

# E-Grocery in Terms of Sustainability

Simulating the Environmental Impact of Grocery Shopping for an Urban Area in Hanover

# USEful Hanover

## *The research project USEful*

„Untersuchungs-, simulations- und Evaluations-Tool für Urbane Logistik“

Goal: “Contribution for a sustainable city and transport planning”



Bundesministerium  
für Bildung  
und Forschung

FKZ 03SF0547

# USEful Hanover

## *Our Hanover*

- Population: 535.000
- Districts: 51
- Households: 296.000
- Surface: 204,14 km<sup>2</sup>



# CITIES ARE RUNNING OUT OF SPACE

## *Our Hanover*

Traffic (loads, jams):



Emissions (CO2, NOx etc.):



Quality of life:



# RESEARCH QUESTION

*The research*

“  
How does the area type  
affect the utility of e-  
grocery in terms of traffic  
volume and emission  
output?”



E-Grocery in Germany



E-Grocery Simulation

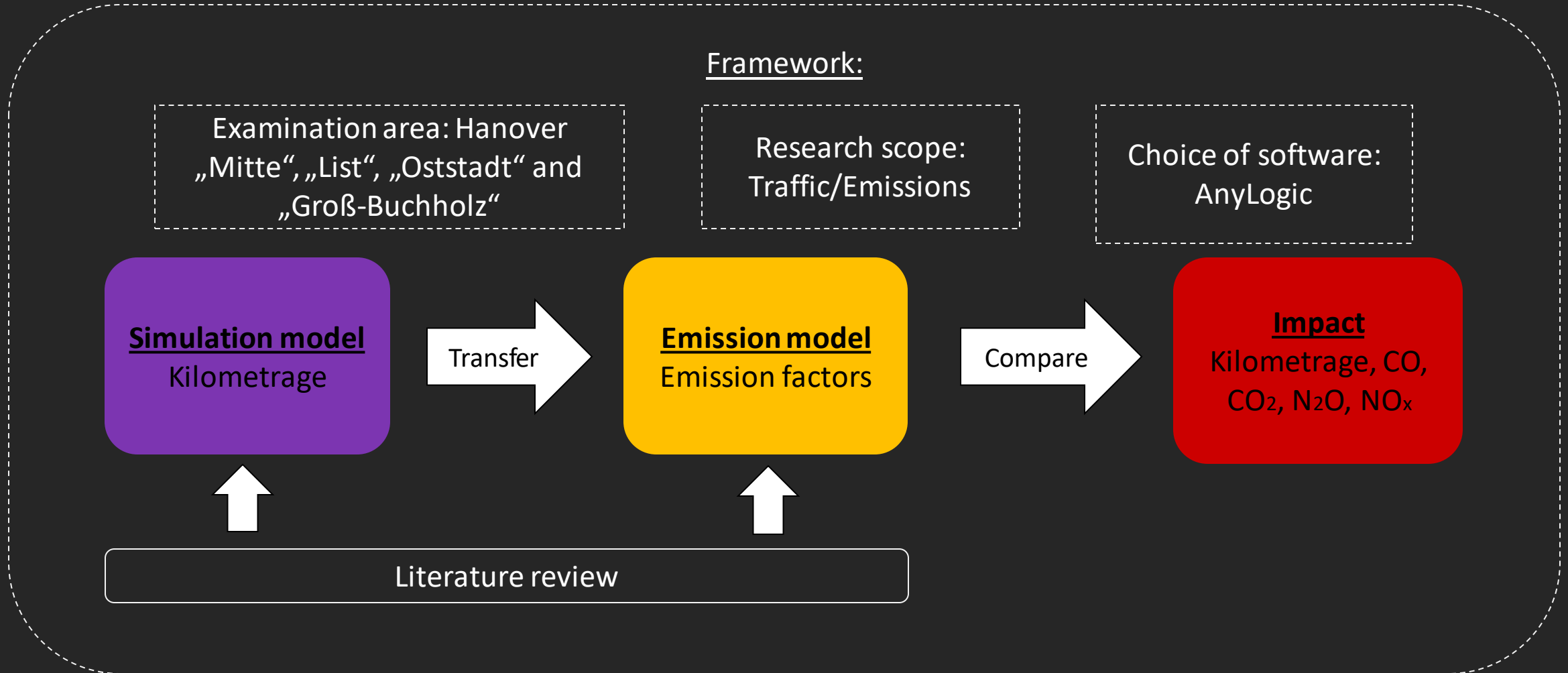


Comparison & Evaluation

Source: <https://www.shutterstock.com/de/image-illustration/techno-mega-city-urban-futuristic-technology-746625394?src=0b4-QBzeY9xrl6M10ucIOl-1-14>

