

FUSION METHODS FOR AN MFD ESTIMATION

SVT

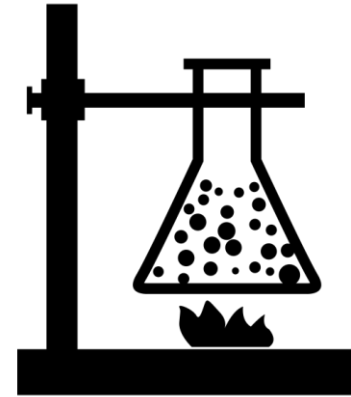
Verkehrsringenieurtag
Lukas Ambühl

ETH Zürich
17. March 2016

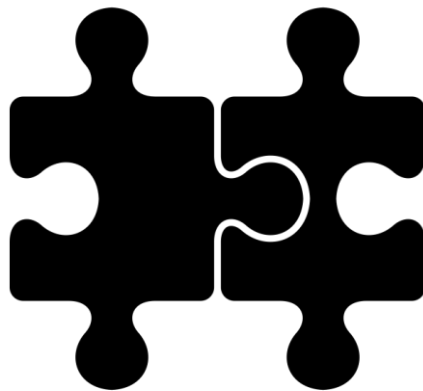
Outline



Introduction



Experimental Setup



Fusion Method



Conclusion

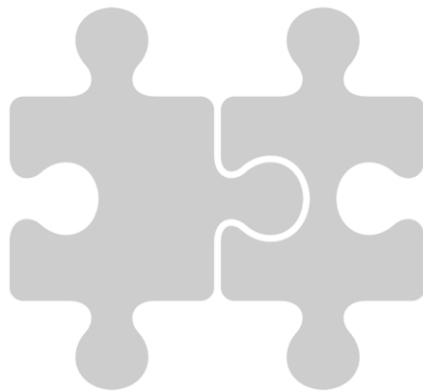
Outline



Introduction



Experimental Setup



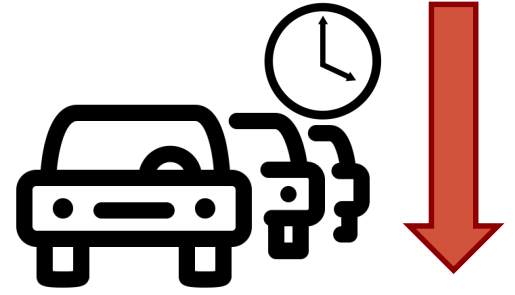
Fusion Method

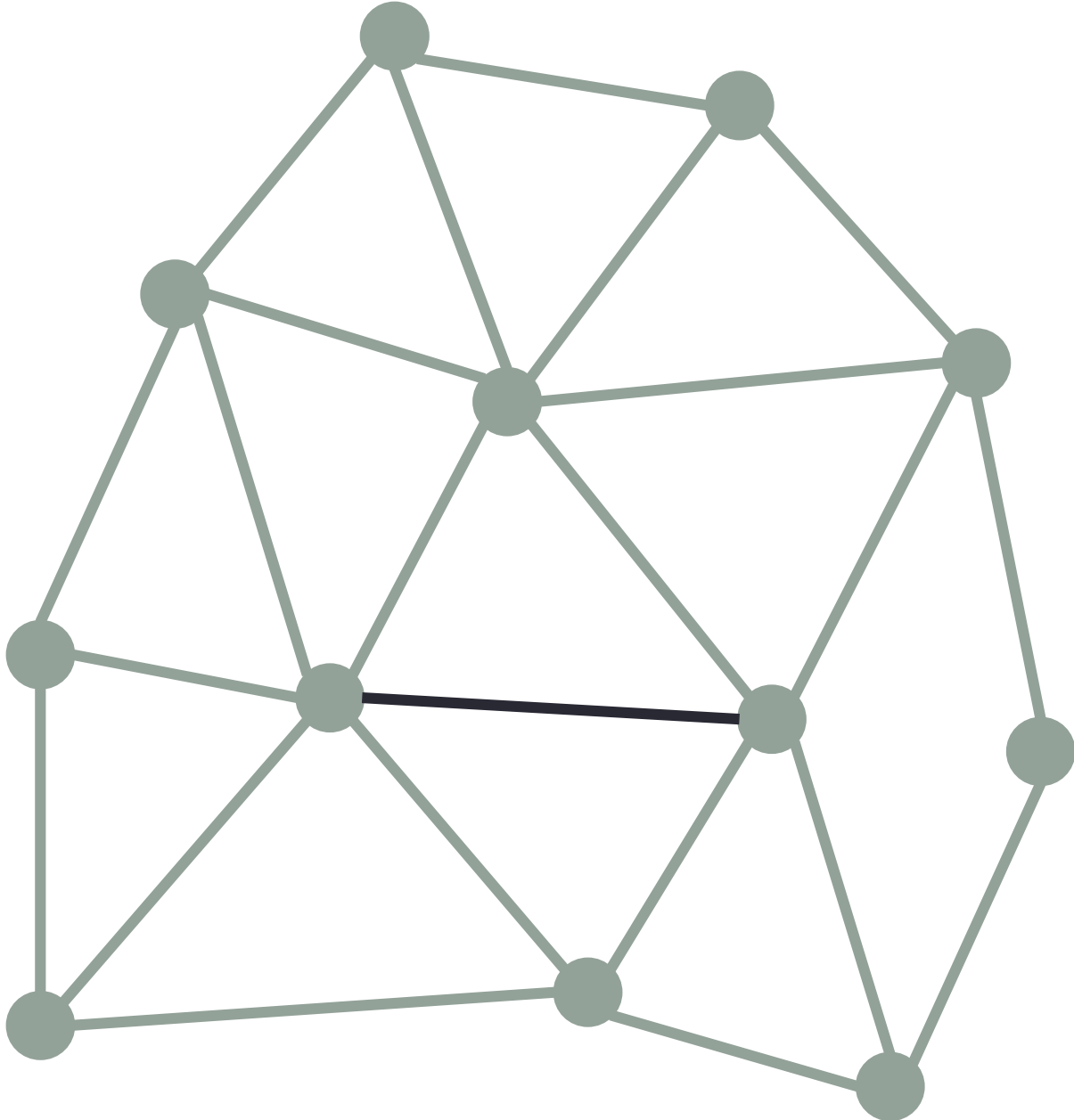


Conclusion

Some Numbers...



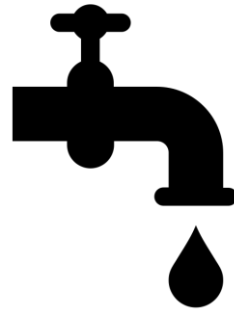




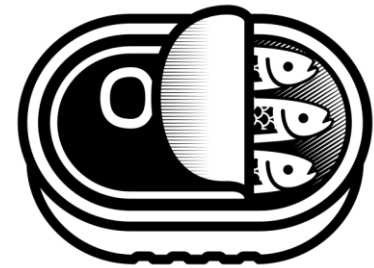
Key Performance Indicator



Speed (v)



Flow (q)



Density (k)

