Remarks on Traffic Signal Coordination (Progression)

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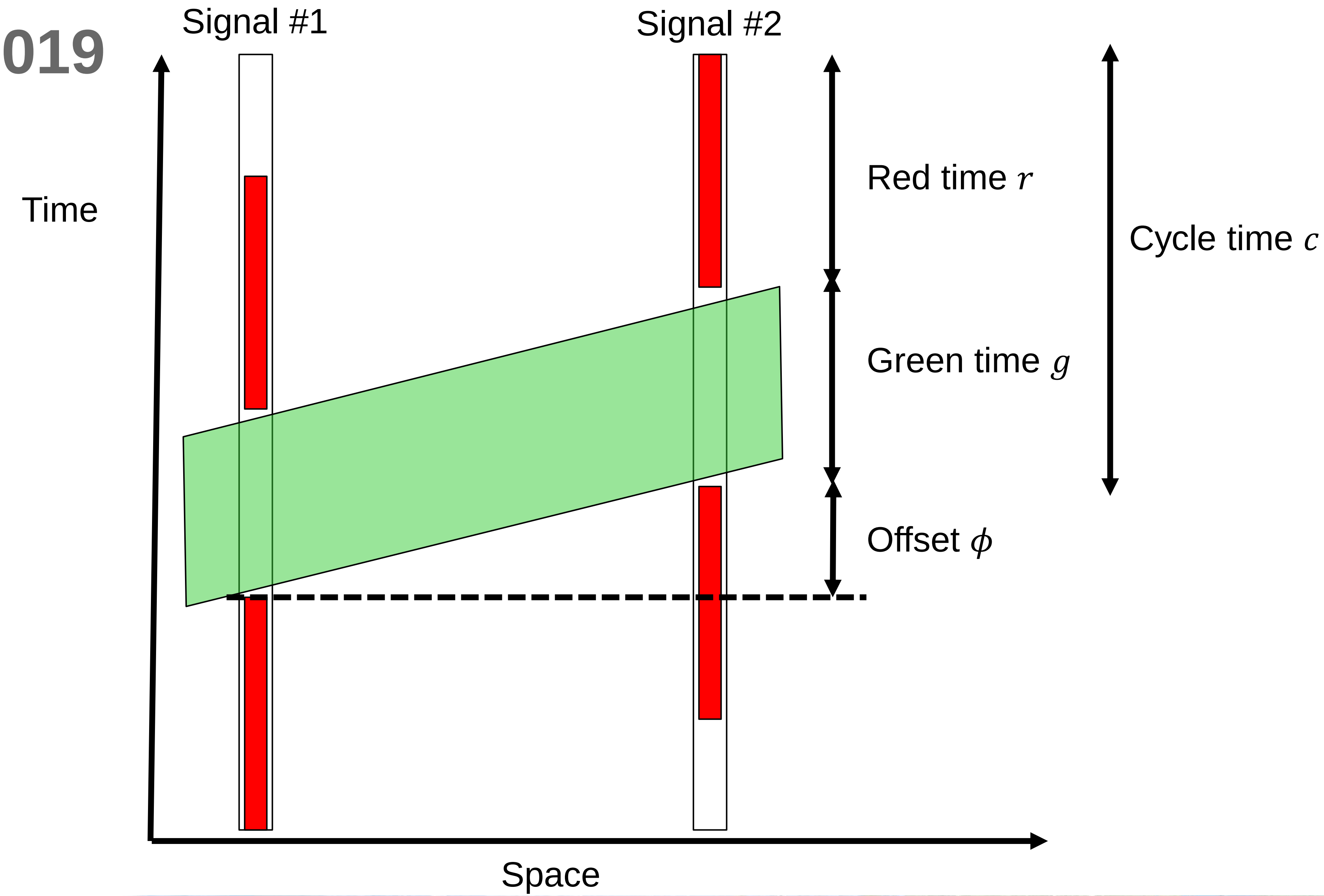
Introduction: Traffic signals in a network

