Injector.createInjector( scenario.getConfig() , new AbstractModule(){
        @Override public void install(){
            install( new ScenarioByInstanceModule( scenario ) );
            install( new AccidentsModule() );
            install( new EventsManagerModule());
        }
    });

    Log.info("Reading network file...");
    String networkFile = this.scenario.getConfig().controller().getOutputDirectory() + "car/" + "output_network.xml.gz";
    new MatsimNetworkReader(scenario.getNetwork()).readFile(networkFile);
    Log.info("Reading network file... Done.");

    Log.info("Reading plans file...");
    PopulationReader popReader = new PopulationReader(scenario);
    String plansFile = this.scenario.getConfig().controller().getOutputDirectory() + "car/" + "output_plans.xml.gz";
    popReader.readFile(plansFile);
    Log.info("Reading plans file... Done.");

    analysisEventHandler.setScenario(scenario);
    analysisEventHandler.setAccidentsContext(accidentsContext);
    Log.info("Reading events file...");
    EventsManager events = injector.getInstance( EventsManager.class );
    MatsimEventsReader eventsReader = new MatsimEventsReader(events);
    String eventsFile = this.scenario.getConfig().controller().getOutputDirectory() + "car/" + "output_events.xml.gz";
    events.addHandler(analysisEventHandler);
    eventsReader.readFile(eventsFile);
    Log.info("Reading events file... Done.");

    calculateIndividualInjuryRisk();
    Log.info("Agent crash risk calculation ... Done");
}
```

Thank you for your listening!

Questions?

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München, 22.March.2021

