day 1 | month 0 | year 0

setup | go | go | clear-all

households 955

public parking 1525 | available spots 882

private parking 256 | cars 1183

parents 1816 | childeren 615

total child wish 108

shared car subscriptions 69 | public transport subscriptions 622

parking-permit-costs 0 €

On Off only-park-designated-spots?

amount-of-shared-cars 8

remove-spots-percentage 0 %

average-neighbour-contacts 4

average-parent-contacts-per-child 10

average-daily-neighbour-contacts 0.5

average-daily-parent-contacts 0.8

subscription-monthly-buy-sell-chance 25 %

chance-of-household-moving 10 %

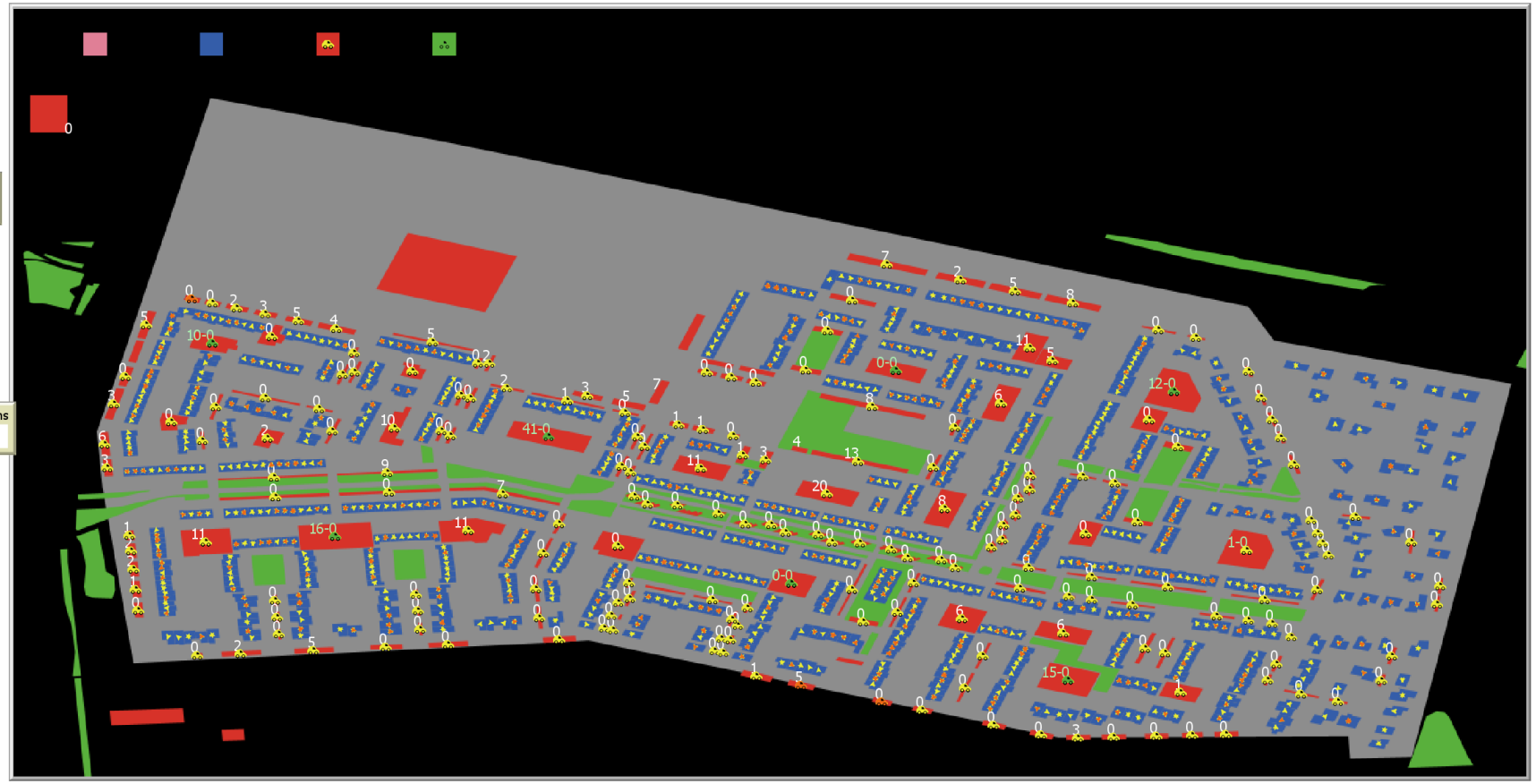
chance-of-moving-out 15 %

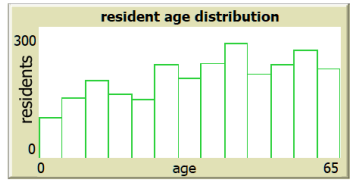
Don't change, not implemented yet.

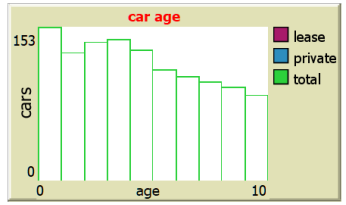
days-in-month 31 | days in year 372

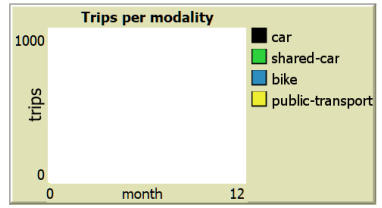
months-in-year 12

TODO: Make time compression working.









mean modality-preference car 0.69293

Distances: Gamma distribution parameters

mean-distance-work 44 km | variance-distance-work 440

mean-distance-other 22 km | variance-distance-other 220

Frequencies: Poisson distribution parameters

mean-weekly-work-trips 4.3 | work trips 4.04

mean-weekly-other-trips 6.8 | other trips 5.82

social-adoption-multiplier 0.10

Higher means more utility focussed

mean-preference-utility-tradeoff 0.50

Means for initial individual preference distribution

initial-car-preference 0.70 | initial-car-chance-parent 65 %

initial-shared-car-preference 0.50 | initial-car-chance-child 20 %

initial-bike-preference 0.50 | initial-public-transport-subscriptions 25 %

initial-public-transport-preference 0.30 | initial-shared-car-subscriptions 2 %

Costs

shared-car-costs-per-km 0.30 € | shared-car-costs-per-hour 3.25 €

car-costs-per-km 0.23 € | fixed-car-costs 257 €

Trip duration

work-trip-length 8 hour

other-trip-length 2.50 hour

Value of (travel) time (Gamma distributed)

mean-value-of-time 8.75 €/hour

variance-value-of-time 12.0

public-transport-fixed-costs 1.08 € | public-transport-costs-per-km 0.20 €

Travel speed

mean-car-speed 46.3 km/h | mean-public-transport-speed 34.8 km/h | mean-bike-speed 11.8 km/h

preference-penalty-parking-outside-neighbourhood 0.5 %

Agent-based car sharing: Model presentation

Mick Princen & Ewout ter Hoeven

27-02-2023

RIVM, Bilthoven

Conceptualisation

Problem identification, system decomposition and conceptual behaviour

Problem identification

Current emergent pattern: many (empty) parking spaces in the neighbourhood, little availability of shared mobility, and a dominance of private car ownership resulting in heavy car use, congested traffic, unsafe streets and a large climate impact.

Desired emergent pattern: modality choice shift from private cars to shared mobility, public transport and other emission-friendly modes of transport to solve congestion and safety problems in addition to making ENKA a more sustainable, circular and comfortable neighbourhood.

