# Simulation-based sketch planning, part III: Calibration of a MATSim-model for the greater Brussels area and investigation of a cordon pricing for the highway ring

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**Abstract**

# 1 Introduction

Setting up a traffic model is a difficult task, and typically the requirements vary from scenario to scenario. However, often a prototype is necessary, for example to convince potential customers. For that work normally the budget is very low or it is done on one's own account. That is, a simple way to create and/or calibrate a scenario with plausible results is necessary to attract customers, but without spending too much time before a contract is signed.

This report describes a quick solution how plausible results may be derived without major effort, but with with certain amount of expert knowledge. The article is structured as follows: A short description of the simulation framework is given, followd by a brief description of the used network, population and calibration data. After that a more detailed description of the simulation setup and the calibration approach is given. Then the simulation results for 2 basecases (with different public transport behaviors) are compared to a toll scenario. The reports closes with a brief conclusion.

# 2 Preliminaries

## 2.1 Transport Simulation

For this work the simulation Framework MATSim [2013] with the MATSim4UrbanSim-extension [Nicolai, 2013] is used. A detailed description of MATSim is given e.g. by Balmer et al. [2005] and Raney and Nagel [2006]. For this work, only a brief description is given.

MATSim is a microscopic traffic simulation based in part on the model of Gawron [1998]. Every single part of a traffic system – e.g. a synthetic traveller – is simulated separately and is represented by a so called agent. These (traveller) agents typically have at least one full daily plan, each containing desired activities and desired transport modes. All agents compete for system-resources, e.g. the flow capacity of a street. Before a typical MATSim-simulation starts, the input data is preprocessed, e.g. the network and the initial demand (daily plans). The main part of MATSim is an iterative loop of the following three steps:

**Physical simulation** All (selected) plans are simultaneously executed in the simulated physical system.

**Scoring** The executed plans are scored as described by Charypar and Nagel [2005].

**Replannning** A (sub)-set of agents create new plans or modify old plans in different degrees of freedom (e.g. time or space).

For the simulation of public transport, two different procedures are used for the investigations presented here. The default MATSim behaviour is based either on beeline distance and average speed, or on the network-based freespeed traveltime multiplied by a certain factor. This means that it is either assumed that public transit behaves uniformly throughout the region, or that its performance is somehow structurally similar to that of the road system. The approach also includes that agents are not forced to walk to a public transit stop. That is, regardless of wether the real world accesibility of the public transport system is good within a certain area, all agents may access it without any penalty. The enhanced MATSim4-UrbanSim (now called matrixBasedPtRouter) behaviour addresses both problems. First, one may define a certain number of public transport facilities. Agents plan to use the public transport are forced to walk to the next facility. How agents travel between those facilities depends on the additional input. Without any further input, the traveltime is calculated as in the default version. For a more realistic simulation

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it is possible to define a fixed travel time for each relation. Such travel times may, e.g., be derived from a real-world transit schedule.

## 2.2 Network and Population

The scenario concerns the greater Brussels area (Belgium). The used network is generated from OpenStreetMap OpenStreetMap [2013] with MATSim's default parameters for conversion as shown in Tab. 1. It consists of 10,861 nodes and 19,830 links.

The population is delivered by an UrbanSim-model and contains 860,214 persons. For this work a one percent sample is used. The resulting population is randomly drawn by MATSim and consists of 8,501 persons. The data derived from Urbansim contains a homelocation and a workplace per person. For each person a daily plan of the type home-work-home is created from that as described by ?.
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## 2.3 Validation data

As the main scope of this work is the calibration of the model, knowledge about the the traffic is necessary. For the present investigation, travel time and mode share data (Tab. 4 and 5) are obtained from a SATURN-model for 7 zones which are arranged concentrically around the city of Brussels (Pentagon).

