Extended Observer for Urban Traffic Control
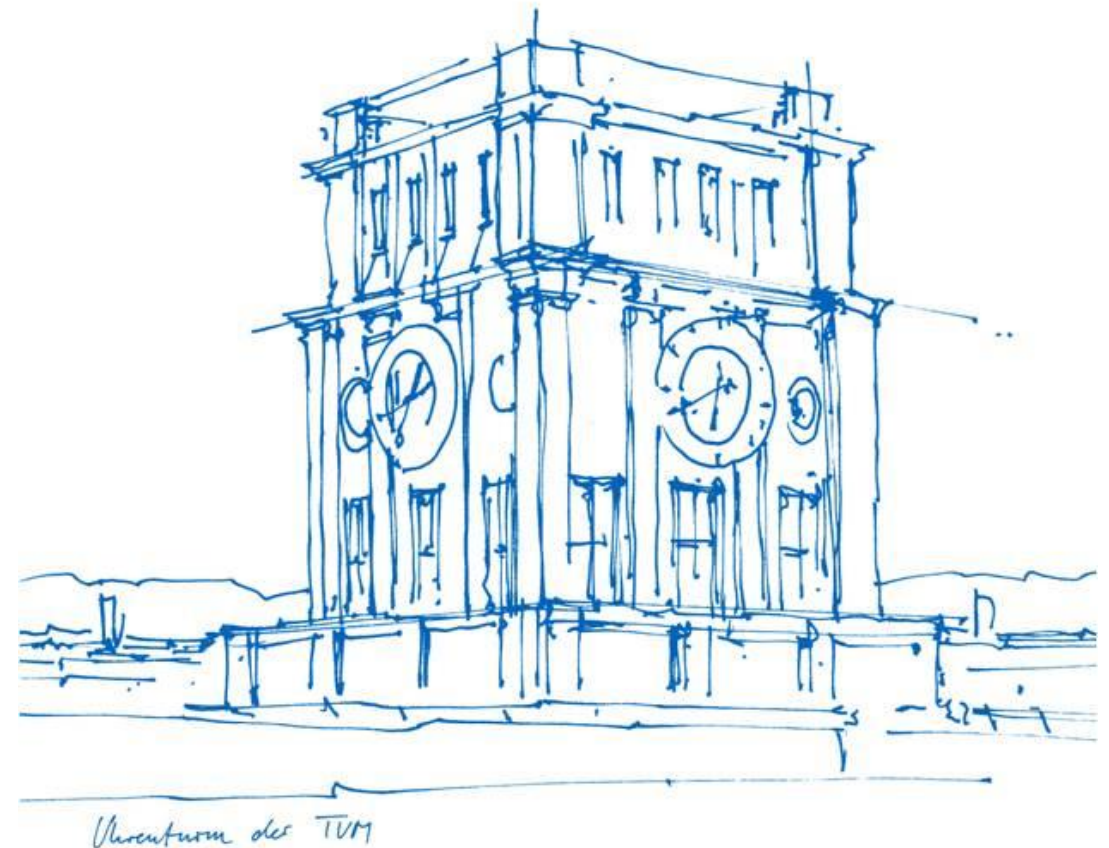
Mobility@TUM 2018

Vorhölzer Forum

24.09.2018

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Content

Research goal

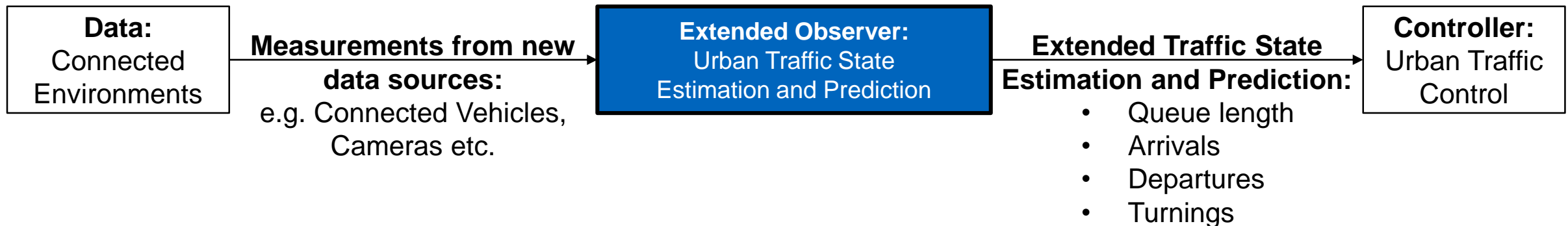**Methodology**

Simulations
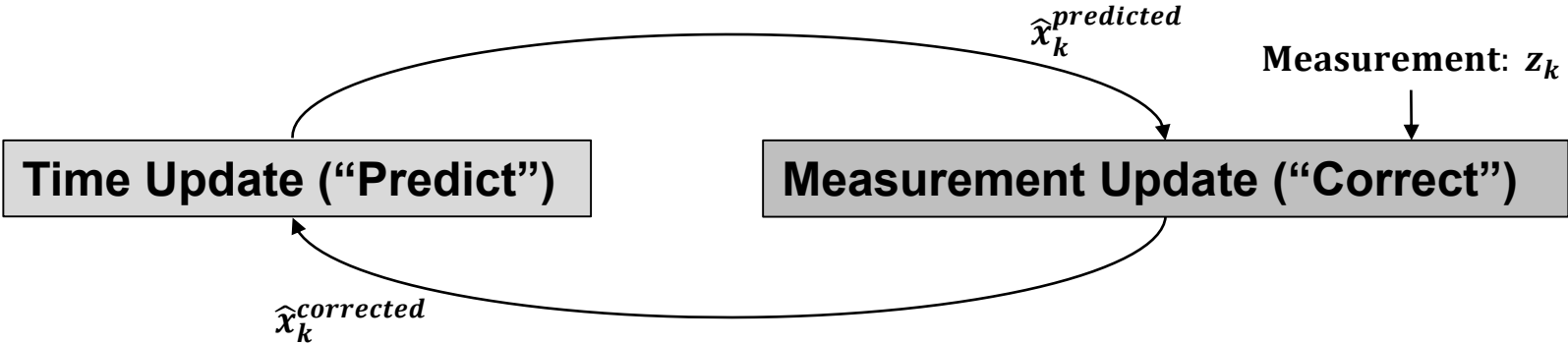
Conclusions/Outlook

Research goal

- **Fusion**
- **Estimation**
- **Prediction**
- **Integration**

for current (legacy) and future (connected) **Urban Traffic Control** systems,

by capitalizing on the new sensing and communication capabilities from **Connected Environments** in urban areas.