- Car-drivers: traffic signals do always display red when I arrive there
- To remedy this, traffic signal co-ordination is attempted
- Most famous: the green wave
- Easy to understood: in a space-time diagram, a platoon of vehicles progresses from one traffic light to the next
- Unfortunately easy to understood: one may think that doing the same in networks is simple, too.
- Not true, of course

https://www.fhwa.dot.gov/publications/publicroads/02janfeb/timing.cfm

A green wave 2019



1929:

Extension to a network…

- Is complicated, only in rare special cases (regular grid networks, other preliminaries) this can be done in a simple manner
- In real networks, this runs into a fairly complicated optimization problem which is, as far as I have understood, NP-complete to solve (Little, 1966), (Gartner, Little, & Gabbay 1977)
- In 2004, Gershenson came up with the idea of a self-organized traffic signal system (SOTL)
- There is a lot of additional work on this especially by (Lämmer, 2007)
- Idea is: let these signals alone, together with the appropriate control mechanism they will find some self-organized optimum

The Great Plan

- SOTL draw criticism. Nicely put by Bernhard Friedrich (in German, unfortunately) where he put
- “The Great Plan” versus “the jungle principle” (translation by me, may be inadequate)
- Bernhard’s Great Plan is charming: such a plan (has some similarity to a bus schedule) forces traffic flow into a pattern of platoons for which down-stream traffic signals can be timed optimally
- Another kind of self-organization, so to speak, but forced by the plan laid out by the traffic management center

From: https://www.athenstransit.org/lines-5-6/

The Big Question

- What is better?
- The following is a kind of test; one may have other things in mind, and there are some things in SUMO’s developer pipeline that can be used to test these ideas more thoroughly.
- Today: stick to the more traditional approach, no i.e. I do not dive into SOTL

Putting these ideas to a test

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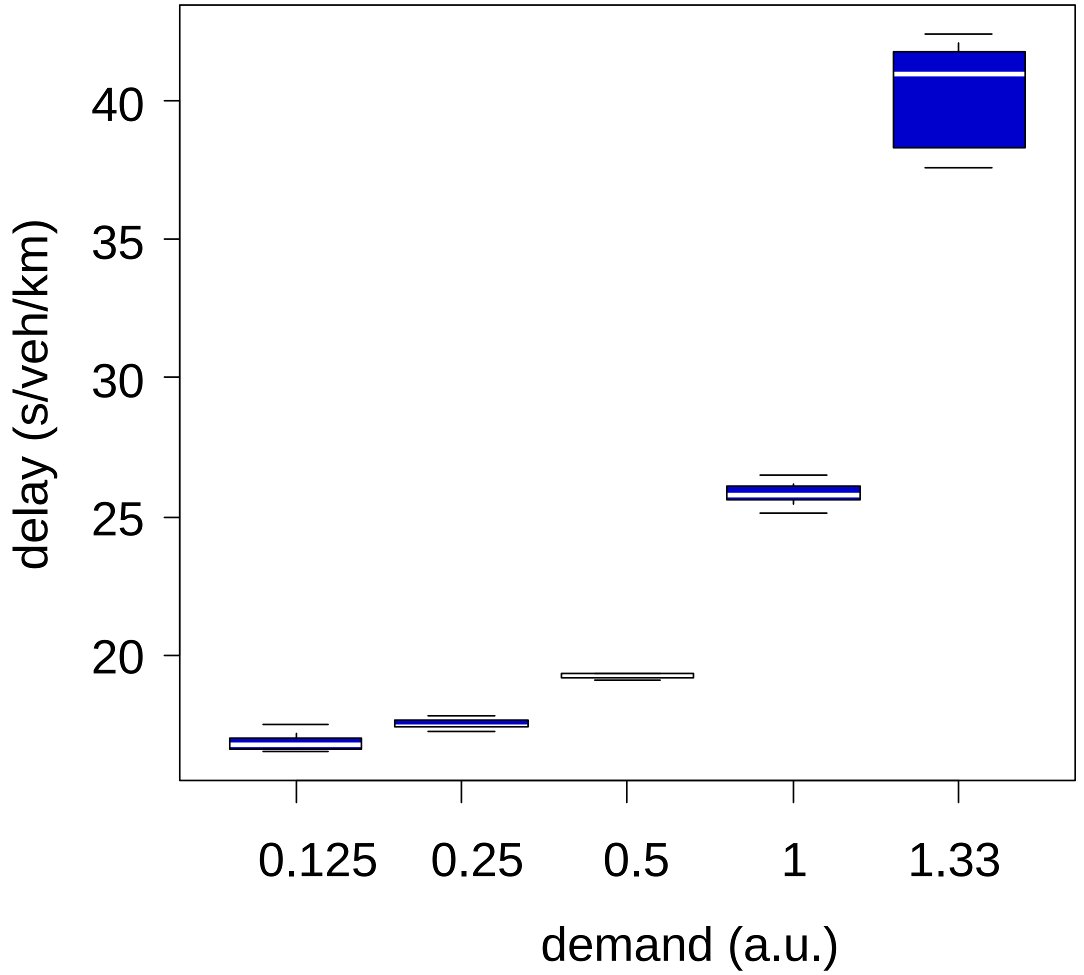
The networks

