Evolution of SUMO's Simulation Model

Michael Behrisch, Laura Bieker, Jakob Erdmann, Melanie Knocke,
Daniel Krajzewicz, and Peter Wagner
Institute of Transport Systems, German Aerospace Center (DLR)

TRB Workshop 172 – Simulation: Looking Back and Looking Ahead
Washington, 12. January 2014

DLR

Content

- Past
- Future

The past

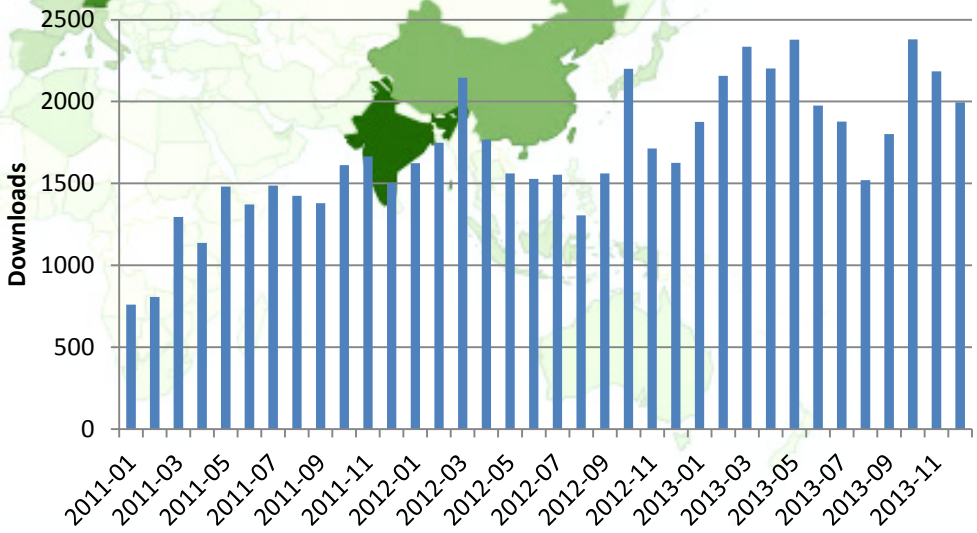
Centered on SUMO

DLR

The SUMO primer
(Simulation of Urban MObility)

- SUMO is DLR‘s open source traffic micro-simulation research tool
- Used by a growing community of researchers world-wide
- It is very often used by communication people
- It is under development since 2001
- Can be accessed via http://www.sumo-sim.org
- Right now, there is a fairly stable download rate of >1,500 per month

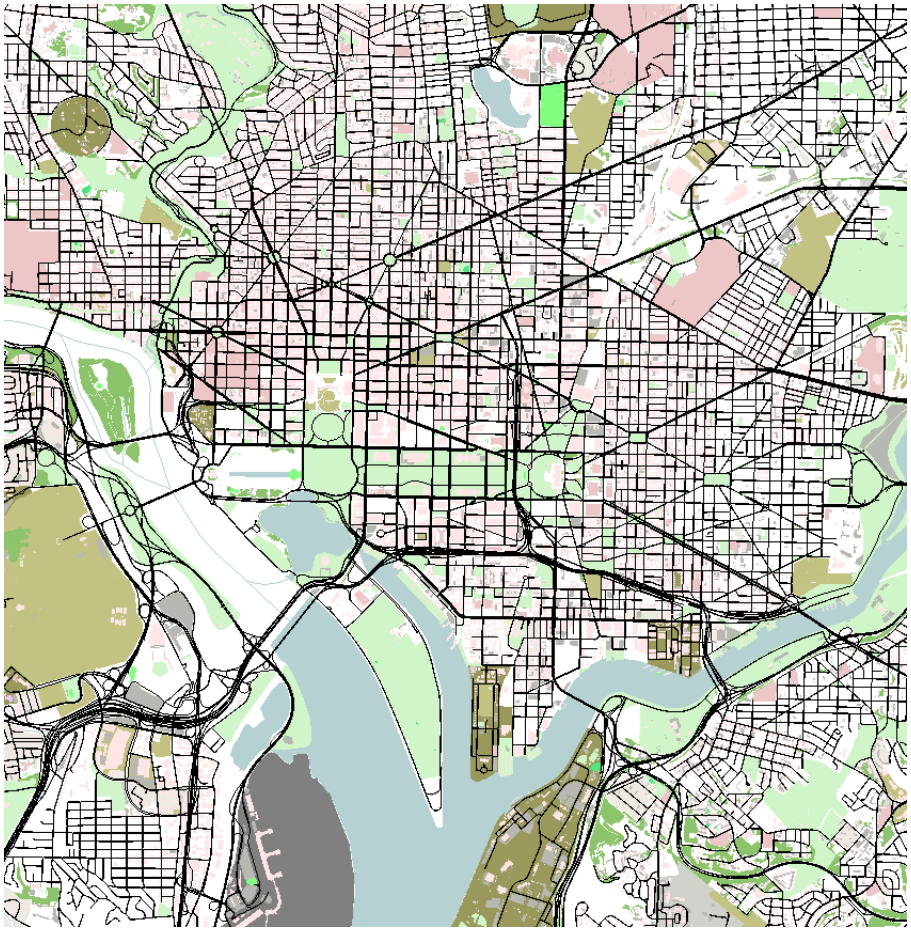
- Finally: next SUMO 2014 conference on
  15. / 16. May 2014
  in Berlin, Germany



Source: sourceforge.net

Traffic Simulation Challenges
(from **our** point of view)

- Flexibility
  - more than just cars
  - choice of models
  - (fast) multi scenario simulation
- Interoperability
  - platform independence
  - communication facilities
- Extensibility
  - rich interface to arbitrary programming languages
  - open source
- Validity
  - Tests, tests, tests