| **Data:** Connected Environments | → **Measurements from new data sources:** e.g. Connected Vehicles, Cameras etc. → | **Extended Observer:** Urban Traffic State Estimation and Prediction | **Extended Traffic State Estimation and Prediction:** → | **Controller:** Urban Traffic Control |

Extended Traffic State Estimation and Prediction:
- Queue length
- Arrivals
- Departures
- Turnings

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Extended Observer based on (Extended) Kalman Filter

$\hat{x}_k^{predicted}$

Measurement: z_k

Time Update ("Predict")　　　**Measurement Update ("Correct")**
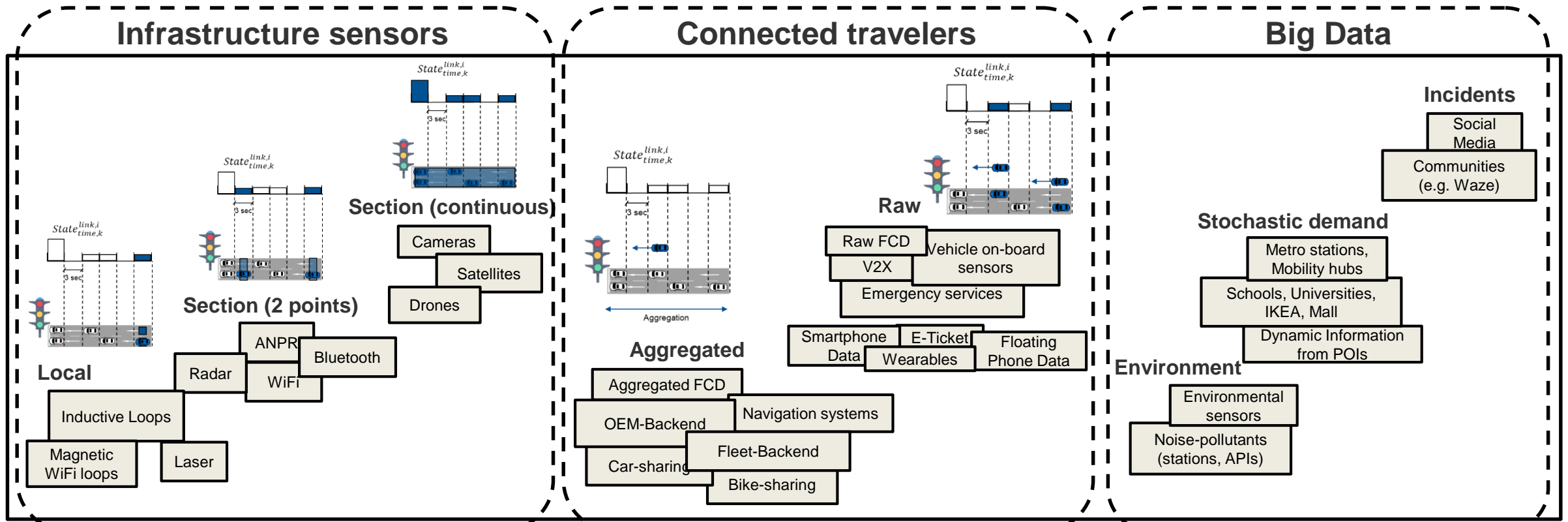
$\hat{x}_k^{corrected}$

State vector:

$$\vec{x}_k = \begin{bmatrix} x_k^{queue\ length} \\ x_k^{arrival\ rate} \\ x_k^{departure\ rate} \\ x_k^{turning\ rate} \end{bmatrix}$$
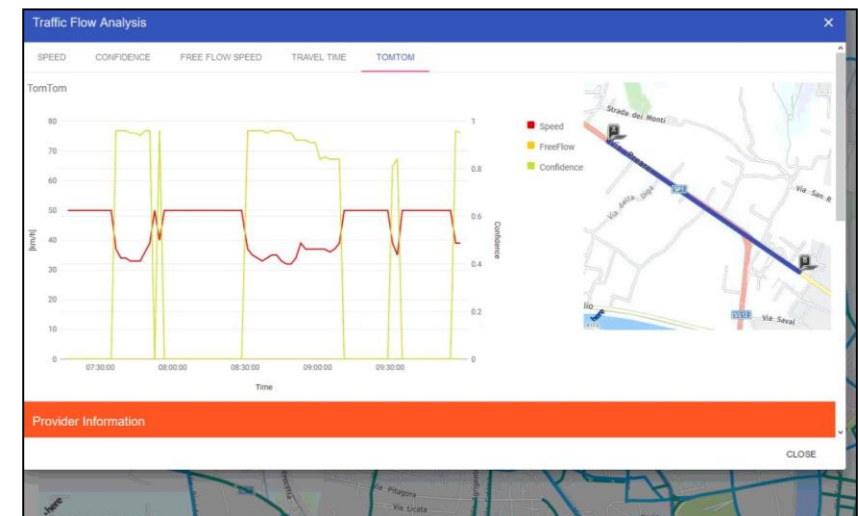
Measurement vector:

$$\vec{z}_k = \begin{bmatrix} z_k^{queue\ length\_cv} \\ z_k^{arrival\ rate\_loop} \\ z_k^{departure\ rate\_camera} \\ z_k^{turning\ rate\_rawFCD} \\ ... \\ ... \\ ... \end{bmatrix}$$
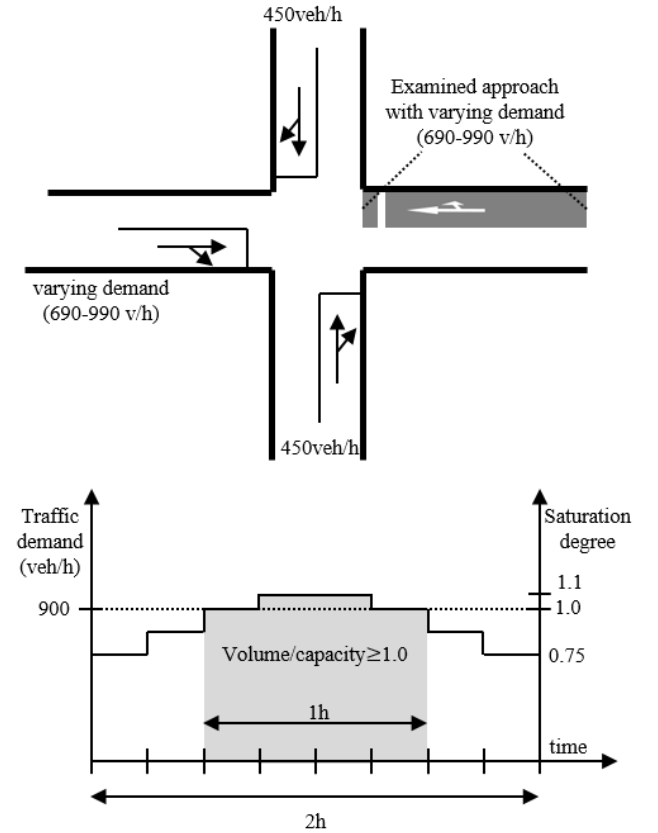