- Can all being done with SUMO’s tool-box:
- Use artificial networks with an artificial demand:
  - `netgenerate`
  - `randomTrips.py`
- Exception: used an additional network from Berlin center as well
- Create traffic signals for these networks
  - `netconvert` – this yields the case default (it is bad, but easy to outperform)
- Do the signal planning with:
  - `tlsCycleAdaptation.py` (compute cycle time and green splits)
  - `tlsCoordinator.py` (compute the offsets between the signals)
  - Actuated signal (well, this might count as SOTL, but…)

The demand

- Generated with `randomTrips.py`
- All in all 5 levels of demand (`randomTrips.py`) has a parameter `p (period) = (8, 4, 2, 1, 0.75)`, which generate vehicles with equidistant departure times p seconds apart
- No user-equilibrium computed

- Delay-times depend on demand (of course)



The traffic signal settings

- Base-net created without traffic signals
- `netconvert (…) --tls.default-type static` ➔ SUMO's fixed time signals
- `netconvert (…) --tls.default-type actuated` generates actuated signals
- For fixed time signals, `tlsCycleAdaptation.py` produces Webster-optimal cycle and green times for each intersection
- From this, the maximum cycle time $c_{\max}$ for the network can be picked…
- All signals forced to $c_{\max}$ for co-ordination
- Meanwhile, `tlsCycleAdaptation.py` has a new option that does this
- Then, `tlsCoordinator.py` computes a set of good offsets (most likely not optimal)

Four scenarios

- Fixed time (SUMO’s default) “**fix**”
- Webster optimized **s**plits and **c**ycle time “**fixSC**”
- In addition, with co-**o**rdination “**fixSCO**”
- Actuated “**actd**”

The most import things last

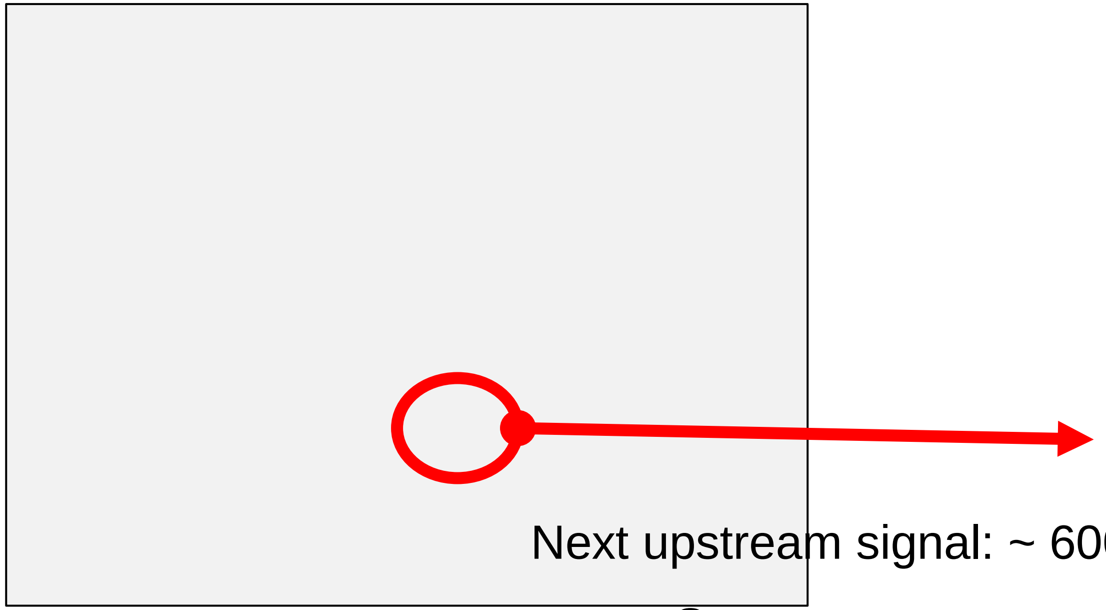
- The networks have two lanes in each direction, that was done intentionally
- Cars are identical (except for the Berlin scenario), but their preferred speed is drawn from a distribution with `speedDev = 0.1`
- Vehicles drive stochastically, parameter sigma of the SK model is at SUMO’s default value (0.5)