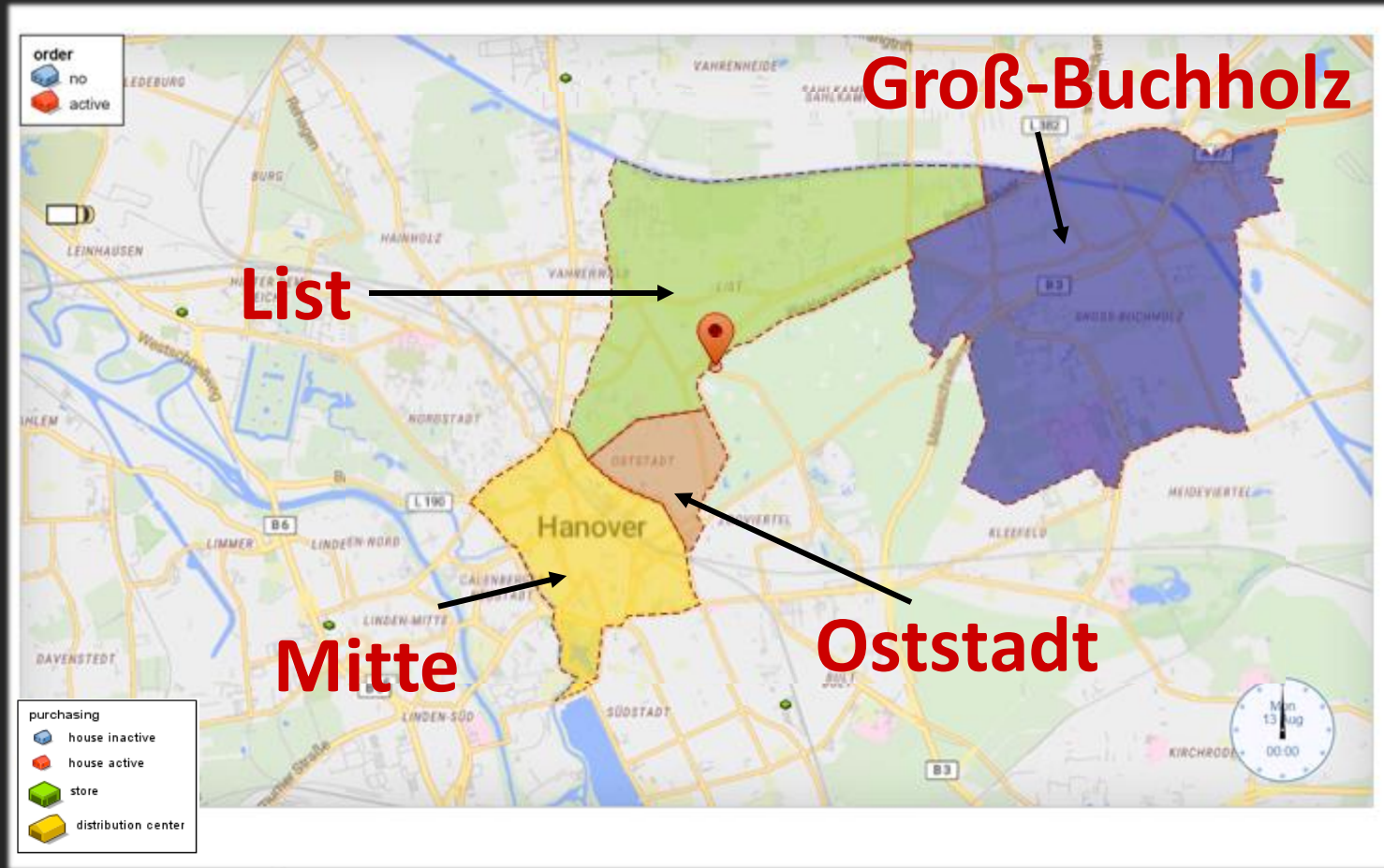
# RESEARCH APPROACH

## *The research*

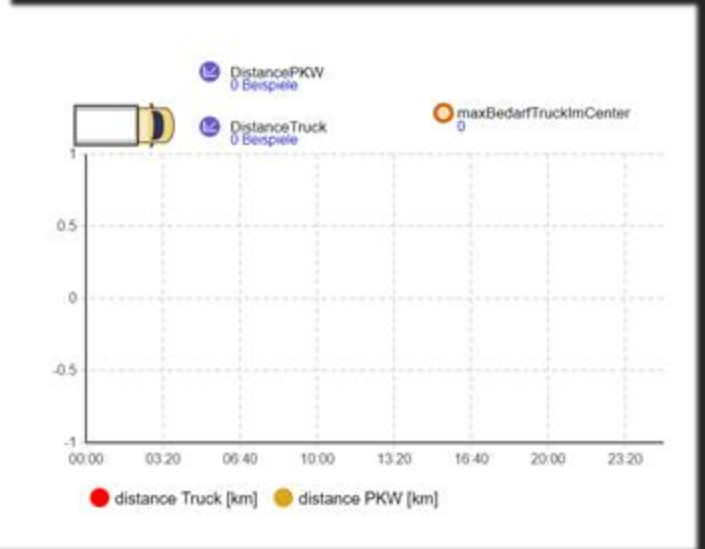


# RESEARCH FRAME

## *Basis modell districts*



- 4 district
- 8700 households
- 84 + 34 supermarkets
- 1 food fulfillment center



# RESEARCH FRAME

## Area types & classification

### City Area

- Trade and industry
- Central facilities (economy, administration and culture)
- Large parking deficits
- Closed construction

**Mitte**

### Residential Area

- Predominantly residential buildings
- Often single and terraced houses

**Oststadt**

### Industrial Area

- Exclusively businesses on large Properties
- Differentiation between tertiary sector (not disturbing) and secondary sector (disturbing)

**Groß-Buchholz**

### Mixed Area

- Mix of all the above

**List**





HOCHSCHULE  
HANNOVER  
UNIVERSITY OF  
APPLIED SCIENCES  
AND ARTS



GEFÖRDERT VOM



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# E-Grocery Simulation

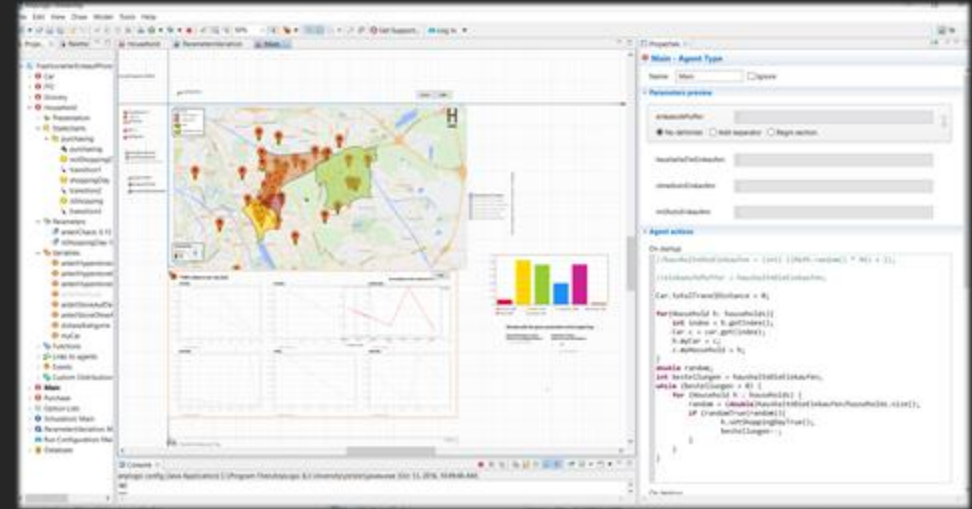
Ein Vergleich zwischen Online-Lebensmittelhandel und stationärem  
Einkauf in Hannover



# Simulation

*With AnyLogic...*

- GIS map (Openstreetmap)
- Incl. Point-Point navigation
- Based on JAVA
- Model building blocks + individual development

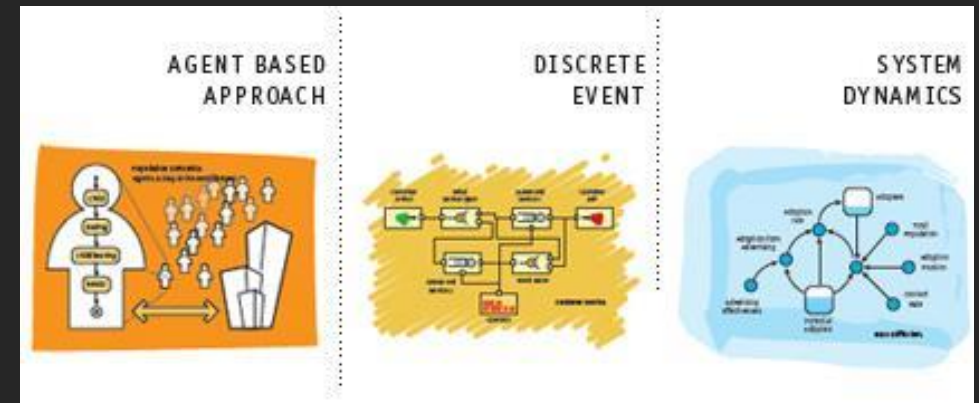


## E-Grocery

- (around 25min / 100 runs)\*

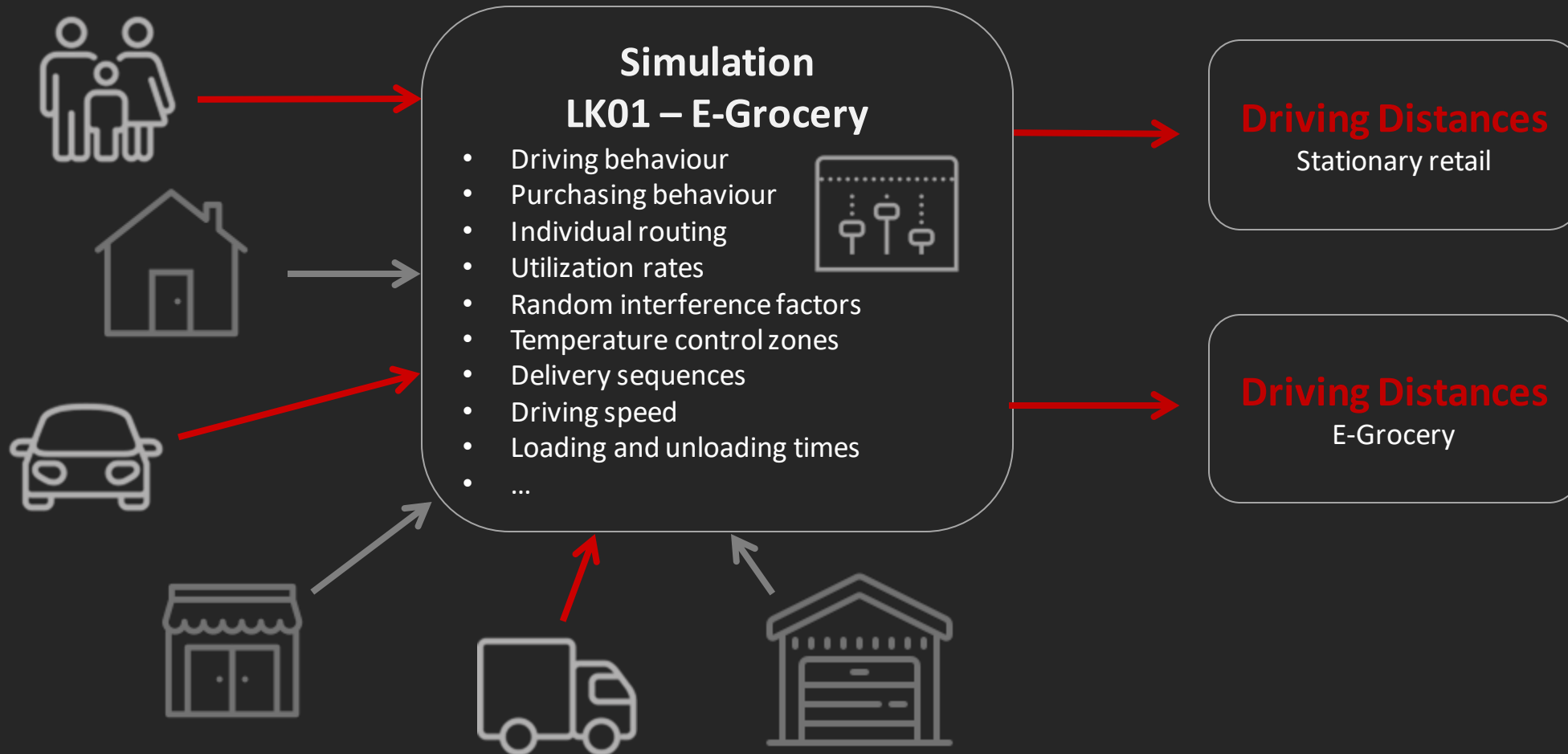
## Traditional shopping

- (around 120min / 100 runs)\*



# EGROCERY MODEL

## *Simulation model scheme*



# EGROCERY MODEL

## *Input parameters*



- 84 stores in pilot area
- 34 discounters in adjoining area
- Variable purchasing times
- 6 days/per week