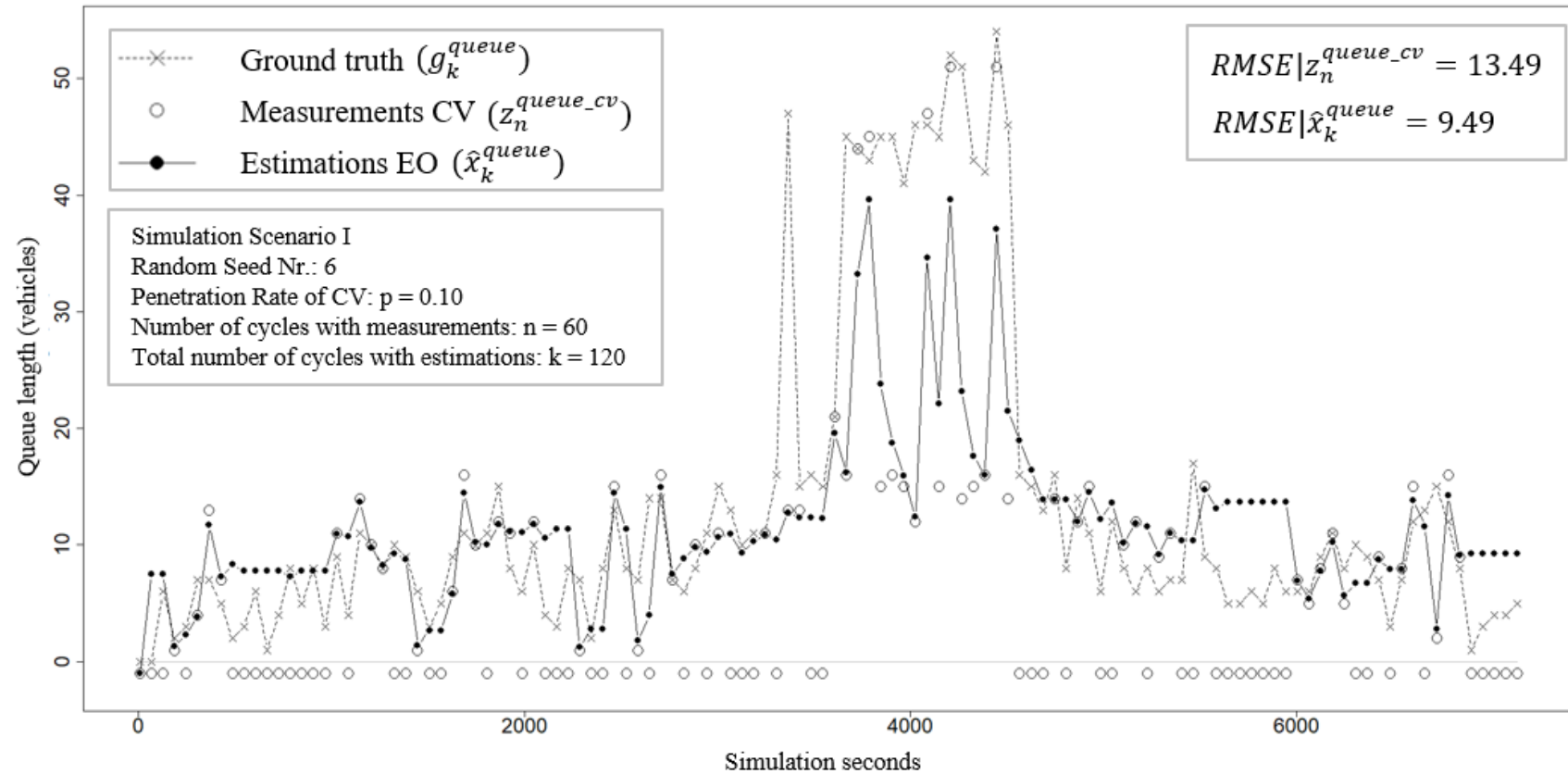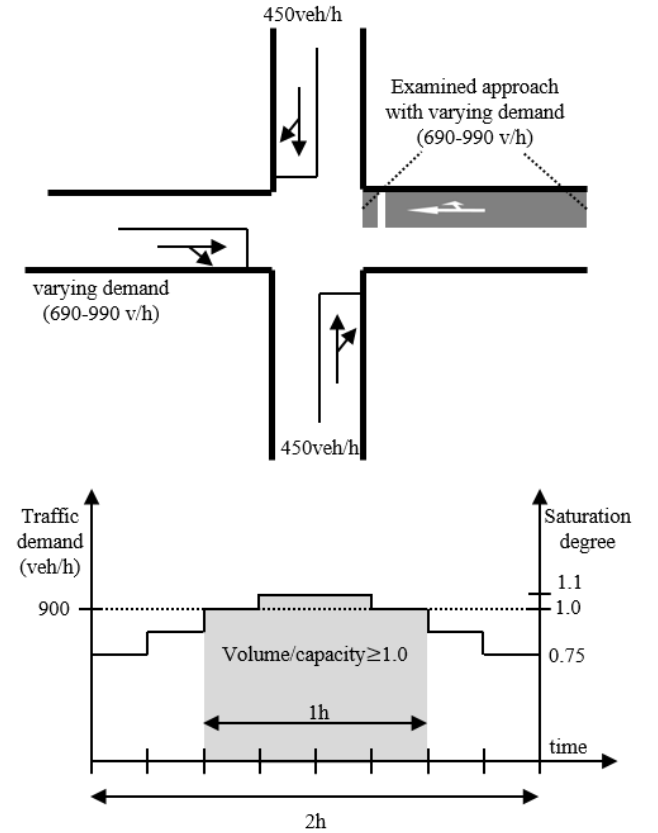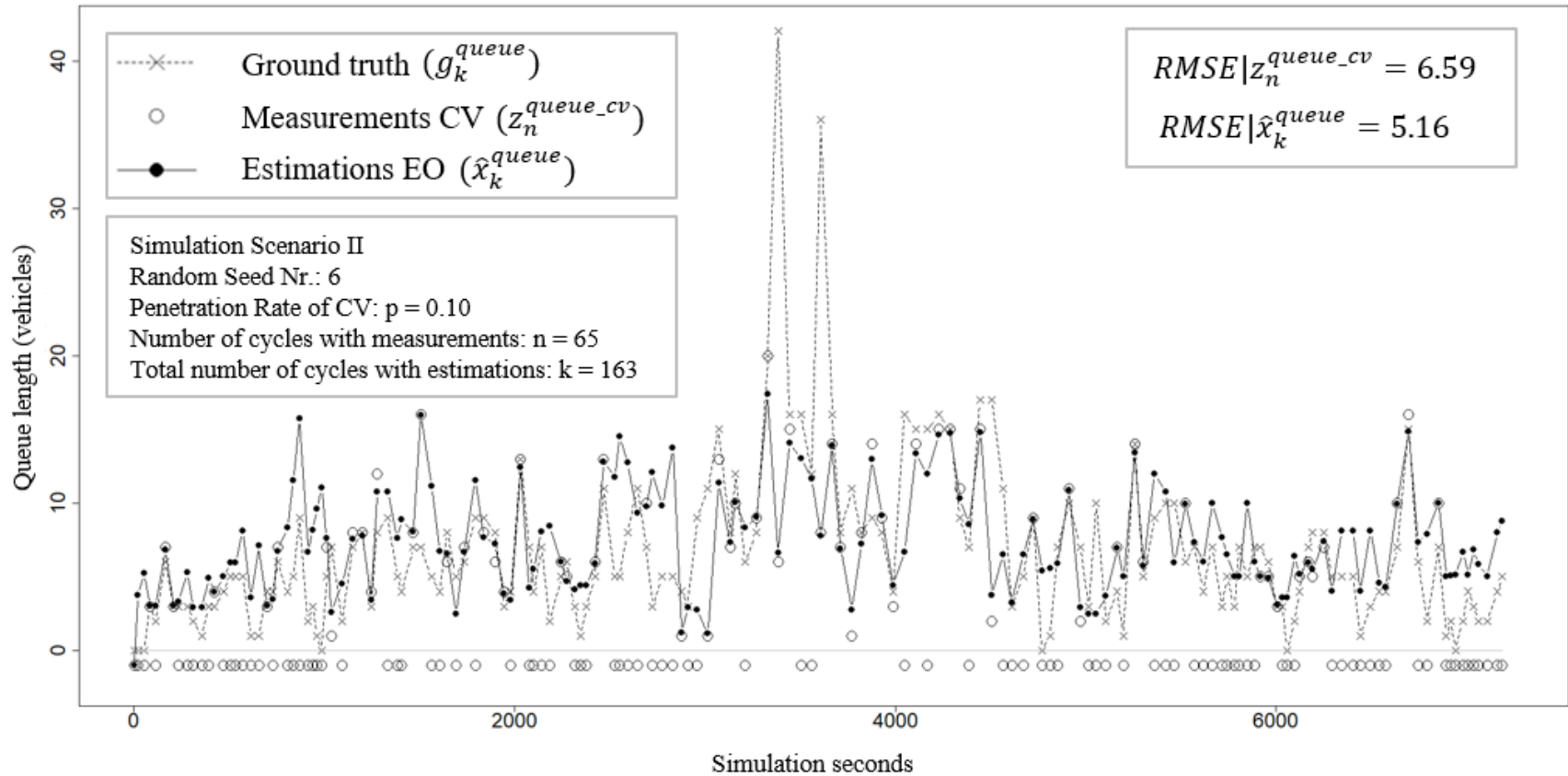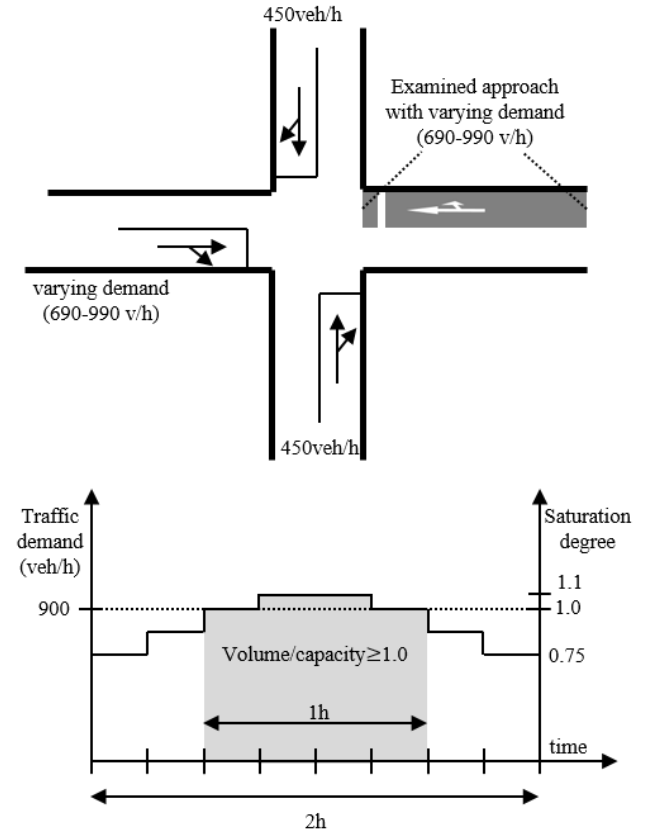
Measurements from new data sources
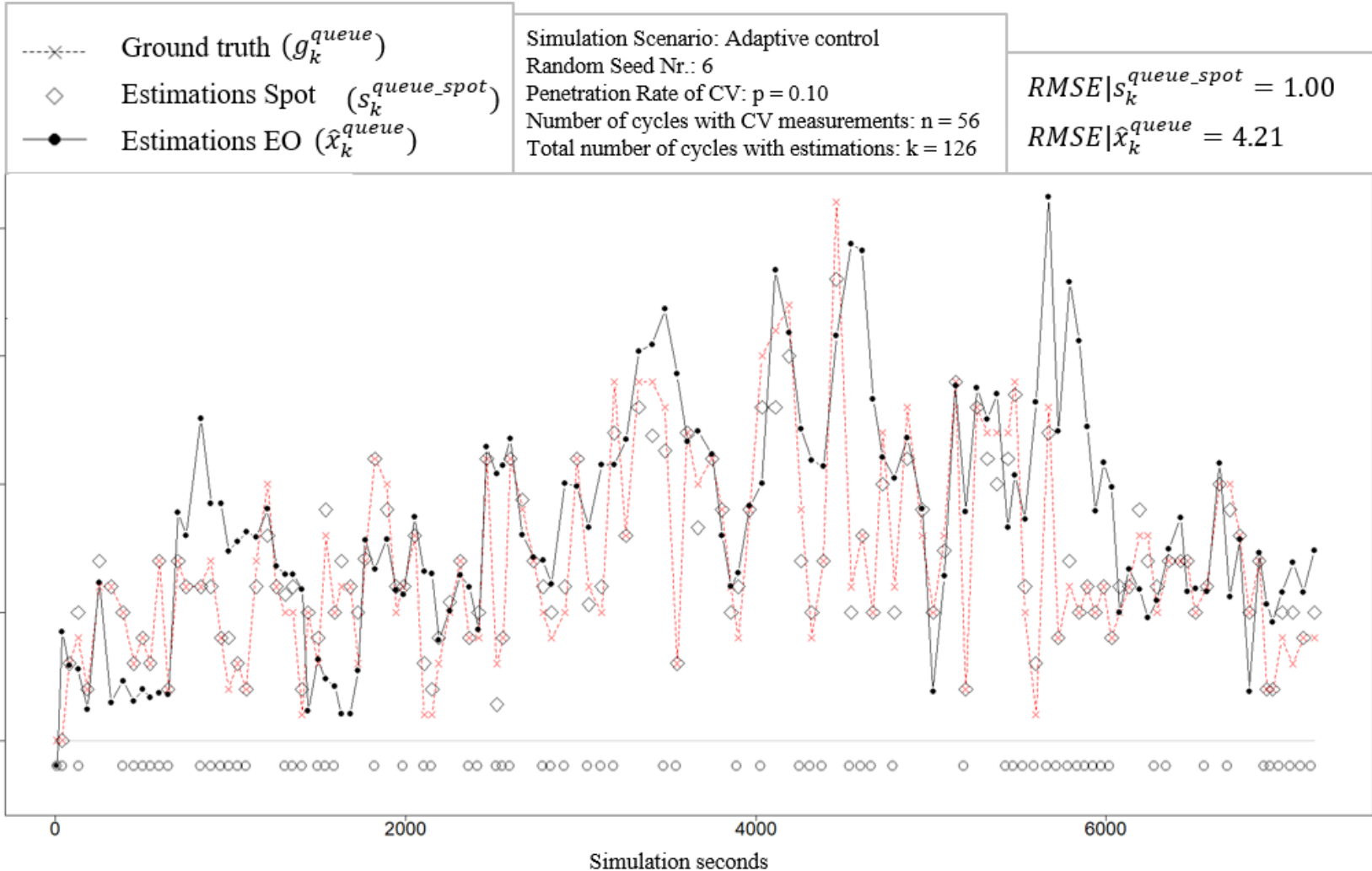
Simulations