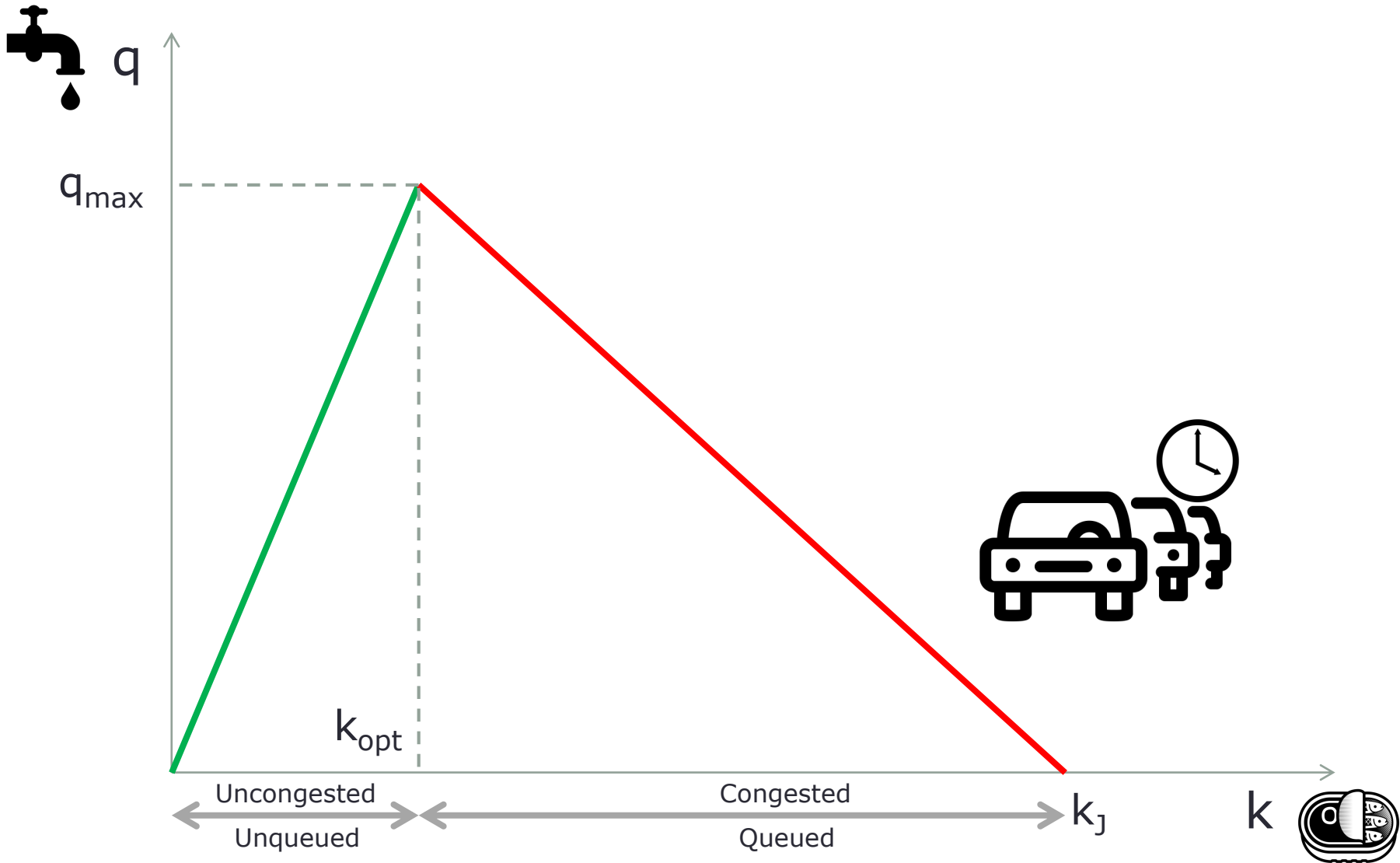


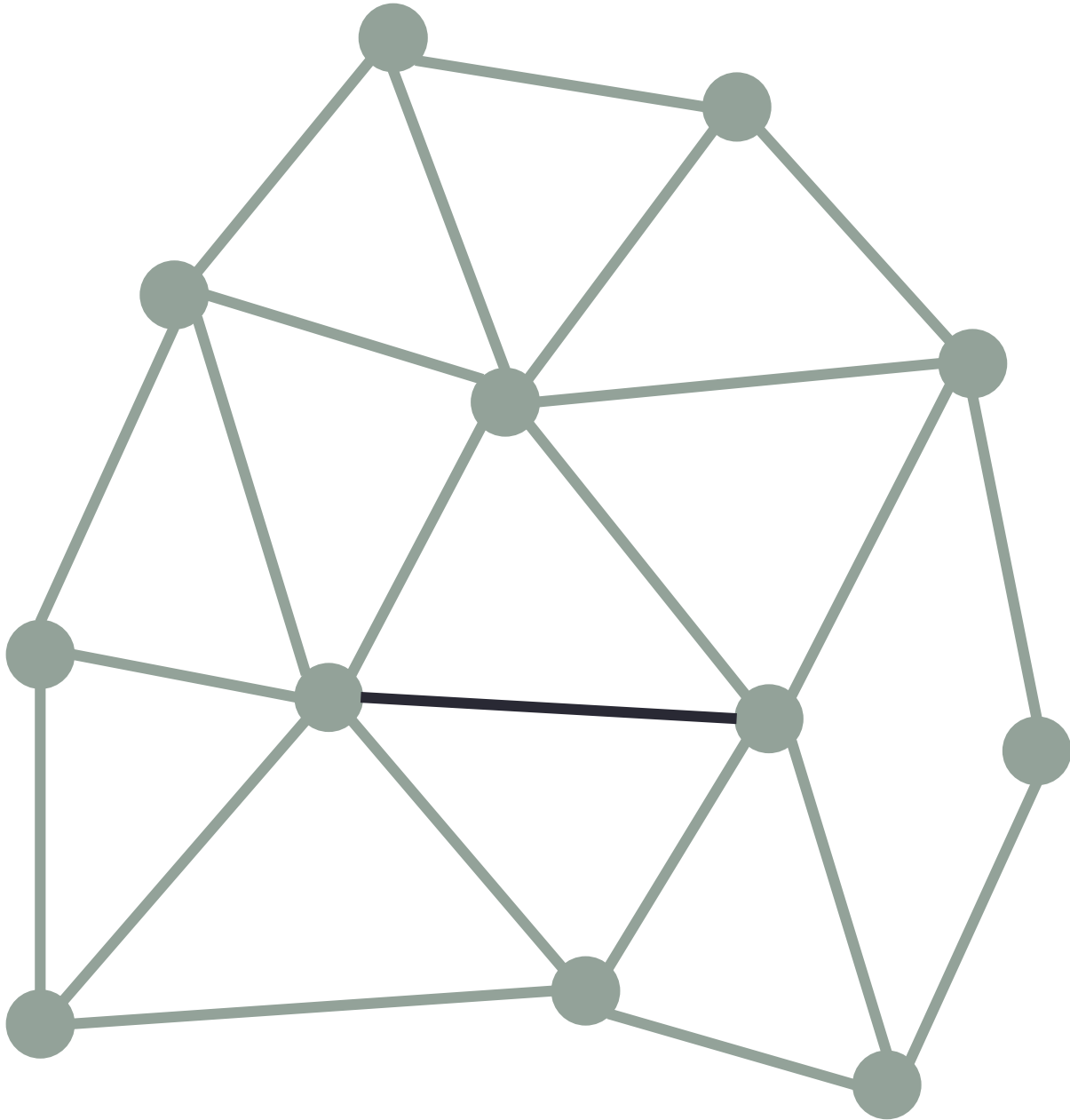
Link i

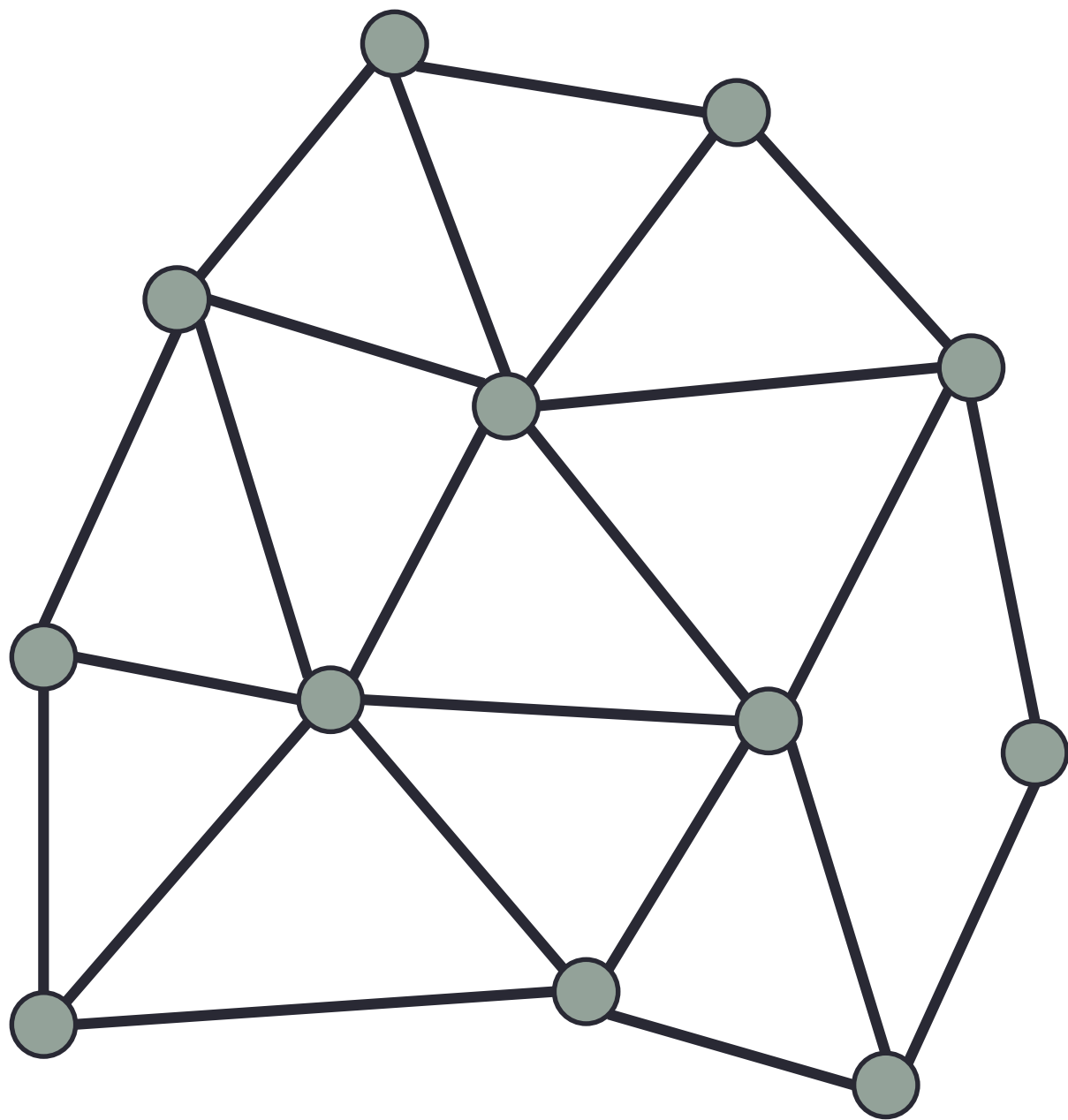
Relation:

$$q = kv$$

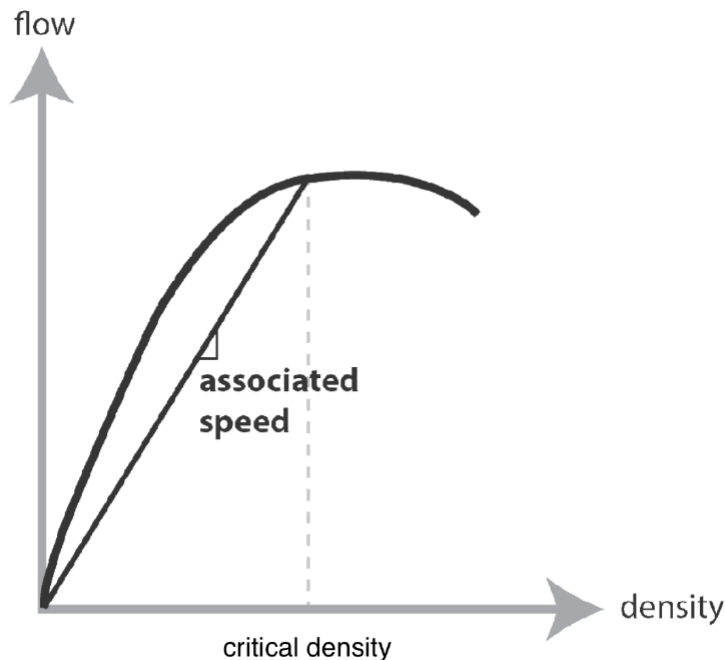
Fundamental Diagram







Macro Fundamental Diagram (MFD)



What?

- relates **average** flow and density
- aggregated view of traffic (e.g. 5min)

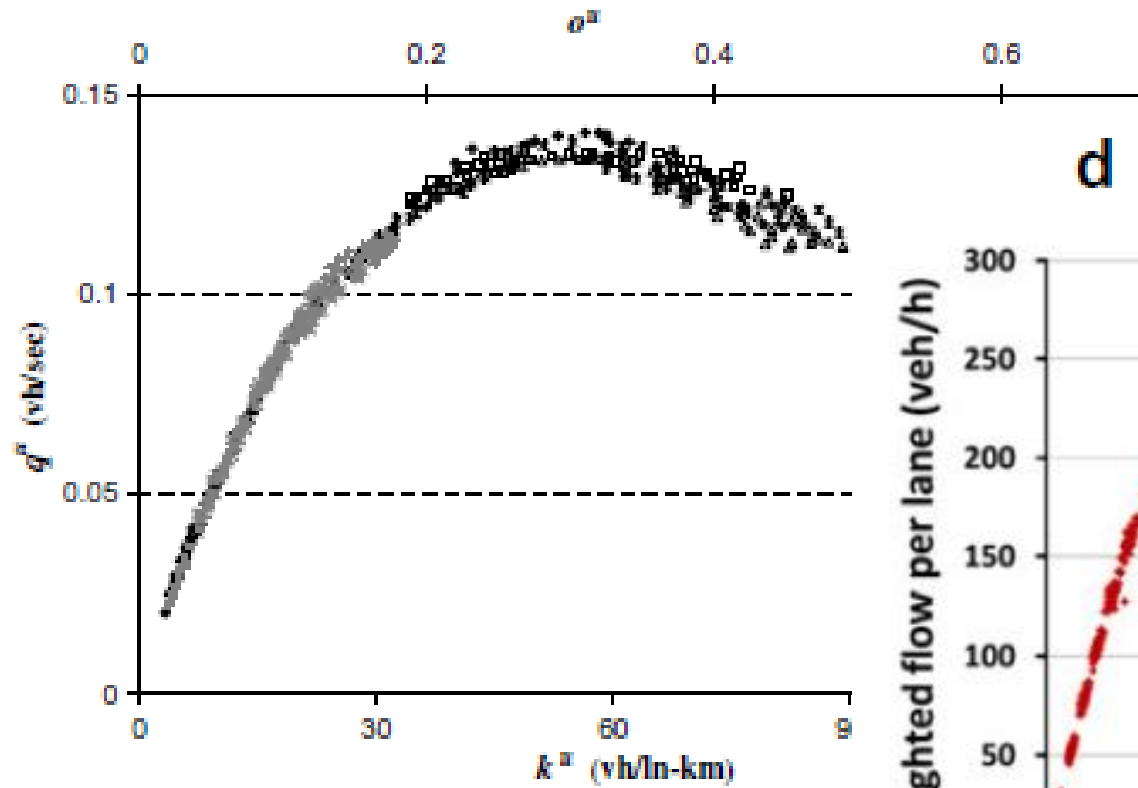
Why?

- easy-to-use
- macroscopic control

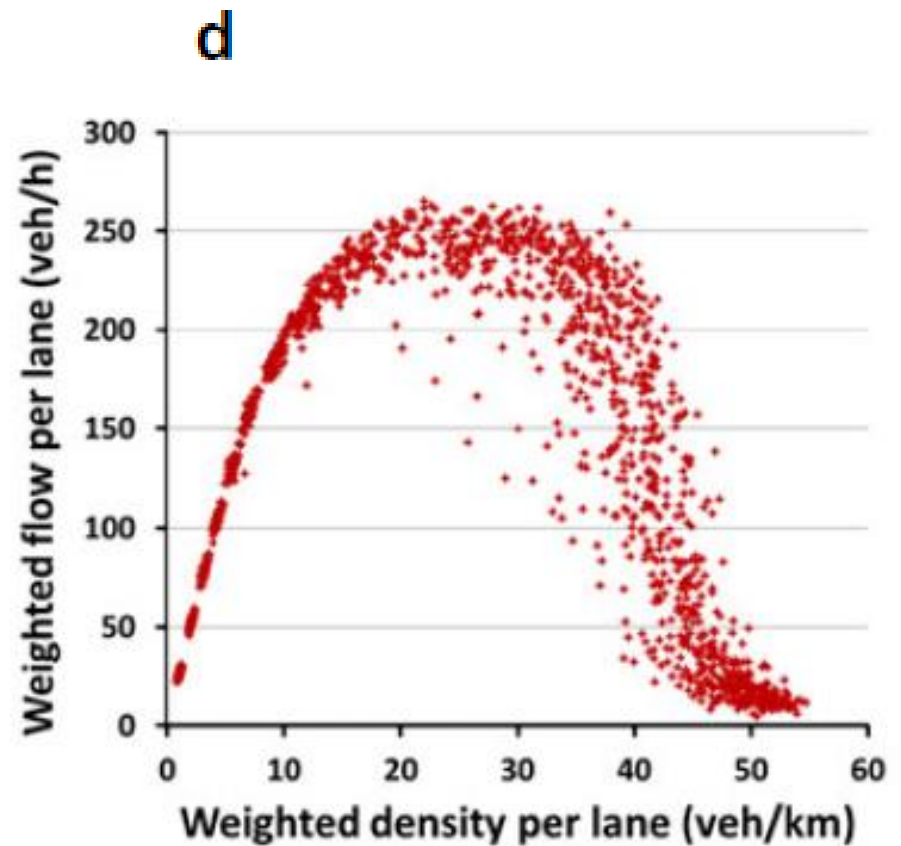
With?