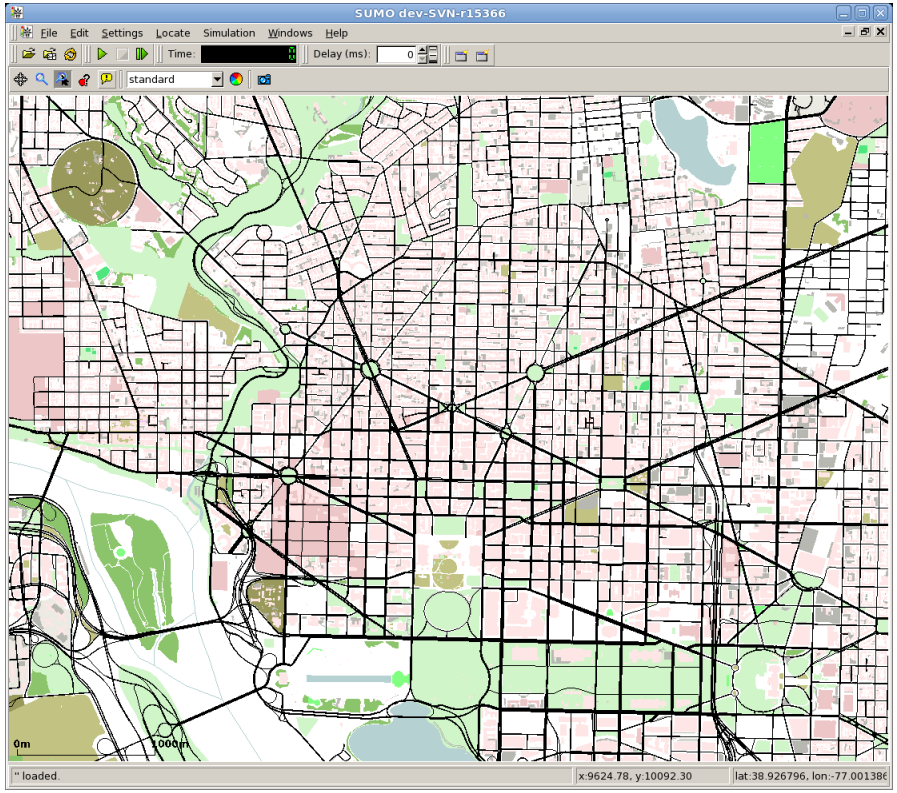
Testing

- SUMO is tested every night using about 3000 tests
- But most of them cover trivialities (is the vehicle inserted at position 100 if we define it to do so?)
- Testing for a proper behavior of a set of vehicles is less trivial
- Probabilistic → test results may (should?) change in every run, but what is acceptable given a scenario?
- Still interesting work to be done, Vincenzo Punzo would name it the modeling of uncertainty

SUMO – Simulation of Urban MObility

Powerful Components

- SUMO: without graphical interface
- SUMO-GUI: with graphical interface
- NETCONVERT: Importer for road networks
- OD2TRIPS: Importer for O/D-Matrix
- JTRROUTER: Router based on junction turning rates
- DFROUTER: Router based on induction loop data
- DUAROUTER: Router based on dynamic user assignment
- ACTIVITYGEN: Generating traffic demand

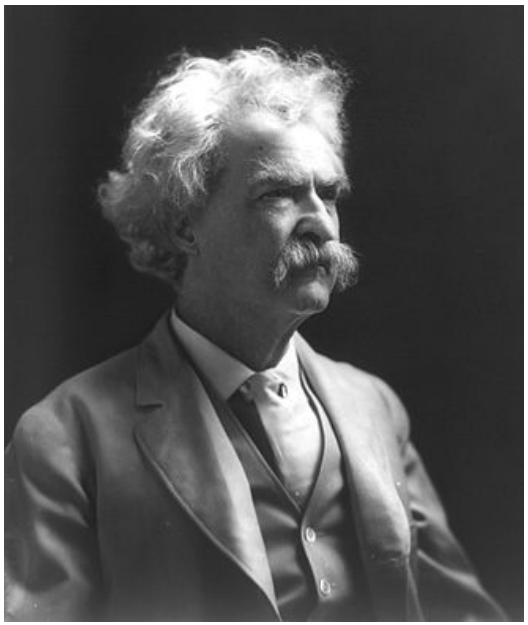


The future (almost nothing about SUMO)

Of course, the following is for discussion

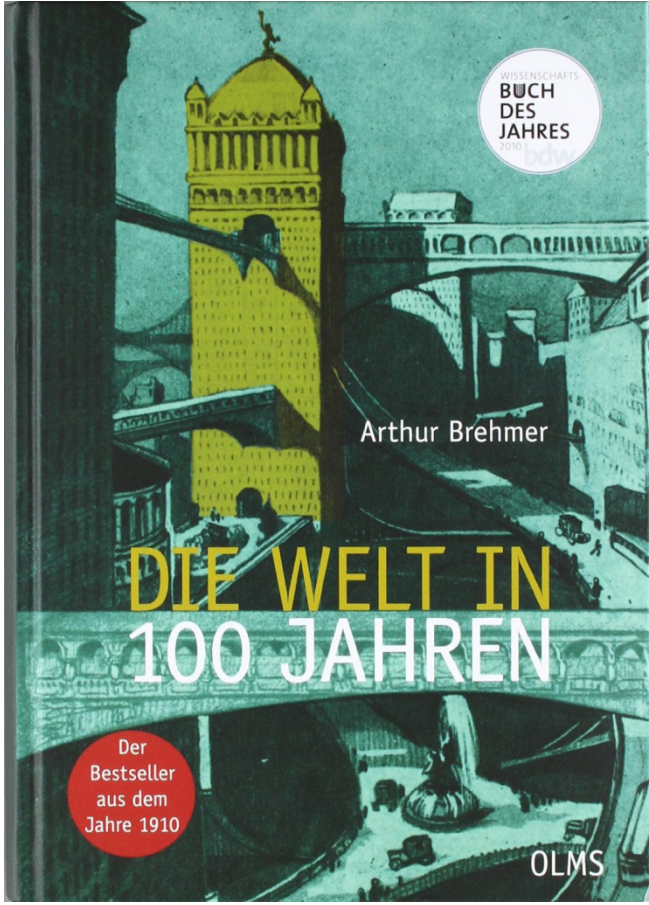
General blurb about the future

- Predictions are difficult, especially if they concern the future
- (Wikipedia assigns this sentence at least to five people, namely Karl Valentin, Mark Twain, Winston Churchill, Niels Bohr, Kurt Tucholsky)
- ➔ to be wise, and that must the goal, just give a few observations that might or might not be relevant for this question



