

**Sebastian Jost**

Chair of economics and transportation

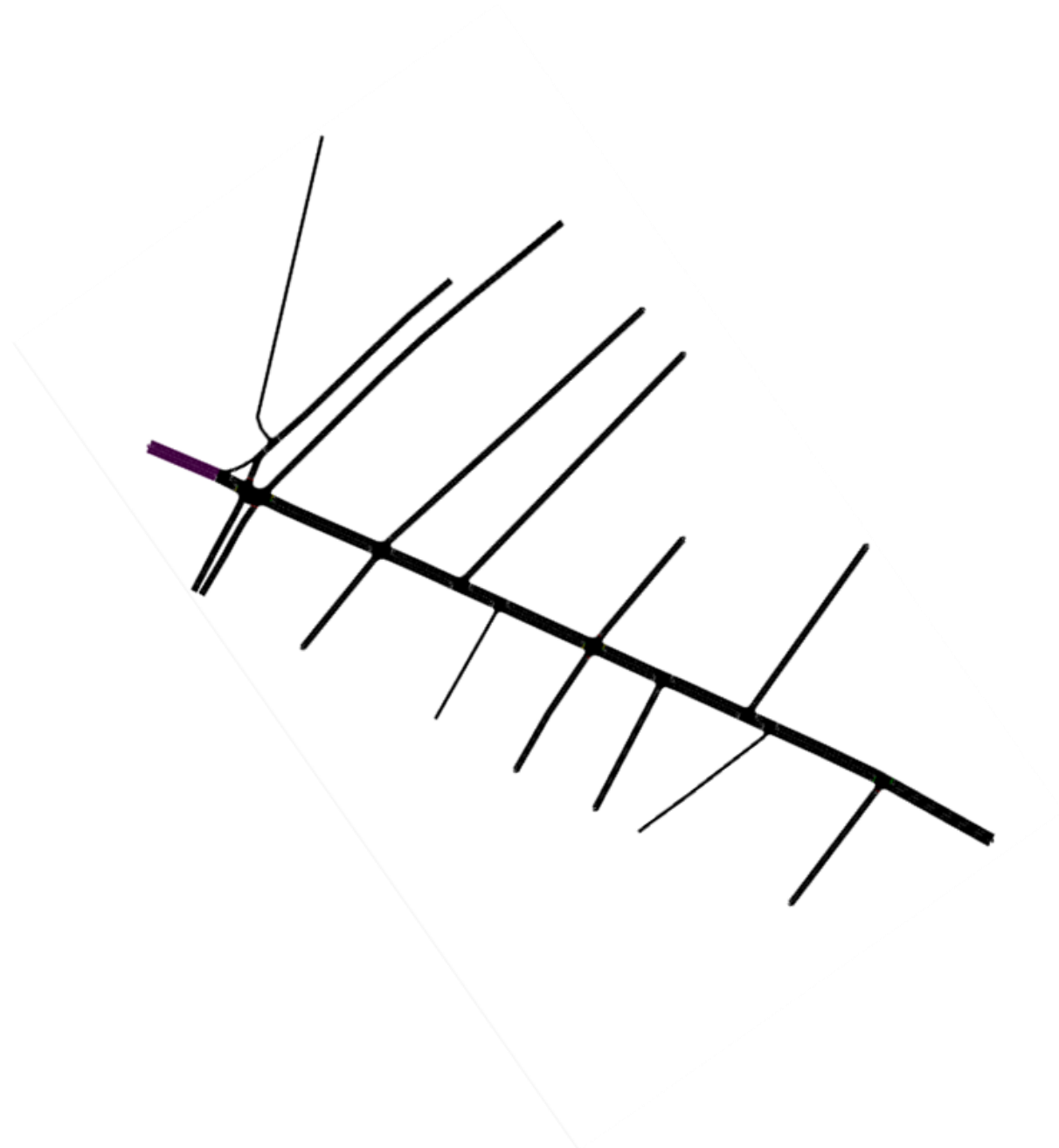
# **Reinforcement Learning for Traffic Signal Control**

## Moving closer to responsible real-world deployment

Research project at TU Dresden 2023

# Overview

- **Problem description**
- **Research questions**
- **Experiment setup**
- **Noise model**
- **Results**
- **Power consumption**