- 1.604 out of 8700 households
- 3%/10%/20% E-Grocery utilization
- 42% share of bulk shopping
- 51% shopping frequency
- 56% car possession rate



- FFC in Langenhagen
- 2h time-window delivery
- 3 tours per day
- 6 delivery days per week



- Capacity: 1 – 3 loads
- Shopping duration: 25min
- Store selection based on distances and shopping purpose



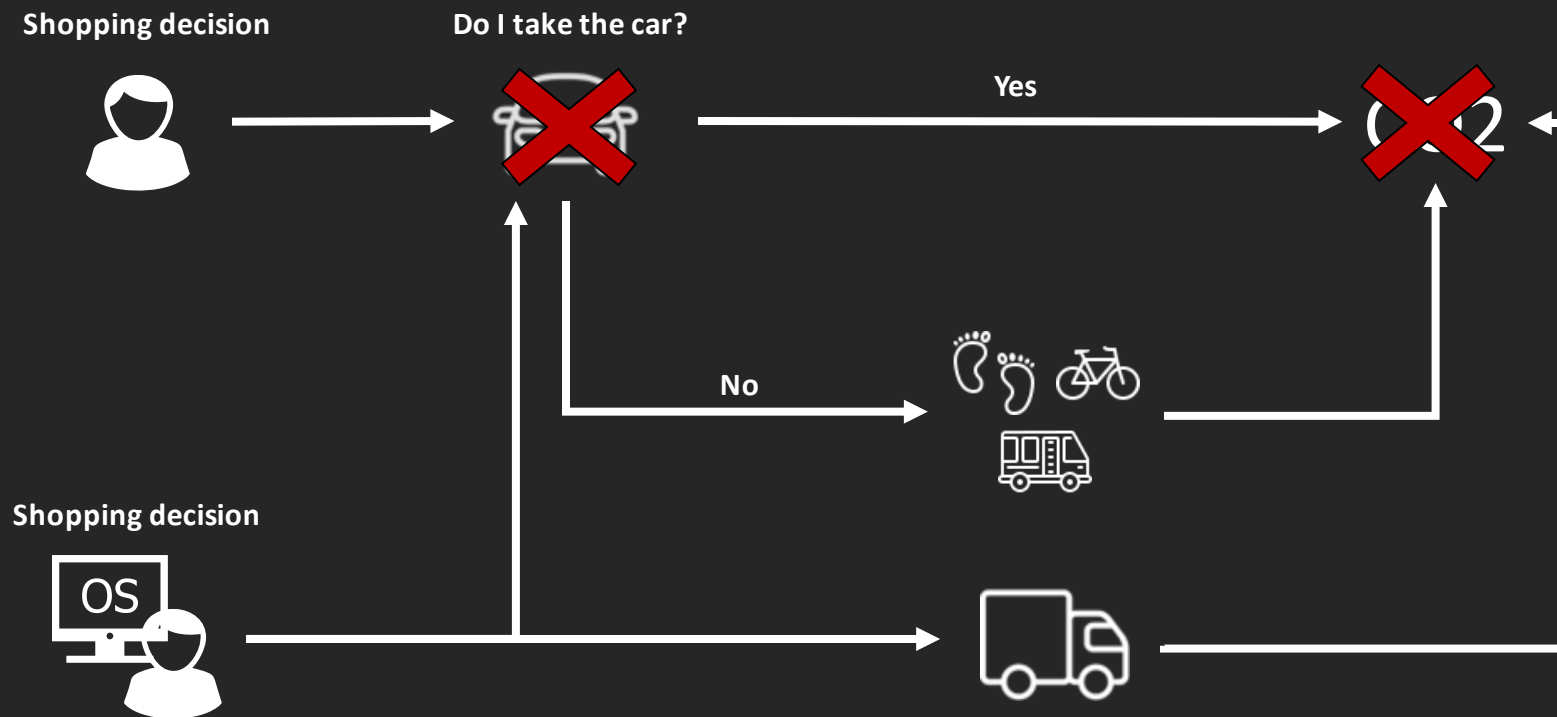
- 18% simulation cope
- 1.000 simulation runs per scenario
- Optimized routing
- Driving speed: 25/30 km/h
- Navigation: Shortest route



- Capacity/vehicle: 18 orders
- Loading time/order: 2 minutes
- Parking duration: 5 minutes
- Unloading time/order: 10 minutes

# EGROCERY MODEL

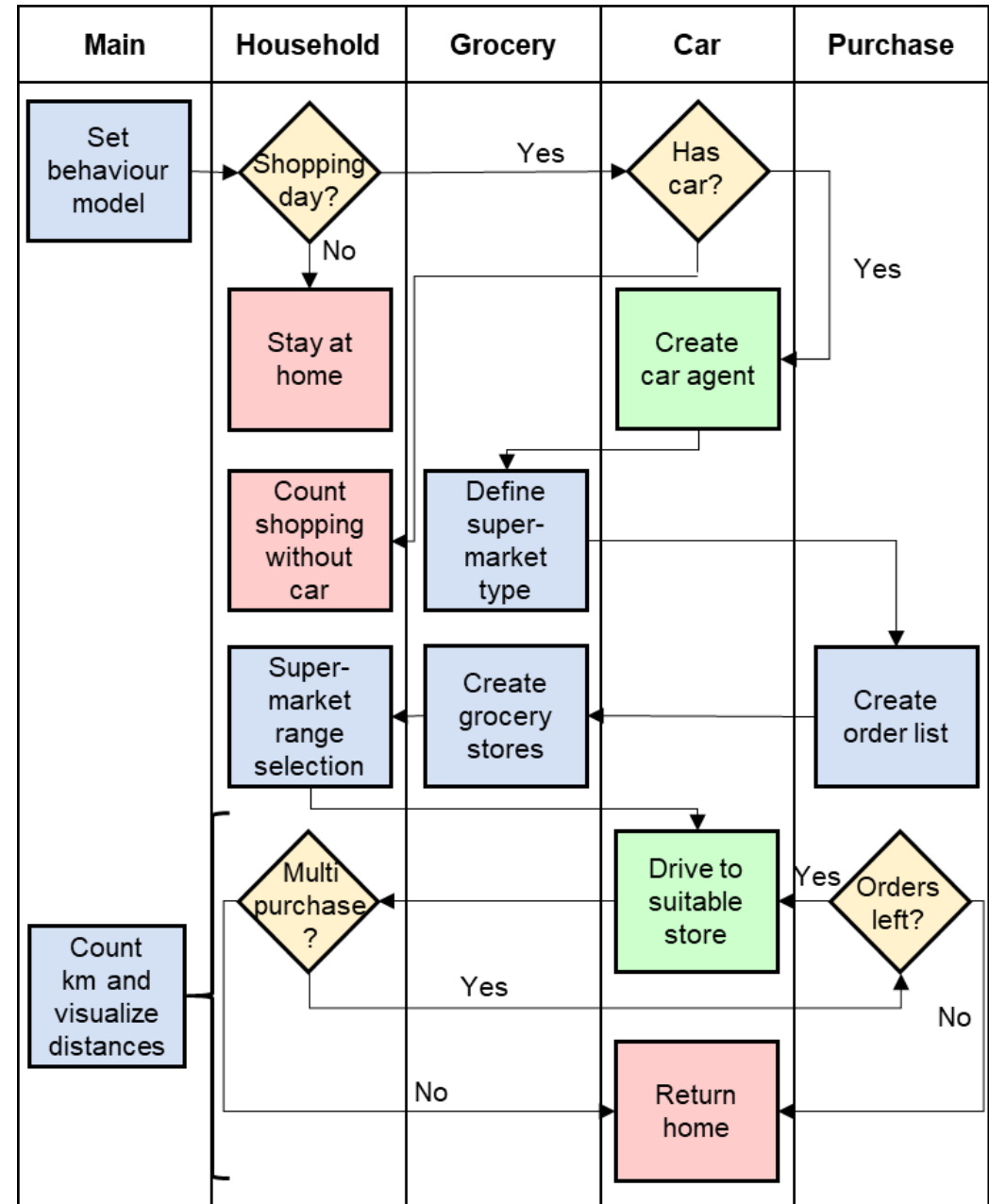
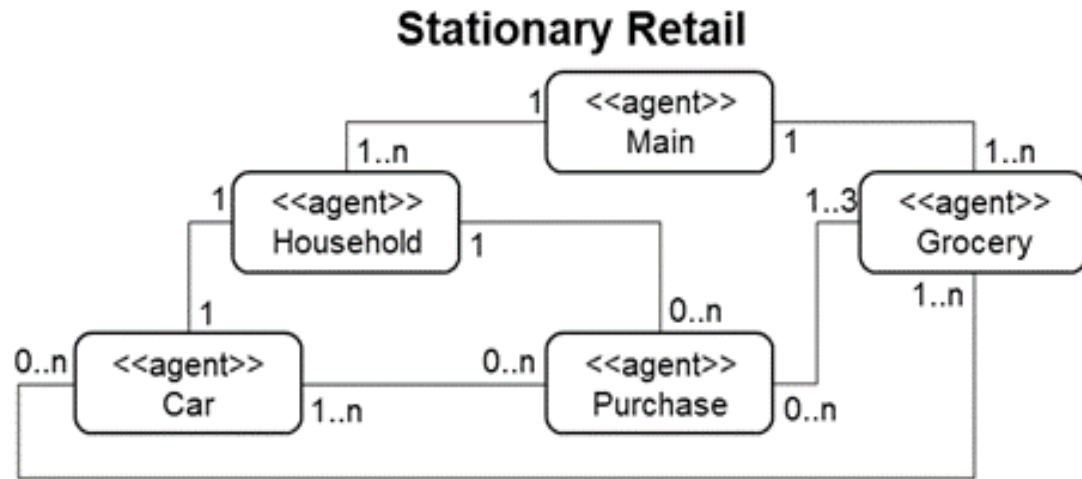
## *Shopping behavior mechanism*