- loop detectors
- floating car data (FCD)

Does it exist?

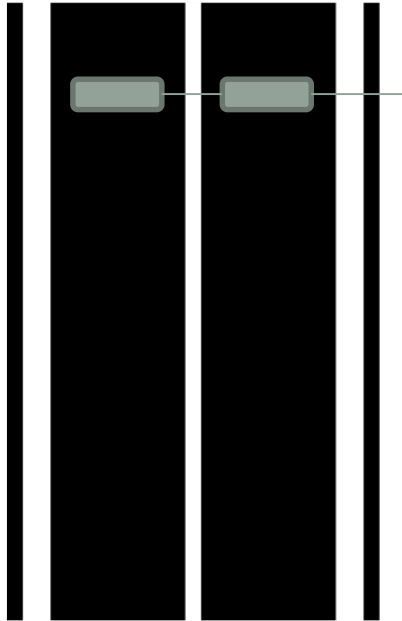


Yokohama (J)



Zurich

Two Data Sources



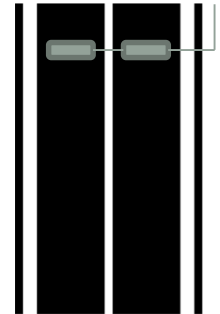
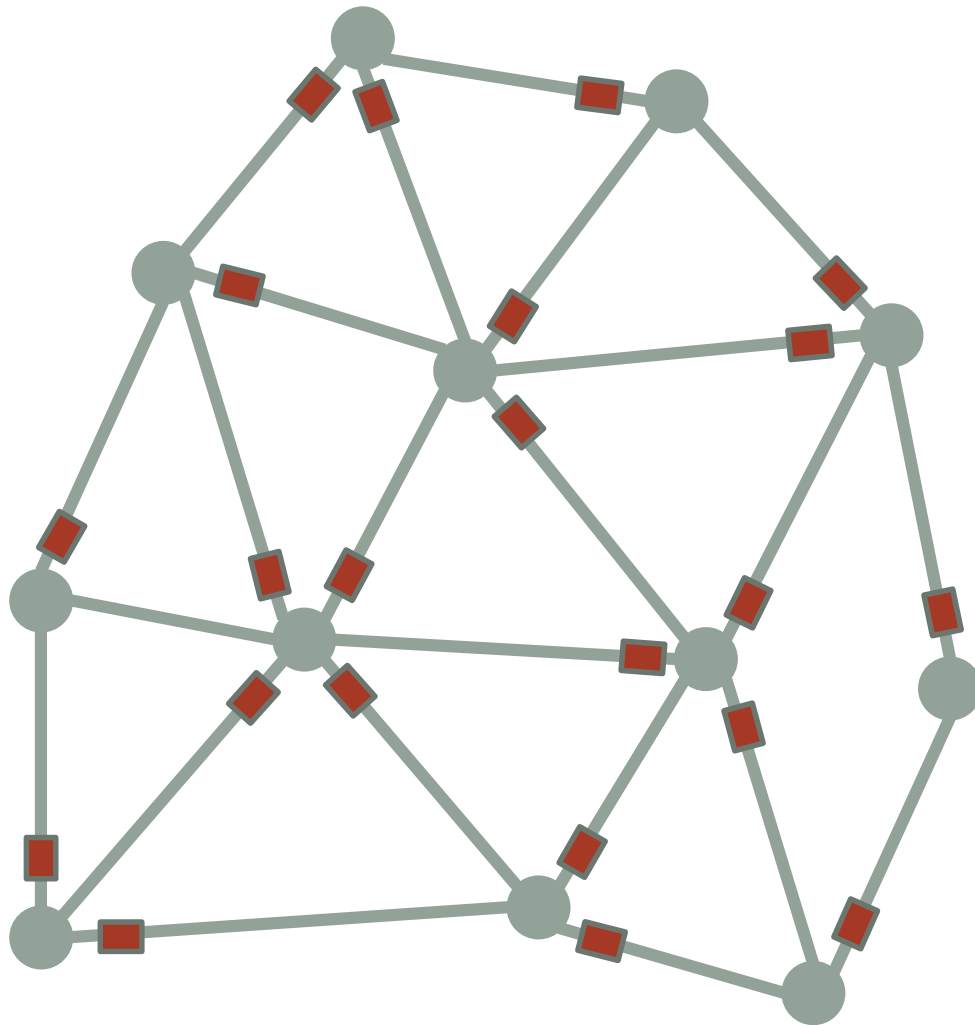
- Already installed in links
- Average flow and density:

$$q_{t,MFD} = \frac{\sum_i q_t^i l^i}{\sum_i l^i} \quad k_{t,MFD} = \frac{\sum_i k_t^i l^i}{\sum_i l^i}$$

- GPS, mobile phones, etc.
- Eddie's generalized definitions:

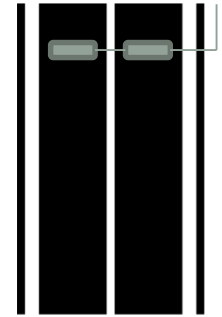
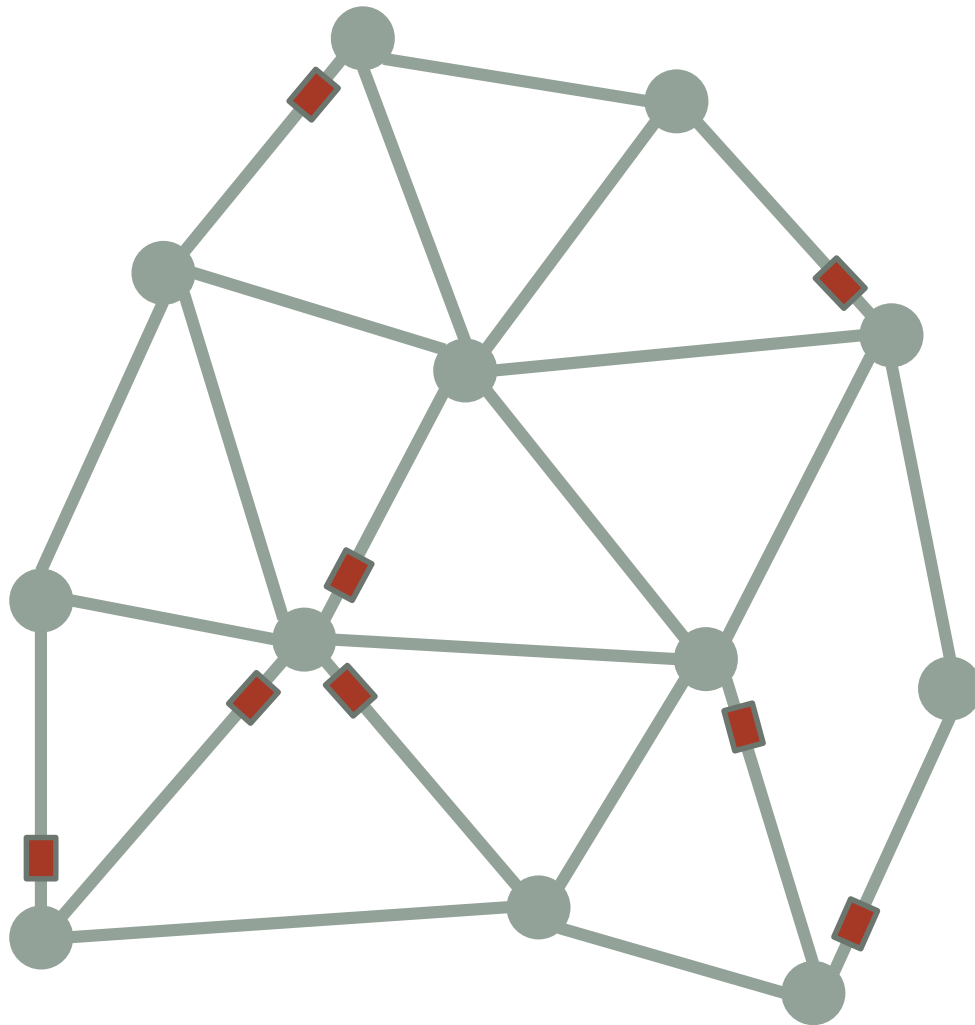
$$q_{t,MFD} = \bar{q}_t = \frac{d_{tot,t}}{LT} \quad k_{t,MFD} = \bar{k}_t = \frac{t_{tot,t}}{LT}$$

Loop Detectors



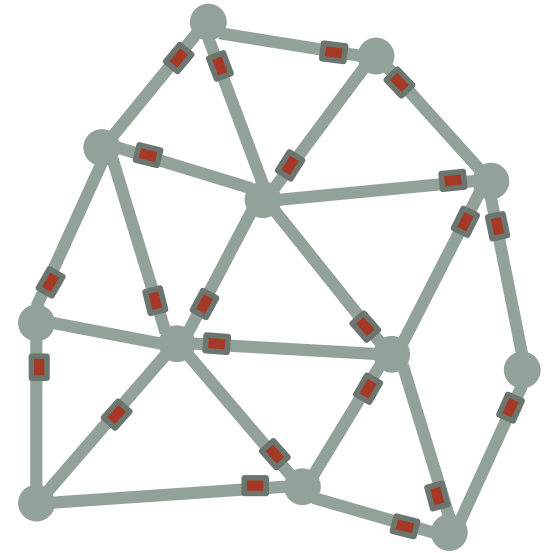
 Loop Detector

Loop Detectors



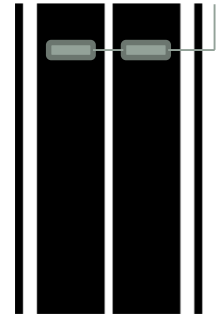
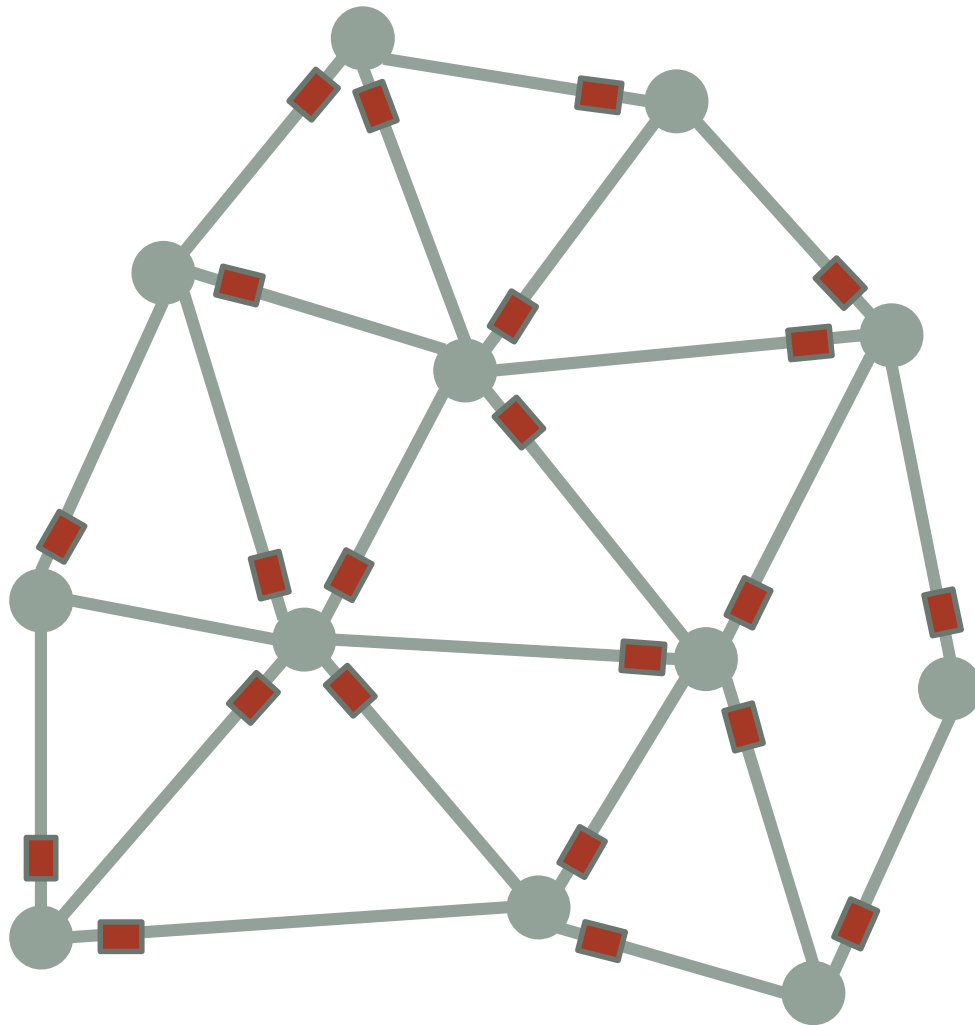
■ Loop Detector