Queue length estimation based only on Connected Vehicles - Example for fixed-time control
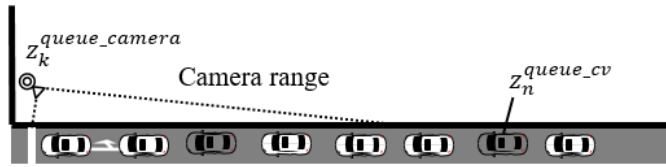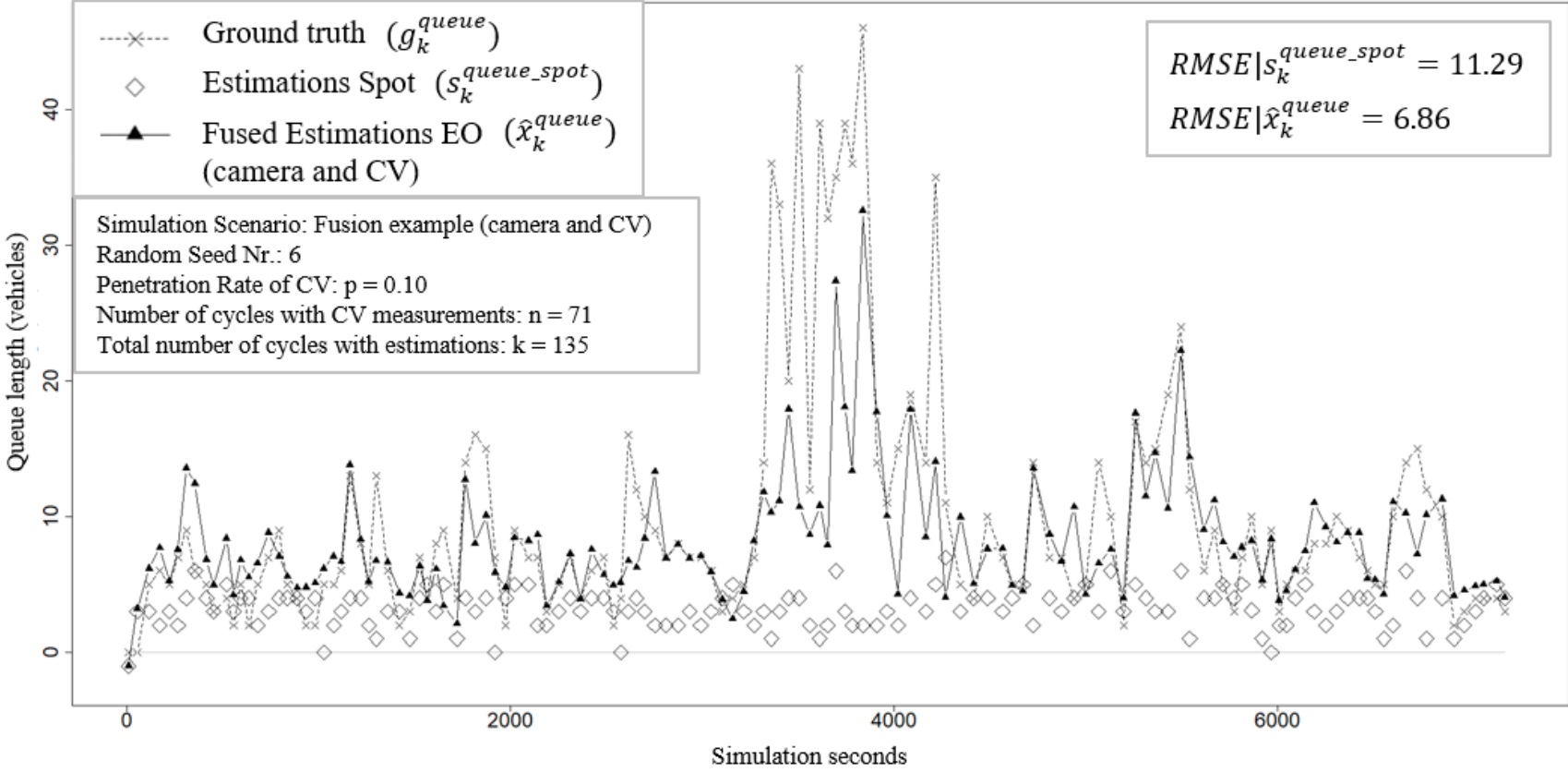
Queue length estimation based only on Connected Vehicles - Example for traffic-actuated control