Goal of using ABM in ENKA Ede

Research questions:

- For RIVM: *'How can transformative, participatory ABM and accompanying data science contribute to policy making and transitional processes, such as the energy transition, mobility transition, and the transition towards a safe and healthy circular economy?'*

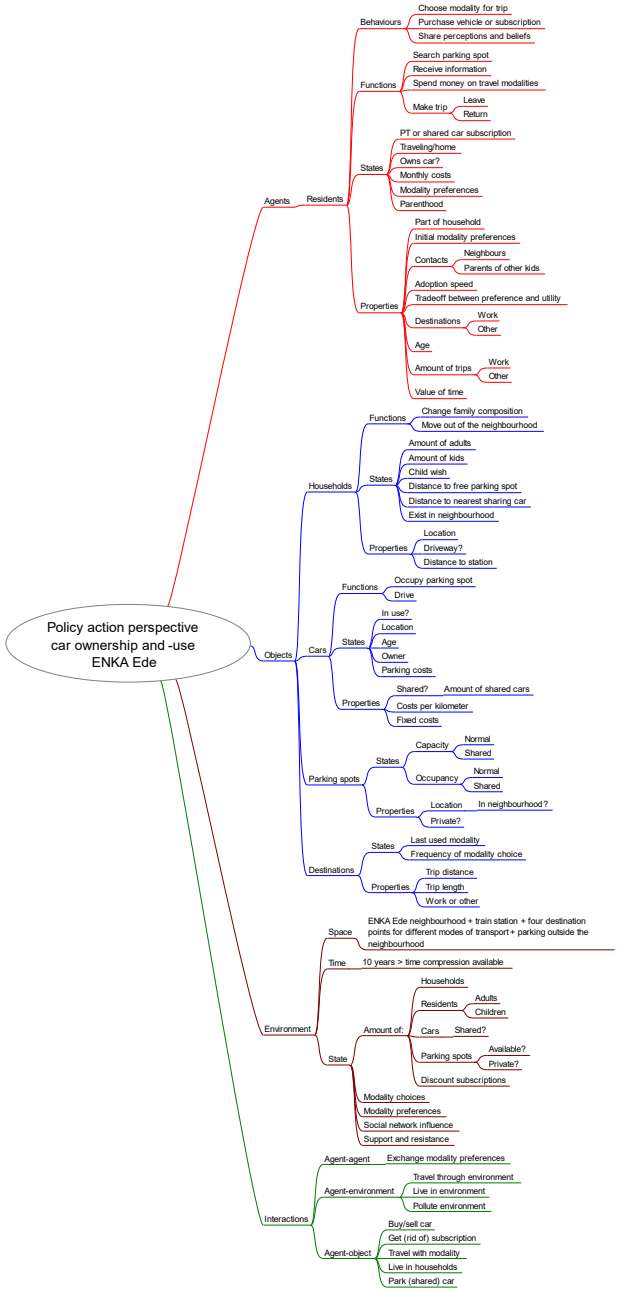
- For this specific model (case study): *'What is the emergent effect of implementing transitional policies that discourage private car ownership and use on modality choice behaviour, quality of living, and the public space in ENKA Ede?'*

System decomposition

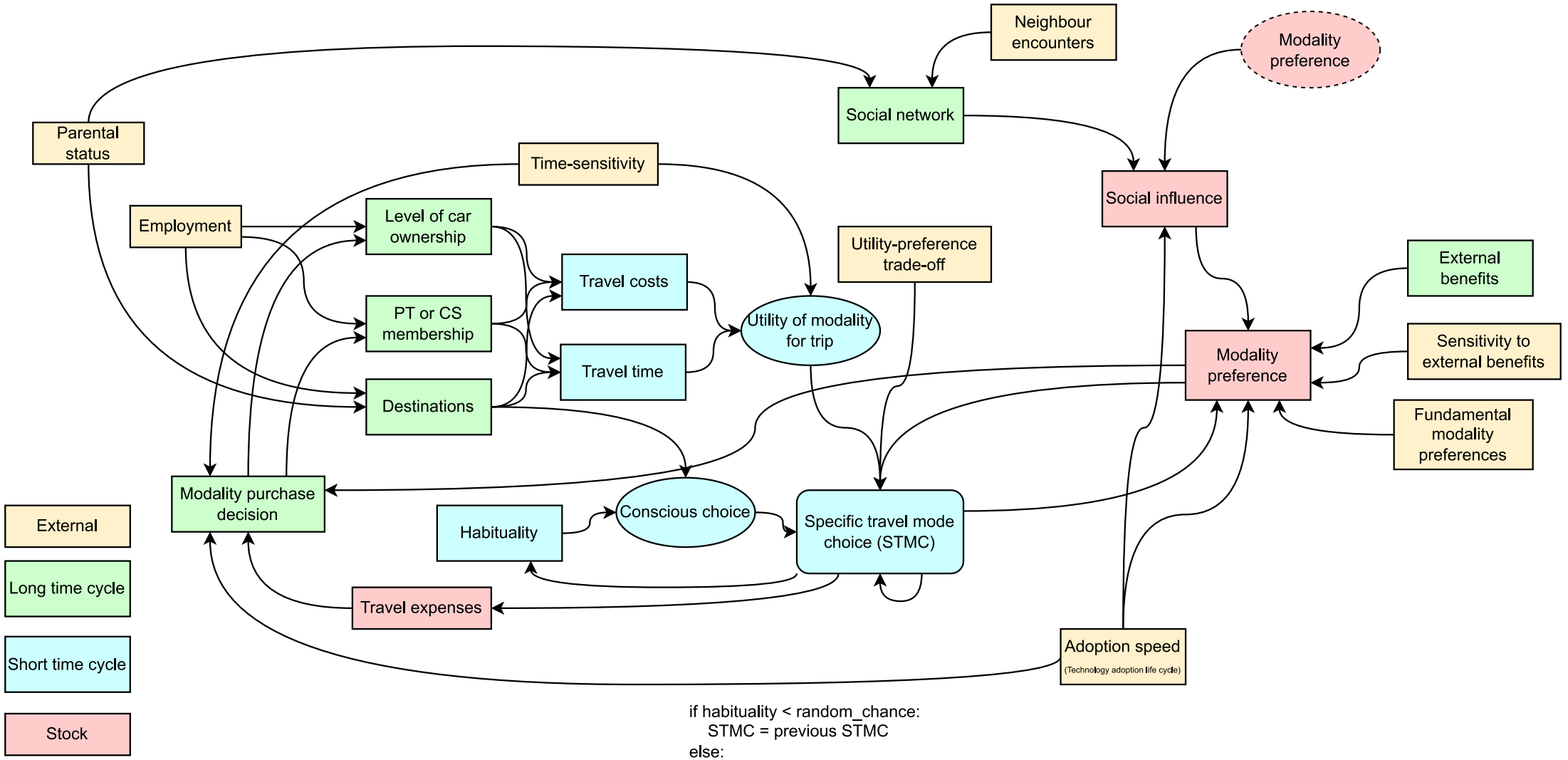
Agents
- Residents

Objects
- Households
- Cars
- Parking spots
- Destinations

KPI’s
- Monthly trips with each modality (modality choices)
- Count of cars and subscriptions (car ownership)
- Average private car opinion (support and resistance)



Conceptual behaviour model




```
if habituality < random_chance:
    STMC = previous STMC
else:
    STMC = Utility * UP-tradeoff + Preference * (1- UP-tradeoff)
```