# Problem description

- Minimize average travel time

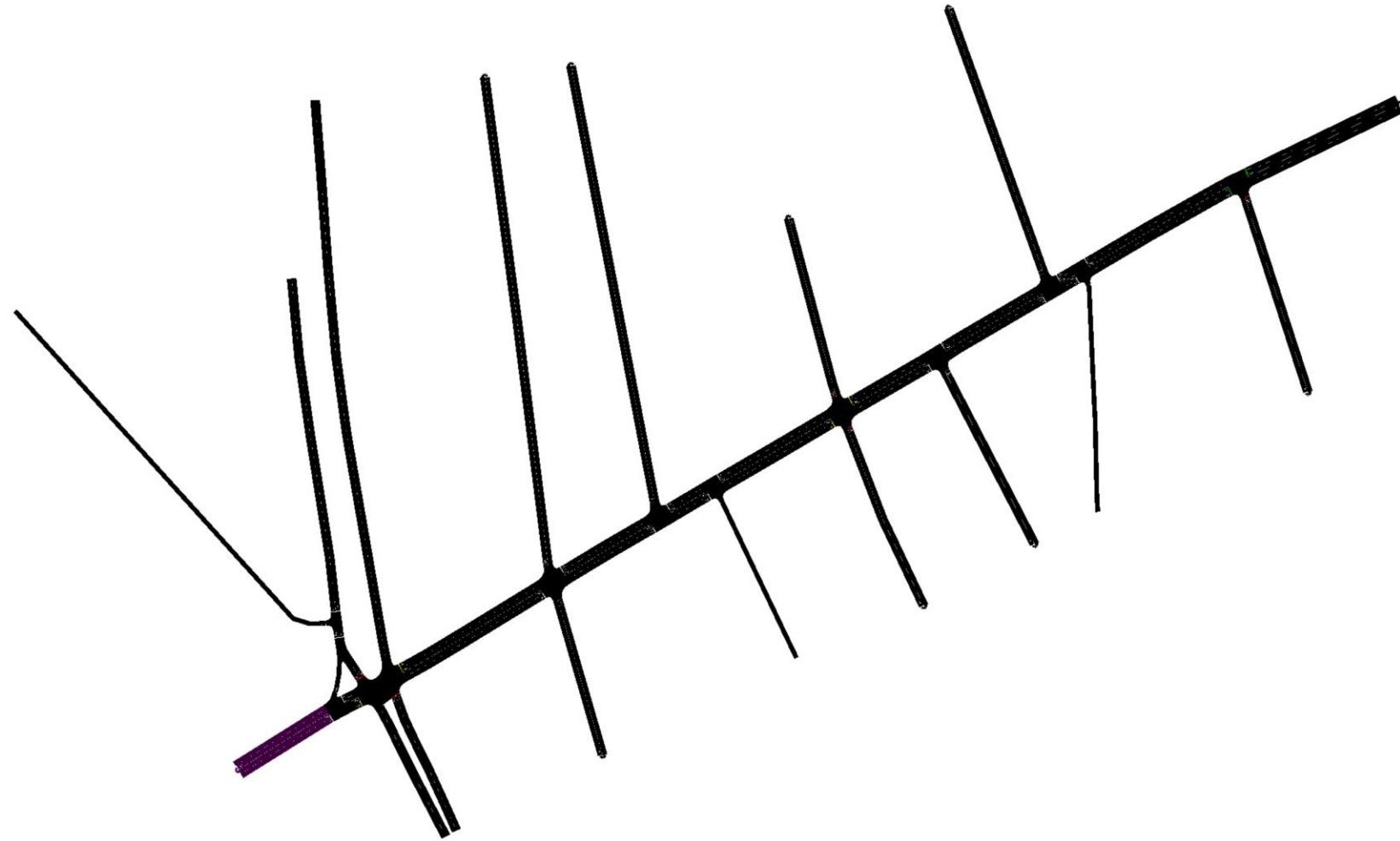
# Research questions

**RQ1: Impact of different sensor failure modes on RL TSC agent performance**

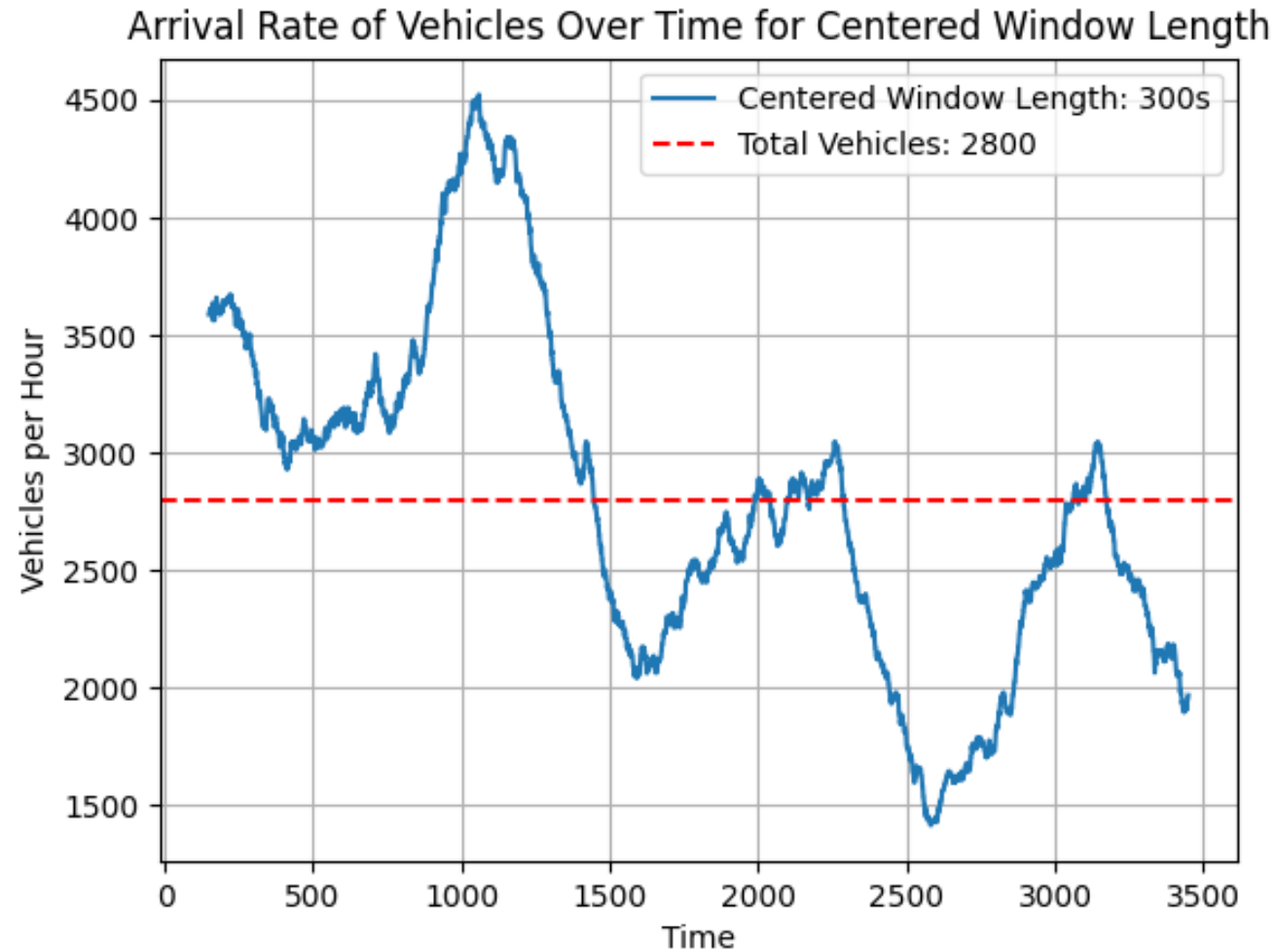
**RQ2: Impact of different sensor noise levels on RL TSC agent performance**