But sometimes, it is not that difficult…

- From a German book (“The world in 100 years”) collected in 1910 by Arthur Brehmer
- A lot of things fit well:
  - Hamlet in London can be viewed worldwide
  - No more printed newspapers – spoken news only
  - Always on – select your new outfit online
  - Of course, portable telephones…
- (they had funny, untranslatable words for the technical gadgets that would do the job)
- Mind you, those predictions had limits:
  - Hats are out of fashion in 2010
  - Only a small amount of people are really interested in watching Hamlet



http://gedankenstrich.org/2010/11/heute-ist-die-zukunft-von-gestern/

Observation #1: Complexity

- Let's look into source code! Update rule of one of the simplest car-following models (Newell's model) reads:
- `vn = v + invT*(xLead – x - xStar)`
- `xn = x + 0.5*deltaT*(v + vn)`
- Old state of vehicle: **`x,v`**, and of lead vehicle **`xLead,vLead`** is transformed into the new (updated) state **`xn,vn`**

- This IS simple, one can immediately recognize what is going on here
- (left out additional lines to check boundaries, e.g. **`0 <= v <= vMax`**)
- Now, let us have a look into SUMO's implementation of one of Boris Kerner's models (named SA-model = speed adaptation model):

Just to watch…

from http://www.mytoys.de

```
g = xLead - x – lCar
acc = 0
if (g<=gJamMax):
        acc = aJam(g,v,vLead)
else:
        if (v> vFreeMin):
                acc = aFree(g,v,vLead)
        else
                acc = aSync(g,v,vLead)
vn = v + deltaT*acc
```

- But: calls three other functions, and these may call additional functions

Good company…

- MITSIM model and Wiedemann models (VISSIM) are similarly complex
- And not to speak of lane changing, this is a real nightmare!

- So what! What's the problem with it?

- Reproducibility!
- You have seen our implementation of Kerner's SAM.
- I'm sure, his own is different.
- Hopefully, that does not do something strange, but who can be sure of this?

Even more…

- We have to deal with this!
- One idea is of course to make the model's code publicly available
- But that is not all, see e.g. Joppa et al., ***Troubling trends in scientific software use***, Science, 2013
- Joppa et al. recommend that the code on which "societal important modelling" relies, must not only be open, but also peer reviewed
- Furthermore, it states that people should use software NOT as a black box but understand what it does; however, the current trend is different
- – can be confirmed from looking into SUMO's mailing list, a developer puts it ironically as the search for the "Deliver my thesis, now!" button

L.N. Joppa, G McInerny, R. Harper, L. Salido, K. Takeda, K. O'Hara, D. Gavaghan, and S. Emmott. Troubling trends in scientific software use. Science, 340:814–815, 2013. doi: 10.1126/science.1231535

Observation #3: The old HCM approach is “out”

- A provocative thesis: the time for the old HCM (and all the others similar to it, like Germany’s HBS) is over.
- Why is this?
- We can do anything with micro-simulation.

- At least in principle.

- However, we should not rely too strongly on some specific tool – I think, there will be a whole bag of different ones, not only your favorite micro-simulation tool.
- To sharpen this point, a short story may help:

A beautiful example (exaggerated, I know)

- Let's look at a fixed time traffic signal
- Webster, in his seminal book, computed almost anything to be needed for setting up such a thing ➔ complicated equations
- (Have you ever tried to follow Webster on his approach how to find the optimum cycle time?)
- HCM has something more, differently from Webster, it can deal with oversaturation
- ➔ even more complicated formulas

- How to get out of here? Webster's and HCM's approach is based on queueing theory; the main variable in this theory is the number of queued vehicles on each leg, let's name it n
- This is an approximation (my poster 14-3153 in poster session 514)