Formalisation

How are the core functionalities specified

Important formulas to implement behaviour

	Formulas
Effective car costs	trip-distance * car-costs-per-km + (trip-distance / mean-car-speed) * value-of-time
Effective bike costs	trip-distance / mean-bike-speed * value-of-time
Effective public transport costs	trip-distance * public-transport-costs-per-km + (trip-distance / mean-public-transport-speed + 2 * distance-station-from-household / mean-bike-speed) * value-of-time
Effective shared car costs	trip-distance * shared-car-costs-per-km + trip-length * shared-car-costs-per-hour + (trip-distance / mean-car-speed) * value-of-time
Modality choice	utility-of-modality * preference-utility-tradeoff + modality-preference * (1 - preference-utility-tradeoff)
Car preference penalty	modality-preference-car * (1 – preference-penalty-parking-outside-neighbourhood * 0.01)
Chance to sell car	(total-car-costs - total-costs) / total-car-costs * preference-utility-tradeoff + (preferences-without-car - modality-preference-car) * (1 - preference-utility-tradeoff)
Chance to buy car	(total-costs - total-car-costs) / total-costs * preference-utility-tradeoff + (modality-preference-car - preferences-without-car) * (1 - preference-utility-tradeoff)
Update preference social network	modality-preference * (1 - alpha) + contact-preference * alpha

Experiments

Testing policy interventions

Experimental design

Stimulate shared cars

- Default = 8 shared cars
- Option 1 = 32 shared cars
- Option 2 = 128 shared cars

Paid parking

- Default = Parking is free
- Option 1 = Parking costs € 93,60 / year (€ 7,80 / month)
- Option 2 = Parking costs € 93,60 / quarter (€ 31,20 / month)

Replace parking spots

- Default option = no parking spaces are removed
- Option 1 = 20% of parking spaces are removed
- Option 2 = 40% of parking spaces are removed

Parking package

Combining Paid parking and Replace parking spots

- Default option = Parking is free and no spaces are removed
- Option 1 = Parking costs € 22 euro per month and 20% of the parking spaces removed
- Option 2 = Parking costs € 93 euro per month and 40% of the parking spaces removed

Full package

Combining all three policy options

- Default option = 8 shared cars, parking is free and no spaces are removed
- Option 1 = 32 shared cars, parking costs € 7,80 p.m. and 20% of parking spaces removed
- Option 2 = 128 shared cars, parking costs € 31,20 p.m. and 40% of parking spaces removed

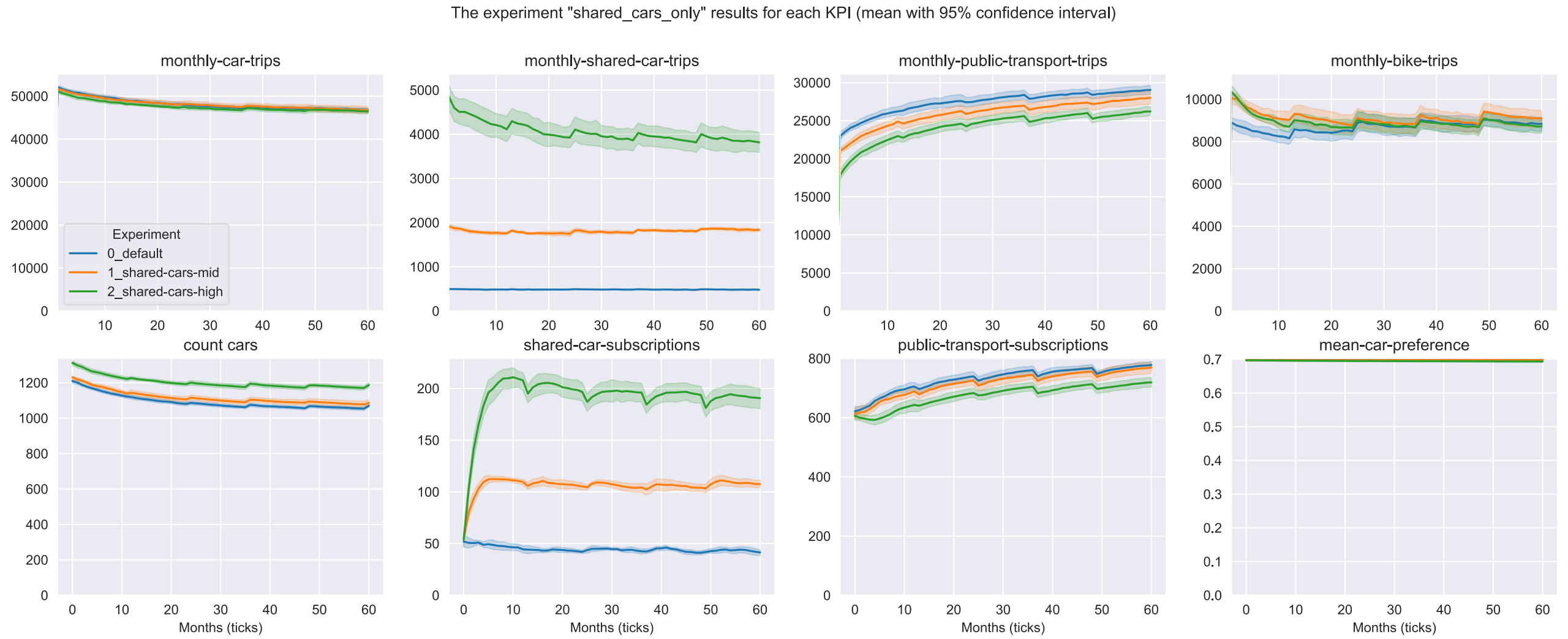
Experimental setup

Simulation parameters

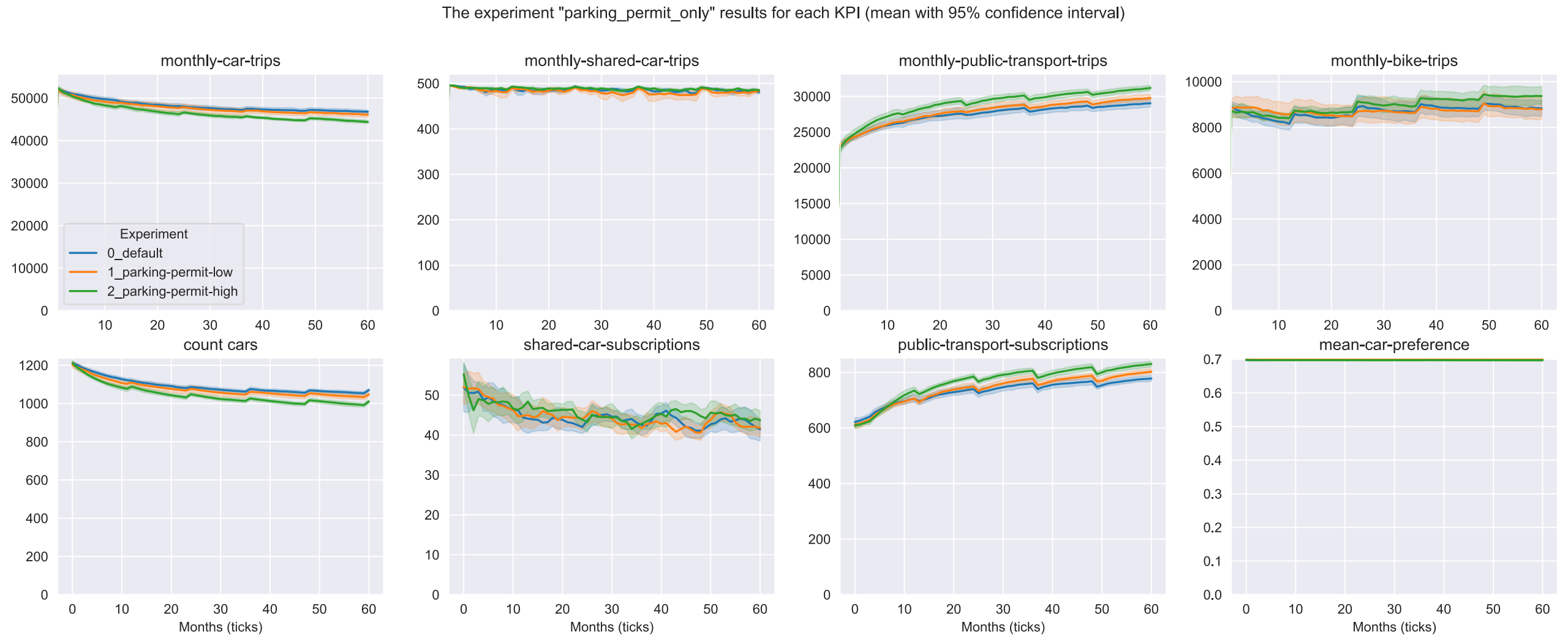
- 60 months runtime
- 10 replications for each experiment
- 5 policy lever sets with each 2 magnitudes + 1 default scenario = 11 experiments
- Approximately one hour runtime per replication (a minute a month)
  XPS 15 9520, Core i7-12700H, NetLogo 6.3.0, Python 3.11, Windows 11

```python
import os
import pyNetLogo
import pandas as pd

os.environ["JAVA_HOME"] = 'C:/Program Files/NetLogo 6.3.0/runtime/bin/server/'

default_values = {
    "parking-permit-costs": 0,
    "amount-of-shared-cars": 8,
    "remove-spots-percentage": 0,
    "mean-value-of-time": 11.25,        # Default 8.75
    "mean-public-transport-speed": 30,  # Default 34.8

    "days-in-month": 31,
    "months-in-year": 12,
}

replications = 10
ticks = 60  # Months
gui = False

exp_nr = 2  # Change this to run different experiment
exp_names = ["default", "all-low", "all-high"]
exp_name = f"{exp_nr}_{exp_names[exp_nr]}"
exp = {
    "parking-permit-costs": [0, 7.8, 31.2],
    "amount-of-shared-cars": [8, 32, 128],
    "remove-spots-percentage": [0, 20, 40],
}

modalities = ["car", "shared-car", "public-transport", "bike"]

series_reporters = [
    *[f"monthly-{m}-trips" for m in modalities],
    "count cars",
    "shared-car-subscriptions",
    "public-transport-subscriptions",
    "mean-car-preference",
]

single_reporters = []

netlogo = pyNetLogo.NetLogoLink(gui=gui)
netlogo.load_model("C:/Users/Ewout/Documents/GitHub/SEN9120-ABC/ABC_model.nlogo")

# single_data = {}
series_data = {}

print(f"Starting experiment {exp_name} with {replications} runs.")
for var, val in exp.items():
    print(f"Using {var} = {val[exp_nr]}")
print("")
```