**RQ3: Does training on noisy data improve robustness?**

# Dataset – Network



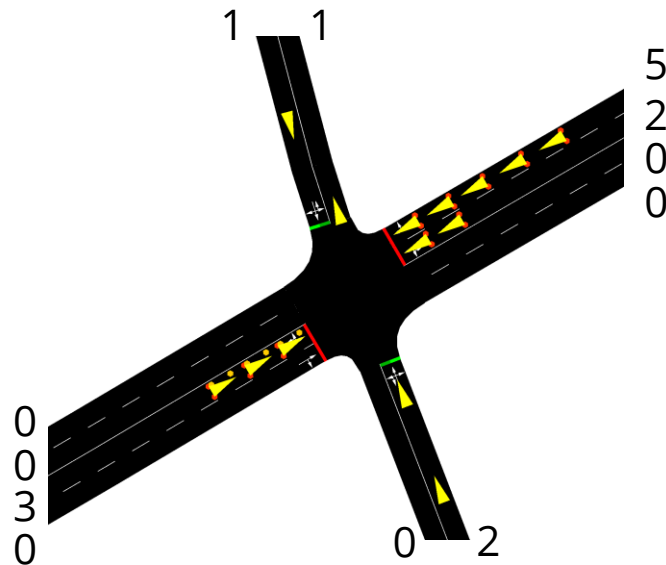
# Dataset – Vehicle arrival rate



# State & Action space

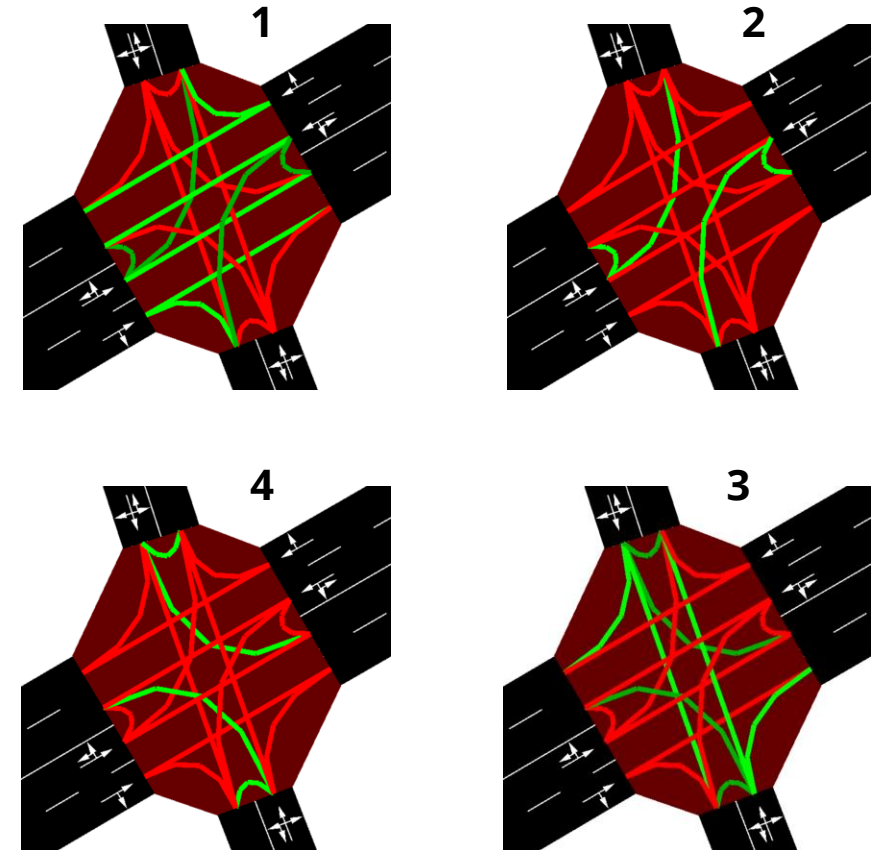
## State space

- Vehicles on each incoming lane
- Vehicles on each outgoing lane
- One-hot phase



## Action space

- Phase:

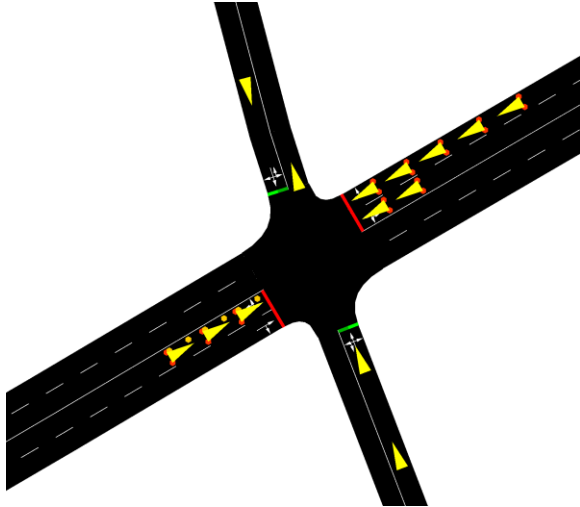


# Rewards & PressLight agent

## Reward

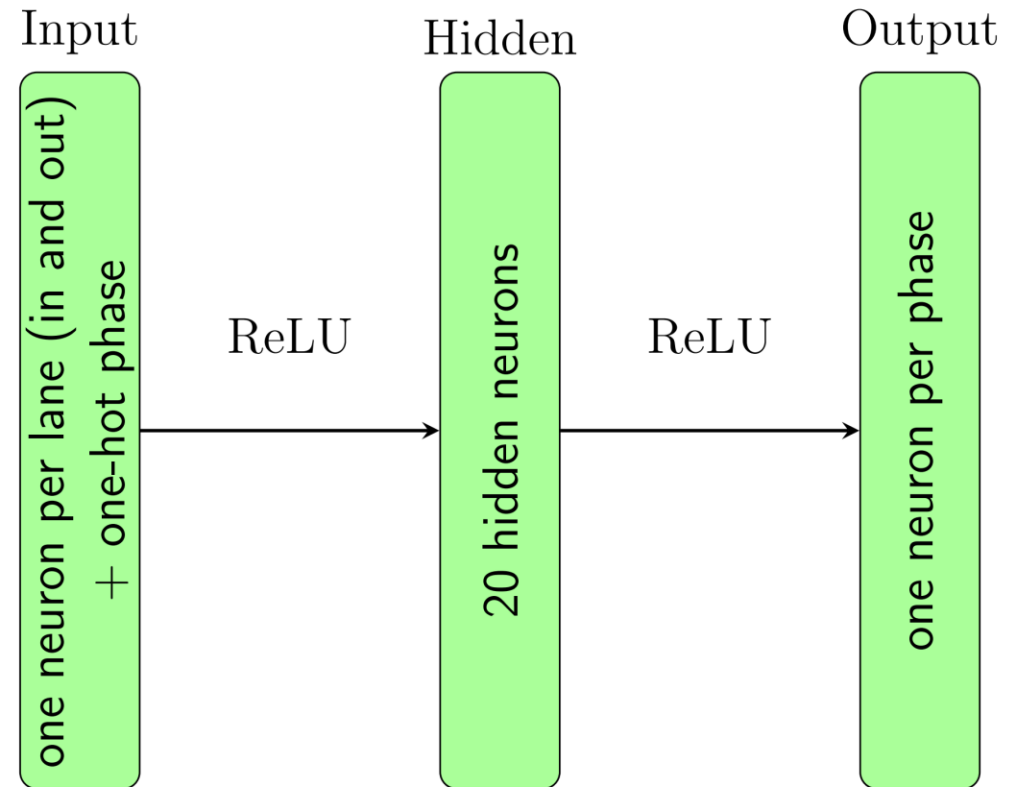
- reward = - pressure of intersection

$$r_i = -P_i = - \left( \sum_{l_{in} \in A_i} x(l_{in}) - \sum_{l_{in} \in B_i} x(l_{out}) \right)$$