Queue length estimation based only on Connected Vehicles - Example for adaptive traffic control

Ground truth (g_k^{queue})

Estimations Spot $(s_k^{queue\_spot})$

Estimations EO $(\hat{x}_k^{queue})$

Simulation Scenario: Adaptive control
Random Seed Nr.: 6
Penetration Rate of CV: p = 0.10
Number of cycles with CV measurements: n = 56
Total number of cycles with estimations: k = 126

$RMSE|s_k^{queue\_spot} = 1.00$

$RMSE|\hat{x}_k^{queue} = 4.21$

450veh/h

Examined approach with varying demand (690-990 v/h)

varying demand (690-990 v/h)

450veh/h

Traffic demand (veh/h)

Saturation degree

900

1.1
1.0

Volume/capacity≥1.0

0.75

1h

time

2h

Queue length (vehicles)

Simulation seconds

8

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Queue length estimation based on Con.Vehicles and camera - Example for degraded adaptive control (missing detector)

Ground truth (g_k^{queue})

◇ Estimations Spot $(s_k^{queue\_spot})$

▲ Fused Estimations EO $(\hat{x}_k^{queue})$ (camera and CV)

Simulation Scenario: Fusion example (camera and CV)
Random Seed Nr.: 6
Penetration Rate of CV: p = 0.10
Number of cycles with CV measurements: n = 71
Total number of cycles with estimations: k = 135

$$RMSE|s_k^{queue\_spot} = 11.29$$

$$RMSE|\hat{x}_k^{queue} = 6.86$$

$z_k^{queue\_camera}$

Camera range

$z_n^{queue\_cv}$

n: number of cycles with CV measurements
k: total number of cycles with camera measurements

Traffic demand (veh/h)

Saturation degree

900

1.1
1.0

Volume/capacity≥1.0

0.75

1h

time

2h
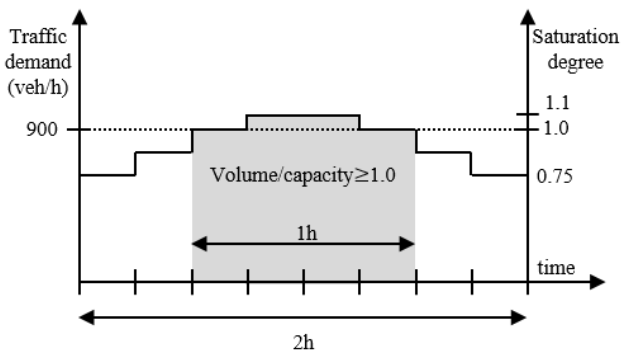
Conclusions

Extended Observer:

- Utilizes **imperfect measurements** from low number Connected Vehicles (**low penetration rates**)
- Provides improved **estimation** in comparison to relying solely on the measurements
- Enables **fusion** of diverse sensors (e.g. camera, Connected Vehicles)
- Provides an **intuitive way for tuning** the filter ("which measurements should I trust more?")