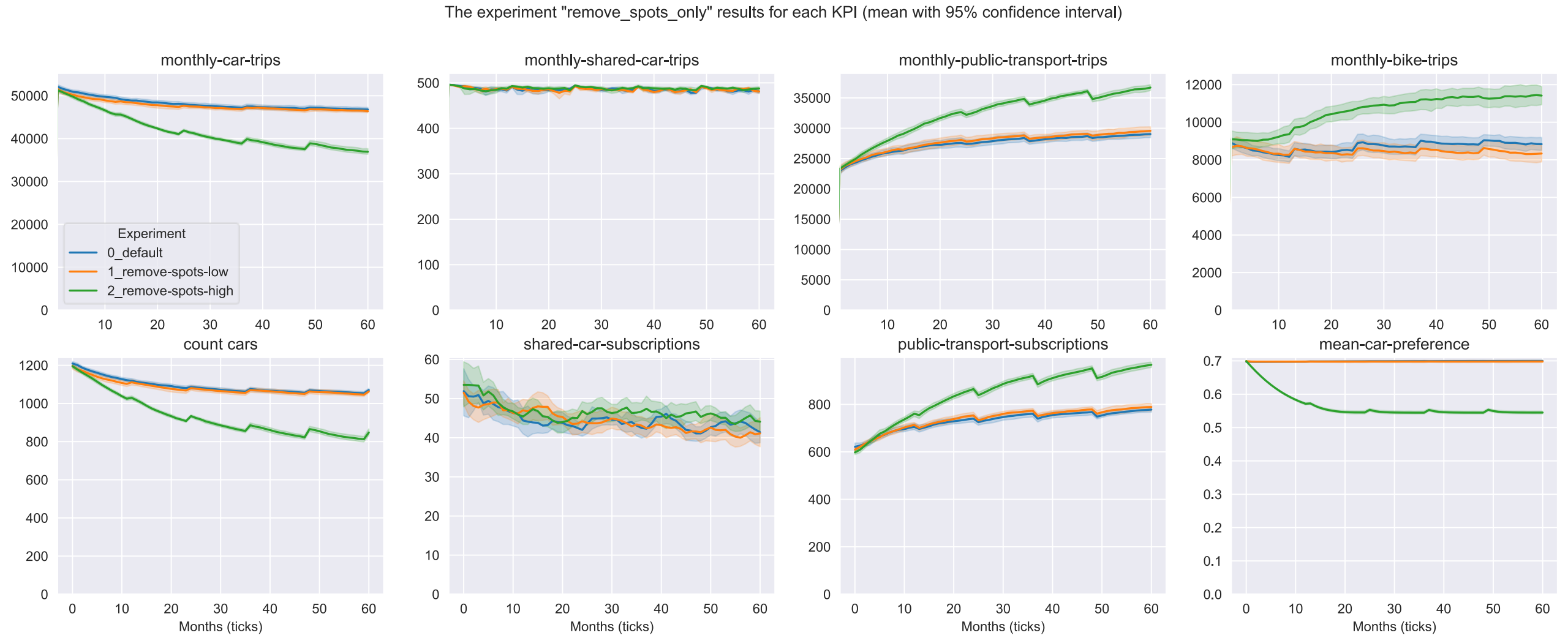
Shared cars: 8, 32 or 128



Parking permit: Free, €7,80 or €31,20

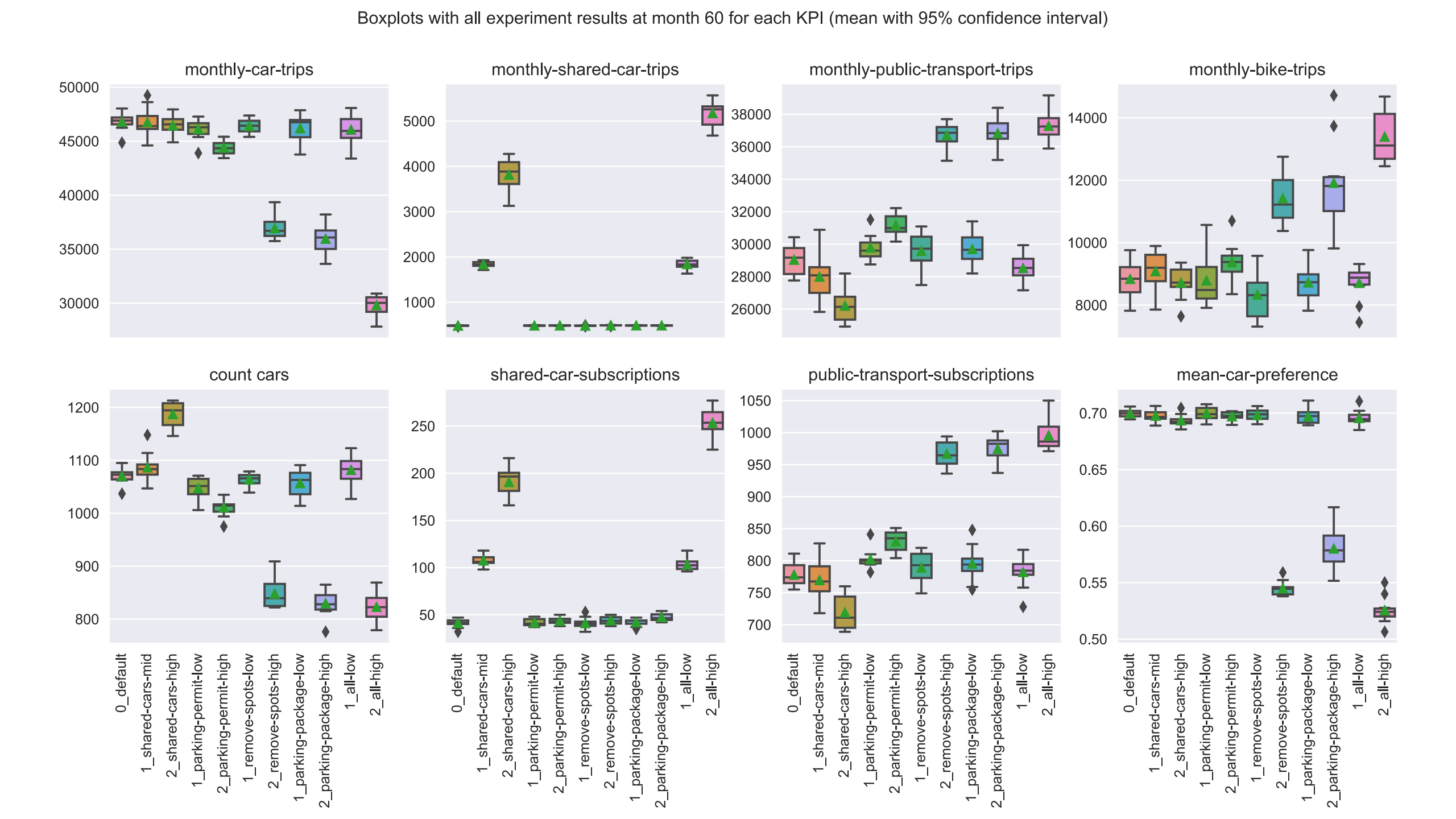


Remove spots: None, 20% or 40%



Parking package

All combined


Boxplots with all experiment results at month 60 for each KPI (mean with 95% confidence interval)
monthly-car-trips
monthly-shared-car-trips
monthly-public-transport-trips
monthly-bike-trips
count cars
shared-car-subscriptions
public-transport-subscriptions
mean-car-preference
0_default
1_shared-cars-mid
2_shared-cars-high
1_parking-permit-low
2_parking-permit-high
1_remove-spots-low
2_remove-spots-high
1_parking-package-low
2_parking-package-high
1_all-low
2_all-high