$$\begin{aligned} r_1 &= -(13 - 1) \\ &= -12 \end{aligned}$$

## Agent



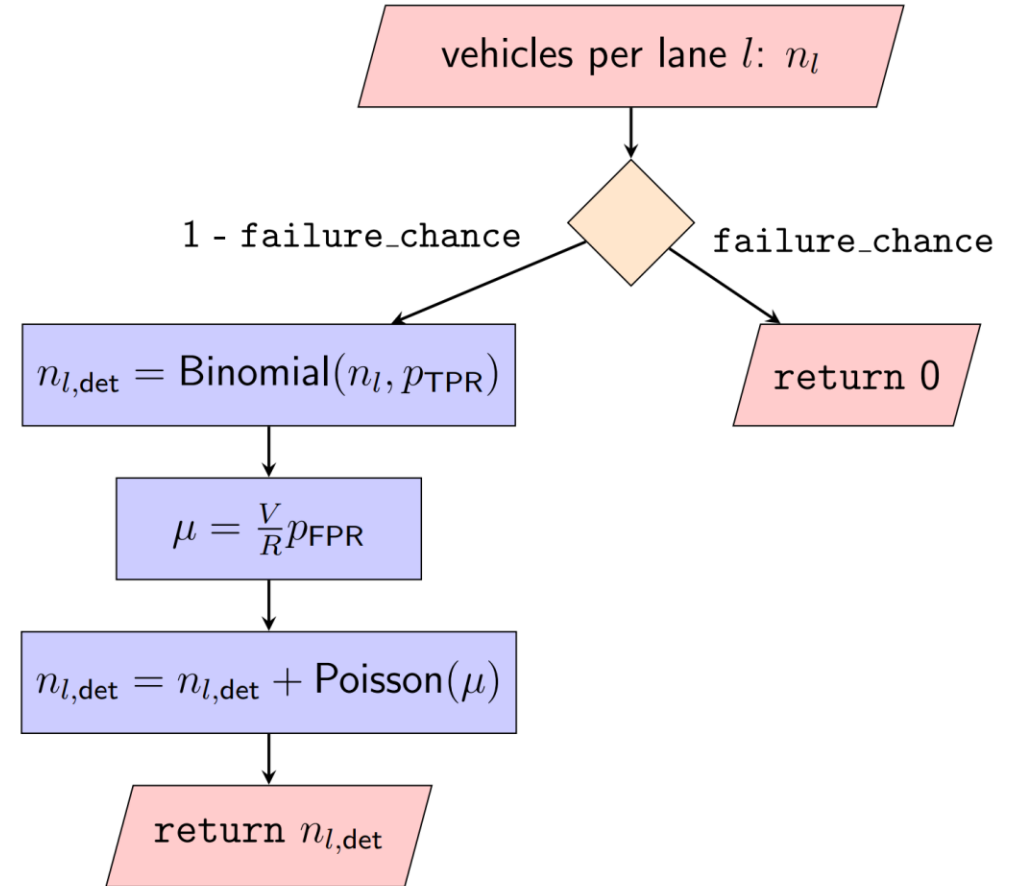


# Noise model

## 1. Sensor failure → failure chance

 $n_l$ 

0



# Parameter settings

## Training parameters

- *n episodes*: 50/ 100
- *Loss*: MSE
- *Optimizer*: RMSProp
- *Learning rate*: 0.001
- *$\gamma$* : 0.95
- *$\epsilon$* : 0.1
- *$\epsilon$  decay*: 0.995
- *min  $\epsilon$* : 0.01
- *Replay buffer size*: 5000
- *Batch size*: 64

## Simulation

- *n vehicles*: 2856
- *Yellow length*: 5s
- *Simulation steps*: 3600
- *Action interval*: 10s
- *Sensor reads per episode*: 360

## Agents

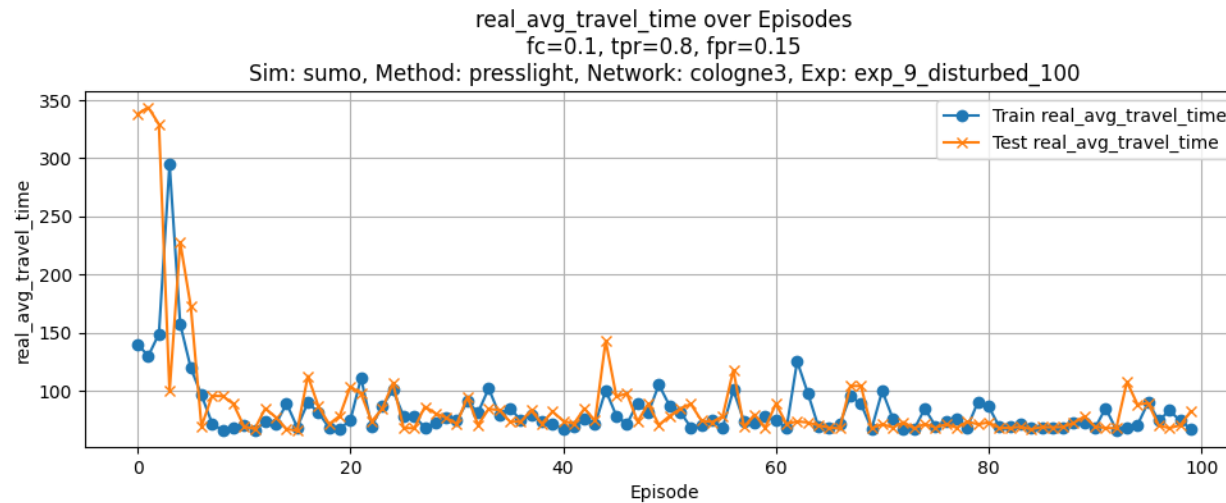
- FixedTime 30s
- MaxPressure
- PressLight undisturbed
- PressLight disturbed