Queueing simulation

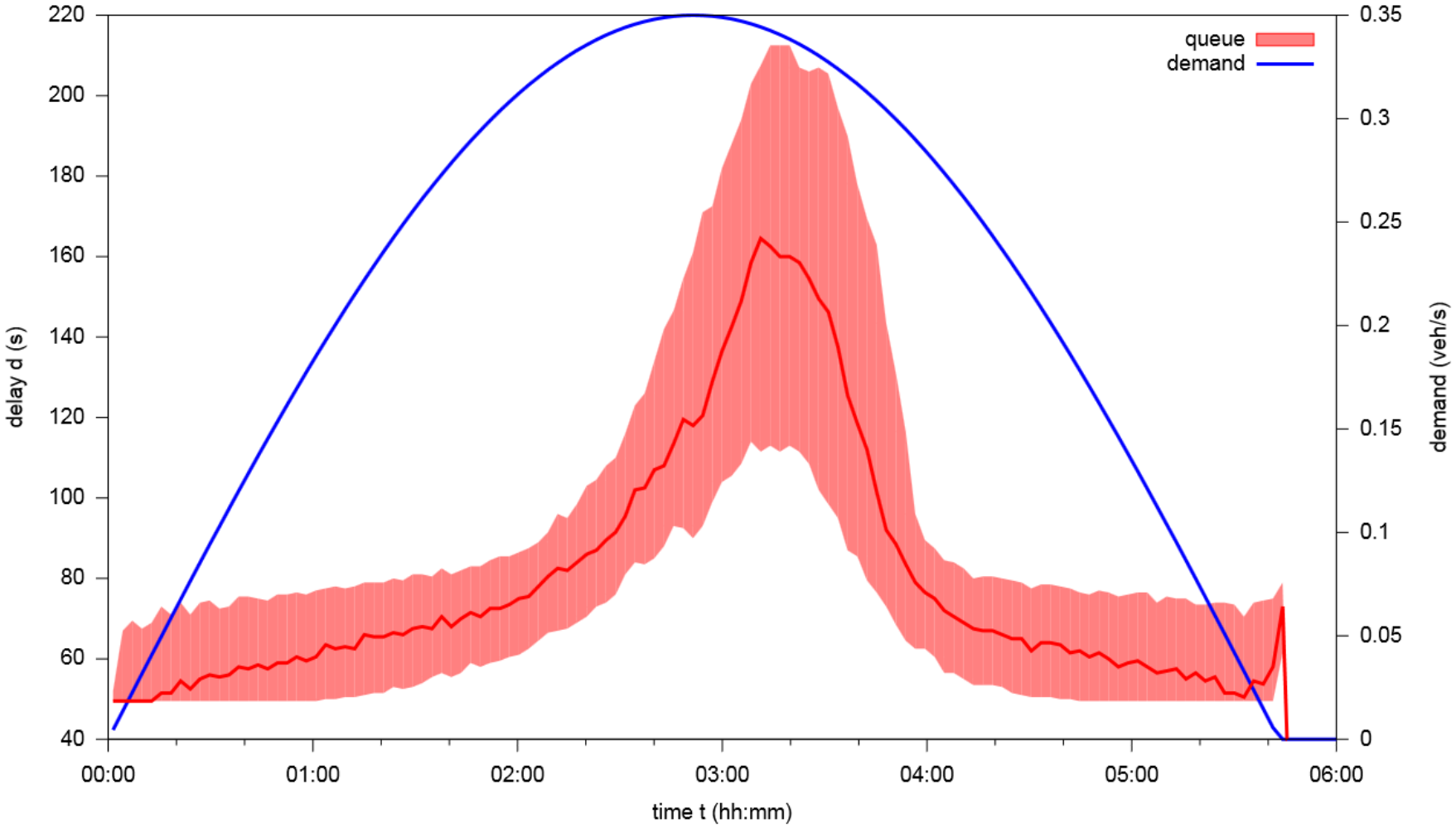
- The simulation code that does this queuing simulation is really simple.

```
for t in arange(0.0, tMax, deltaT):
    if rand() < q(t)*deltaT and n<nMax then:
        n = n + 1
    if mod(t,c)<=g and t>=tLast + invSat and n>0 then:
        n = n - 1
        tLast = t
```

Fast

- That is very similar to Webster's own code (see appendix of his book)
- And it runs very, very fast (1 ms or so) for a peak period
- So fast, that one can throw in any demand function **`q(t)`** for a peak period and run the same simulation 1000 times to get beautiful statistics… (takes 1 second)

One example


queue
demand
delay d (s)
demand (veh/s)
time t (hh:mm)
220
200
180
160
140
120
100
80
60
40
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
00:00
01:00
02:00
03:00
04:00
05:00
06:00

Fast

- That is very similar to Webster's own code (see appendix of his book)
- And it runs very, very fast (1 ms or so).
- So fast, that one can throw in any demand function **`q(t)`** for a peak period and run the same simulation 1000 times to get beautiful statistics… (takes 1 second)
- Something, that is not easy in reach for queueing theory
- (Webster needed a couple of hours for ONE simulation with 5,000 cars in 1958)

- Unfortunately, it runs many times faster than, well, SUMO.

- But it is dedicated code, while SUMO is a general purpose tool (like all the other micro-simulation tools)

HCM 2020+

- A new HCM might consists of many small tools
  (better and different from the idea sketched here)
- The respective kernels (where the real traffic is modelled) should be open source
- They may even been peer reviewed, as demanded by Joppa et al.
- It may come as a collection of apps, the apps themselves do not need to be open source
- I my view, there is no need to use just one monolithic micro-simulation tool for the whole HCM

No conclusion

- We will see, what will happen
- My feeling is, that my observations are not too far off
- But remember: it is not clear whether I was talking about the hats or the smart-phones of the future

- Thanks for listening!

Evolution of SUMO's Simulation Model

Michael Behrisch, Laura Bieker, Jakob Erdmann, Melanie Knocke,
Daniel Krajzewicz, and Peter Wagner
Institute of Transport Systems, German Aerospace Center (DLR)

TRB Workshop 172 – Simulation: Looking Back and Looking Ahead
Washington, 12. January 2014

www.sumo-sim.org

DLR

Additional material

User Acceptance and Feedback

- Of course, there are dark sides of providing a service to a community…
- Most users do not care about the model at all – it should be correct
- Some of them are working on their thesis and use the simulation as a tool – they want a “Deliver my Thesis, now”-button

Model Improvement in practice

- One could assume a gradual improvement of the simulation's quality
- But my (D.K.) feeling is that "the quality" oscillates
- Why?
  - Improvement is usually done by extending the model (cross the intersection, time-line of approaching an intersection, move over an intersection only if there is enough place behind, impatience, etc.)
  - Now, when looking at large networks, the extensions improve the simulation in most cases (read: intersections)
  - But almost always, you'll find some "special" intersections that start to jam or behave strange when run with the extended model
  - … and one intersection is capable to destroy your complete scenario

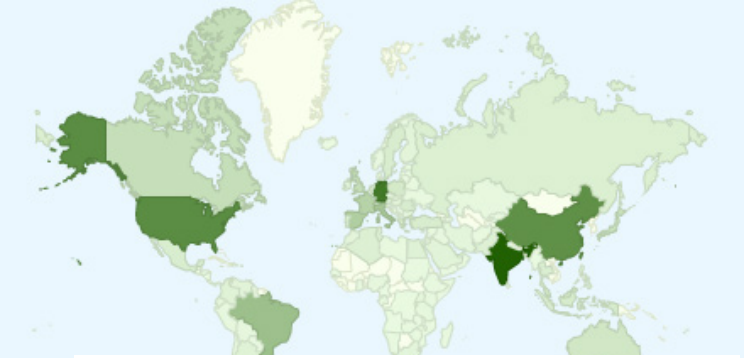
Software Development

It turned out to be a good approach

- tests (even the trivial ones)
- using XML for both input and output formats (it's very flexible, especially for being extended)
- an (attempted to be hierarchical) software modules
- using a single language for all major applications and portable libraries (high portability)
- using an own framework for parsing options, files, etc.
- GUI realisation (classes built on top of plain, command line simulation classes extending them by visualisation and instantiating them using so-called "factory classes" - same behaviour, same building, but with drawing)