Table 1: (Default) parameters to convert OSM-data (column 1 & 2) into MATSim links.

| hierarchy-layer | highway-type | freespeed [km/h] | FlowCapacity [Veh/h/lane] | one way |
|---|---|---|---|---|
| 1 | motorway | 120 | 2,000 | true |
| 1 | motorway_link | 80 | 1,500 | true |
| 2 | trunk | 80 | 2,000 | false |
| 2 | trunk_link | 50 | 1,500 | false |
| 3 | primary | 80 | 1,500 | false |
| 3 | primary_link | 60 | 1,500 | false |
| 4 | secondary | 60 | 1,000 | false |
| 5 | tertiary | 45 | 600 | false |
| 6 | minor | 45 | 600 | false |
| 6 | unclassified | 45 | 600 | false |
| 6 | residential | 30 | 600 | false |
| 6 | living_street | 15 | 300 | false |

# 3 Setup and calibration of the model

The main scope of this work is the calibration of a transport model. This should be done as simple as possible. That is, the simulation should meet the reality as good as possible, but without a major effort. Approaches like that, namely creating a traffic model prototype with a small amount of time and budget, are presented by Nagel [2008, 2011] before.

## 3.1 Speeds and Capacities

During the calibration process the network attributes, generated from MATSim's OSM-defaults (see Tab. 1), were perceived as problematic. In particular, it was perceived that inner-urban travel times were too low.

New freespeeds are set, as shown in Tab. 2, based on the experience also with other models that a free speed/speed limit value of 50km/h more often than not respresents an actual speed of 25km/h or less because of signals, cars stopping in the rightmost lane, bicycles, pedestrian crosswalks, and other disturbances common in urban situations. In contrast, a free speed/speed limit value of 100km/h often is quite realistic since it represents a freeway where such disturbances are absent, and speed reductions are typically caused by congestion only.

These were the first steps towards more plausible speeds. As the next step, it was found out that, because of an error in the mode choice model, the number of car trips was much too low, and thus the model did not display any congestion at all. In consequence, the changes in the network free speeds may not have been necessary at all, but because of time pressure and because overall results looked plausible, they were not touched again.

Table 2: Link-modifying-scheme for calibration

| capacity [veh/h] | freespeed [km/h] | new freespeed [km/h] | example |
|---|---|---|---|
| ≤ 1,000 | any | 15 | one-lane local street |
| ≤ 2,000 | < 61 | 20 | two-lane slow arterial |
| ≤ 3,000 | < 61 | 25 | three-lane boulevard |
| ≤ 3,500 | < 81 | 60 | narrow two-lane tunnel |

## 3.2 Utility function

The monetary distance cost rate was given for the modes car and public transport with 5.885 respectively 1.762 Eurocent per km and was not modified for the present work.

The mode choice model was given by

```
marginal utility of time (same for pt and car) =  -0,025 (1/min)
marginal utility of cost = -0,1667 (1/Eu2001)
value of time = 0,025 *60/0,1667 = 9 Eu2001/heure
set car mode constant to 0
```

The relevant part of the MATSim utiltiy function reads, in linearized form,

$$U_{mode} = Const_{mode} + \beta_{money} \cdot money + (\beta_{tt,mode} - \beta_{perf}) \cdot tt_{mode}$$

This means, in particular, that the marginal utility of time needs to be divided between the marginal opportunity cost of time, $\beta_{perf}$, and the (additional) marginal utility of spending time traveling by mode, $\beta_{tt,mode}$. A useful starting point is to absorb the marginal disutility of traveling by car into $\beta_{perf}$, accordingly set $\beta_{tt,car}$ to zero, and set all other $\beta_{tt,mode}$ relativ to the car mode.

Overall, the following settings were adopted:

| math notation | MATSim param | value | comment |
|---|---|---|---|
| $\beta_{money}$ | marginalUtilityOfMoney | 0.1667/Eu | sign is positive since having more money is good |
| $\beta_{perf}$ | performing | 1.5/h | sign is positive since spending more time at activity is good |
| $\beta_{tt,car}$ | traveling | 0 | |
| $\beta_{tt,pt}$ | travelingPt | 0 | |
| $\beta_{tt,walk}$ | travelingWalk | 0 | |
| $Const_{car}$ | constantCar | 0 | |
| $Const_{pt}$ | constantPt | $-1$ | see below |
| $Const_{walk}$ | constantOther | 0 | |

The only parameter that was somewhat calibrated is the alternative specific constant for the public transport, $Const_{pt}$. This parameter describes the inhibition threshold to use public transport. A certain number of experiments, varying this parameter between $-4$ and $-1$, was done. $-1$ has been found to deliver the most plausible results and is used for the case studies in the next section.