Loop Detectors



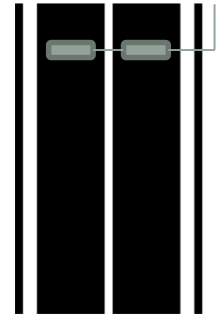
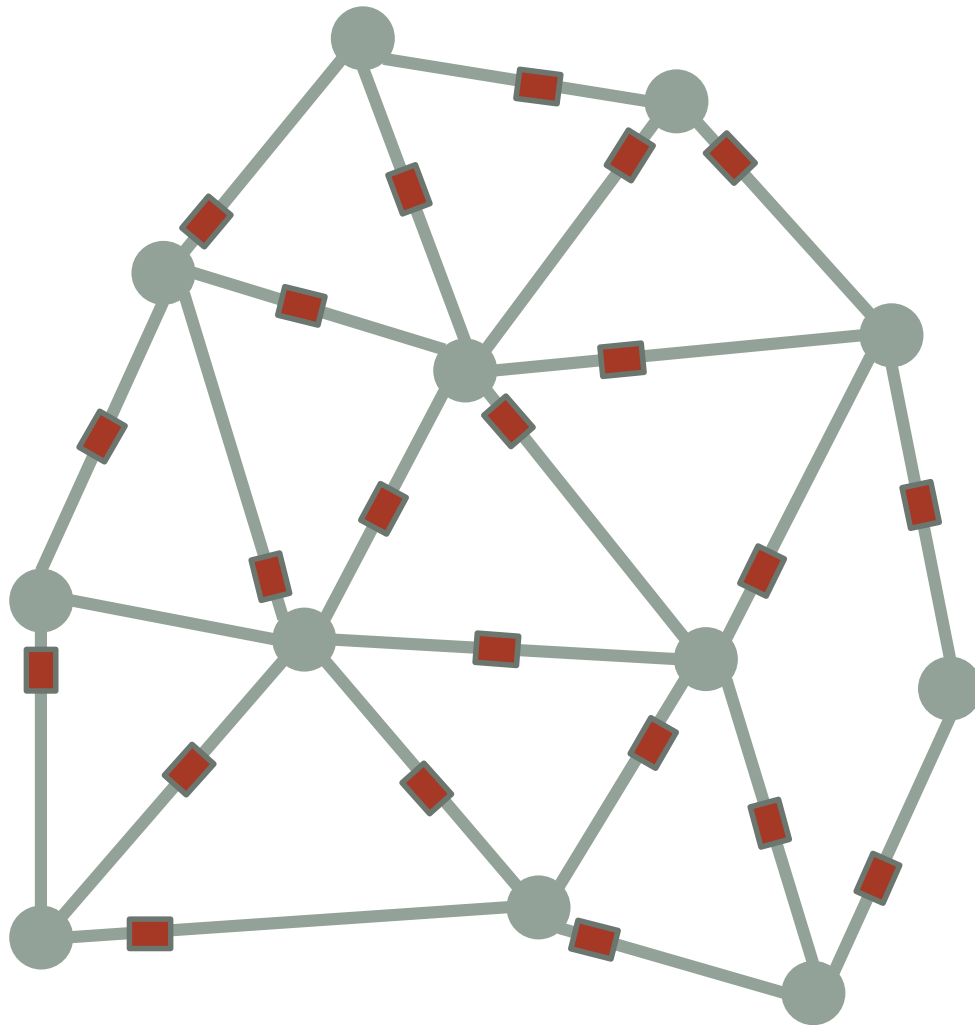
Overestimation of density

Loop Detectors



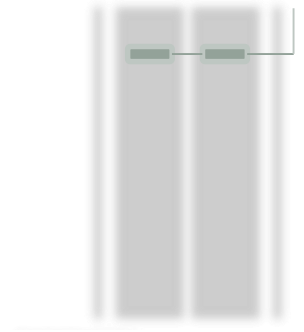
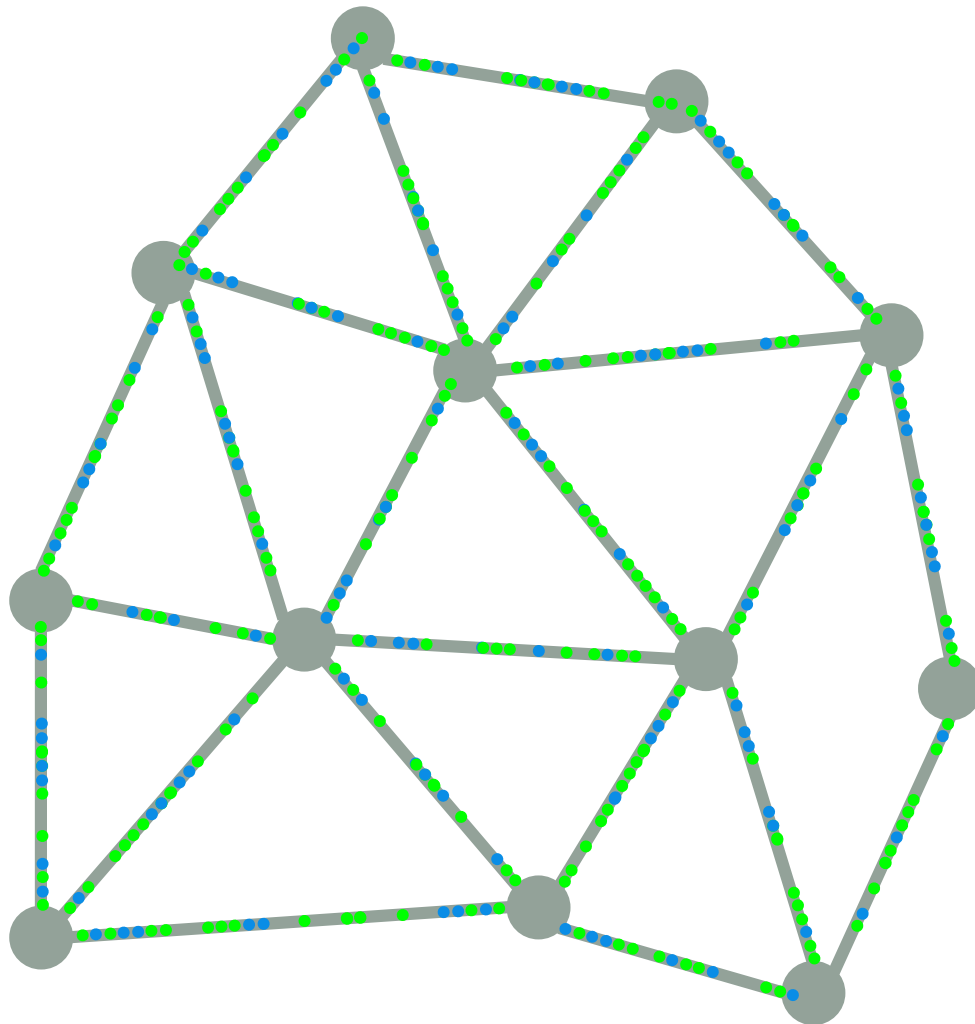
■ Loop Detector



Loop Detectors



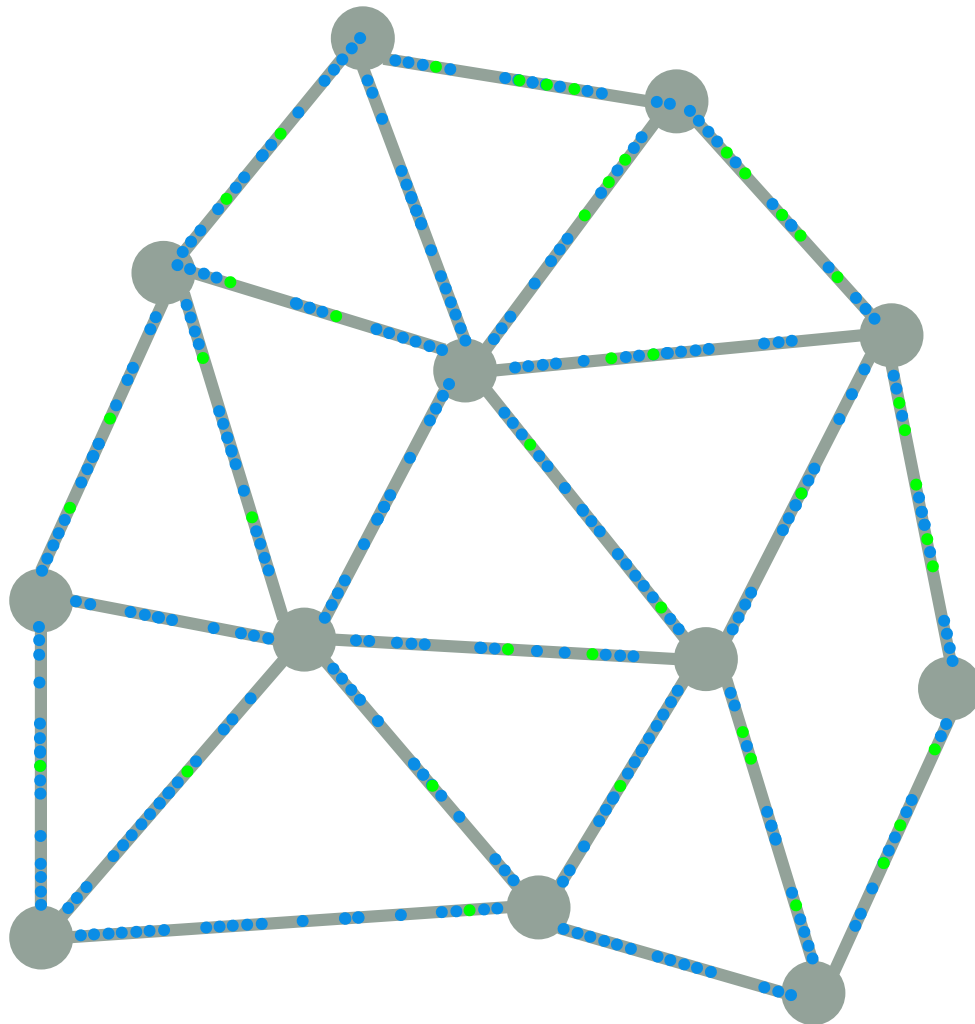
■ Loop Detector



Floating Car Data (FCD)



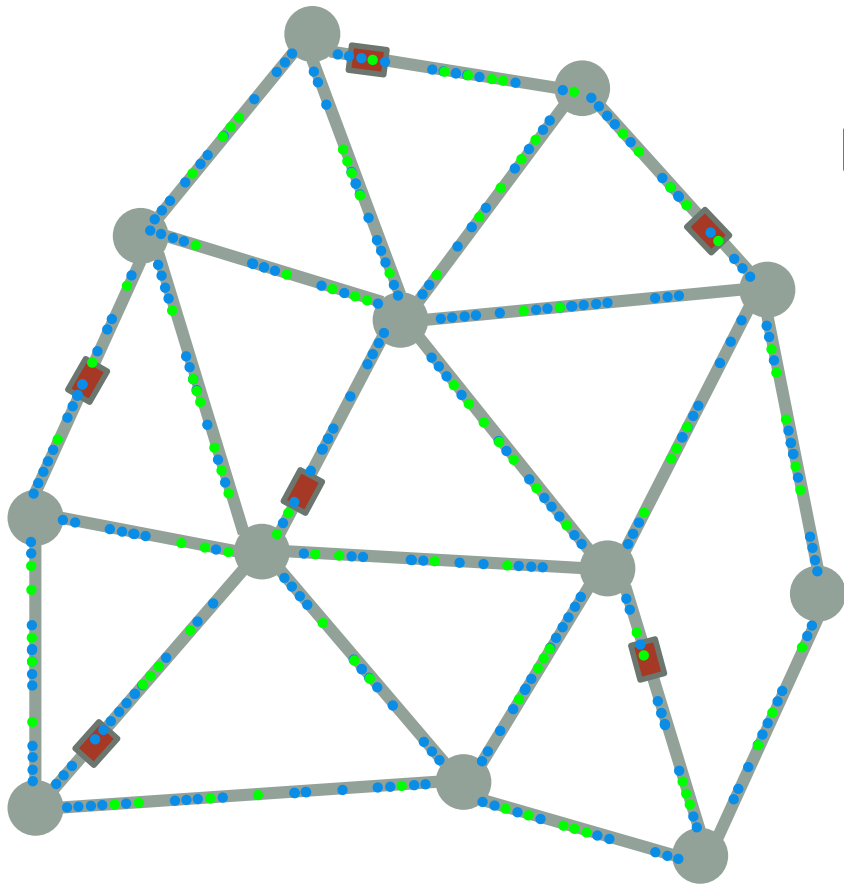
-  normal vehicle
-  mobile probe (FCD)