*In E-Grocery, shopping activities of population fractions usually not employing a vehicle for shopping result in additional distances and emissions.*

# EGROCERY MODEL

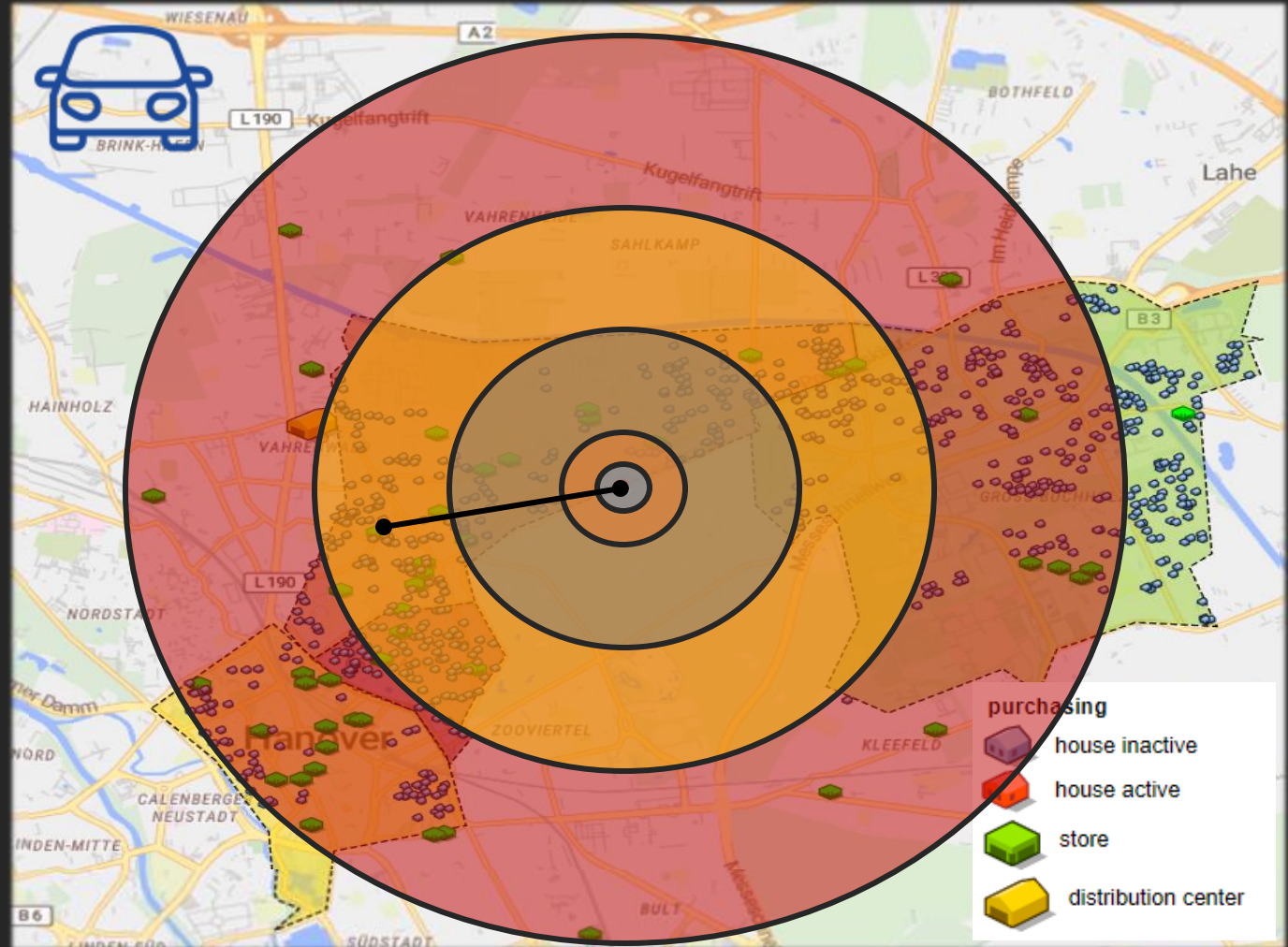
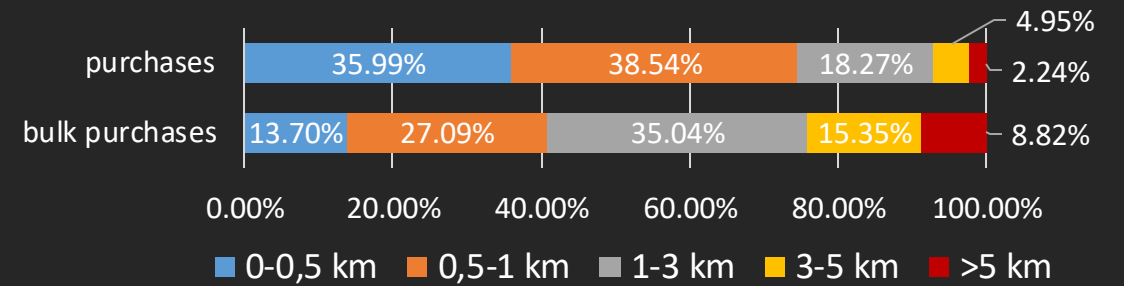
## Process flow – Stationary retail