➔ Strong platoon dispersion, not unrealistic:

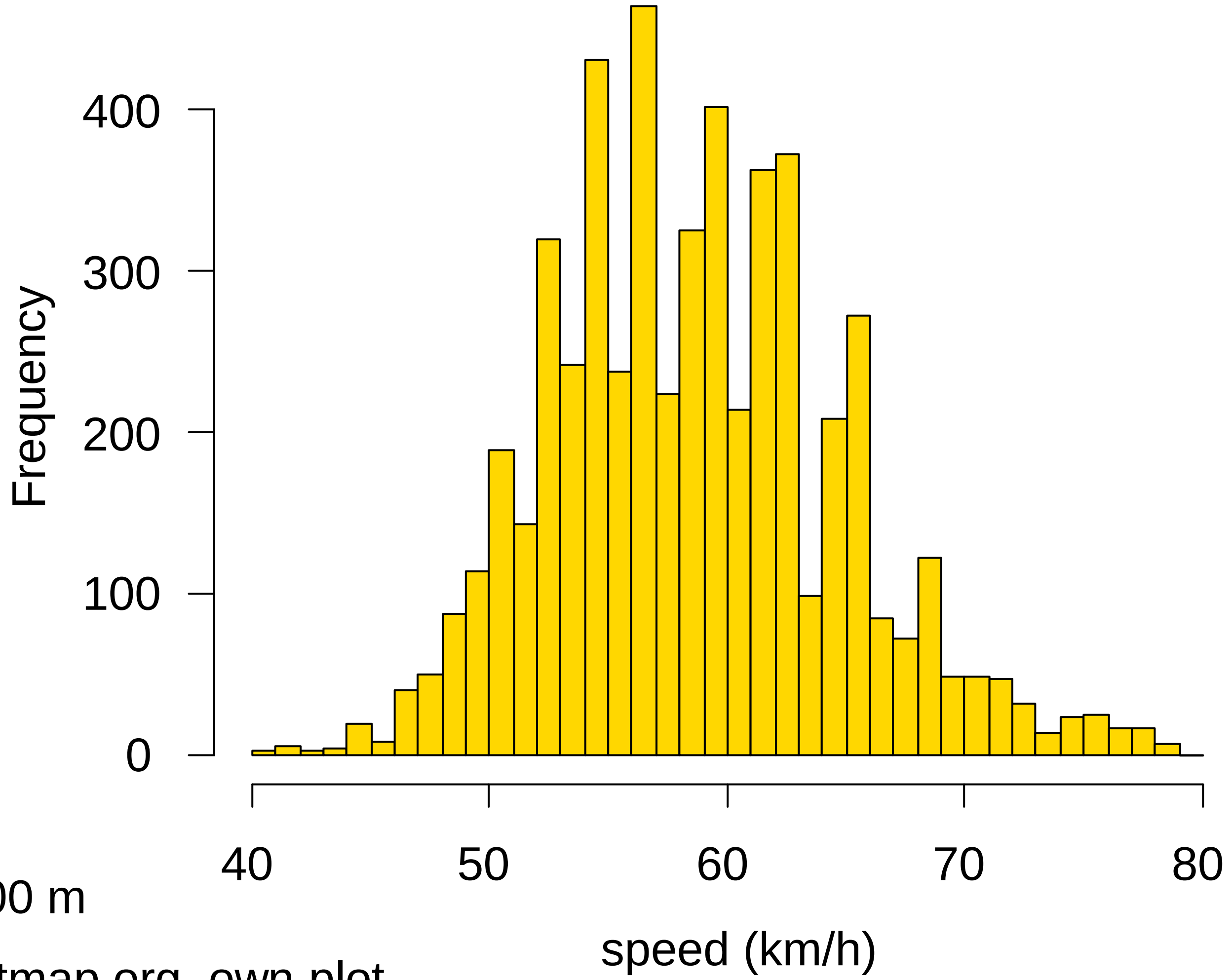
Taken from Gartner, Little, & Gabbay

Real-life speed distribution (Ernst-Ruska-Ufer, 2015)

- Data between 20…80 km/h (138 max!)
- Mean = median = 59 km/h (50 km/h SL
- Sd = 6 km/h ➔ `speedDev = 0.1`
- Interquartile: 55…63 km/h