## 3.3 Other parameters and config settings

The simulations are executed for 100 iterations, using the strategy-modules Change-ExpBeta (75%), TimeAllocationMutator (8.3%), ReRouteDijkstra (8.3%) and Change-LegMode (8.3%). Numbers in brackets depict the probability to be choosen during replanning. All modules, except of ChangeExpBeta, are disabled after 80 iterations. Besides public transport and car, agents are allowed to walk. Public transport traveltimes in basecase 1 are calculated by multiplying the freespeed traveltimes (by car) with 2. In basecase 2 and the roadpricing scenario the improved public transport module is used. Traveltimes for agents walking are calculated with the beeline distance and an average speed of 1 m/s. The mode walk is opened for the simulation because the density of the street network is very low, especially in the center.

# 4 Results

In the following the results for 3 different scenarios are displayed. The first is set up with the simple public transport module. The second and the third are set up with the improved public transport model. Furthermore a cordon pricing is introduced in the third scenario, namely each agent entering the freeway ring (including the ring itself) between 6 and 10 am is charged with 10 euros.

The comparison between MATSim and SATURN for macrozone-to-macrozon travel times looked better at some point. Possibly, averaging over all zones within a macrozone may be a better way than to average over all actual trips. kn, jun'13

## Basecase 1 – default public transport

As shown in Tab. 4, the realized average morning traveltimes by car are seriously higher compared to the SATURN-model. However, tendencies are correct: The numbers evaluated for trips heading towards the city center are higher than these heading towards the outside zones. For example an average trip from zone 1 to zone 4 needs approximately 44 minutes, reverse trips are measured with approximately 95 minutes. The same tendency is determined for trips between zone 1 and the zones 2, 5 and in some parts 6. A meaningful analysis of trips from and to zone 7 seems not possible, as the number trips is very low.

For the carshare as shown in Tab. 5 the resulting numbers are closer to the SATURN-model as it is found for the traveltimes. A clear tendency is noticeable. Trips leaving the center are mainly performed by car. Trips heading towards the center are more often performed by other mode. A clear deviation should be noticed for trips within one zone. Here the MATSim model clearly underestimates the car share. This results from the opportunity for agents to walk in MATSim. That is, short trips are more often performed by foot.

## Basecase 2 – improved public transport modelling

As it has been found for basecase 1 the deviation of the average traveltimes for basecase 2, as it is shown in Tab. 4, is plainly noticeable as well. The characteristics of the resulting matrix are similar, trips heading towards the take more time than trips leaving. However, it should be noticed that the total number of trips (compare Tab. 3) leaving zone 1 is very small, thus it is not statistically significant.

The realized carshare (compare Tab. 5) for basecase 2 fit the expectations – the numbers derived from the SATURN-model – much better. The tendency, found in

the SATURN-model, that trips heading towards the city are significantly more often not performed by car is much noticeable as it has been found in basecase 1.

## Scenario – toll and improved public transport modelling

For this scenario a toll of 10 Euro is charged when entering the area within the freeway or the freeway itself between 6 and 10 am by car. Fig. 1 (blue links) show at which links the toll exactly is charged. The systems reaction may be clearly found when looking at Tab.3. The number of car trips heading towards the center significantly decreases, as well as the number of car trips heading towards the center. However, the difference in traveltimes (Tab. 4 and Fig. 4) within the tolled area is not as distinct as it might have been expected. This results from the fact that the carshare (compare Tab. 5 and Fig. 4) for trips within the area and leaving it increases.