Sensivity

Testing effect of changing external factors

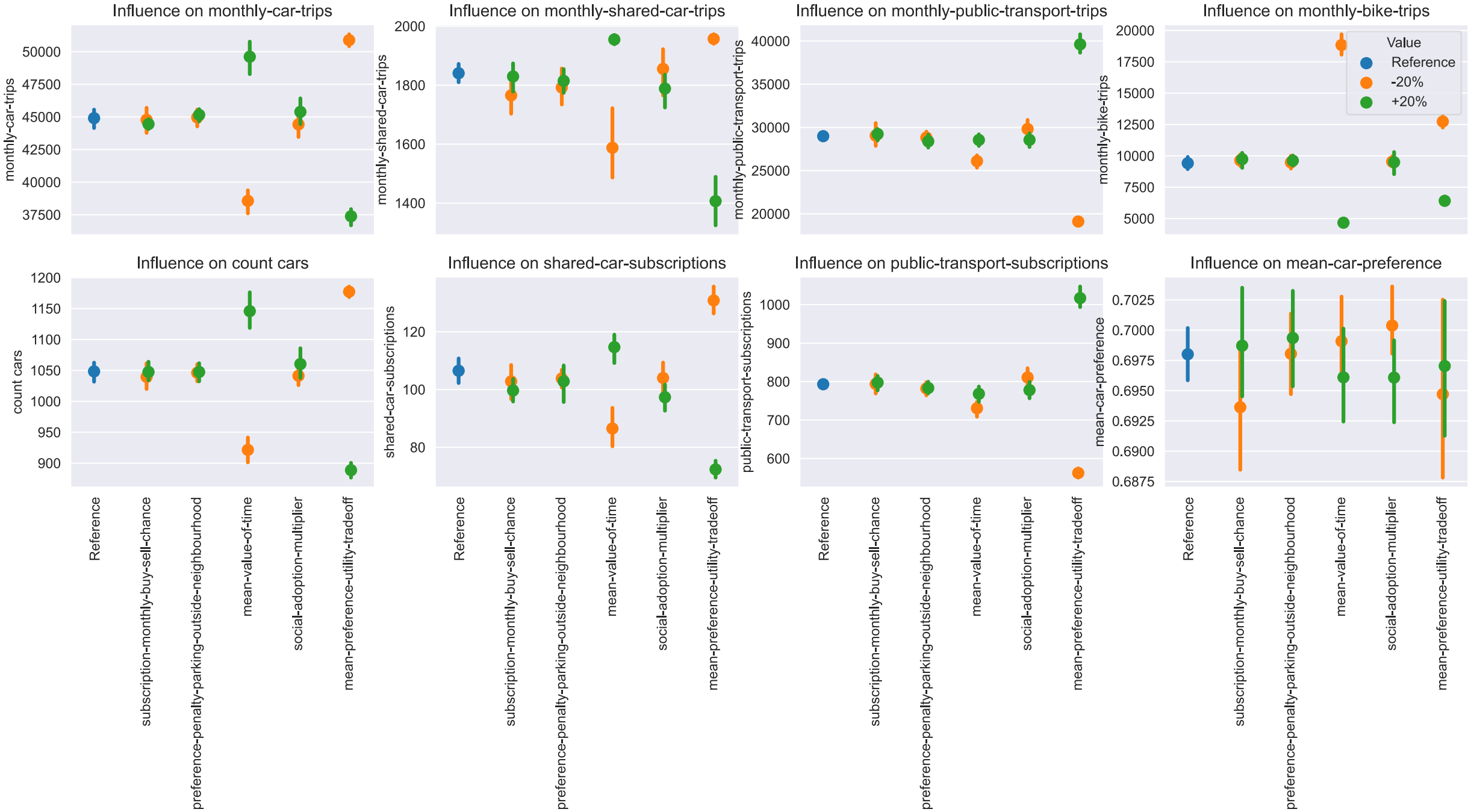
Sensitivity design

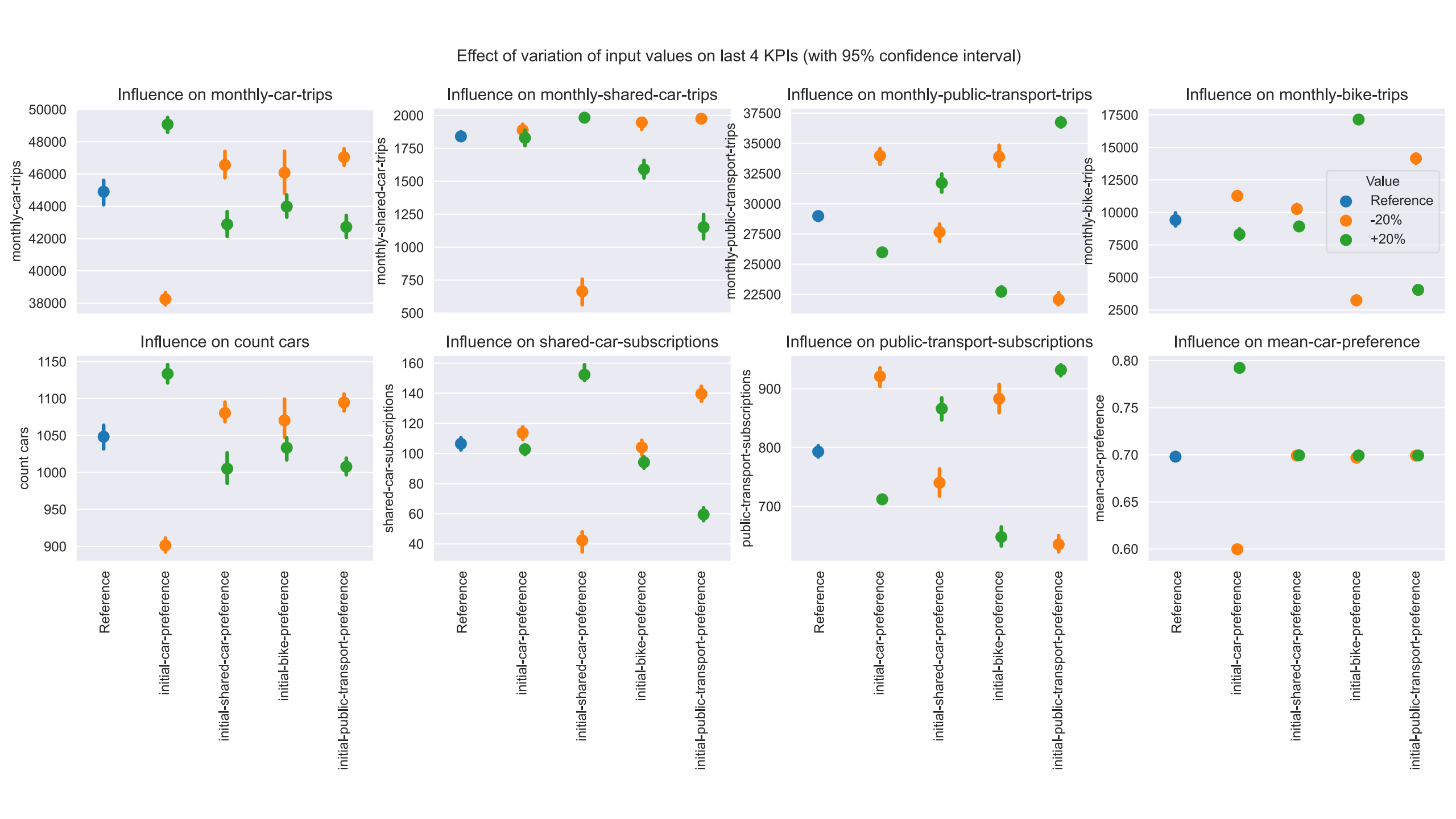
- Changing one variable at a time, and testing the effect on the KPIs
  - +/- 20% for regular coefficients
  - +/- 10% of total range for distribution parameters

Simulation parameters

- 48 months runtime
- 12 replications for default scenario
- 6 replications for all others scenarios
- KPIs measured at last month

Variable	Default	Low	High	Low change	High change	Change type
subscription-monthly-buy-sell-chance	25	20	30	-20%	20%	+-20% from default
preference-penalty-parking-outside-neighbourhood	0,5	0,4	0,6	-20%	20%	
mean-value-of-time	11,25	9	13,5	-20%	20%	
social-adoption-multiplier	0,1	0,08	0,12	-20%	20%	
mean-preference-utility-tradeoff	0,5	0,4	0,6	-20%	20%	+-10% from range (= +-0.1)
initial-car-preference	0,7	0,6	0,8	-14%	14%	
initial-shared-car-preference	0,5	0,4	0,6	-20%	20%	
initial-bike-preference	0,5	0,4	0,6	-20%	20%	
initial-public-transport-preference	0,3	0,2	0,4	-33%	33%	


Effect of variation of input values on the first 5 KPIs (with 95% confidence interval)
Influence on monthly-car-trips
monthly-car-trips
Influence on monthly-shared-car-trips
monthly-shared-car-trips
Influence on monthly-public-transport-trips
monthly-public-transport-trips