Next upstream signal: ~ 600 m



Sources: openstreetmap.org, own plot

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Results

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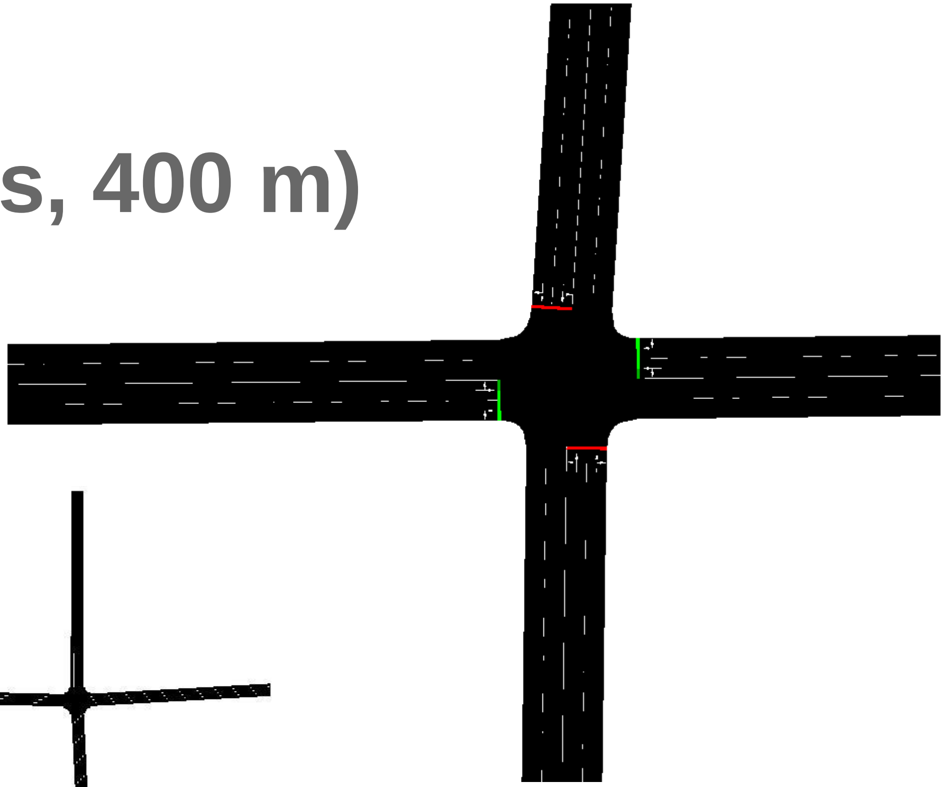
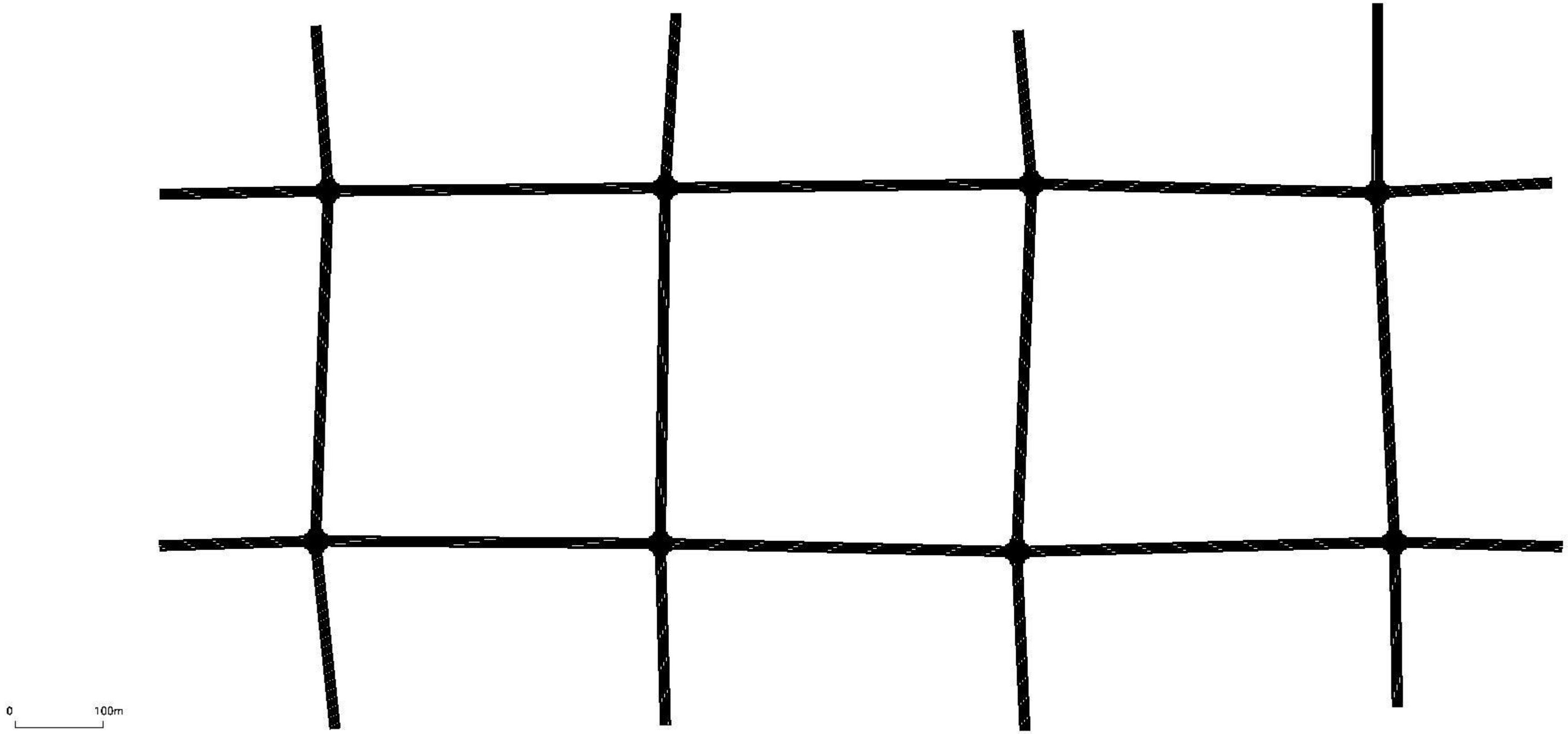
Example of a network (disturbed grids, 400 m)