# EGROCERY MODEL

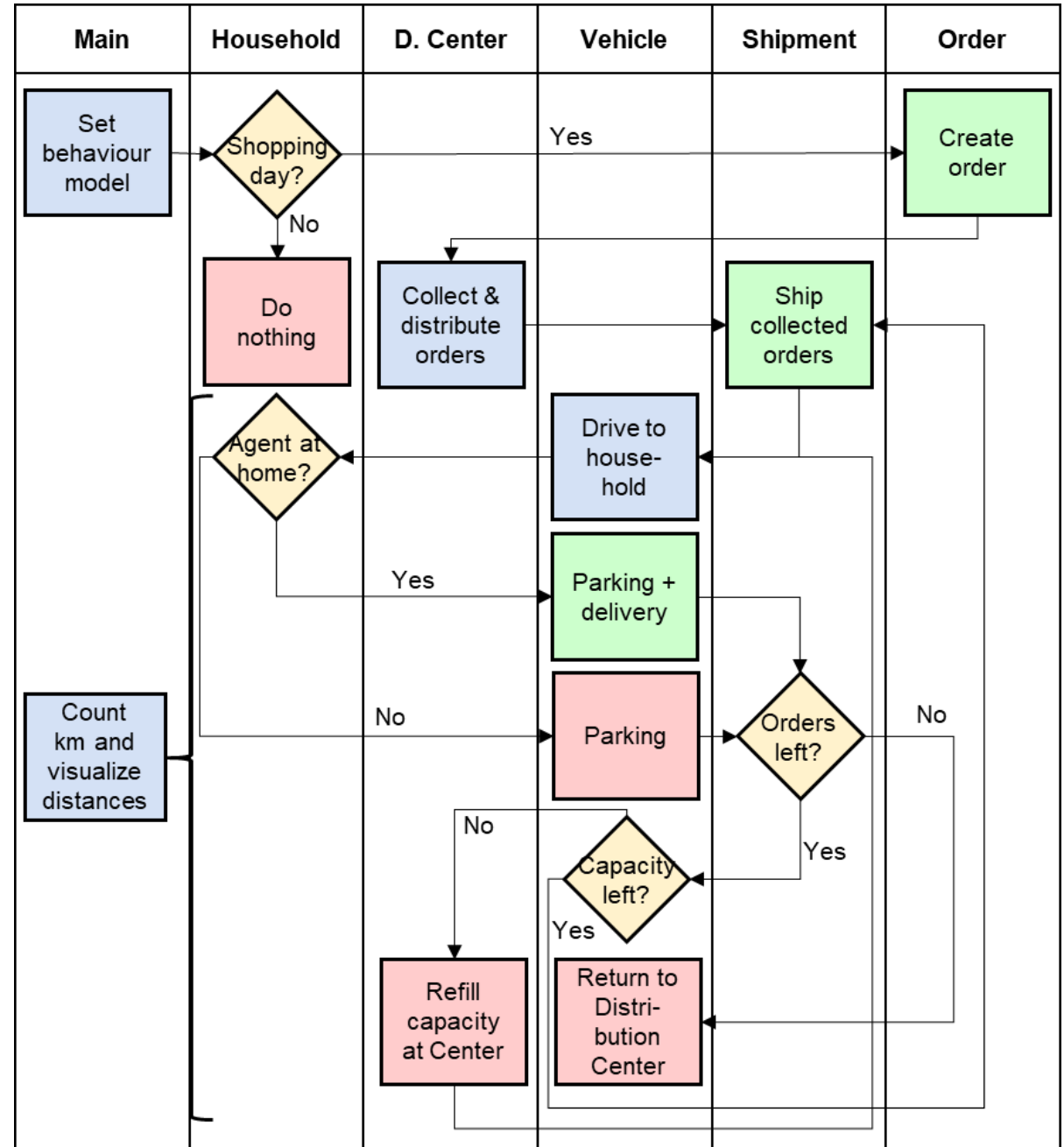
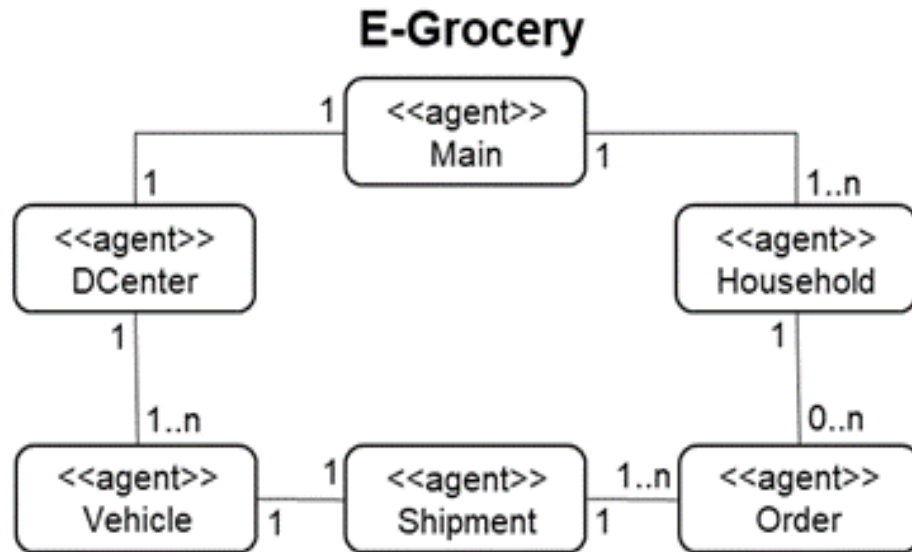
## Supermarket range selection

1. Random demand
2. Selection of stores in distance area
3. House takes random shop in distance area
4. Car determines distances



# EGROCERY MODEL

## Process flow – E-Grocery

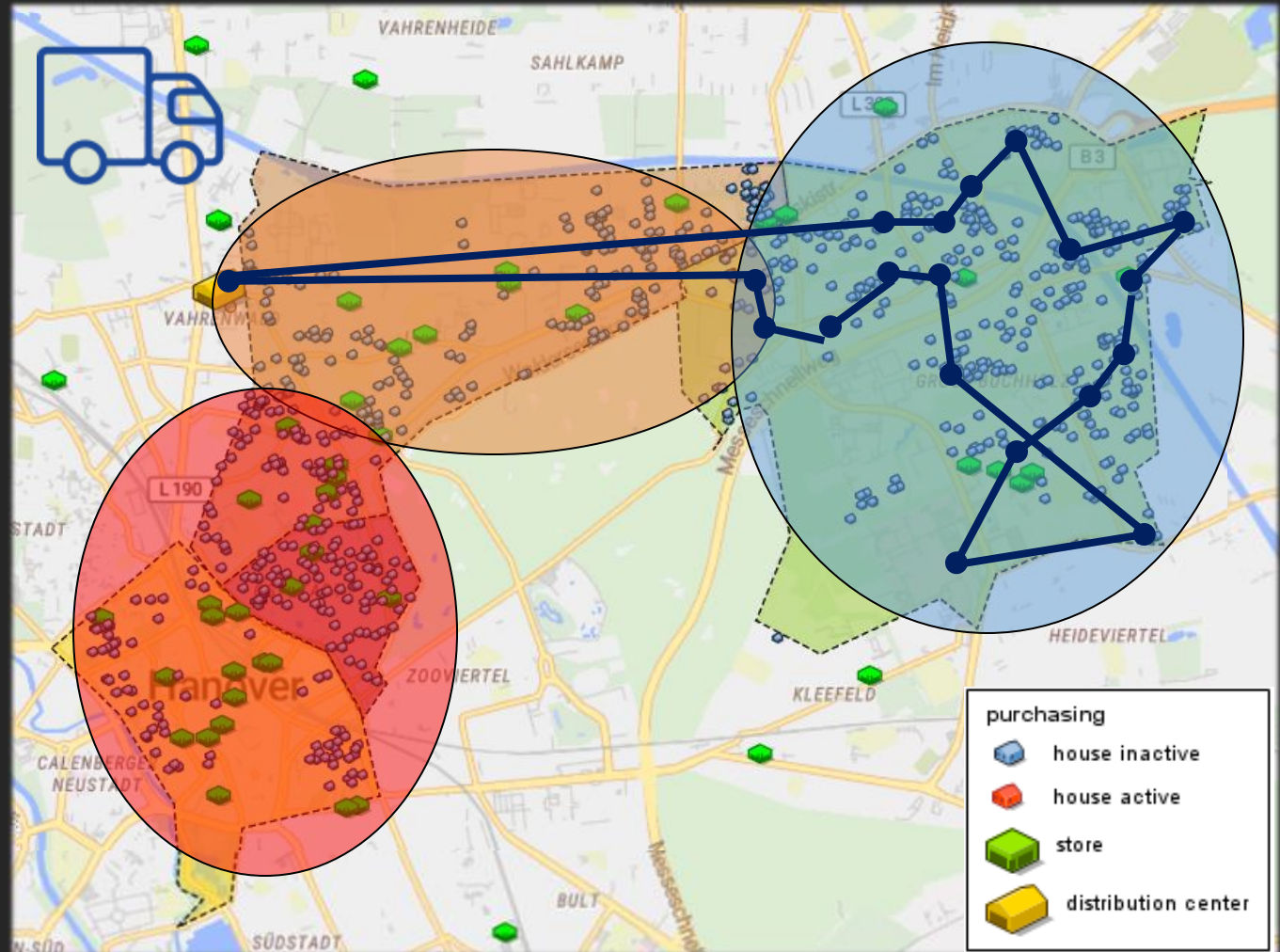




# EGROCERY MODEL

## *Truck navigation*

1. Random orders
2. Sort orders by district
3. Create tours
4. Delivery route calculation (next neighbor t.w.)
5. Truck determines distances