When looking at the accessibility results in Fig. 1, a clear tendency is found. Almost the whole area within the freeway ring benefits from the toll, at least when looking at the car accessibility. For areas outside the freeway ring, accessibility decreases significantly. This is due to the fact that the toll is included in the generalized cost of travel, and thus even when congestion is reduced, access to facilities behind the cordin now comes with a higher generalized cost than before.
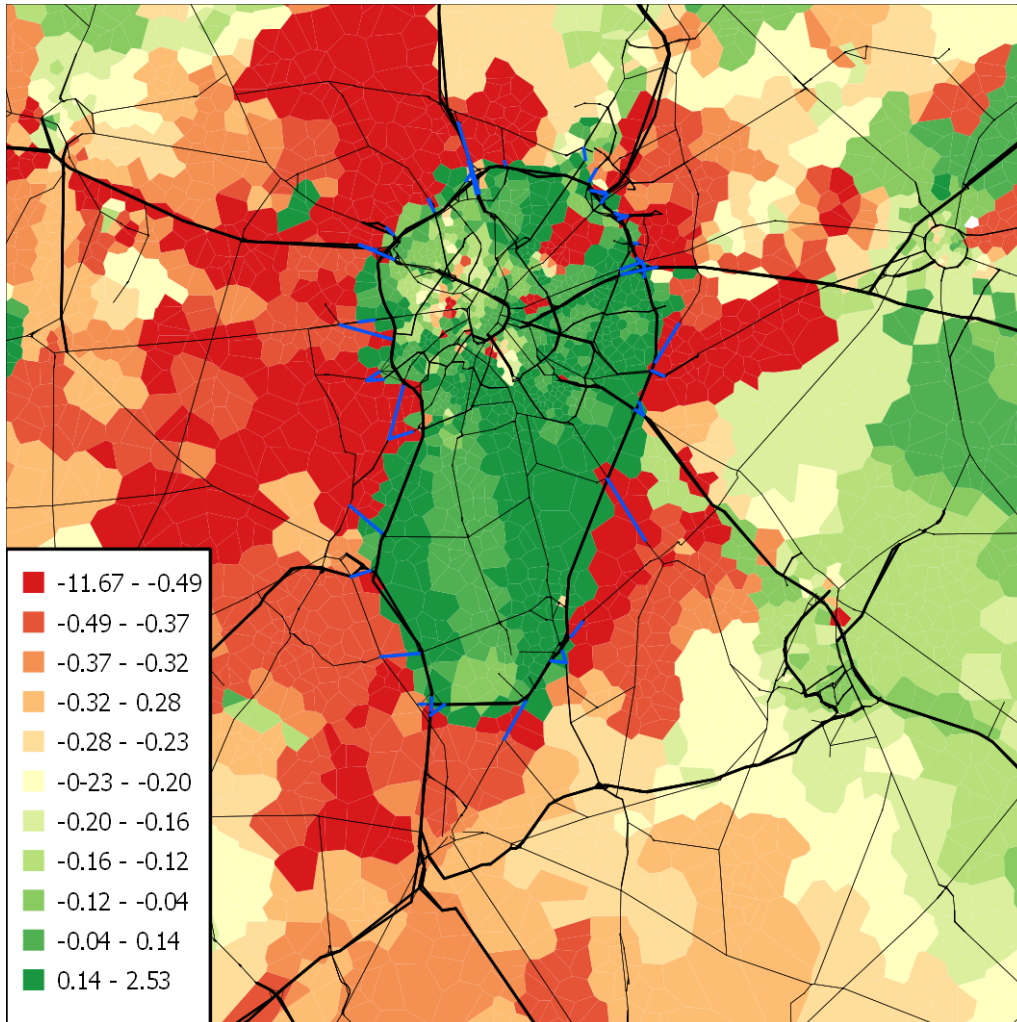
Figure 1: Changes in car accessibility between basecase 2 and the scenario.

Displayed are the Voronoi diagrams around the centroids of the UrbanSim zones. Red and yellow areas experience a disadvantage due to the roadpricing. Green areas experience a small loss or a even a win. At blue painted links travellers are charged with the toll.