Influence on monthly-bike-trips
monthly-bike-trips
Value
Reference
-20%
+20%
Influence on count cars
count cars
Influence on shared-car-subscriptions
shared-car-subscriptions
Influence on public-transport-subscriptions
public-transport-subscriptions
Influence on mean-car-preference
mean-car-preference
Reference
subscription-monthly-buy-sell-chance
preference-penalty-parking-outside-neighbourhood
mean-value-of-time
social-adoption-multiplier
mean-preference-utility-tradeoff

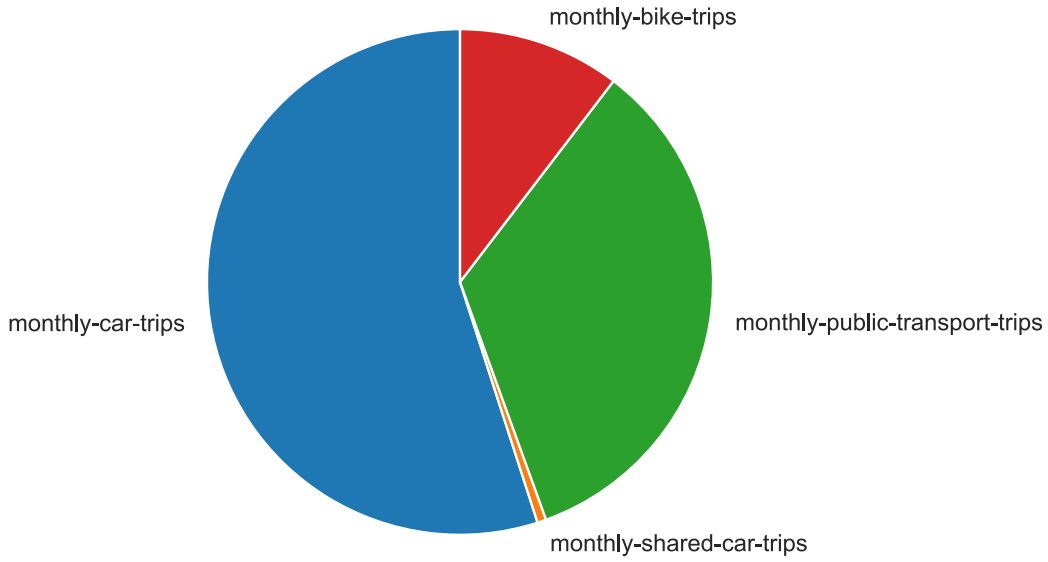

Effect of variation of input values on last 4 KPIs (with 95% confidence interval)
Influence on monthly-car-trips
monthly-car-trips
Influence on monthly-shared-car-trips
monthly-shared-car-trips
Influence on monthly-public-transport-trips
monthly-public-transport-trips
Influence on monthly-bike-trips
monthly-bike-trips
Value
Reference
-20%
+20%
Influence on count cars
count cars
Influence on shared-car-subscriptions
shared-car-subscriptions
Influence on public-transport-subscriptions
public-transport-subscriptions
Influence on mean-car-preference
mean-car-preference
Reference
initial-car-preference
initial-shared-car-preference
initial-bike-preference
initial-public-transport-preference

Validation

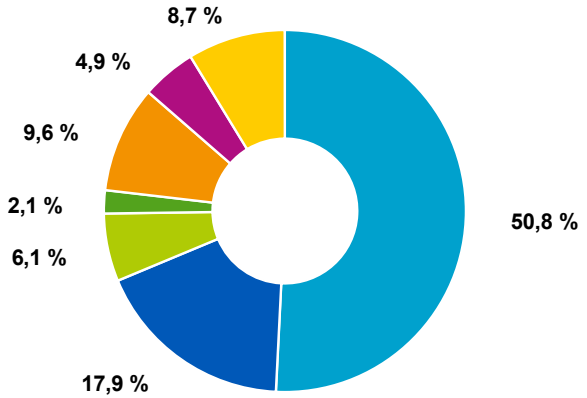
Is the model consistent with real-world behaviour?