Outlook

- Evaluate the **impact** on signal control
- Test different **data availability** combinations
- Compare with estimation from **loop** detectors
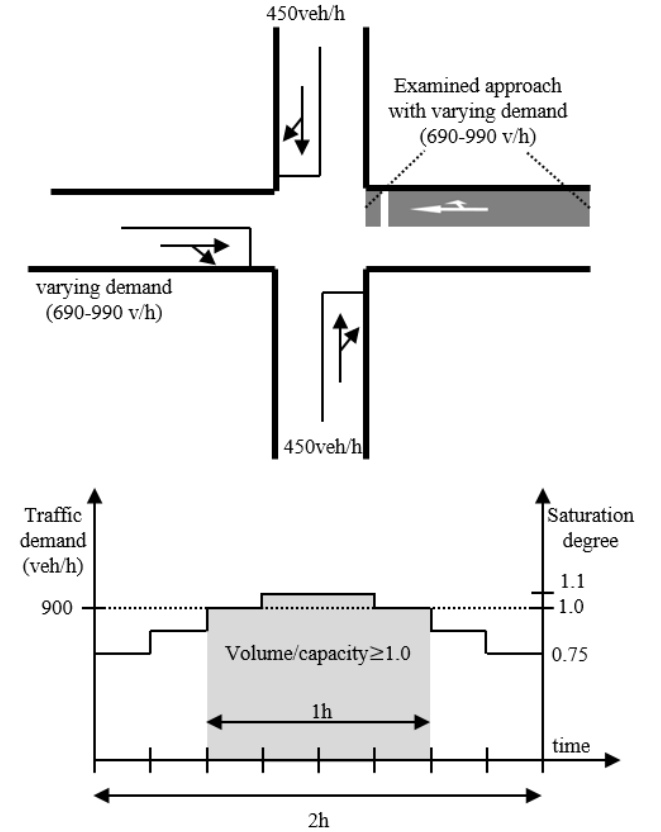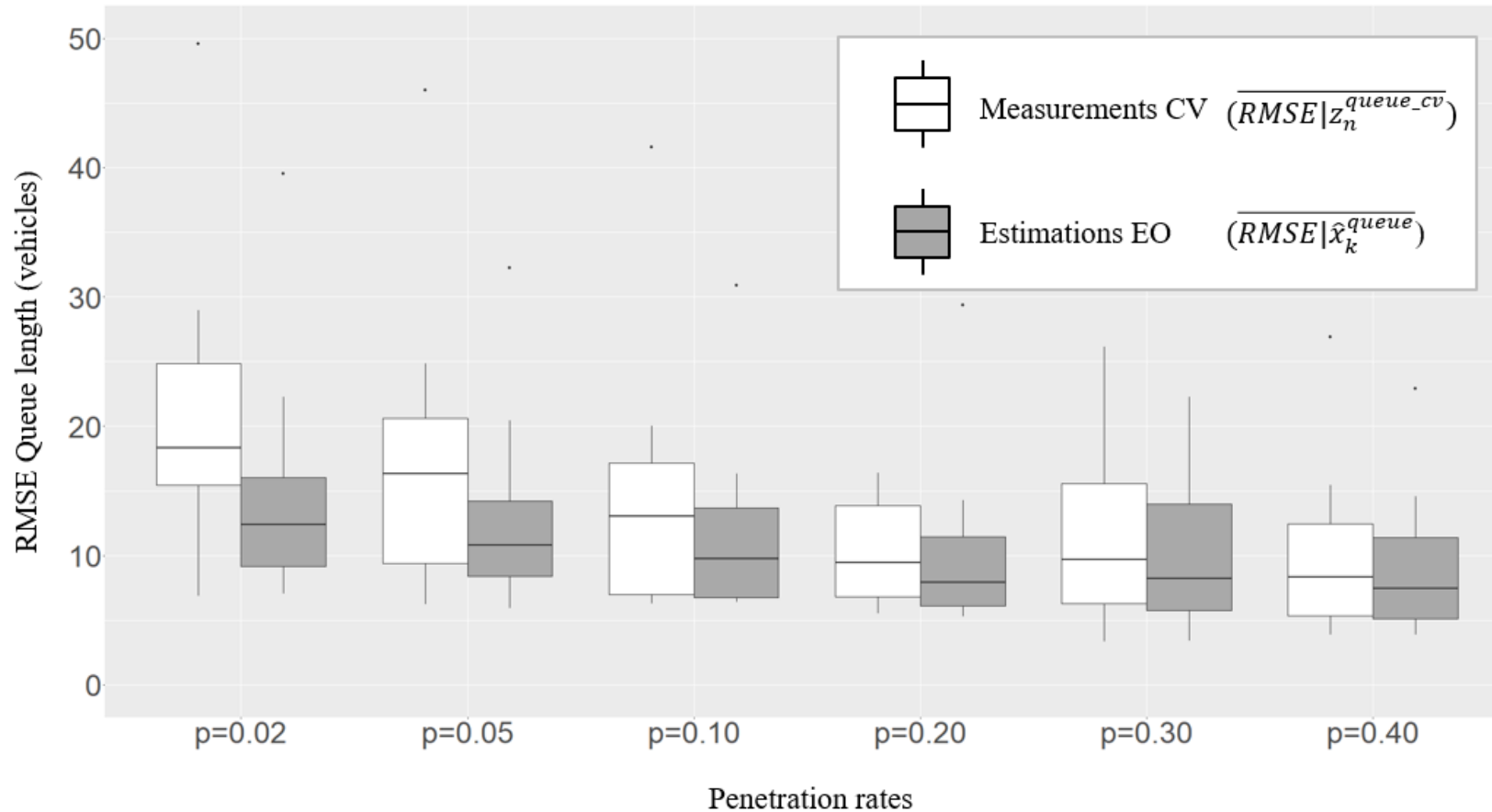- Derive **requirements** for connected environments