Floating Car Data (FCD)




-  normal vehicle
-  mobile probe (FCD)

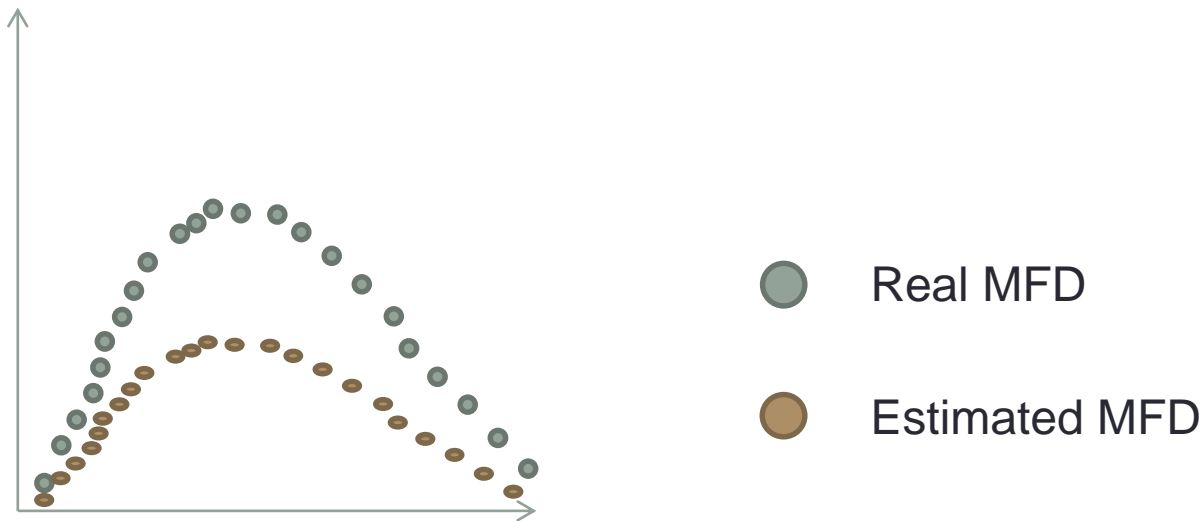
Network Coverage: Example



 Loop detectors: **loop coverage**
 $6/23 \approx 26\%$

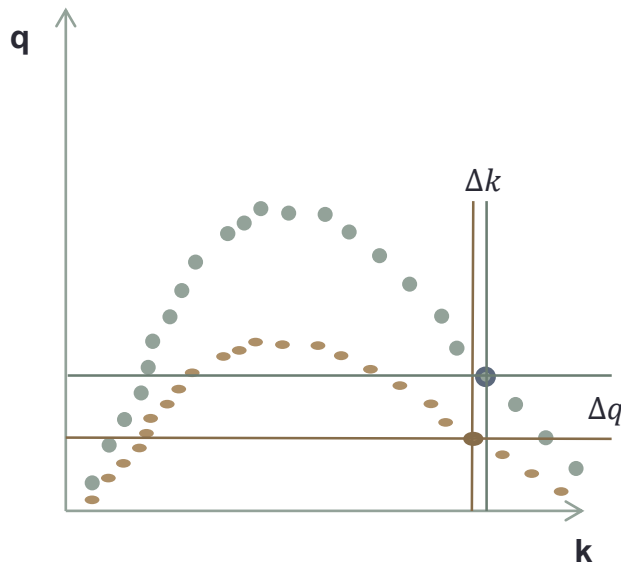
 Mobile probes: **probe penetration rate**
- exact: $72/201 \approx 36\%$
- estimated with 6 loops: $20/53 \approx 38\%$

Errors of an Estimated MFD



Errors of an Estimated MFD

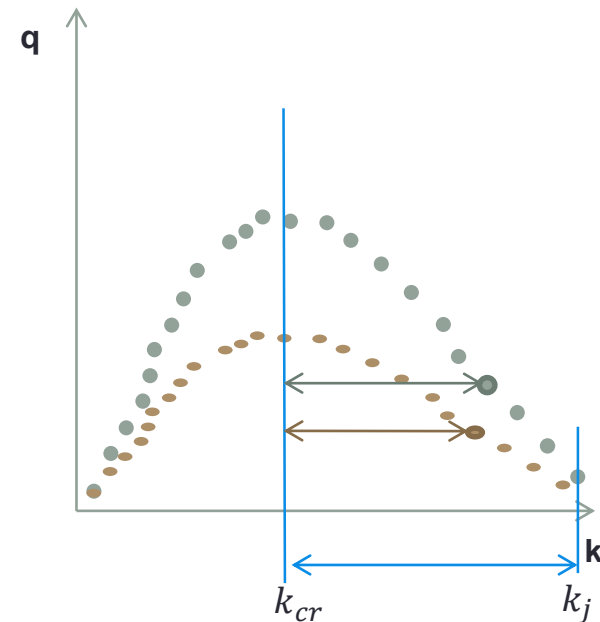
- Sum of the relative errors



$$\Delta S_t(MFD, eMFD) = \frac{\Delta q_t}{q_{real,t}} + \frac{\Delta k_t}{k_{real,t}}$$

$$\overline{\Delta S} = \frac{1}{m_t} \sum_t \Delta S_t(MFD, eMFD)$$

- Ortigosa et al.



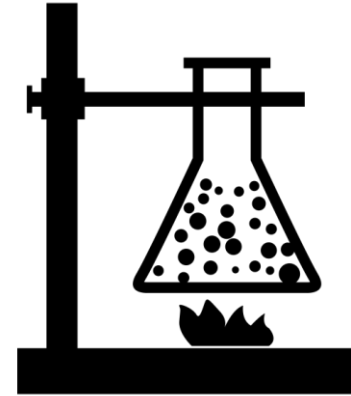
$$\Delta R_t(MFD, eMFD) = \begin{cases} \frac{k_t - k_{cr}}{k_{cr}} - \frac{k'_t - k'_{cr}}{k'_{cr}} & \text{if } k_t < k_{cr} \\ \frac{k_t - k_{cr}}{k_j - k_{cr}} - \frac{k'_t - k'_{cr}}{k'_j - k'_{cr}} & \text{if } k_t > k_{cr} \end{cases}$$

$$\overline{\Delta R}(MFD, eMFD) = \frac{1}{m_t} \sum_t |\Delta R_t(MFD, eMFD)|$$

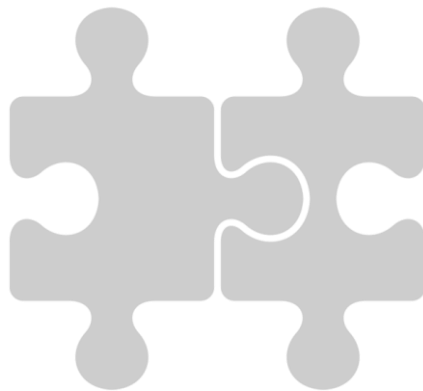
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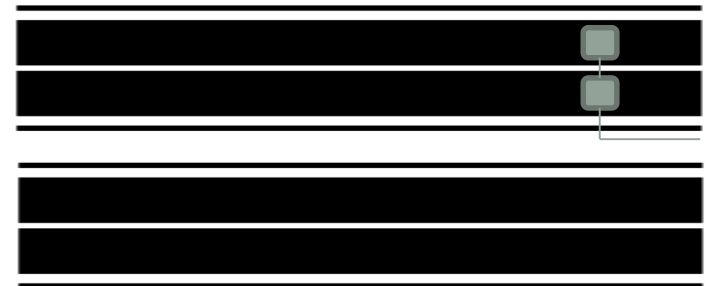
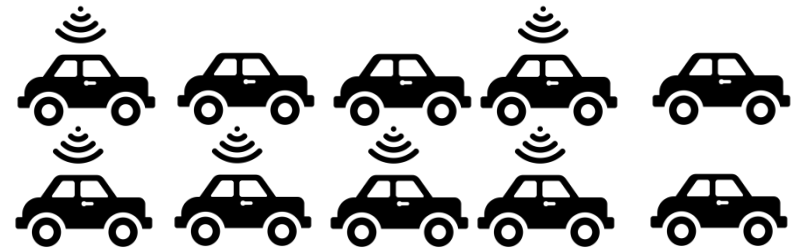
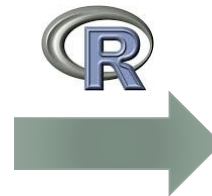
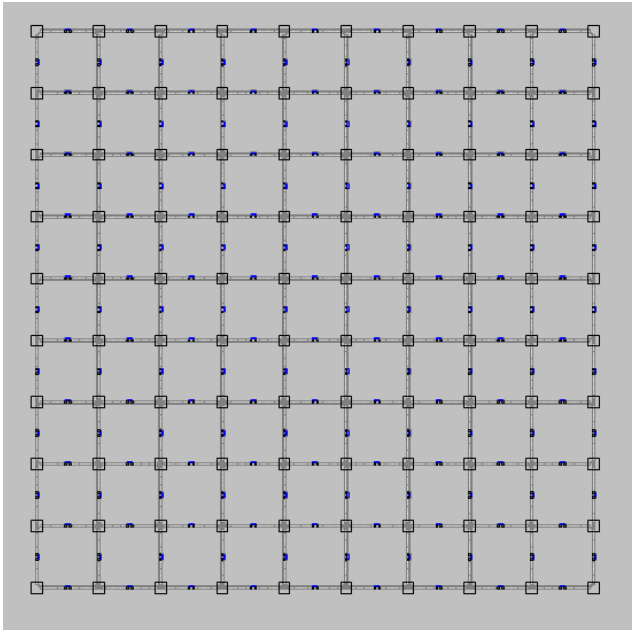
Experimental Setup



Fusion Method



Conclusion



VISSIM

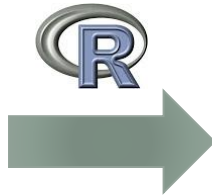
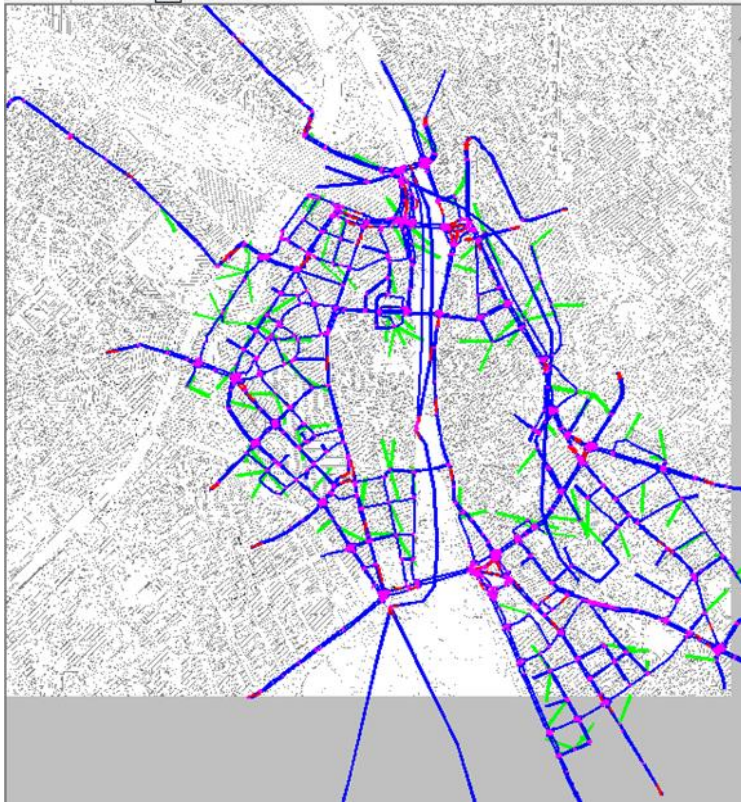
- 10x10
- one-way, 2 lanes, 120m
- DTA
- homogeneous demand
- 5 random seeds
- 4x 1 hour simulation

Network Coverage

- 30 levels in [3%-100%]
- 1000 subsets
- probe penetration rate estimated with loops



5x 900'000 eMFD vs 1 real MFD



VISSIM

- 2.6 km²
- 4 random seeds
- emulates city's public transport prioritization

Network Coverage

- 30 levels in [3%-100%]
- 1000 subsets
- probe penetration rate estimated with loops