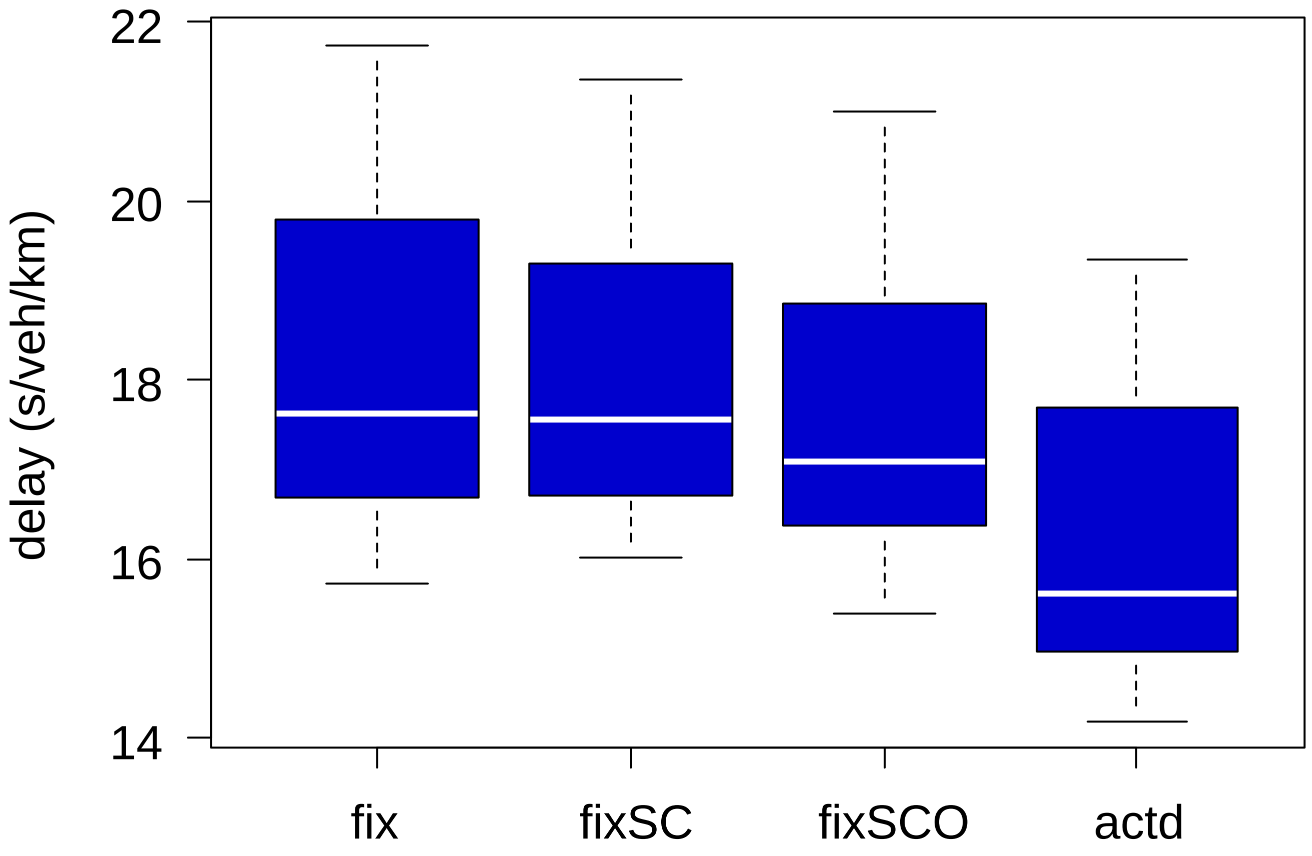
- 4 x 2, ..., 14 x 8
- (4,6,10,14) x (2,4,6,8) x 5 repetitions





Main result

- Webster is slightly better than SUMO's default: it cuts some of the large delay times
- Co-ordination helps Webster: getting slightly better
- But: actuated control is better, despite the fact, that demand is constant during one run
- (Difference might be even bigger for time-varying demand)
- Distribution of 80 mean values