## Noise parameters

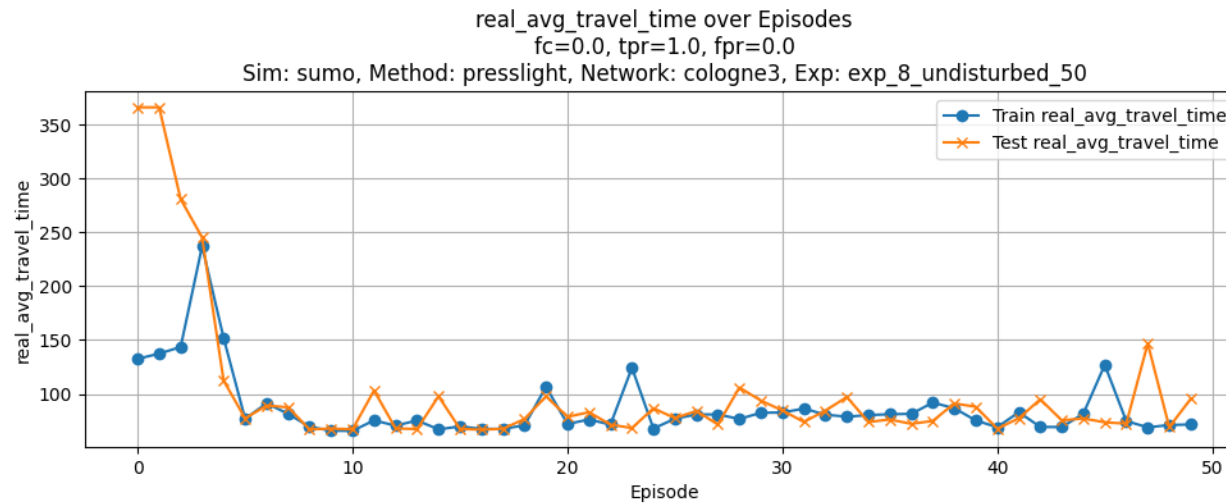
- *failure chances*:  
0, 0.05, 0.1, 0.15
- *True positive rates*:  
1, 0.95, 0.8, 0.6
- *False positive rates*:  
0, 0.15, 0.3, 0.65