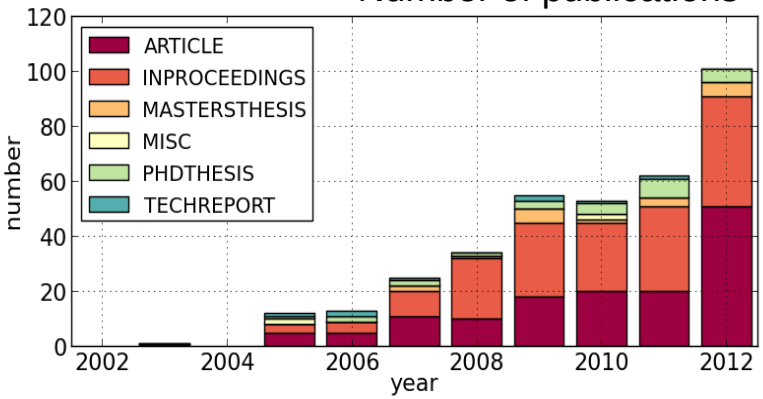
What about the users?

- SUMO was first released in 2002
- Used Worldwide
- Increasing number of users
- High level of awareness in science

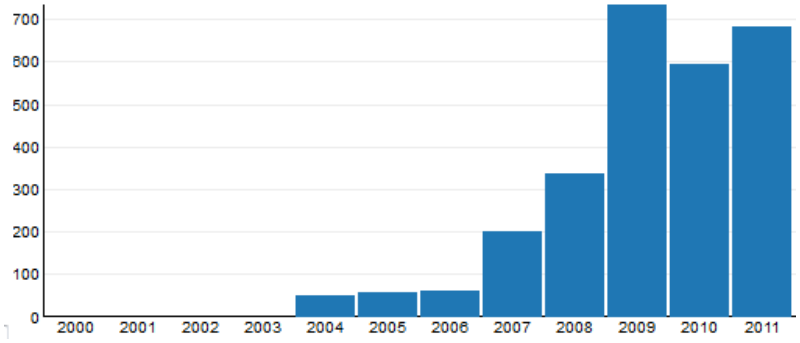


Sourceforge downloads by country 2012

Number of publications



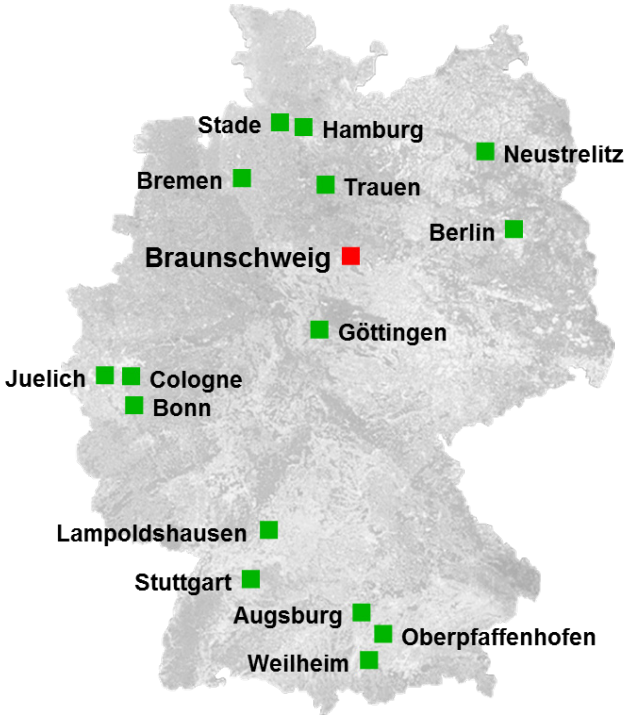
mails on sumo-user



SUMO case study: Traffic Management to reduce emissions in Braunschweig (Brunswick)

DLR

SUMO case study: Traffic Management to reduce emissions in Braunschweig (Brunswick)



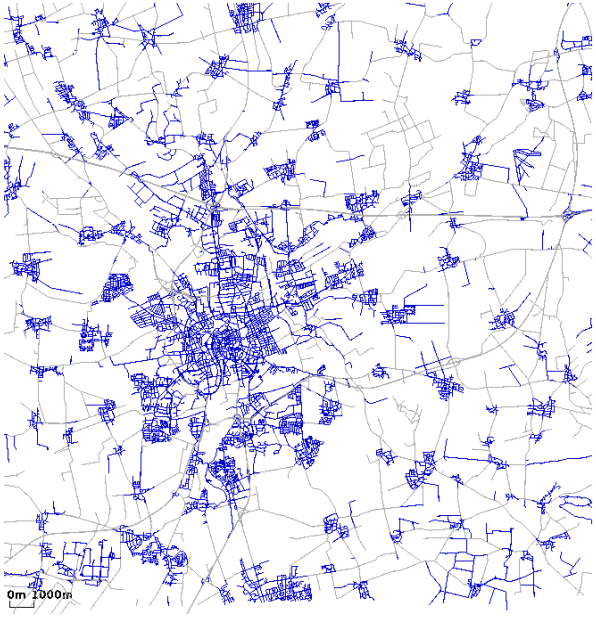
DLR

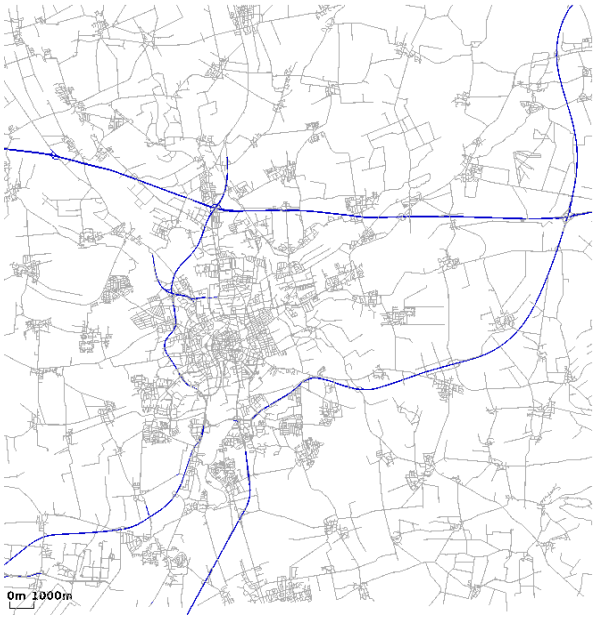
Real traffic management

Three simple strategies:

(Note: speed limit in German cities 50 km/h)

- Reduce speed-limit on city roads to 30 km/h (“City30“)
- Increase speed-limit on city roads to 60 km/h (“City60“)
- Reduce speed-limit on freeways to 80 km/h (“Freeway80”)





Question to the audience

- What do you think, in which scenario does the total CO_2 emissions increase / decrease?
- Test yourself, not enough time to poll the audience

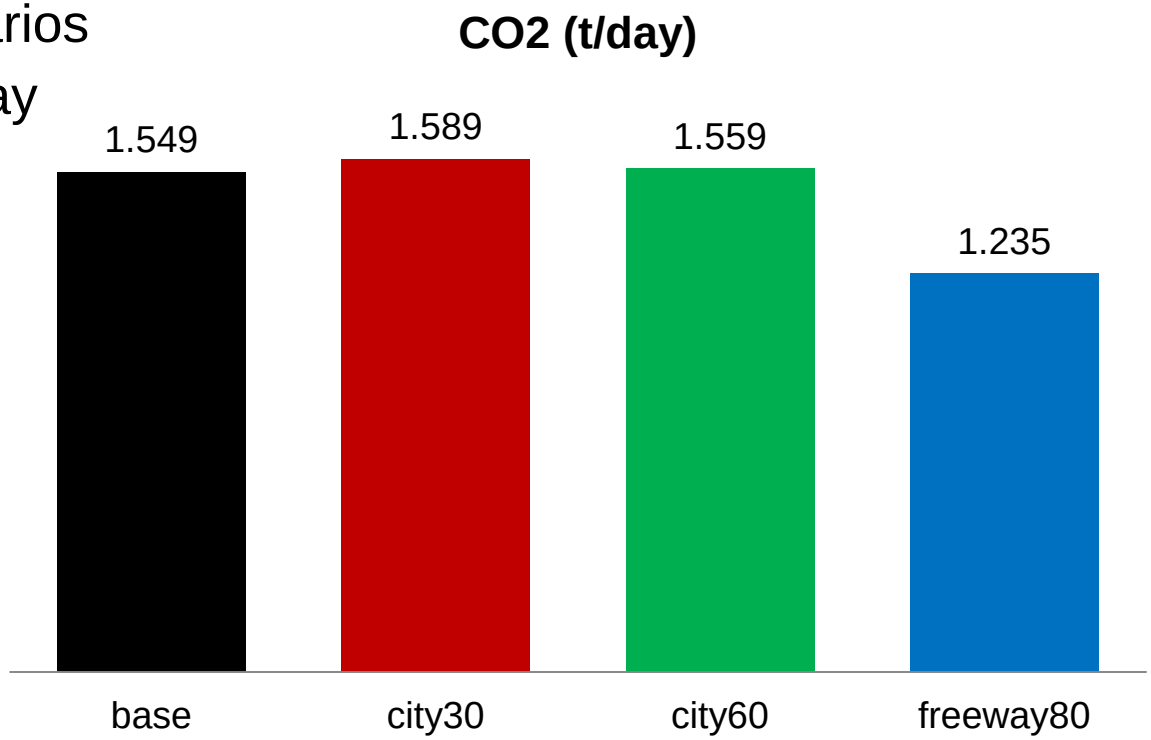
Scenario	Decrease	No change	Increase
City30			
City60			
Freeway80	6	0	4

How is it done (on a high level)