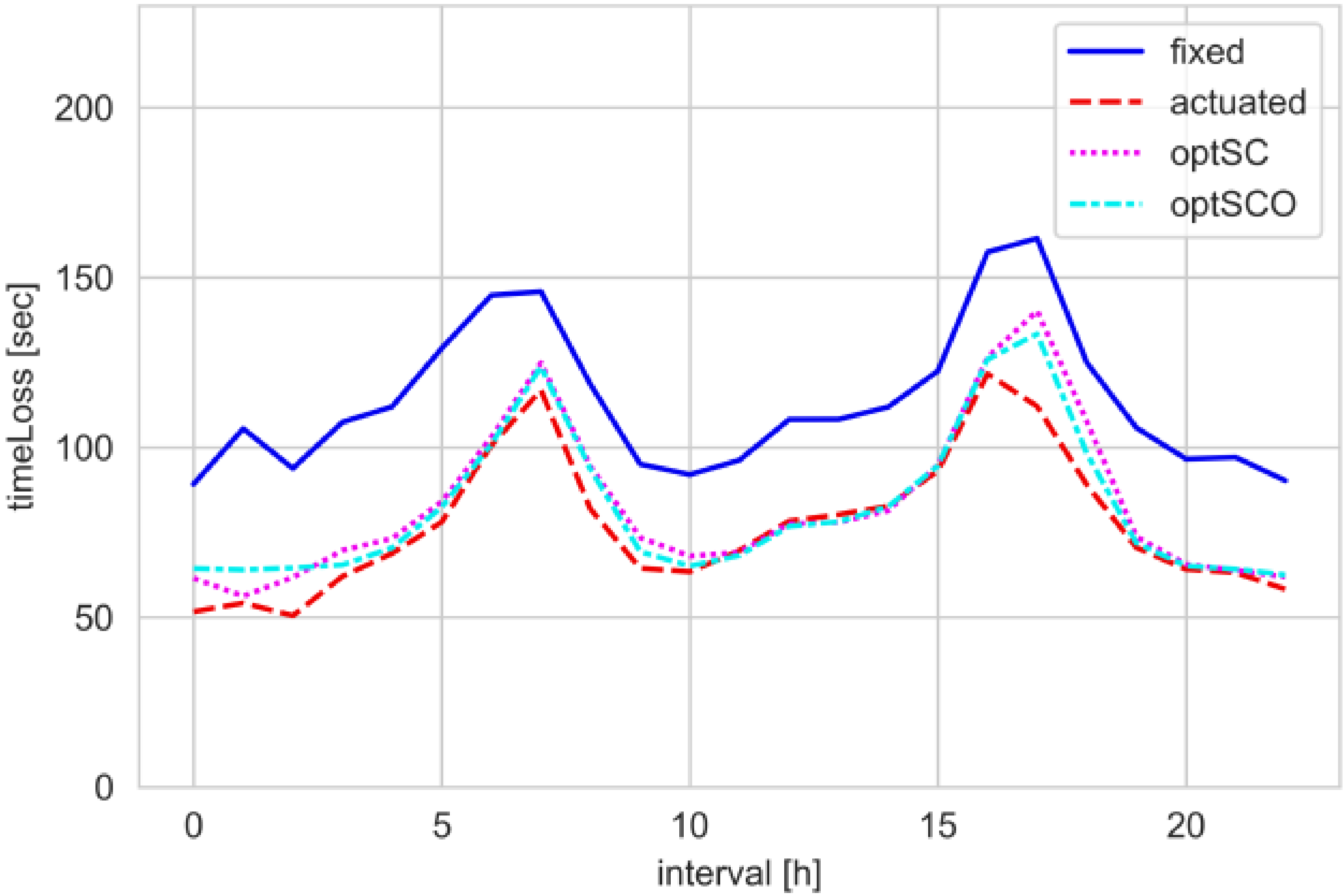


Berlin Center

- Real-life network
- 120 traffic signals
- 242 km network length
- 190,000 trips,
- Created by TAPAS + one-shot
- (So far, no check against counts)
- Network is at the border of capacity
- 24 hour simulation, time-dependent demand

Results are similar…

- But not the same.
- Difference between fixed and Webster larger
- Small gains with co-ordination
- Small gains with actuation



Conclusion & Outlook

- In real world chaos, the Great Plan seems to be underperforming
- In the ideal case of small platoon dispersion, it may have an edge
- If results can be transferred to real life, then running all signals actuated is sufficient to yield smooth traffic in a city
- And: from single intersection control it is known that even actuated traffic controllers can be outperformed by something like AGLOSA…
- Which adds a short-term prediction & planning to the objective function

Conclusion & Outlook

- But, you know: if you improve traffic signals, what will happen?
- (Transportation planners curse)

- **Thank you for listening!**

https://www.scienceabc.com/innovation/ready-steady-go-the-evolution-of-traffic-lights.html