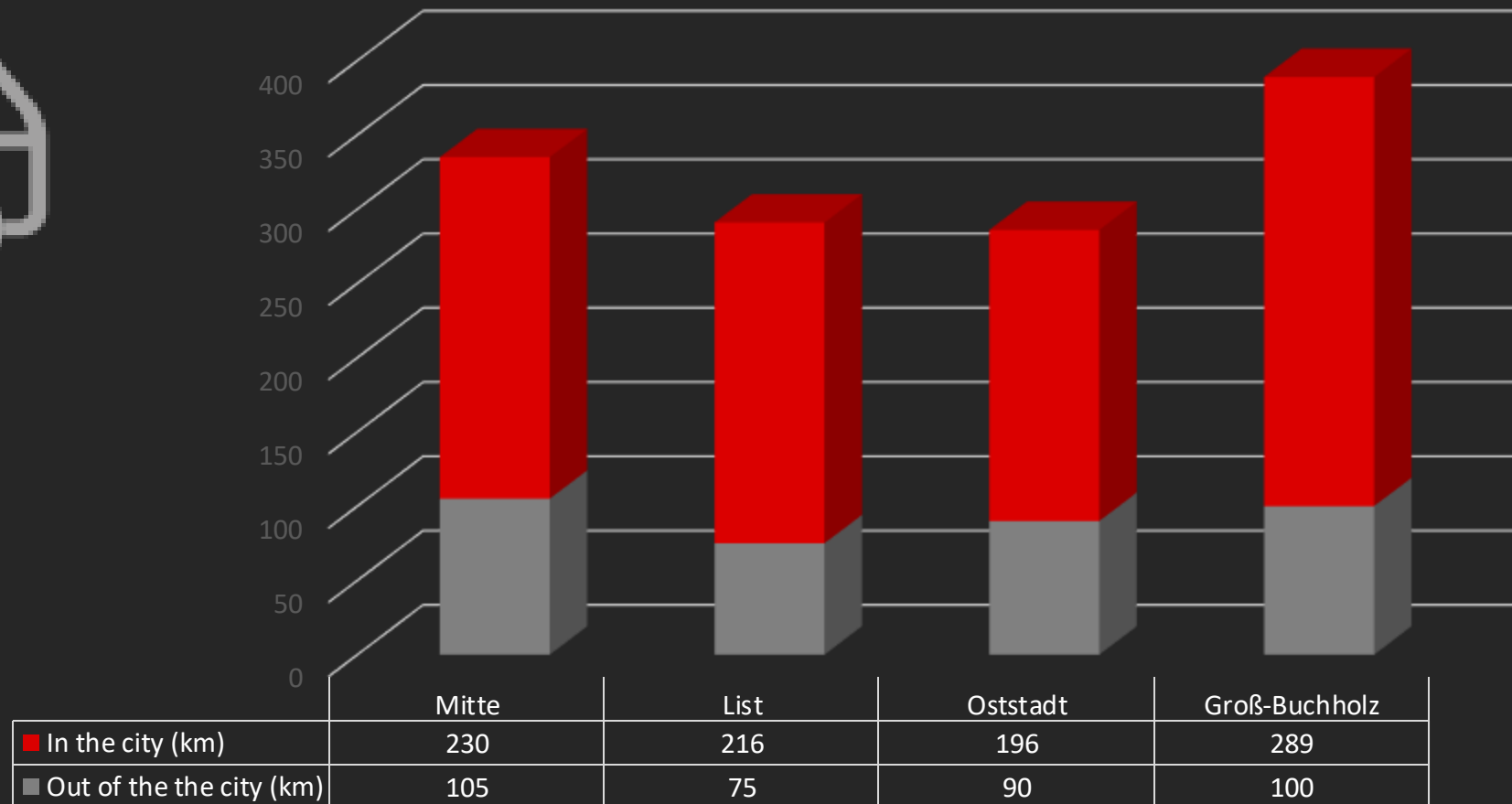


# RESULTS

## *Kilometres driven by transporter*

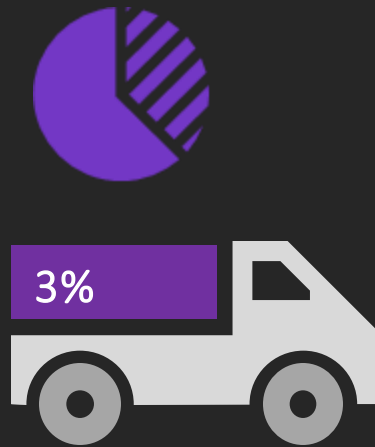


Truck (km)



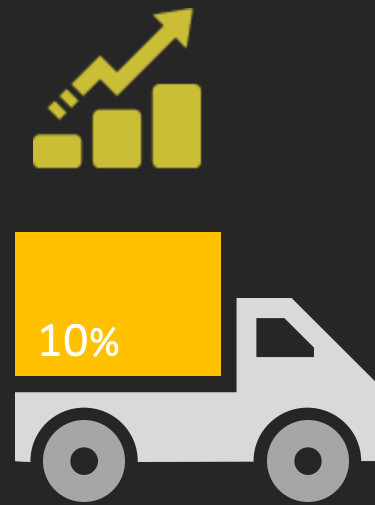
# RESULTS

## *Simulated scenarios*



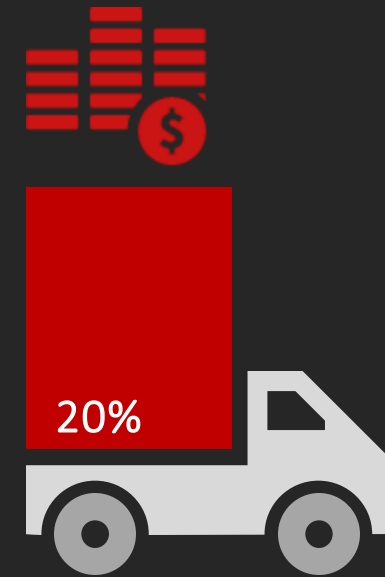
### Scenario 1

3 % E-Grocery  
utilization rate



### Scenario 2

10 % E-Grocery  
utilization rate



### Scenario 3

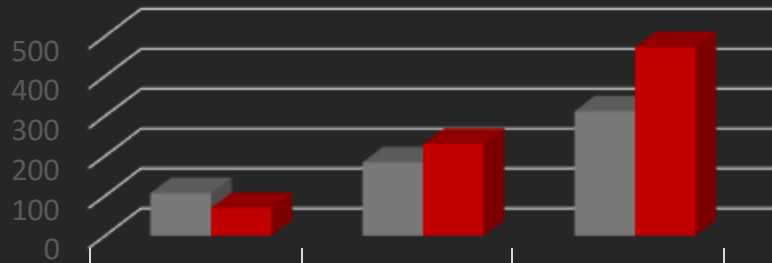
20% E-Grocery  
utilization rate

# RESULTS

## Total distances in kilometers

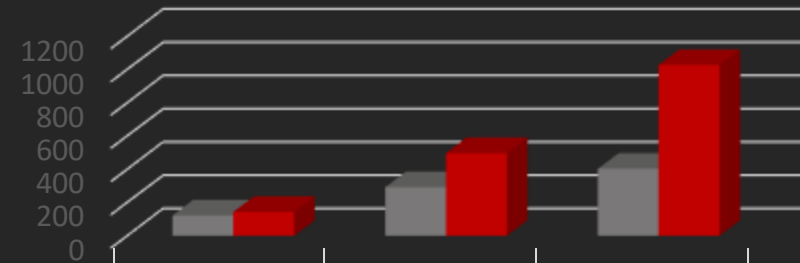


### Hanover "Mitte"



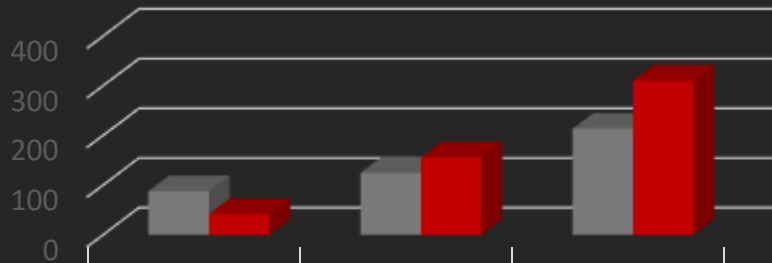
■ Transporter (km)	107	184	312
■ Car (km)	69	230	473