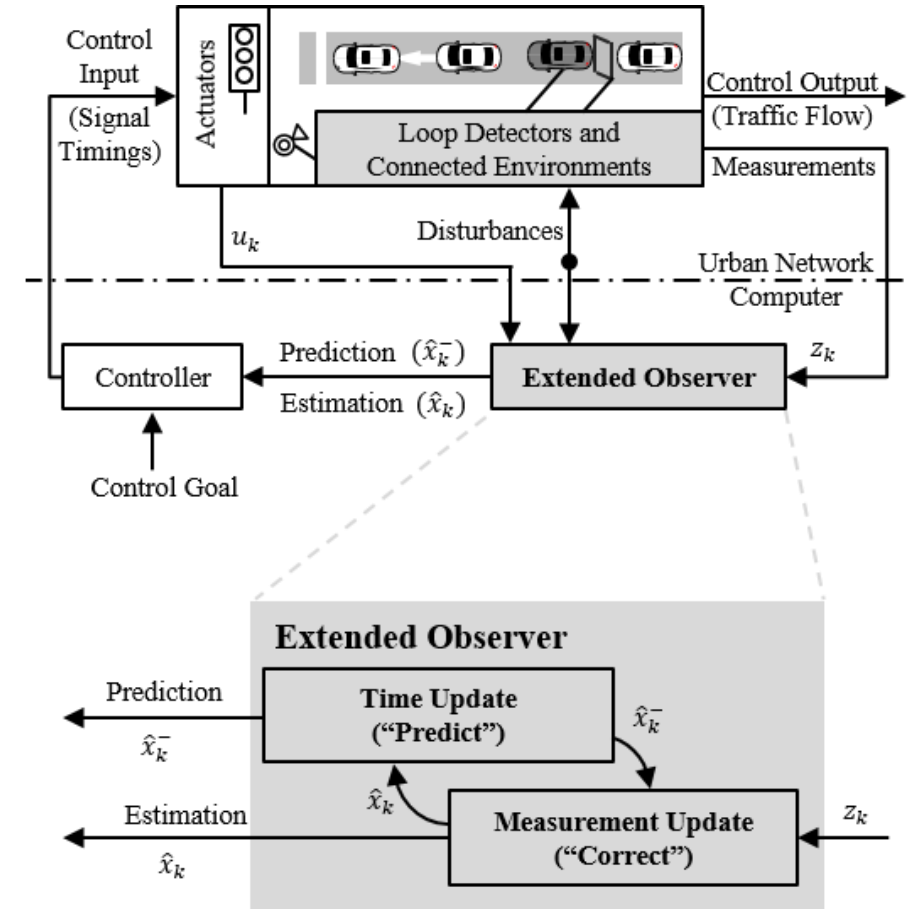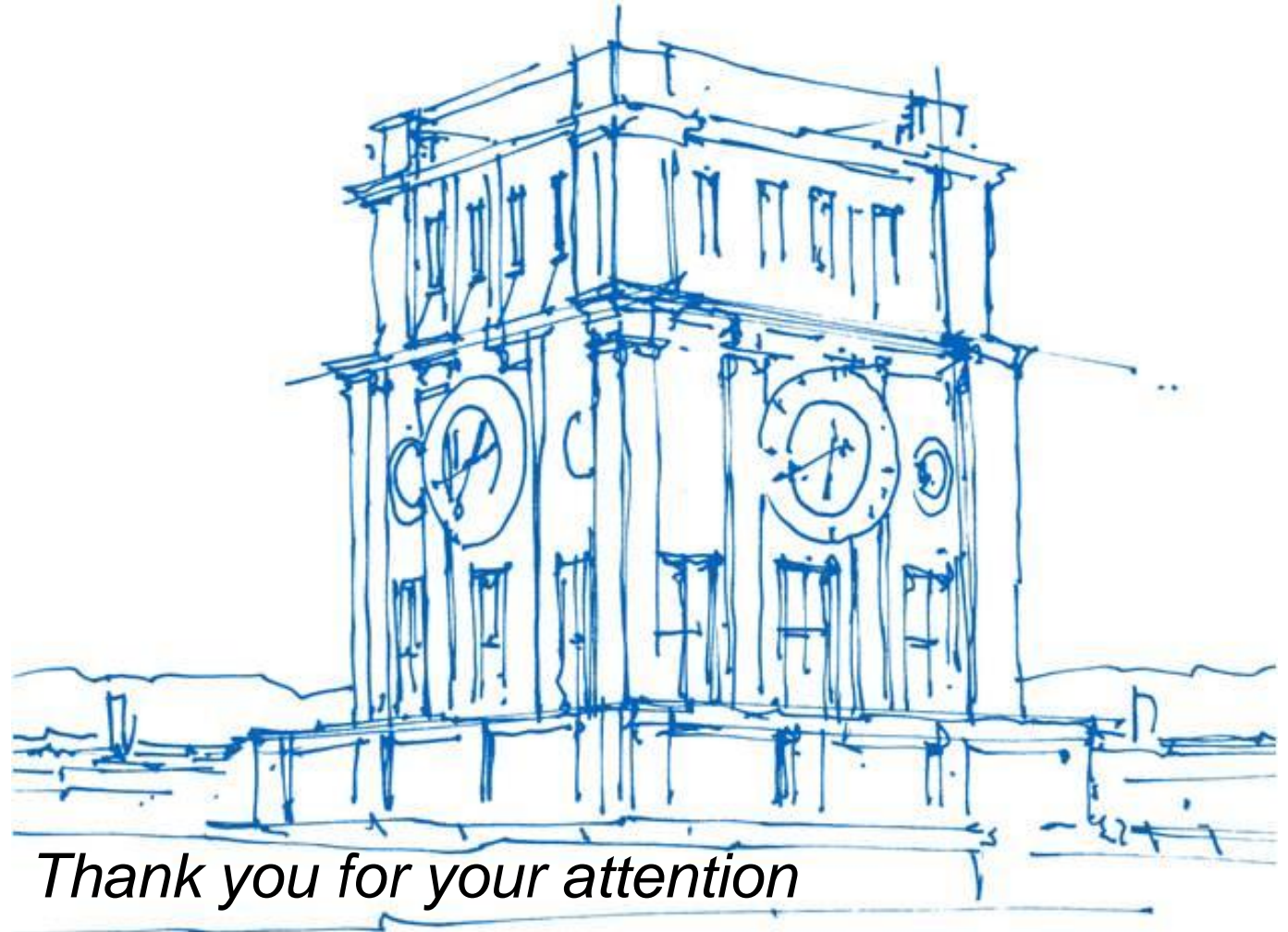
Thank you for your attention

Queue length estimation based only on Connected Vehicles - Example for fixed-time control

Queue length estimation based only on Connected Vehicles - Example for traffic-actuated control