Table 3: MATSim car trips per OD-relation between 6 and 10 am [#]

| O/D | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | 15 | 17 | 2 | 1 | 4 | 0 |
| | 2 | 38 | 167 | 166 | 50 | 22 | 41 | 1 |
| | 3 | 42 | 221 | 299 | 57 | 38 | 70 | 4 |
| basecase | 4 | 17 | 68 | 116 | 170 | 71 | 52 | 2 |
| | 5 | 17 | 49 | 89 | 92 | 164 | 106 | 3 |
| | 6 | 46 | 175 | 204 | 166 | 166 | 1826 | 54 |
| | 7 | 11 | 23 | 32 | 12 | 12 | 110 | 187 |
| | 1 | 4 | 13 | 18 | 5 | 0 | 3 | 0 |
| | 2 | 43 | 160 | 164 | 40 | 20 | 40 | 1 |
| | 3 | 46 | 262 | 313 | 52 | 39 | 64 | 3 |
| basecase 2 | 4 | 22 | 89 | 140 | 191 | 79 | 54 | 1 |
| | 5 | 13 | 66 | 105 | 102 | 172 | 105 | 2 |
| | 6 | 36 | 155 | 183 | 169 | 179 | 1890 | 56 |
| | 7 | 8 | 26 | 35 | 16 | 13 | 116 | 198 |
| | 1 | 3 | 15 | 20 | 5 | 1 | 4 | 0 |
| | 2 | 42 | 164 | 187 | 46 | 22 | 38 | 1 |
| | 3 | 55 | 251 | 310 | 54 | 39 | 64 | 4 |
| roadpricing | 4 | 13 | 73 | 126 | 161 | 81 | 53 | 2 |
| | 5 | 13 | 54 | 89 | 83 | 165 | 102 | 4 |
| | 6 | 31 | 110 | 156 | 140 | 177 | 1877 | 55 |
| | 7 | 5 | 31 | 36 | 9 | 14 | 116 | 194 |

Table 4: Average car traveltimes per OD-relation between 6 and 10 am respective exact 8 am for the SATURN-results [min]. ==The MATSim values were closer to the SATURN values at some point. Need to investigate. kn, jun'13== Values from or to macro-zone 7 are removed from the MATSim values since not all of that zone is contained in the model and thus travel times will systematically be too small. Also values derived from 7 or fewer entries are removed.

|  | O/D | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| SATURN | 1 | 5.56 | 15.83 | 27.80 | 36.55 | 44.55 | 65.99 | 91.20 |
|  | 2 | 19.52 | 26.04 | 34.31 | 41.99 | 51.04 | 72.43 | 96.75 |
|  | 3 | 35.55 | 38.41 | 37.66 | 41.95 | 49.11 | 72.54 | 94.49 |
|  | 4 | 51.79 | 50.04 | 43.95 | 36.95 | 47.14 | 69.75 | 87.66 |
|  | 5 | 80.61 | 80.50 | 71.81 | 64.95 | 64.45 | 82.75 | 101.50 |
|  | 6 | 123.25 | 124.19 | 119.03 | 113.22 | 108.37 | 112.25 | 123.11 |
|  | 7 | 162.51 | 159.71 | 149.26 | 140.81 | 139.08 | 131.41 | 128.58 |
|  |  |  |  |  |  |  |  |  |
| basecase | 1 | - | 31.91 | 61.41 | - | - | - | - |
|  | 2 | 46.00 | 43.30 | 50.69 | 61.98 | 69.12 | 72.56 | - |
|  | 3 | 83.43 | 64.22 | 52.99 | 55.70 | 60.95 | 75.66 | - |
|  | 4 | 95.90 | 84.74 | 61.52 | 44.02 | 48.41 | 57.41 | - |
|  | 5 | 120.02 | 106.18 | 82.68 | 64.00 | 36.32 | 54.56 | - |
|  | 6 | 121.29 | 114.99 | 98.22 | 78.16 | 64.29 | 34.47 | - |
|  | 7 | - | - | - | - | - | - | - |
|  |  |  |  |  |  |  |  |  |
| basecase 2 | 1 | - | 39.55 | 59.46 | - | - | - | - |
|  | 2 | 64.63 | 53.17 | 60.43 | 63.76 | 80.08 | 84.64 | - |
|  | 3 | 94.77 | 84.78 | 65.08 | 63.21 | 71.32 | 80.36 | - |
|  | 4 | 126.93 | 106.67 | 77.80 | 56.50 | 66.62 | 70.82 | - |
|  | 5 | 138.54 | 121.64 | 93.49 | 81.13 | 42.12 | 58.51 | - |
|  | 6 | 125.99 | 125.40 | 107.86 | 87.99 | 70.84 | 36.93 | - |
|  | 7 | - | - | - | - | - | - | - |
|  |  |  |  |  |  |  |  |  |
| roadpricing | 1 | - | 39.16 | 61.00 | - | - | - | - |
|  | 2 | 72.63 | 56.88 | 64.75 | 67.21 | 87.37 | 85.53 | - |
|  | 3 | 102.26 | 82.16 | 59.40 | 69.91 | 78.81 | 81.03 | - |
|  | 4 | 95.95 | 87.37 | 70.32 | 47.32 | 59.22 | 66.10 | - |
|  | 5 | 124.76 | 99.54 | 78.95 | 60.71 | 38.09 | 58.11 | - |
|  | 6 | 120.79 | 106.49 | 89.17 | 71.49 | 68.81 | 37.65 | - |
|  | 7 | - | - | - | - | - | - | - |