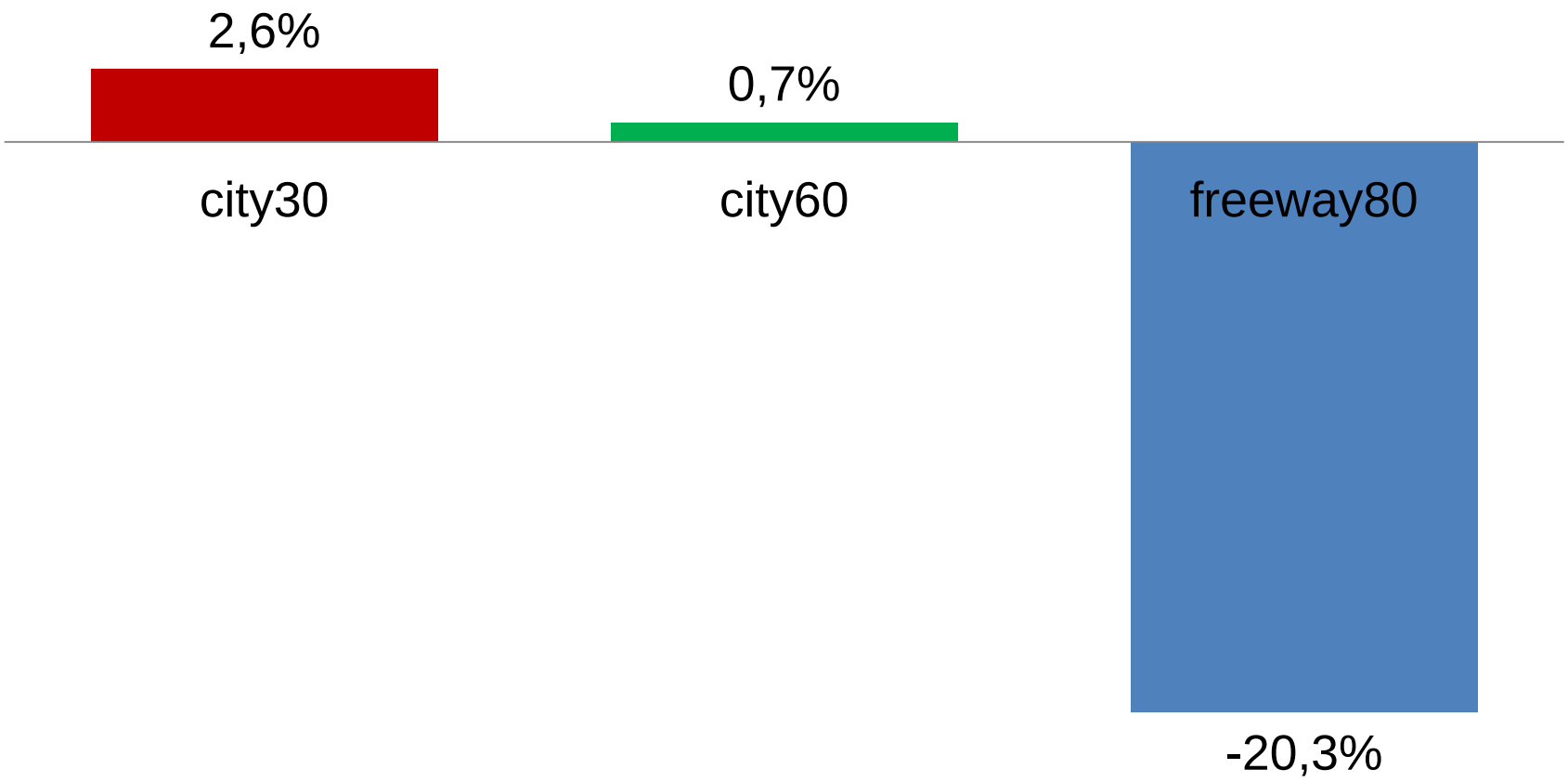
- Change the speed-limits accordingly
- Dynamic Traffic Assignment via so called one-shot algorithm
- SUMO has an emission computation in its toolbox
- Compare against base scenario
- Compute and display
  - Utilization of roads (#vehicles / link)
  - Emissions (per link)

Executive summary

- Total emissions (CO_2):
- Small effect in city scenarios
- Stronger effect by freeway speed-reduction

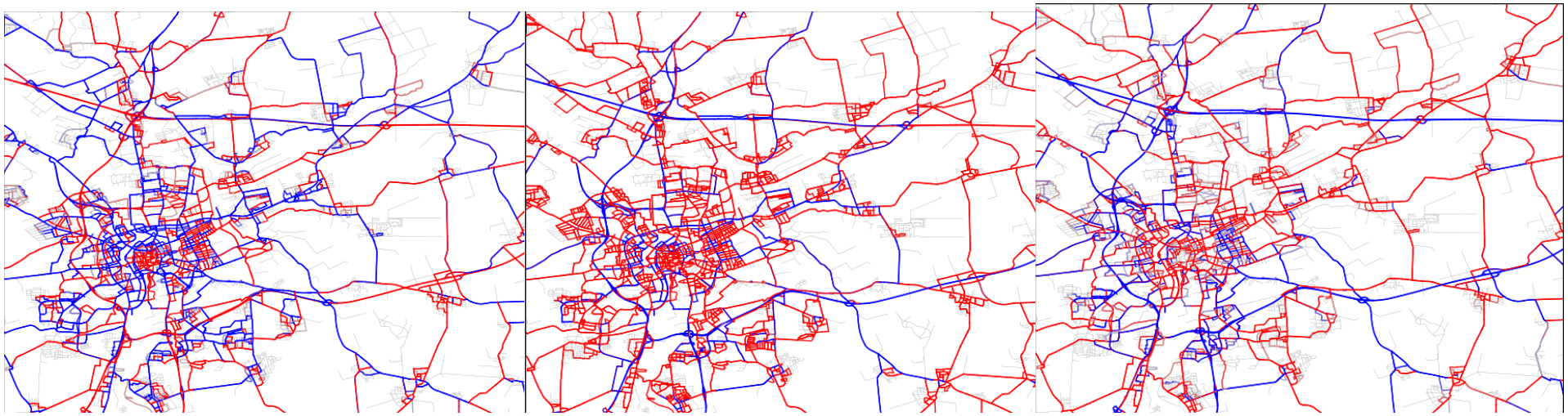


Even more summarized (CO_2 again)



Road utilization

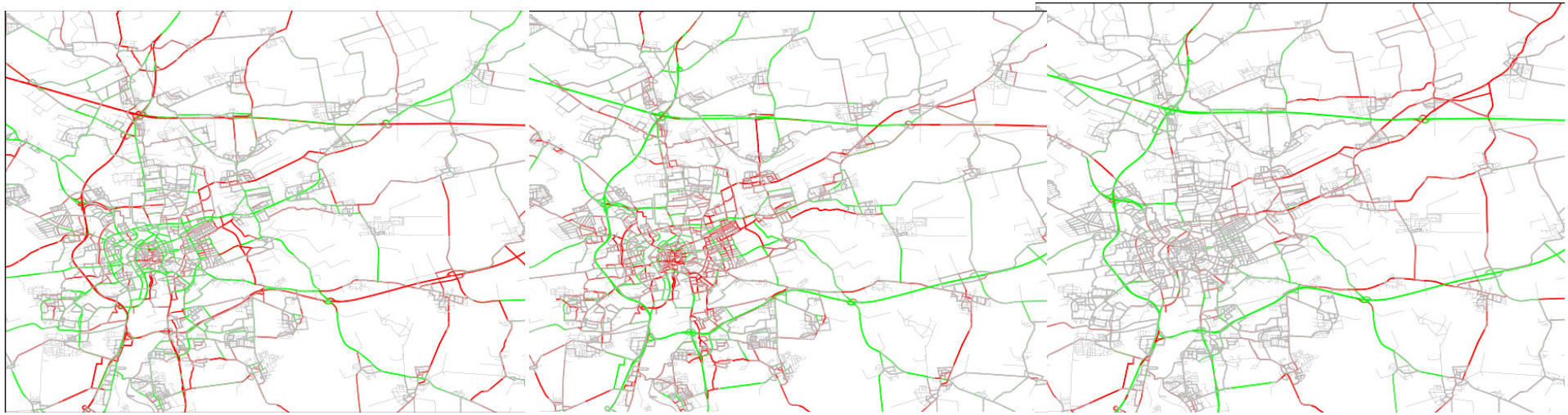
- blue: less vehicles compared to base, red: more vehicles