# Results – training time – travel time

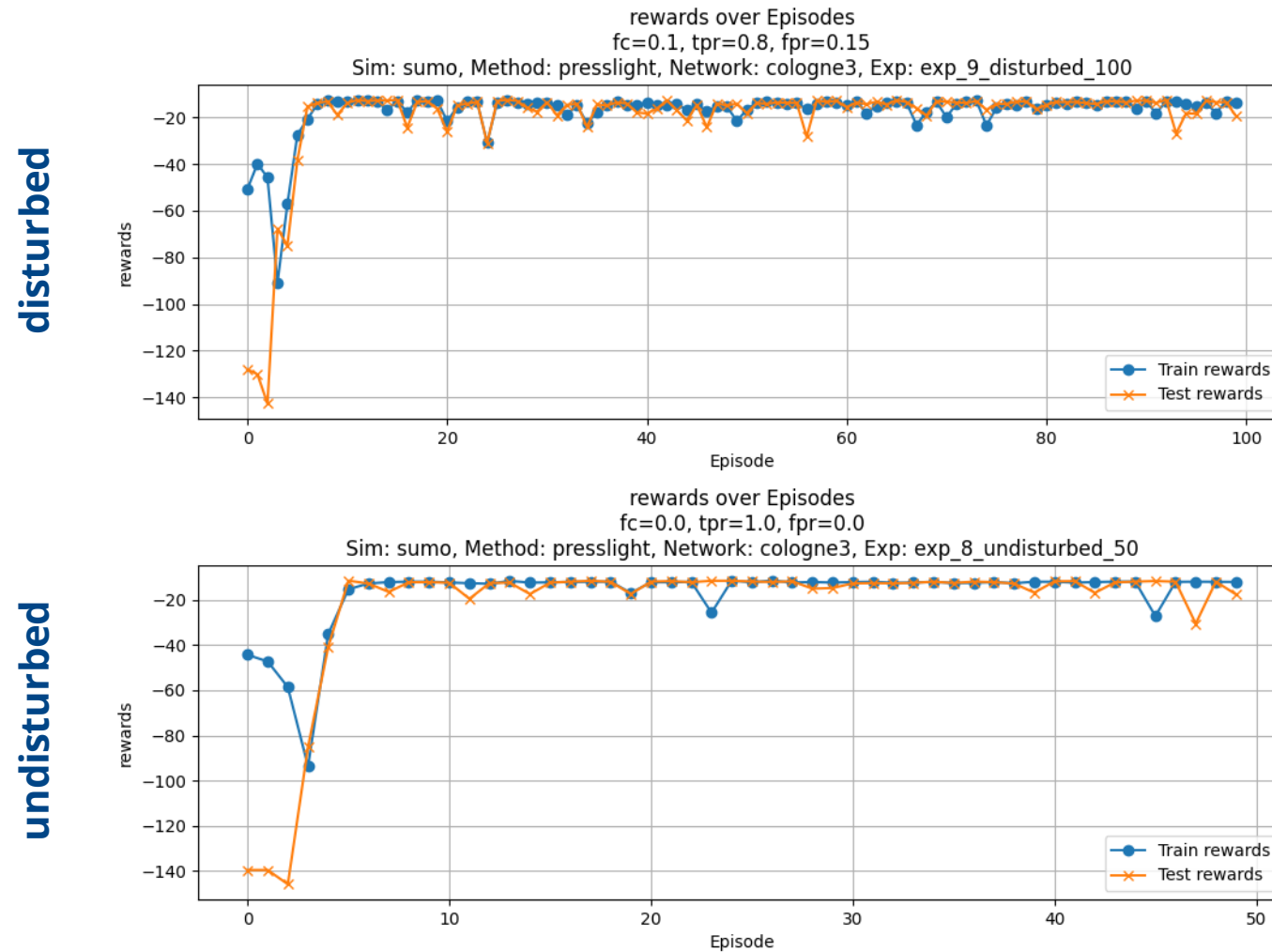
disturbed



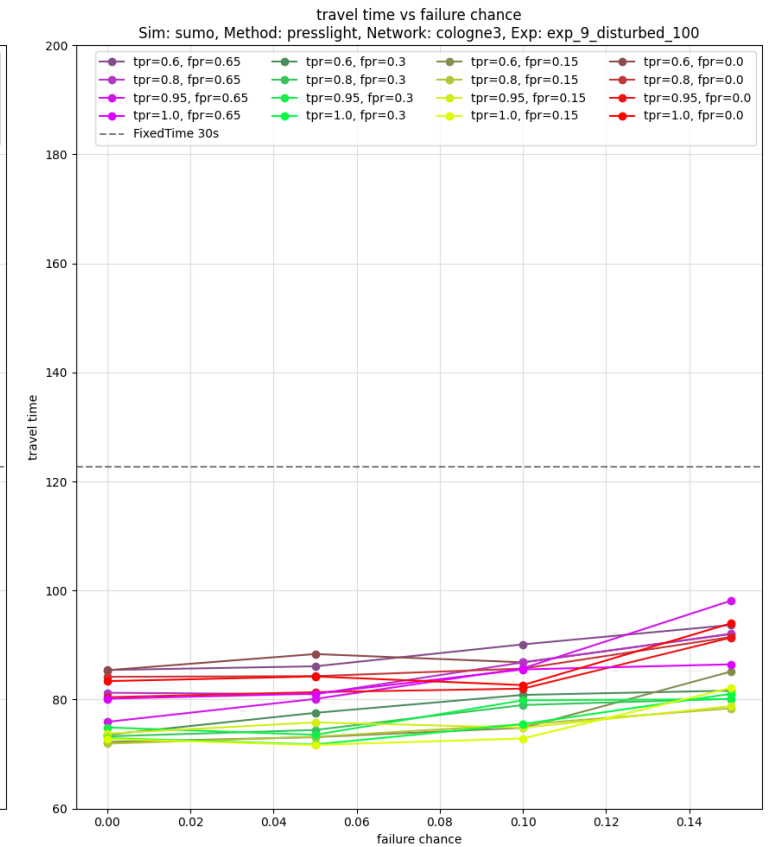
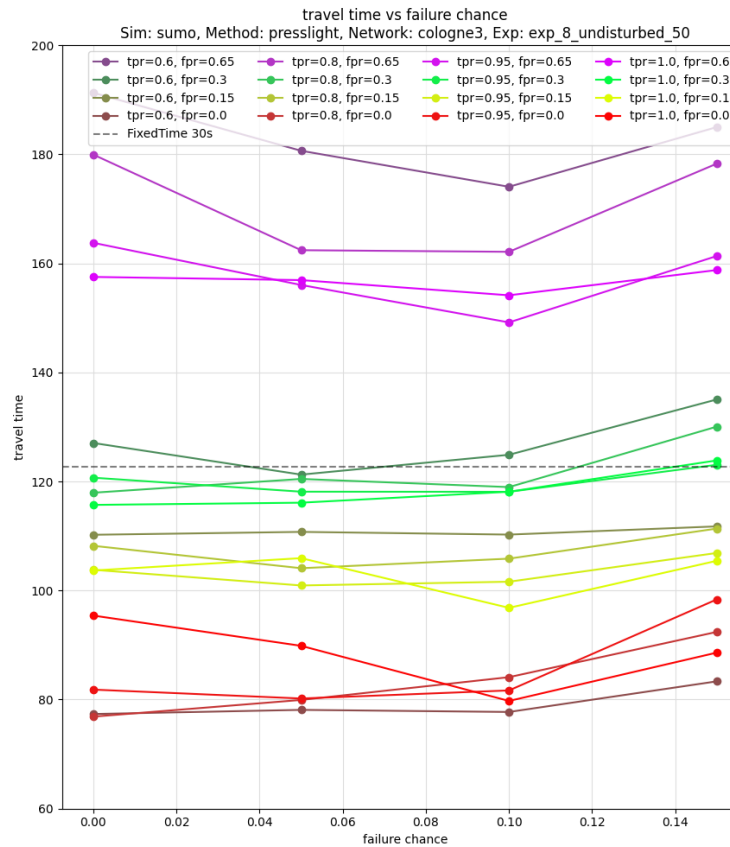
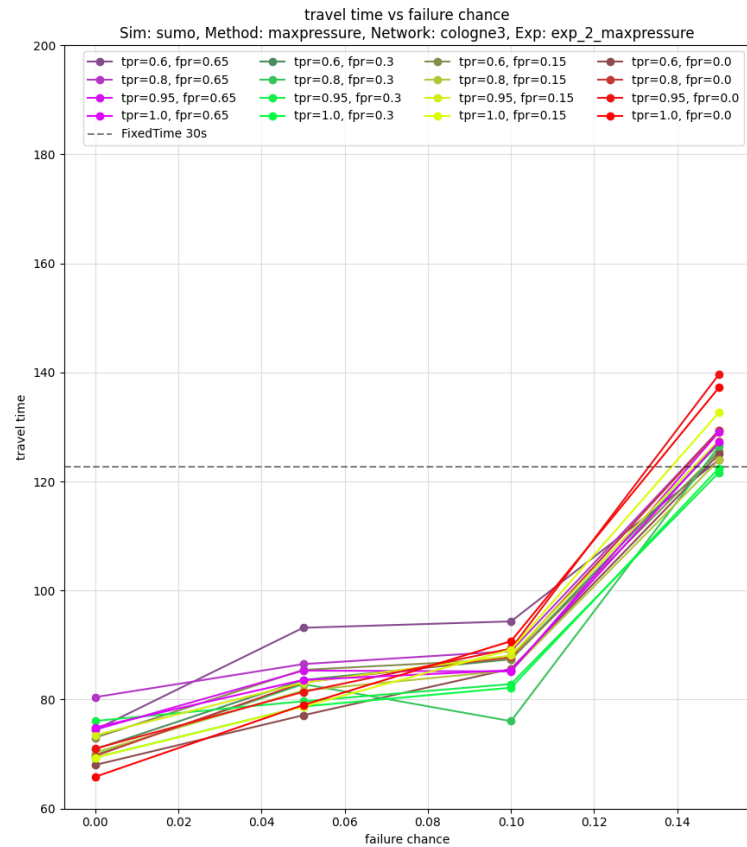
undisturbed