4x 900'000 eMFD vs 1 real MFD

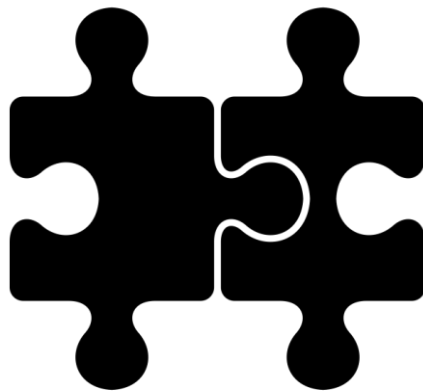
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Experimental Setup

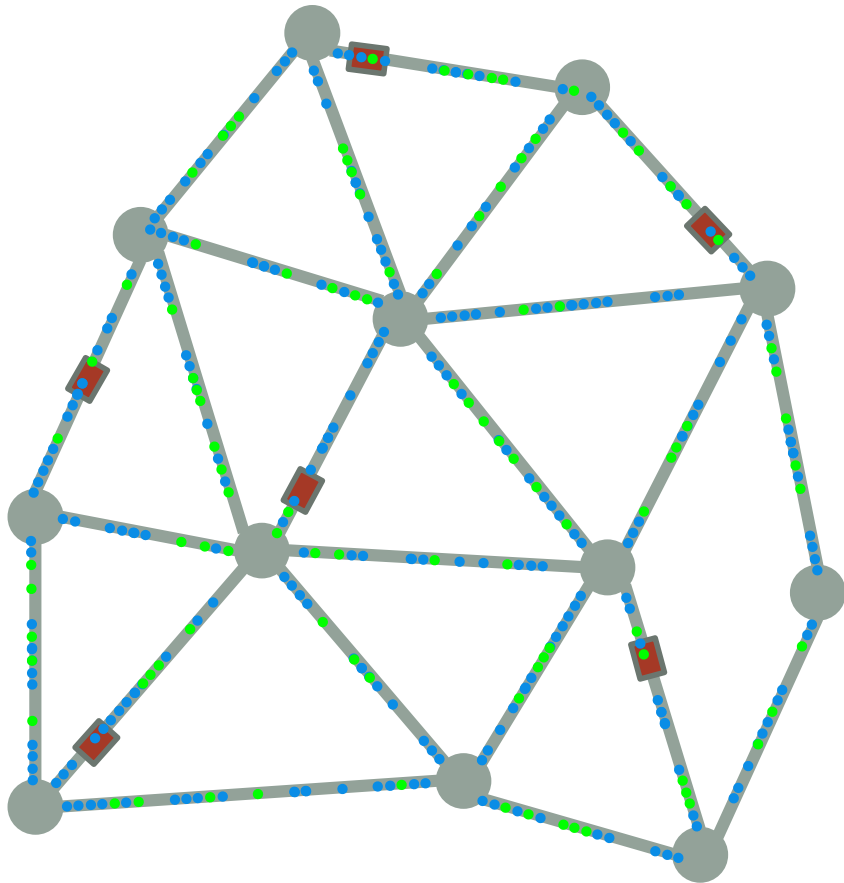


Fusion Method



Conclusion

No Fusion



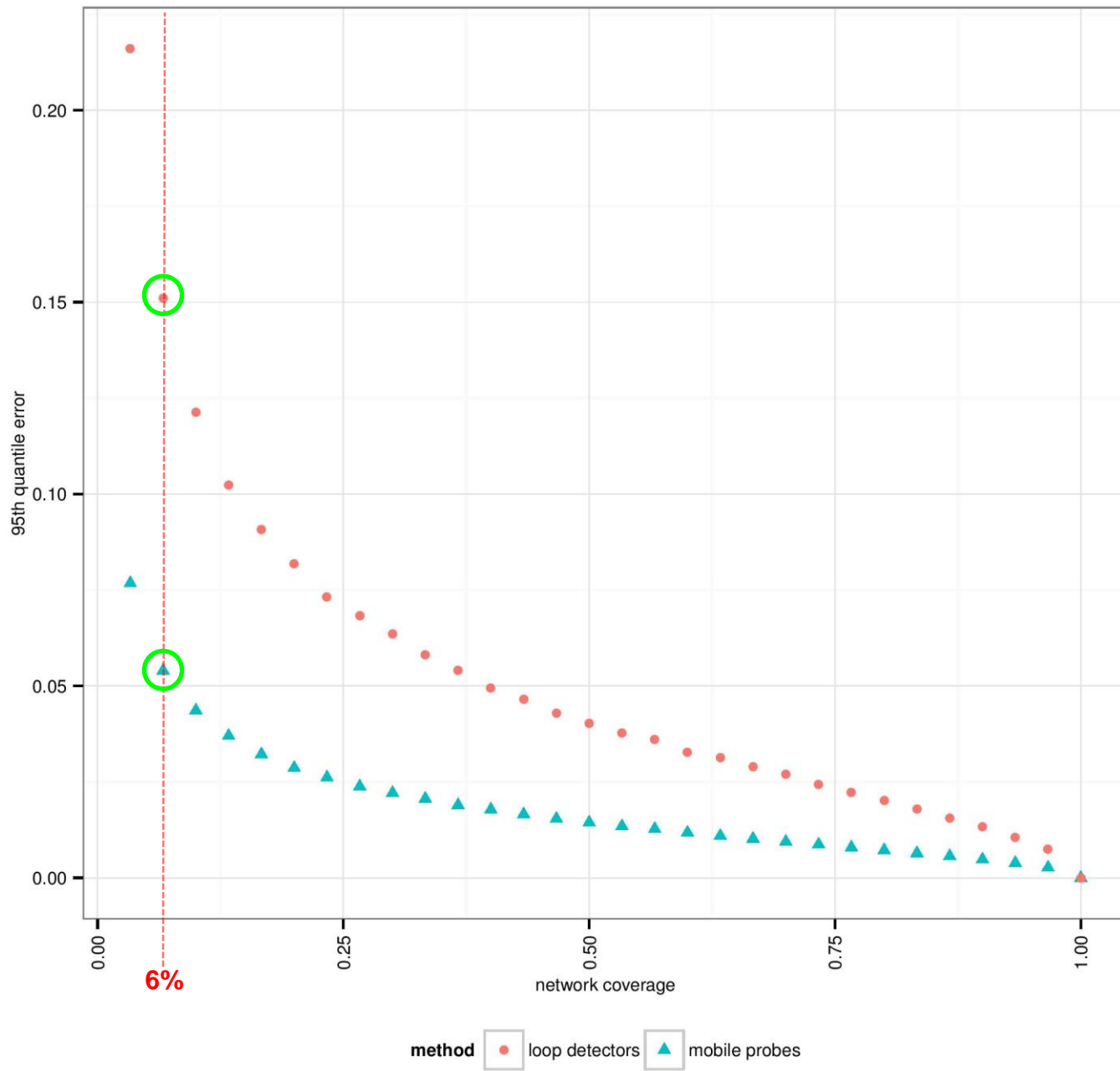
- estimation based on one source solely

$$\hat{q} = \begin{cases} \frac{D_p}{\rho LT} & \text{for probes} \\ \bar{q}_{loops} = \frac{D_l}{\phi LT} & \text{for loops} \end{cases}$$

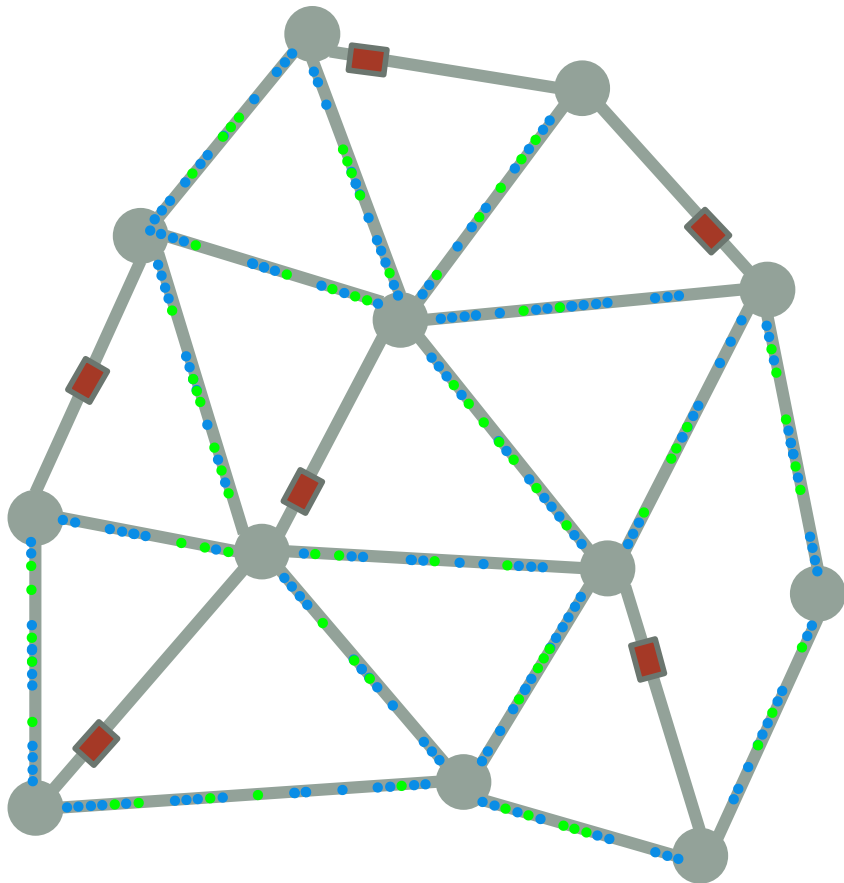
$$\hat{k} = \begin{cases} \frac{T_p}{\rho LT} & \text{for probes} \\ \bar{k}_{loops} \approx \frac{T_l}{\phi LT} & \text{for loops} \end{cases}$$

● Mobile probes

■ Loop detectors

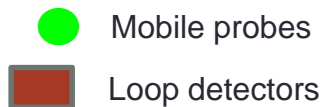


Fusion Algorithm

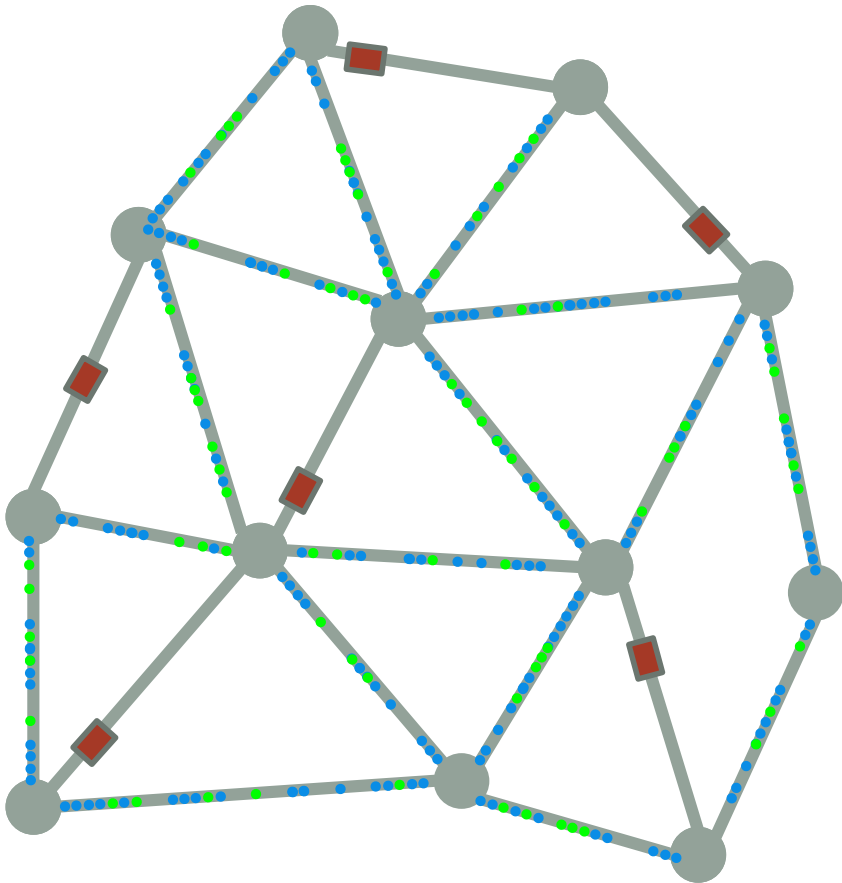


Data Fusion Algorithm:

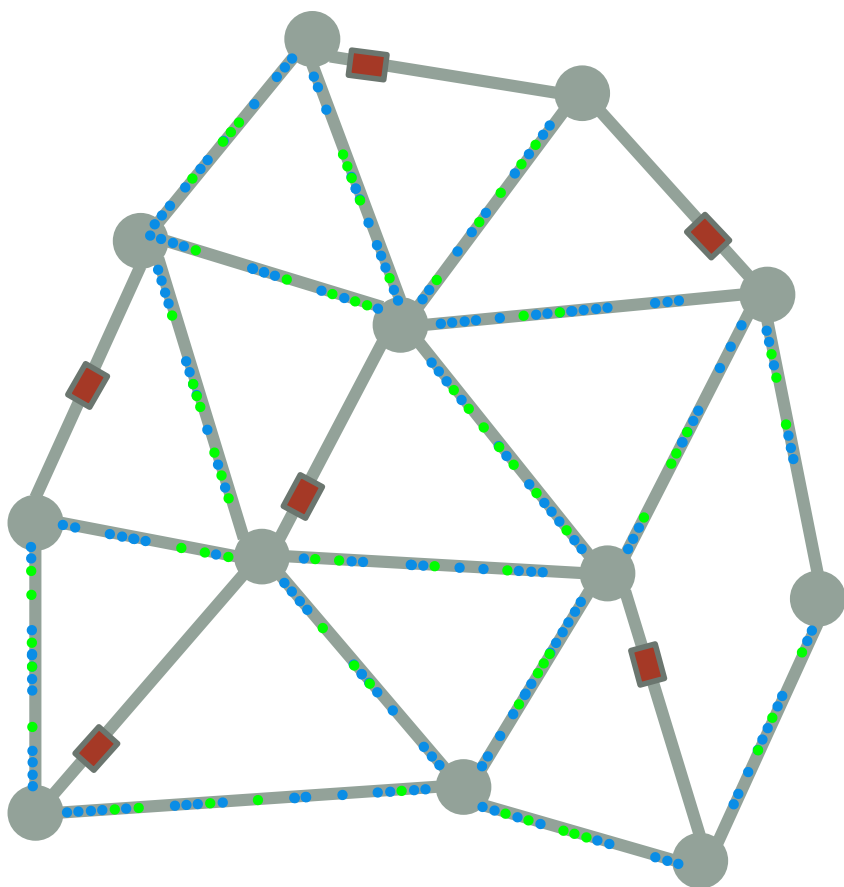
1. Separate network
 - a. Sub-network loop detectors
 - b. Sub-network mobile probes
2. Calculate average flows and densities
3. Weight the two sub-networks



Network Separation



Proposed Fusion Algorithm



- Weight according:
 - Loop detector coverage,
 - Square root of mobile probes coverage

Example @ 3% mobile probes and 30% loops

0.07

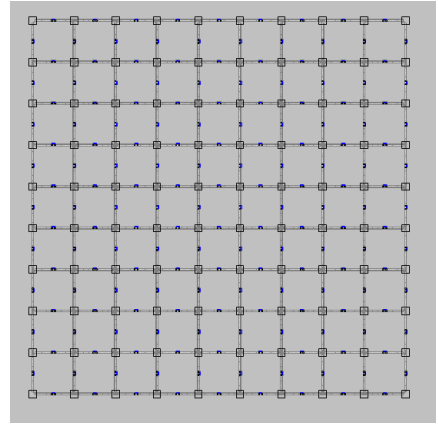
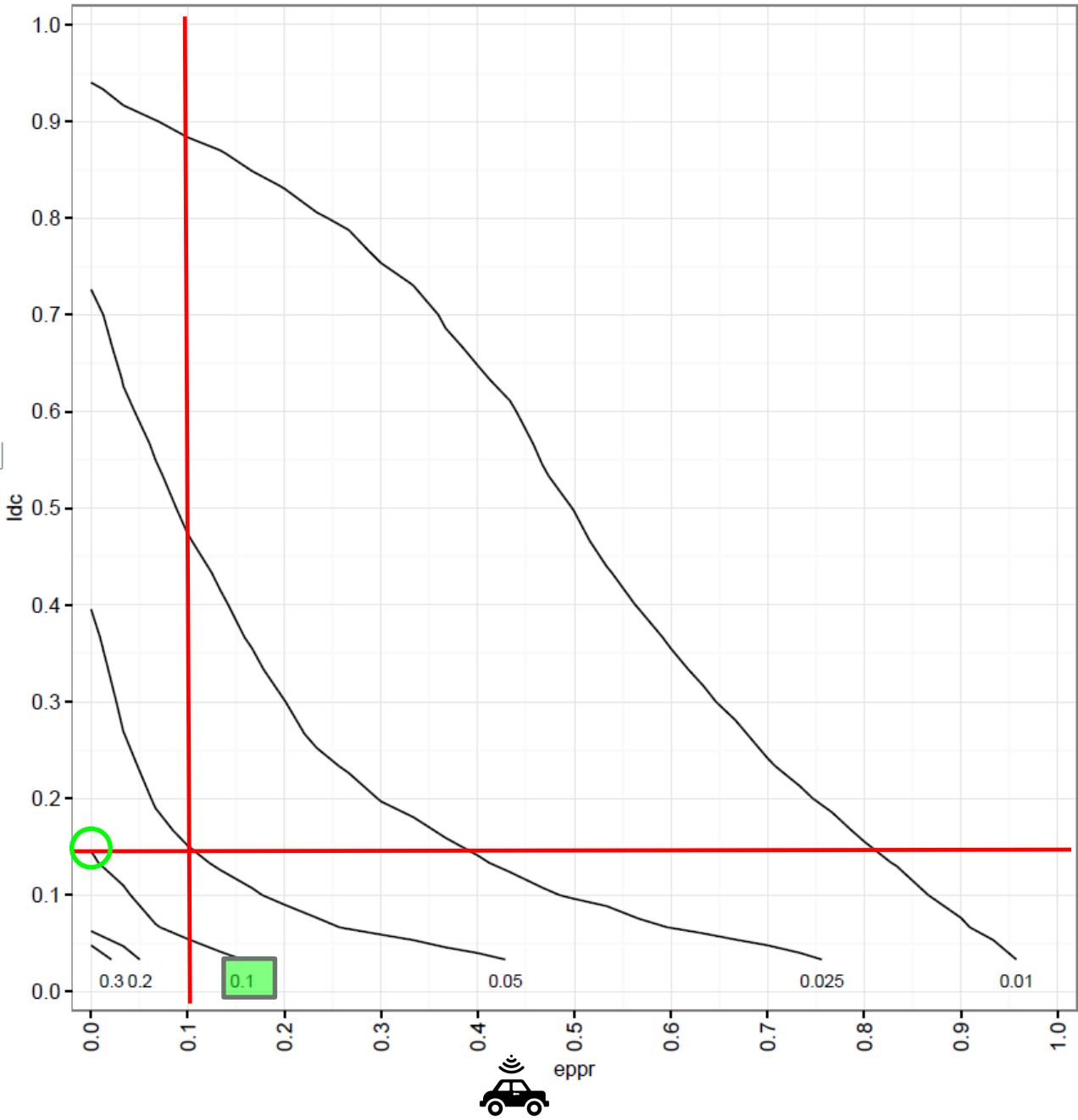
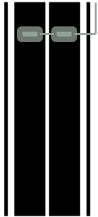
0.93

$$\tilde{q} = \frac{\phi \hat{q}_l + \sqrt{\rho}(1 - \phi) \hat{q}_{p-l}}{\phi + \sqrt{\rho}(1 - \phi)}$$

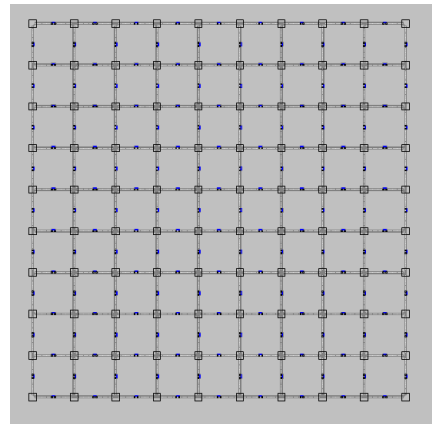
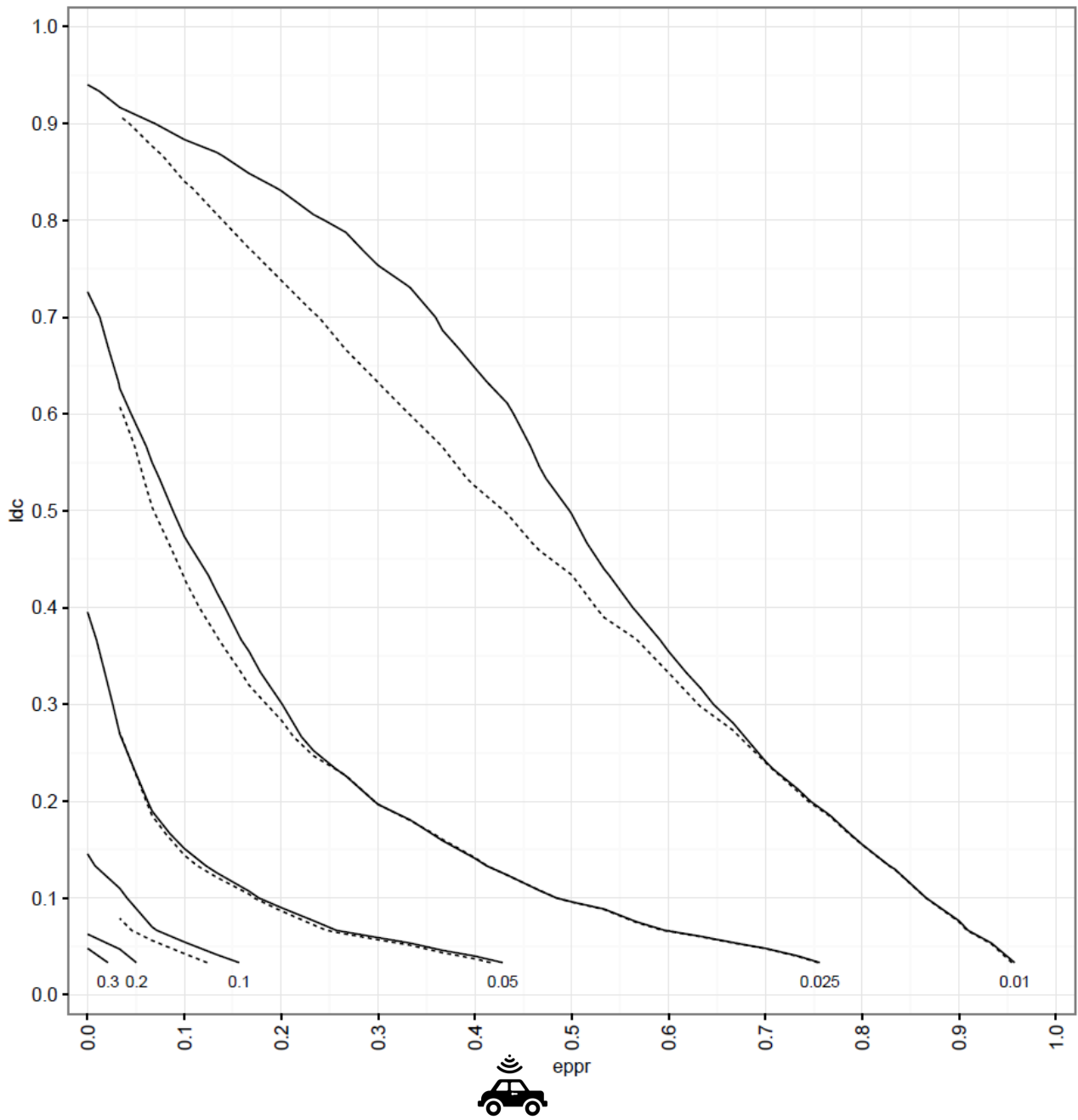
$$\tilde{k} = \frac{\phi \hat{k}_l + \sqrt{\rho}(1 - \phi) \hat{k}_{p-l}}{\phi + \sqrt{\rho}(1 - \phi)}$$