- City30: load moves into the smaller roads and to freeways
- City60: load moves away from freeway
- Freeway80: load moves into city

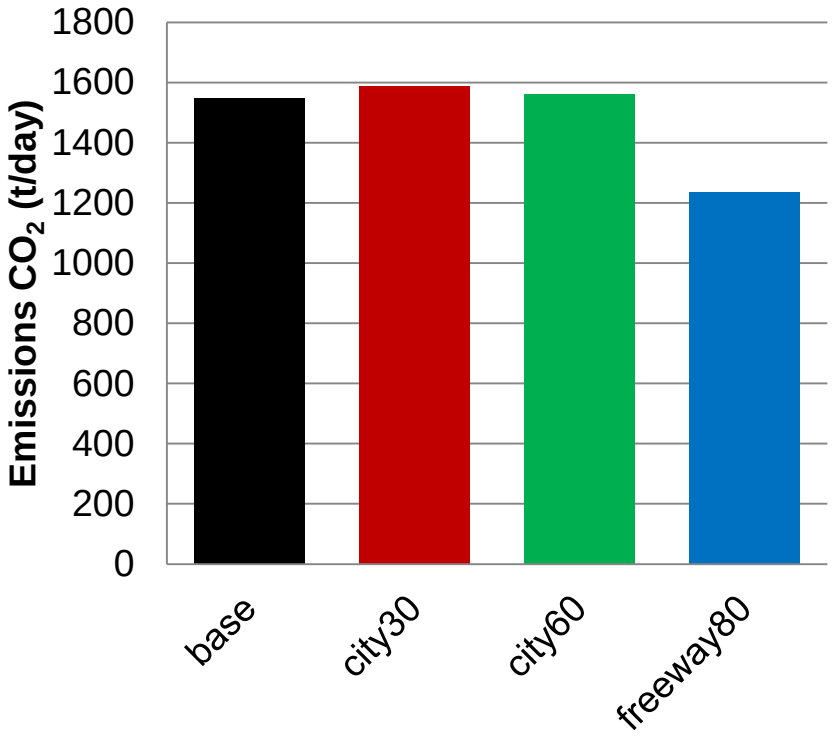
Emissions, spatially

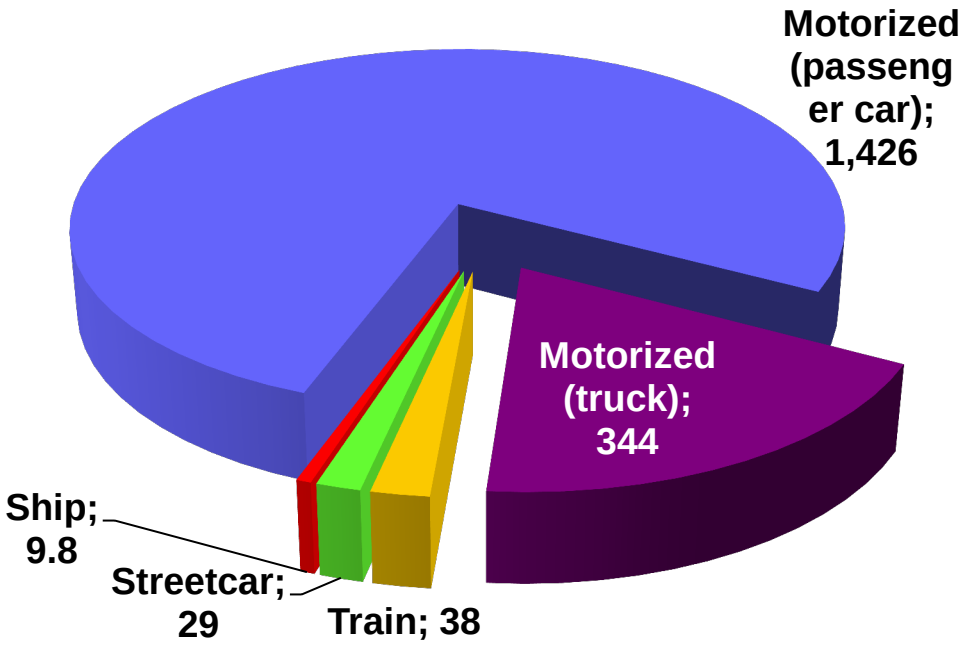
- Green: less CO2-Emissions as in base scenario, red more



- City30: more emissions on freeways, partly on smaller roads
- City60: more emissions in inner city, less on freeway
- Freeway80: more emissions on rural roads

Quality / uncertainty





- ~ 1600 t/day ~ 1,770 t/day

(*) GEO-NET Umweltconsulting GmbH (2010). Integriertes Klimaschutzkonzept für die Stadt Braunschweig.

Back on the envelope…

- …at least matches roughly:
- Braunschweig has 250,000 inhabitants
- 4 trips/day, of these 3 per car
- Distance around 8 km per trip
- Makes 6,000,000 km / day
- 200 g/km ➔ 6,000,000 × 0.2 kg = 1200 t / day

- (this is only passenger traffic, no freight)

Is it a good result?

- No and yes.
- Do you know how emissions are modeled?

➔ there is uncertainty here, and from recent work I hope we can write a 10%, i.e. have 1600 $\pm$ 160 t CO_2

- What about the 1770 t/day? No idea which error to apply here, number is from heaven.
- But decision makers work with it. Do they?

- [Back to main]