Table 5: Carshares per OD-relation between 6 and 10 am respective exact 8 am for the SATURN-results [%]

| O/D | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| SATURN | 1 | 44.0 | 69.0 | 54.0 | 75.0 | 84.0 | 48.0 | 67.0 |
| | 2 | 43.0 | 60.0 | 66.0 | 76.0 | 73.0 | 69.0 | 82.0 |
| | 3 | 28.0 | 67.0 | 67.0 | 78.0 | 73.0 | 72.0 | 87.0 |
| | 4 | 24.0 | 65.0 | 78.0 | 77.0 | 82.0 | 86.0 | 95.0 |
| | 5 | 26.0 | 67.0 | 79.0 | 89.0 | 83.0 | 83.0 | 95.0 |
| | 6 | 22.0 | 59.0 | 78.0 | 94.0 | 91.0 | 84.0 | 85.0 |
| | 7 | 29.0 | 56.0 | 75.0 | 96.0 | 96.0 | 86.0 | 85.0 |
| basecase | 1 | - | 65.2 | 73.9 | - | - | - | - |
| | 2 | 38.0 | 46.0 | 56.7 | 75.8 | 91.7 | 97.6 | - |
| | 3 | 35.3 | 46.3 | 61.0 | 77.0 | 88.4 | 92.1 | - |
| | 4 | 30.9 | 35.2 | 59.2 | 72.6 | 77.2 | 91.2 | - |
| | 5 | 33.3 | 33.1 | 59.7 | 79.3 | 82.0 | 91.4 | - |
| | 6 | 35.1 | 49.7 | 66.0 | 77.6 | 87.4 | 89.8 | - |
| | 7 | - | - | - | - | - | - | - |
| basecase 2 | 1 | - | 59.1 | 75.0 | - | - | - | - |
| | 2 | 42.6 | 47.2 | 61.7 | 70.2 | 83.3 | 93.0 | - |
| | 3 | 42.6 | 59.4 | 67.5 | 81.3 | 95.1 | 95.5 | - |
| | 4 | 40.0 | 50.6 | 75.7 | 84.5 | 95.2 | 98.2 | - |
| | 5 | 28.9 | 48.2 | 72.4 | 93.6 | 88.7 | 97.2 | - |
| | 6 | 29.3 | 46.0 | 67.5 | 87.1 | 96.2 | 94.8 | - |
| | 7 | - | - | - | - | - | - | - |
| roadpricing | 1 | - | 65.2 | 80.0 | - | - | - | - |
| | 2 | 42.4 | 48.8 | 68.8 | 76.7 | 95.7 | 90.5 | - |
| | 3 | 48.7 | 56.9 | 68.4 | 84.4 | 97.5 | 91.4 | - |
| | 4 | 30.2 | 42.2 | 74.1 | 73.9 | 97.6 | 96.4 | - |
| | 5 | 27.7 | 41.5 | 66.9 | 79.0 | 89.2 | 98.1 | - |
| | 6 | 25.0 | 31.8 | 62.2 | 80.0 | 96.7 | 93.5 | - |
| | 7 | - | - | - | - | - | - | - |