### Hanover "List"



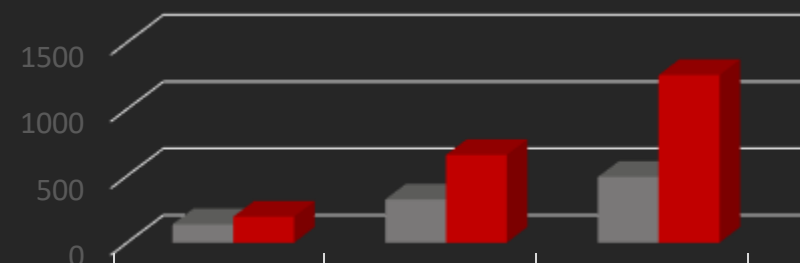
■ Transporter (km)	123	292	403
■ Car (km)	143	497	1027

### Hanover "Oststadt"



■ Transporter (km)	88	125	214
■ Car (km)	42	156	311

### Hanover "Groß-Buchholz"



■ Transporter (km)	138	324	493
■ Car (km)	195	658	1256

# RESULTS

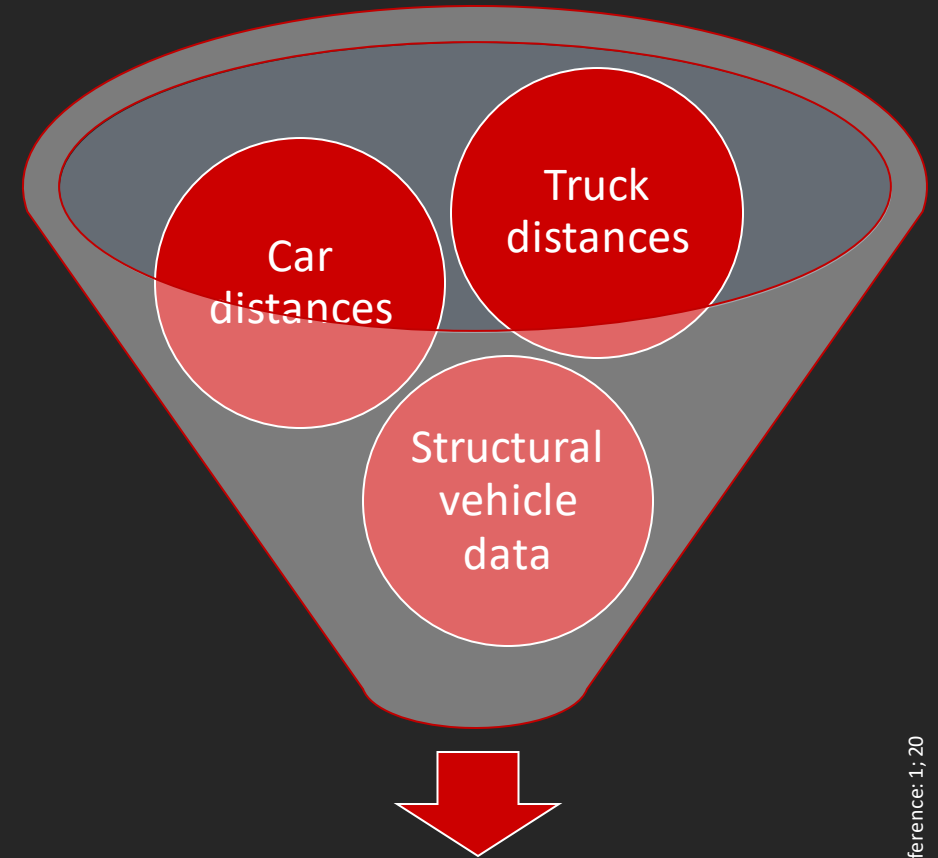
## Emission Model

$$E_{ij} = \sum_k \left( N_{j,k} \times M_{j,k} \times EF_{i,j,k} \right)$$

$N_{j,k}$  - Number of vehicles in a nation's fleet of category  $j$  and technology  $k$

$M_{j,k}$  - Average annual distance driven per vehicle of category  $j$  and technology  $k$  in km per vehicle

$EF_{i,j,k}$  - Technology-specific emission factor of pollutant  $i$  for vehicle category  $j$



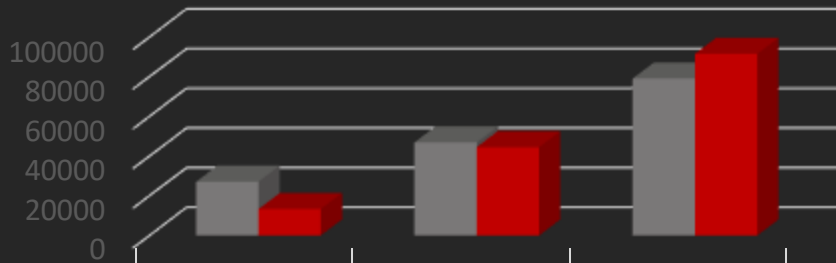
Emission output values: CO, CO<sub>2</sub>, N<sub>2</sub>O, NH<sub>3</sub>, NO<sub>x</sub>

# RESULTS

## Total Emissions: Carbon Dioxide (CO2)

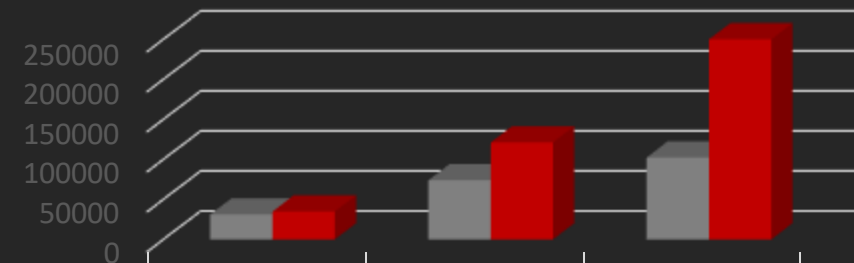


### Hanover "Mitte"



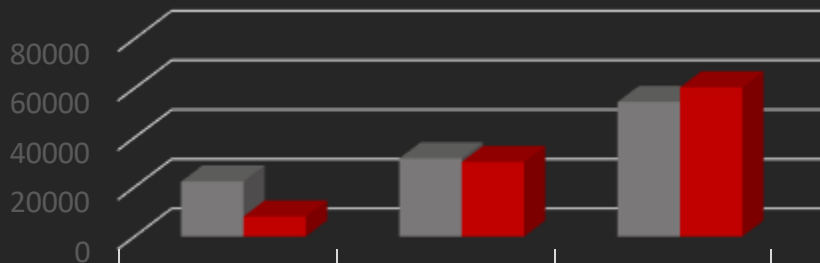
	3%	10%	20%
■ Transporter (g)	27127	46901	79098
■ Car (g)	13353	44511	91538

### Hanover "List"



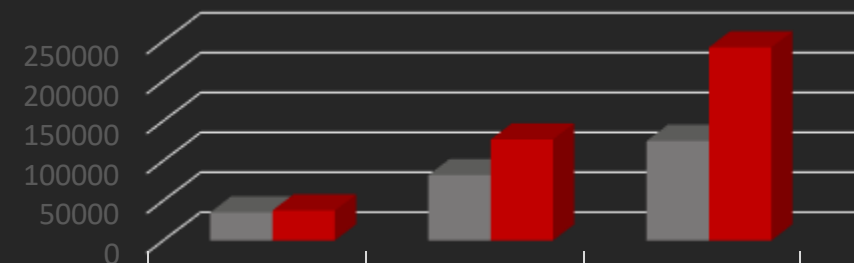
	3%	10%	20%
■ Transporter (g)	31183	74027	102422
■ Car (g)	34805	121207	249959

### Hanover "Oststadt"



	3%	10%	20%
■ Transporter (g)	22310	31690	54507
■ Car (g)	8128	30190	60380

### Hanover "Groß-Buchholz"



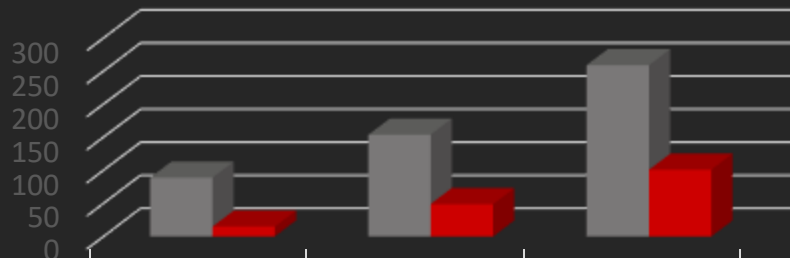
	3%	10%	20%
■ Transporter (g)	35239	82140	124985
■ Car (g)	37577	126797	242209