● Mobile probes

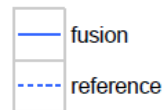
■ Loop detectors

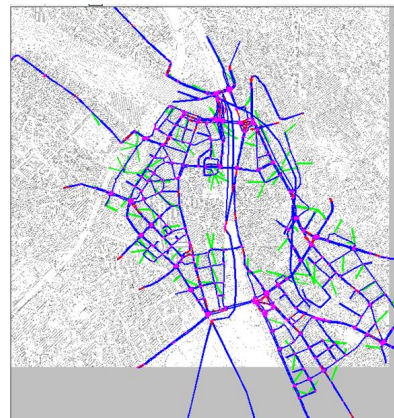
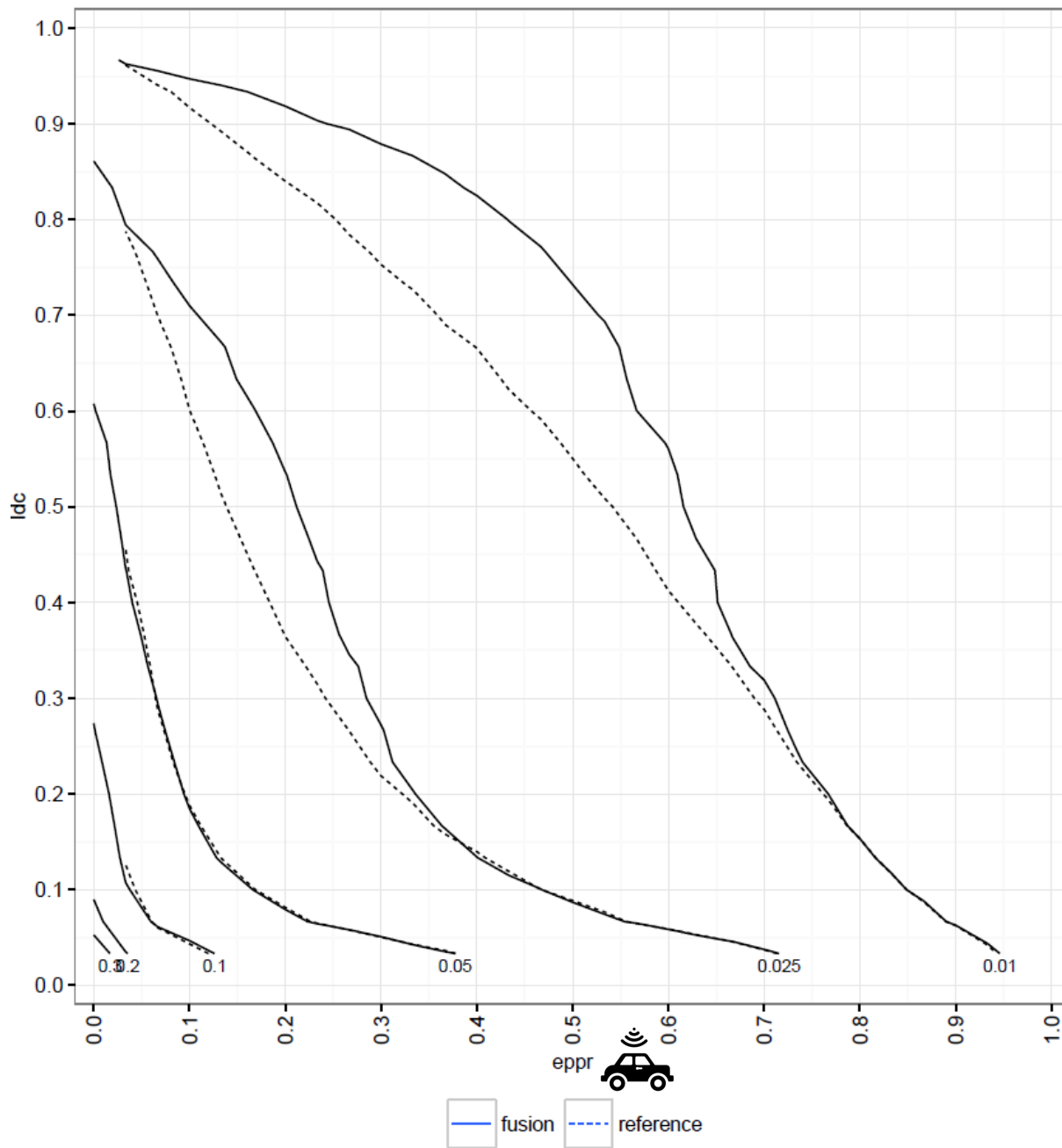


Grid Network

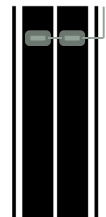


Grid Network





Zurich Network



fusion reference

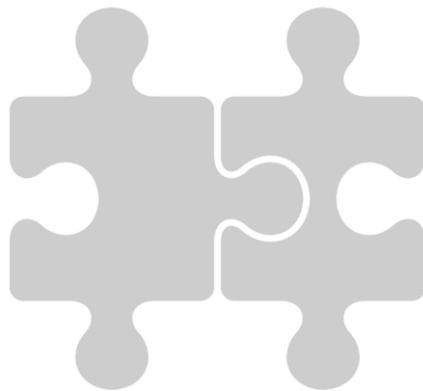
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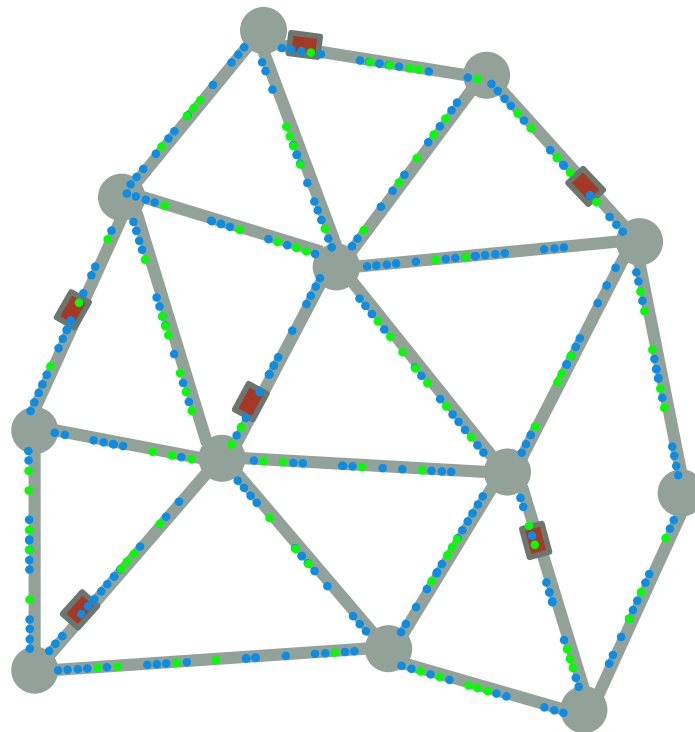
Fusion Method



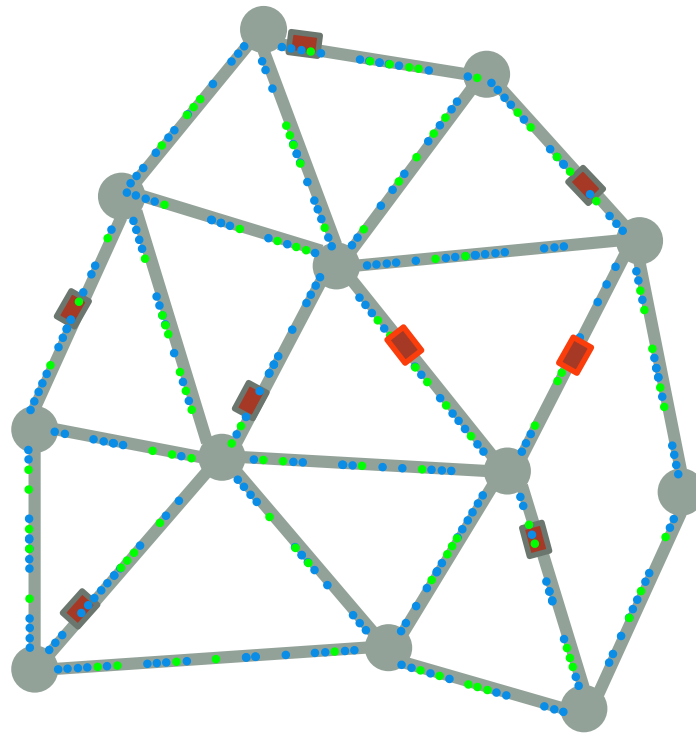
Conclusion

Conclusion

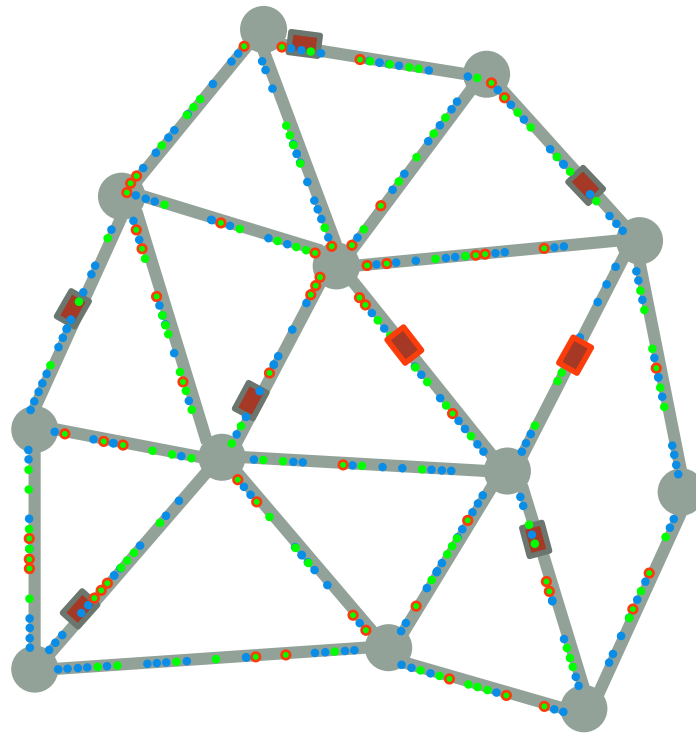
If loop detectors are well distributed within the links, our data fusion algorithm improves the estimated MFD significantly.

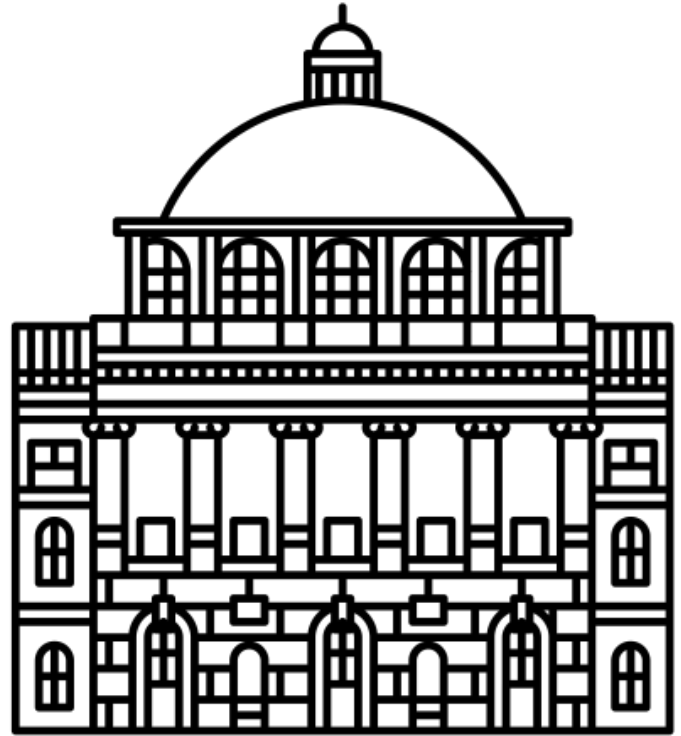
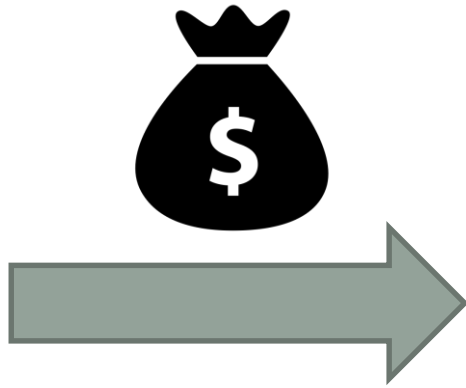
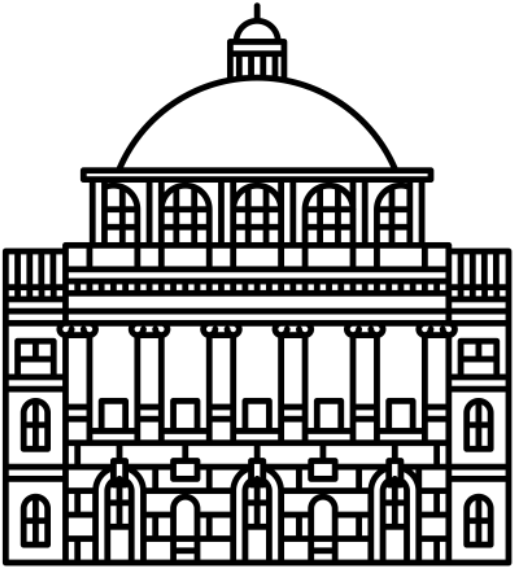


So what?



So what?





References

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- Ortigosa, J., Menendez, M., and Tapia, H. (2014). Study on the number and location of measurement points for an MFD perimeter control scheme: a case study of Zurich. EURO
- cf. Also MSc. Thesis

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SVT

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17. March 2016