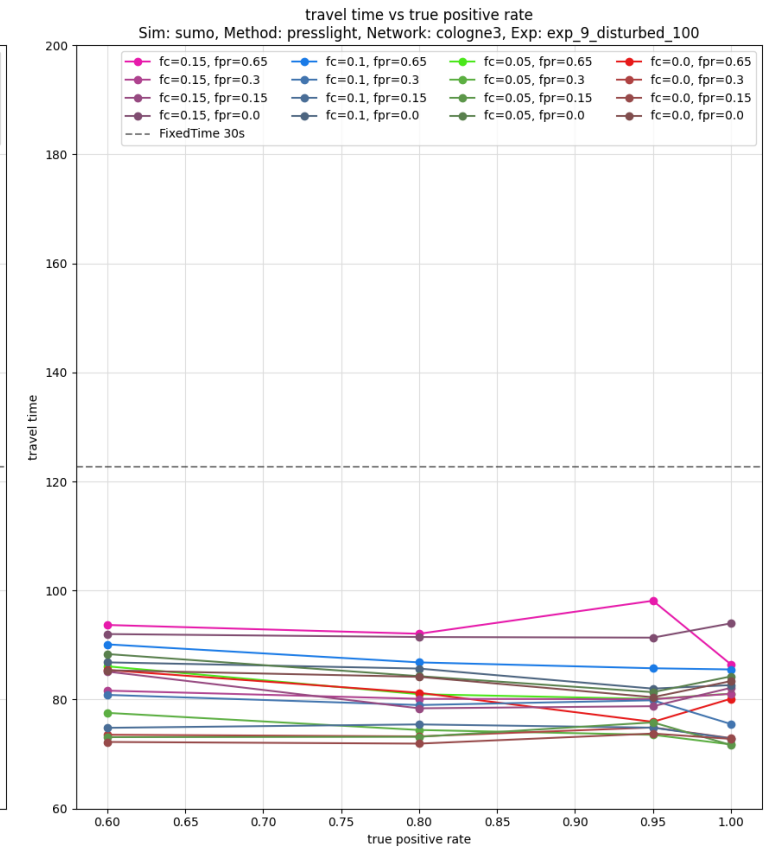
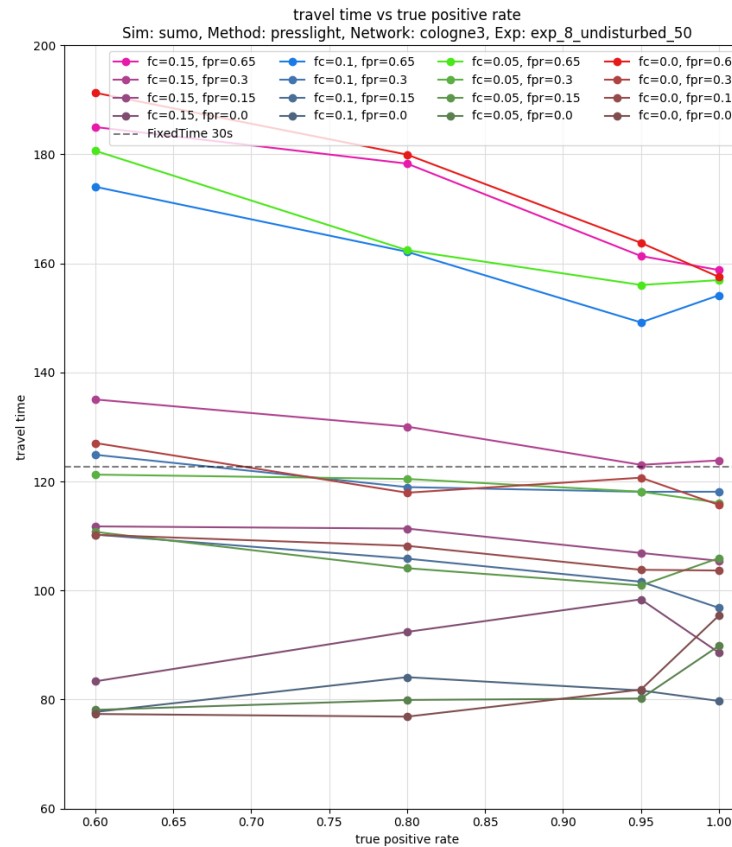
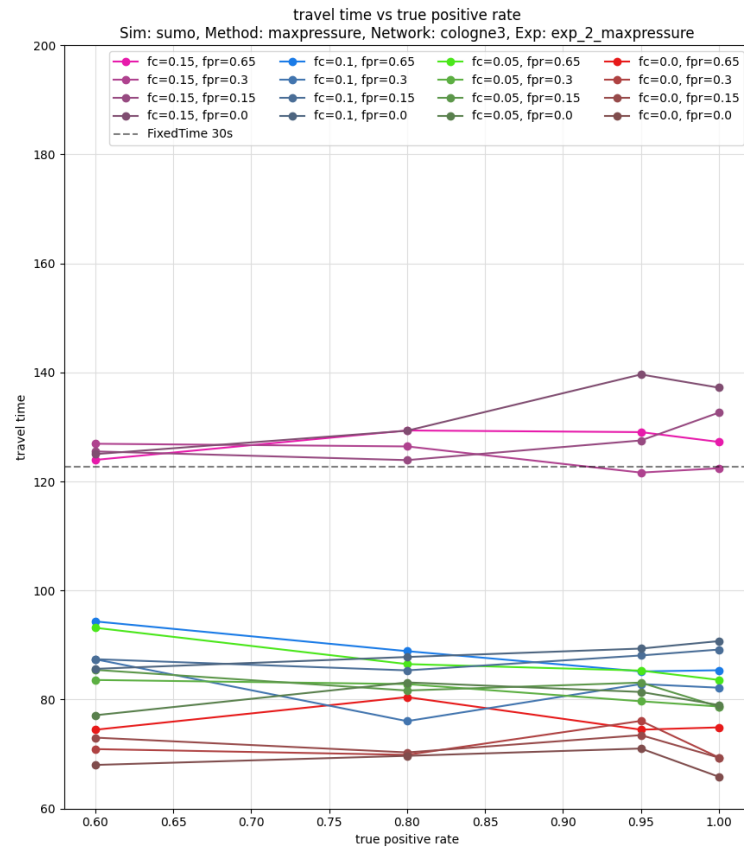
# Results – training time – rewards