# RESULTS

## Total Emissions: Nitrogen Oxide (NOx)

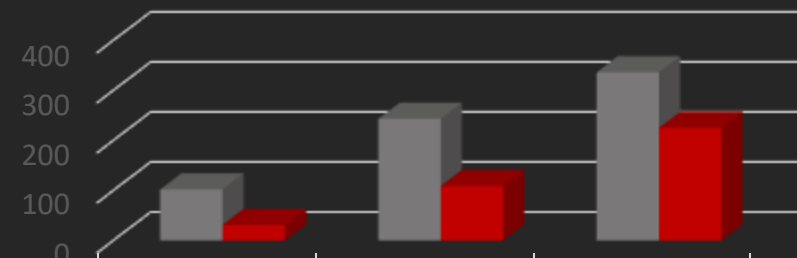


### Hanover "Mitte"



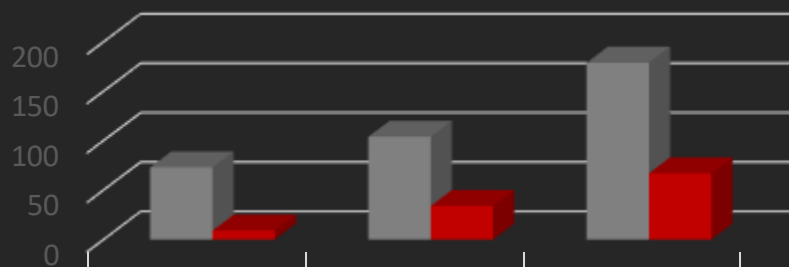
	3%	10%	20%
■ Transporter (g)	89	154	259
■ Car (g)	15	49	101

### Hanover "List"



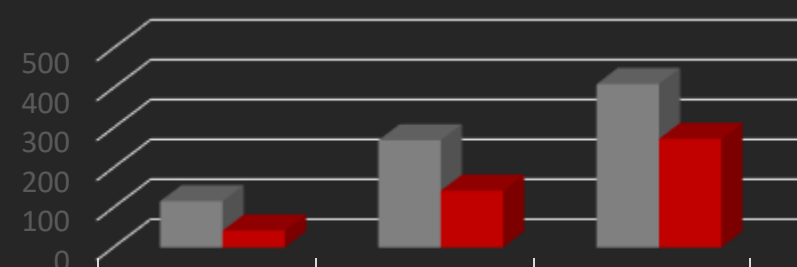
	3%	10%	20%
■ Transporter (g)	102	243	336
■ Car (g)	31	109	225

### Hanover "Oststadt"



	3%	10%	20%
■ Transporter (g)	73	104	179
■ Car (g)	9	34	67

### Hanover "Groß-Buchholz"



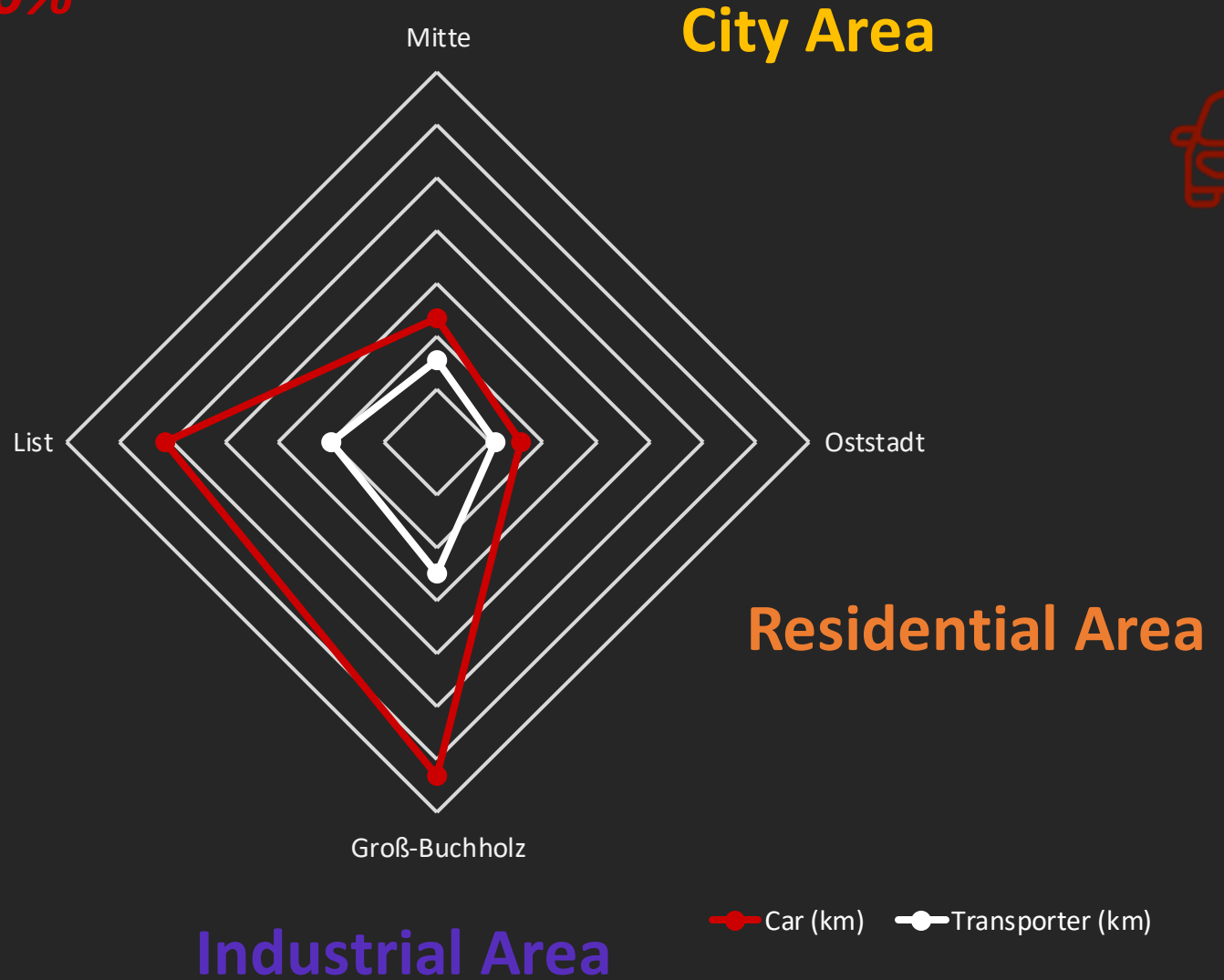
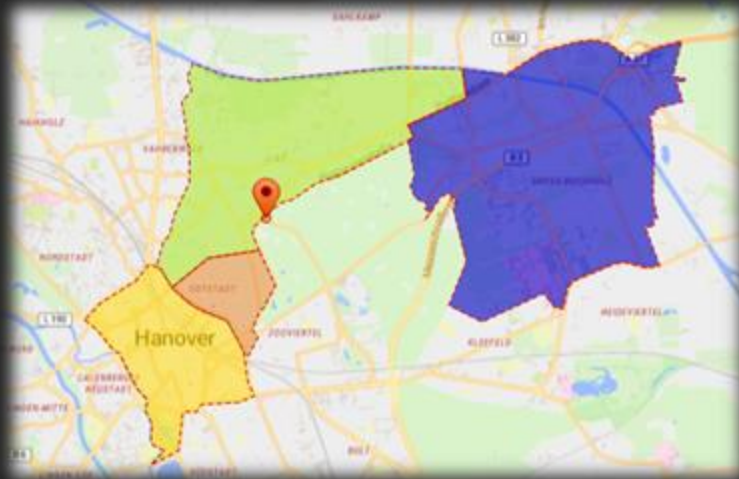
	3%	10%	20%
■ Transporter (g)	116	269	410
■ Car (g)	42	142	272

# RESULTS

*Total distances scenario 20%*



Mixed Area





# CONCLUSION

## *The environmental impact of E-Grocery*



### Emission saving potential

The potential to reduce emissions by means of E-Grocery heavily depends on the utilization rate and the area type. Residential and industrial areas show the most improvement in kilometers traveled and emitted emissions, especially CO and CO<sub>2</sub> (about 40% reduction).



### Uniform, transferable model

Our simulation model offers a sophisticated framework for analyzing and assessing the impact of E-Grocery in different contexts and scenarios. The model is easily transferable to other districts as well as cities and can be used to identify an ideal set-up for saving emissions by leveraging on the advantages of E-Grocery.



### Future research

- Extension of simulation area
- Route combinations
- Sensitivity analysis regarding FFC location
- Cost analysis for individual fulfillment elements
- Extension of the emission model (additional emission factors)
- Crowd-purchasing concept
- Impact of vehicle electrification

# Discussion



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INITIATIVE  
**URBANE**  
**LOGISTIK**  
HANNOVER



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FKZ 03SF0547

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# ANNEX

## Discussion