Modality choices

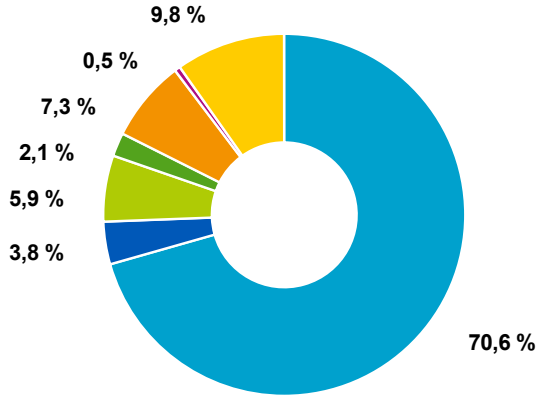
- (Too) large bias towards public transport
- Bike in the right order of magnitude
- Might be useful to make distinction between work and other trips



Reizigerskilometers naar vervoerwijze, personen van 6 jaar of ouder, 2021



Afgelegde afstand van en naar het werk naar vervoerwijze, 2021



Discussion

What are the limitations of our model?

Limitations

- Preferences diffusion > experiences limited
- External benefits limited
- Rational behaviour
- Amount of trips
- Households empty construct (no sharing of cars i.e.)
- Social networks and destinations don’t change
- Costs don’t change

Alternative KPI’s

- Occupancy and capacity rates of parking spots
- Other modality preferences
- Influence of social diffusion

Conclusion

What are the main takeaways and next steps?

Conclusions

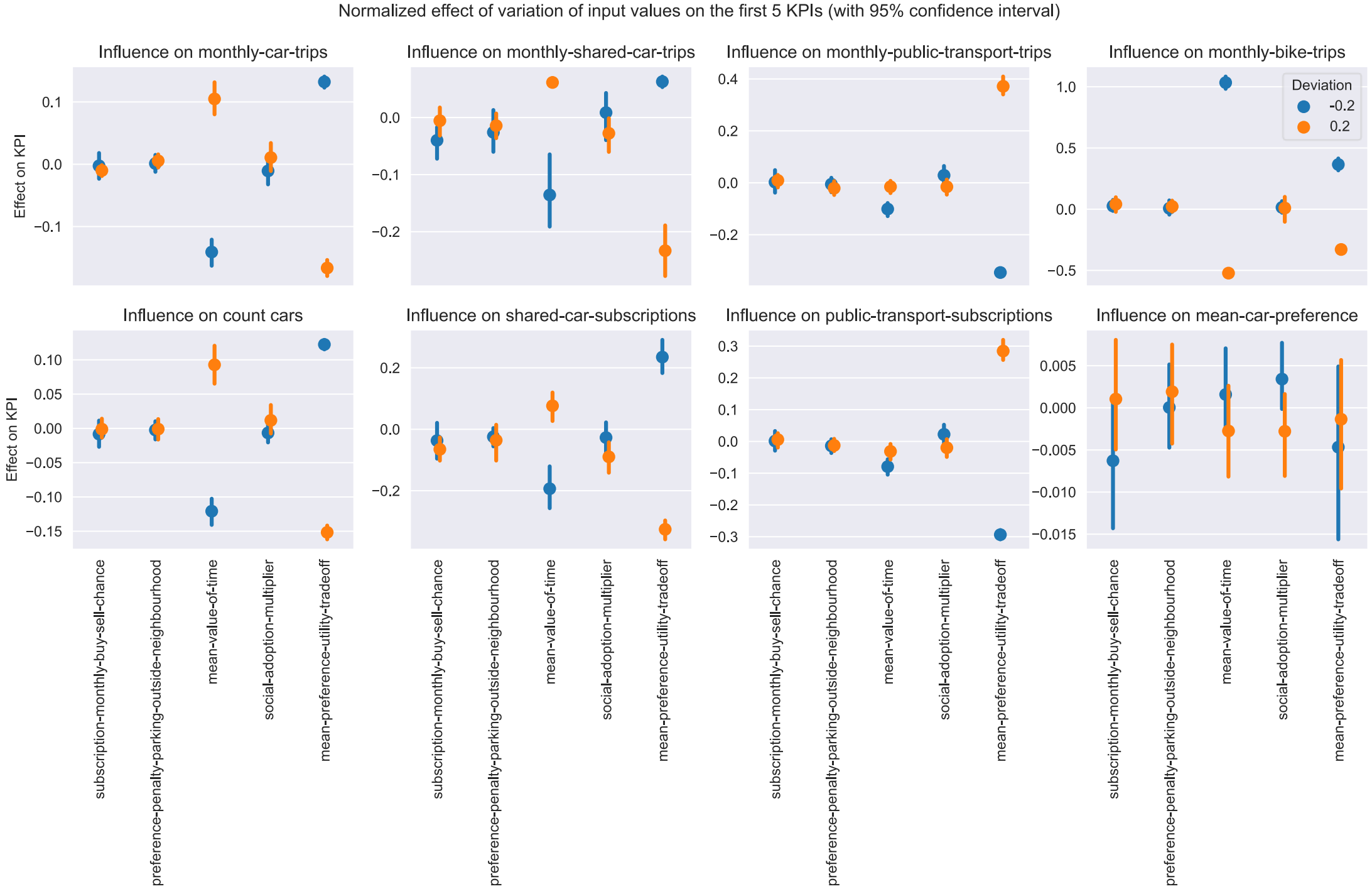
- Implementing shared cars alone in ENKA will not necessarily decrease the use and ownership of cars.
- Parking permit costs have no significant impact.
- 20% of the parking spots can be removed without any change in emergent behaviour > no resistance.
- Removing 40% of parking spots significantly reduces car ownership and use. Car opinion also changes, likely to come with some resistance in the first 12 months.
- Combining all policy interventions is effective, shared car trips replace a large part of normal car trips.