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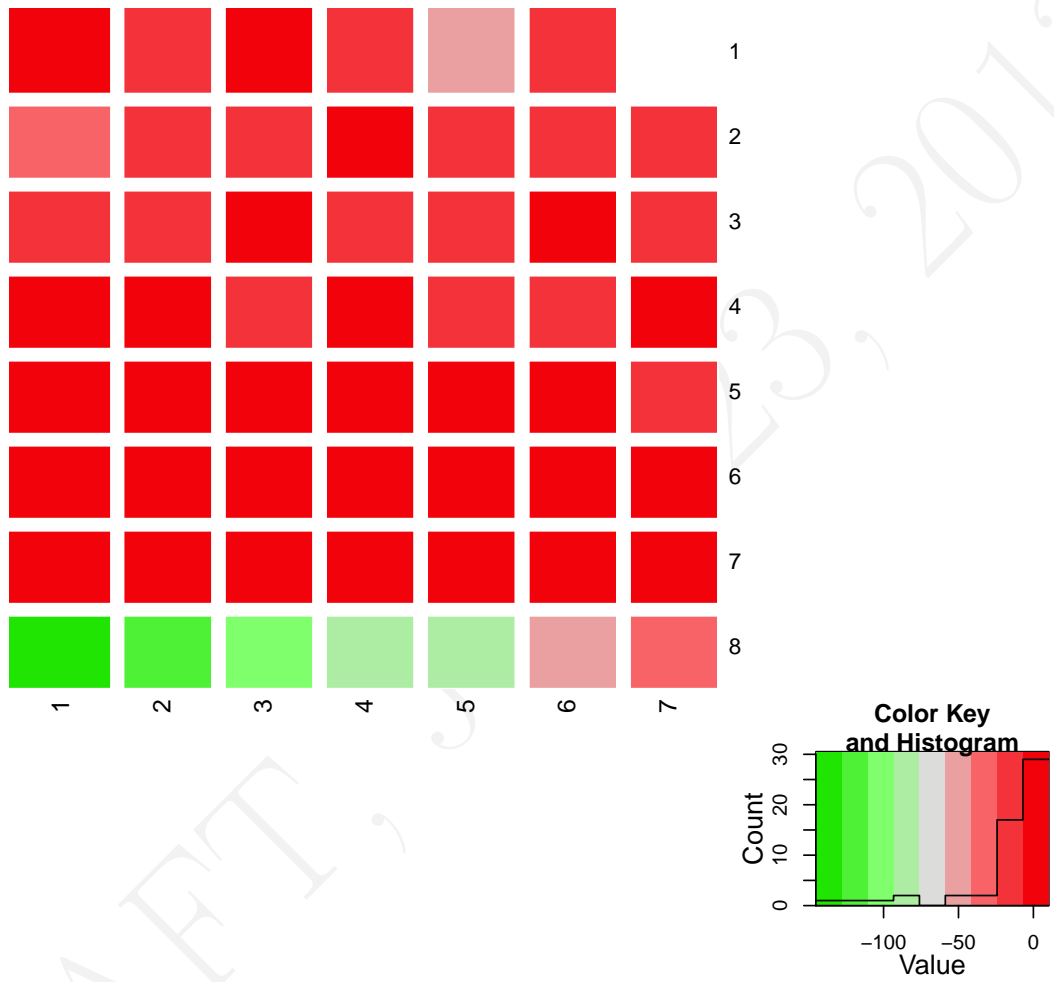
Figure 2: Difference of the avg. car traveltime between basecase2 and the scenario in minutes. The right axis shows the origin. The axis at the bottom shows the destination.
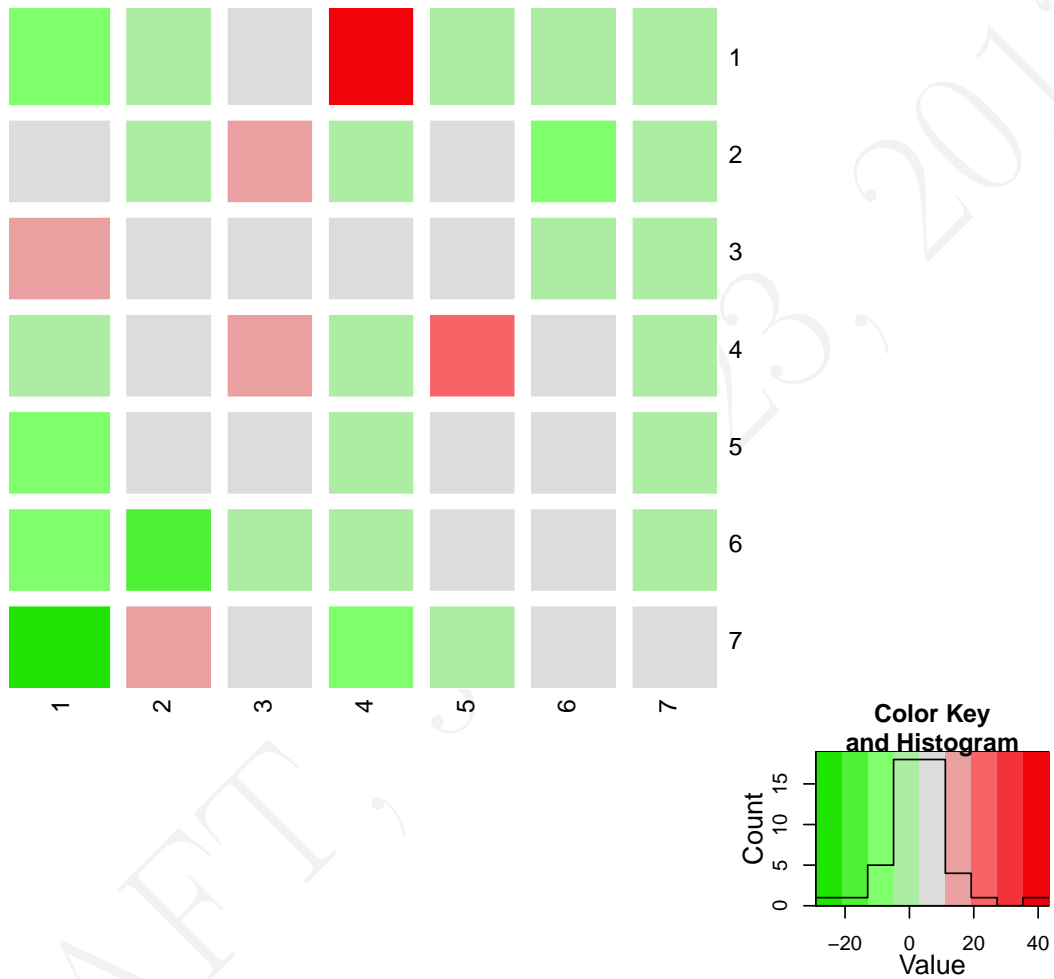
Figure 3: Difference of the car share between basecase2 and the scenario in percent. The right axis shows the origin. The axis at the bottom shows the destination.

# 5 Conclusion

The presented approach of calibrating a traffic model deliver realiable results. The resulting mode shares come close to the validation data. Certainly, the resulting travel times deviate. Here the model clearly overestimates. This might be a problem of the network and should be researched in future. A further problem seems to be the population-sampling. Experiments show a difference in spatial distribution of the resulting population. Probably this results either from the very small sample or from the drawing-procedere. It should be researched in future. However, this approach also shows a) that it is difficult to a calibrate a traffic model without expert knowledge and b) that a simple model deliver acceptable but not good or perfect results. For a detailed analysis or even policy recommendations more effort seems to be necessary and recommendable.

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