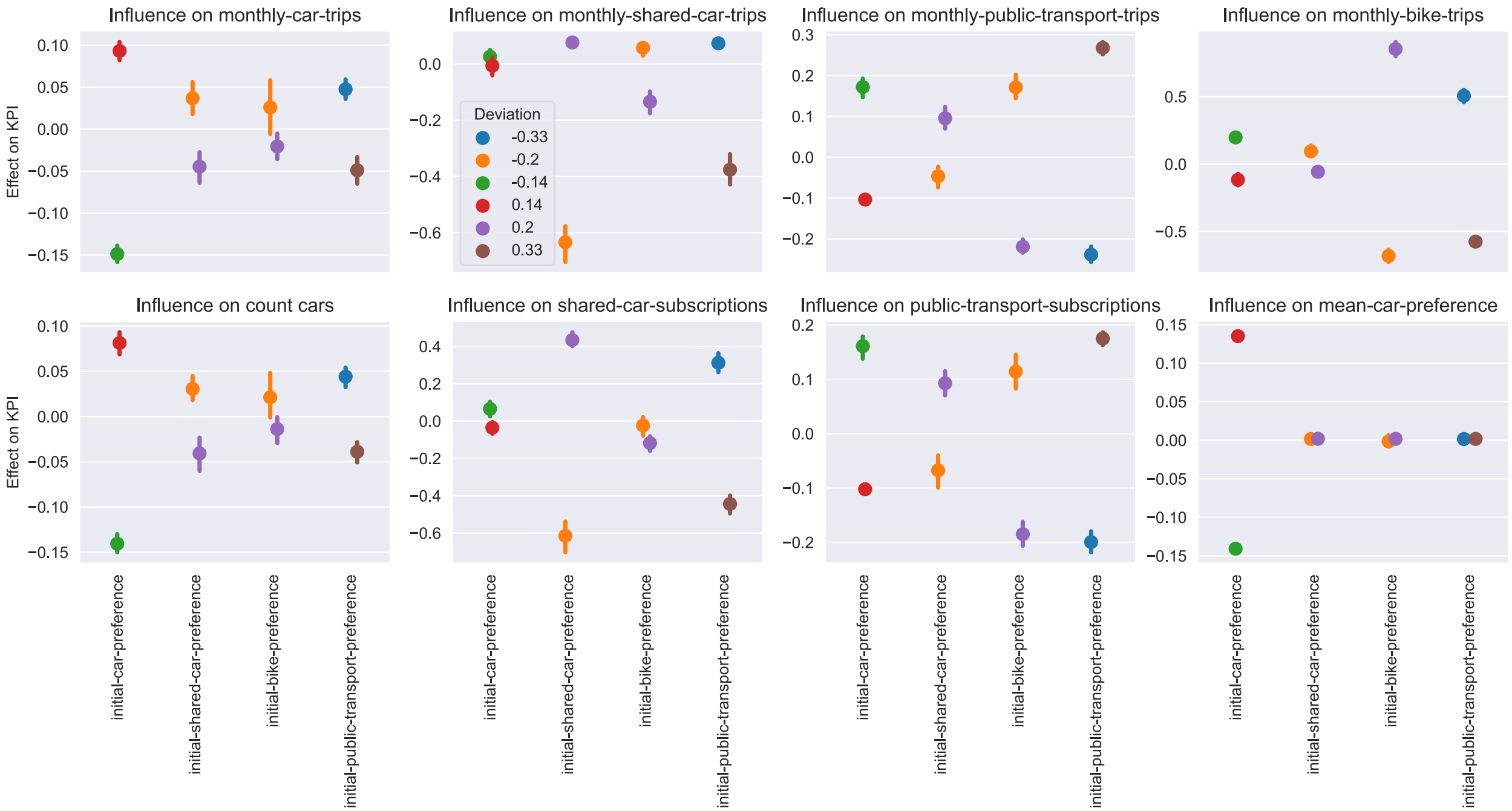
What is next?

- Sensitivity analysis shows that the initial modality preferences as well as the preference-utility trade-off and value of time variables are very sensitive.
- Therefore: data collection on people's preferred mode of transport in ENKA is crucial. Additionally, it is important to find out how important they find utility and time.
- Then: more external variables can be implemented to measure the change in preferences more accurately over time.

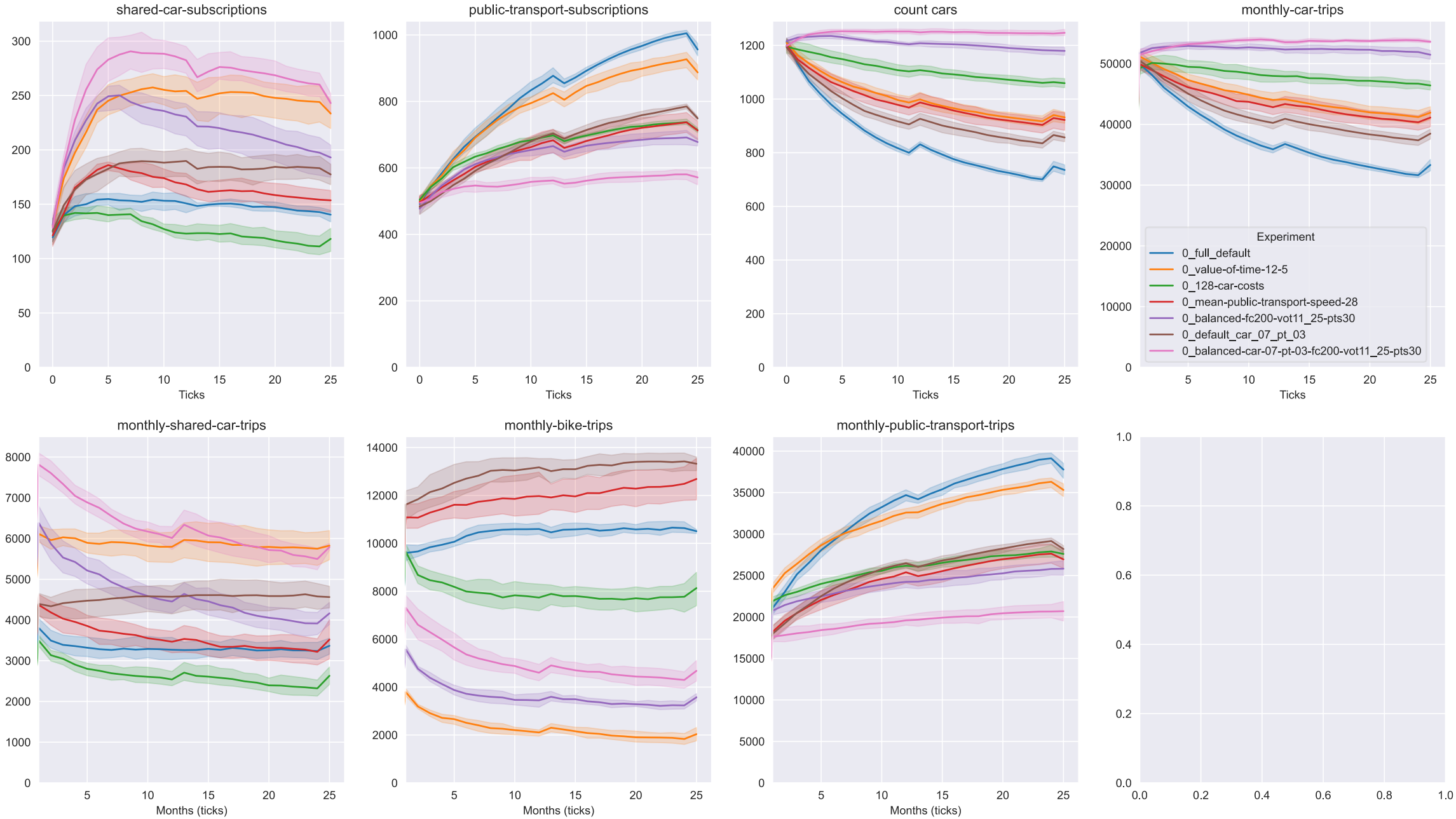
Backup slides

Background information


Normalized effect of variation of input values on the first 5 KPIs (with 95% confidence interval)
Influence on monthly-car-trips
Influence on monthly-shared-car-trips
Influence on monthly-public-transport-trips
Influence on monthly-bike-trips
Influence on count cars
Influence on shared-car-subscriptions
Influence on public-transport-subscriptions
Influence on mean-car-preference
Effect on KPI
Deviation
-0.2
0.2
subscription-monthly-buy-sell-chance
preference-penalty-parking-outside-neighbourhood
mean-value-of-time
social-adoption-multiplier
mean-preference-utility-tradeoff


Normalized effect of variation of input values on the second 4 KPIs (with 95% confidence interval)
Influence on monthly-car-trips
Influence on monthly-shared-car-trips
Influence on monthly-public-transport-trips
Influence on monthly-bike-trips
Influence on count cars
Influence on shared-car-subscriptions
Influence on public-transport-subscriptions
Influence on mean-car-preference
Effect on KPI
Deviation
-0.33
-0.2
-0.14
0.14
0.2
0.33
initial-car-preference
initial-shared-car-preference
initial-bike-preference
initial-public-transport-preference

The initialization experiment results for each KPI (mean with 95% confidence interval, out of 5 replications)



The initialization experiment results for each KPI (mean with 95% confidence interval, out of 5 replications)