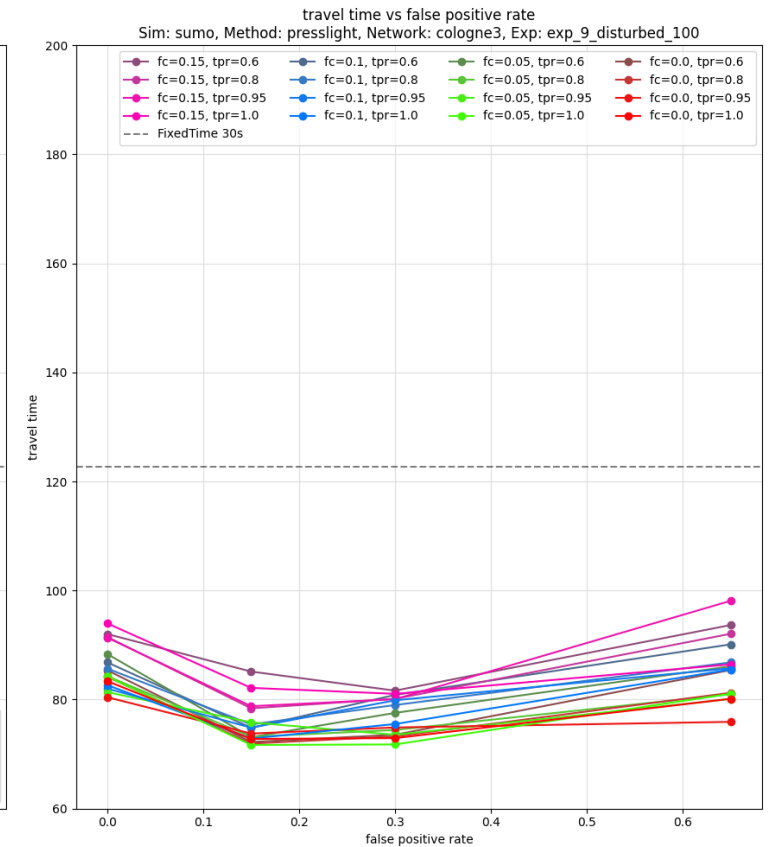
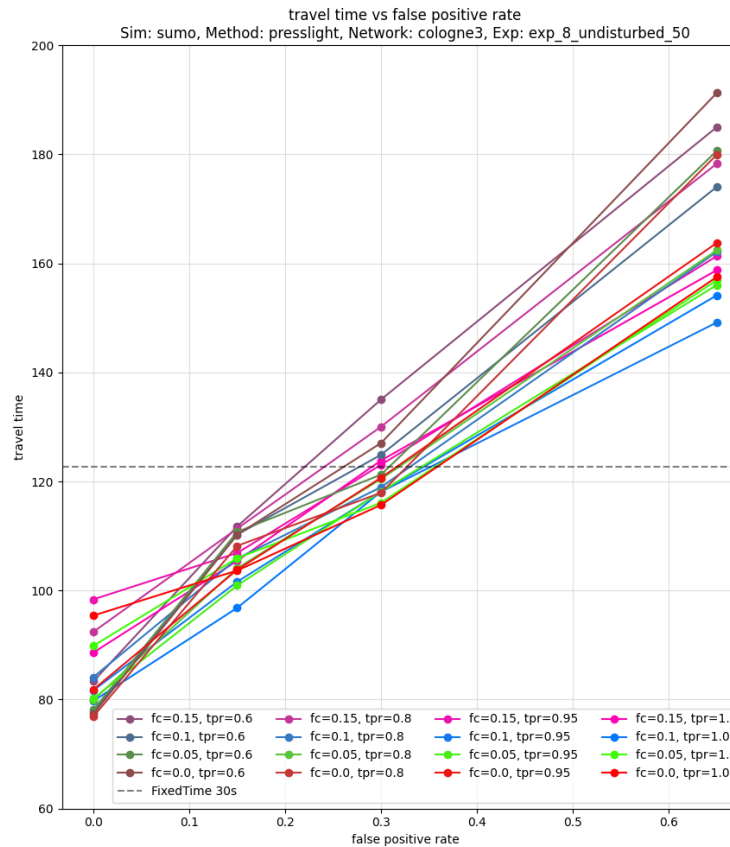
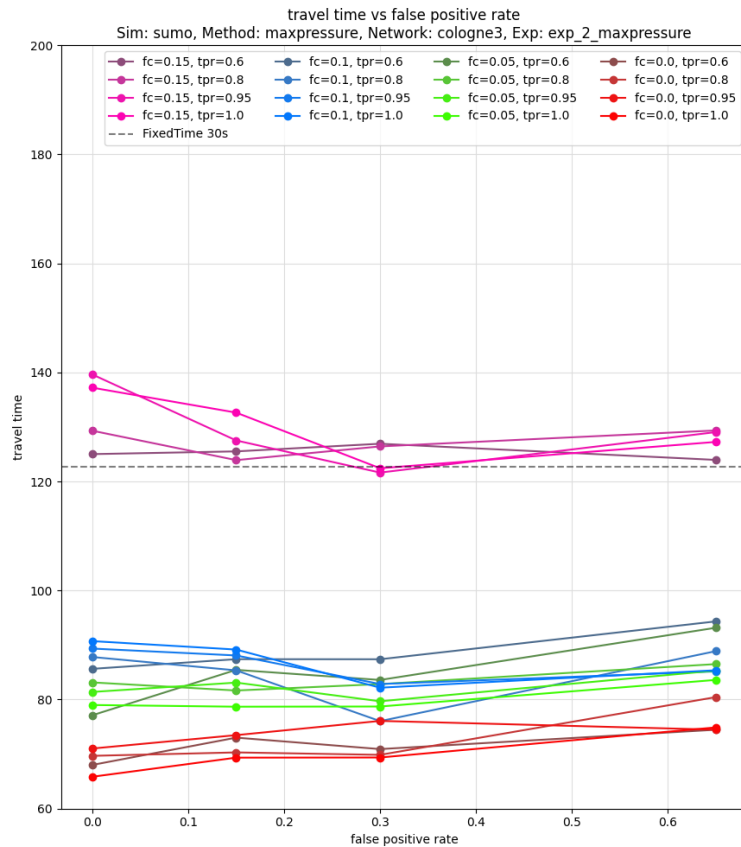
# Results – travel time vs. failure chance



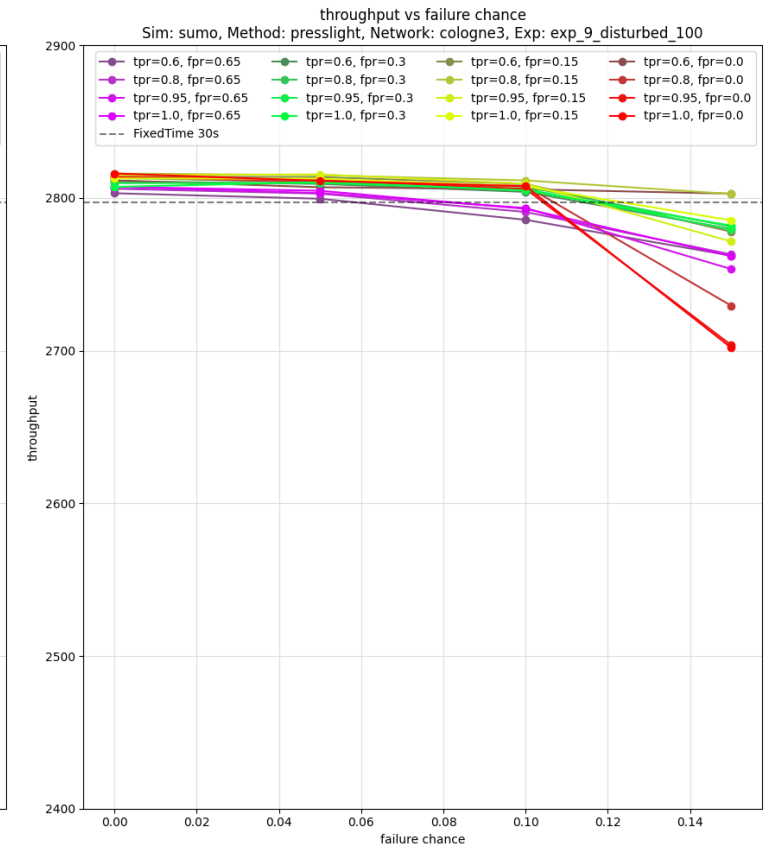
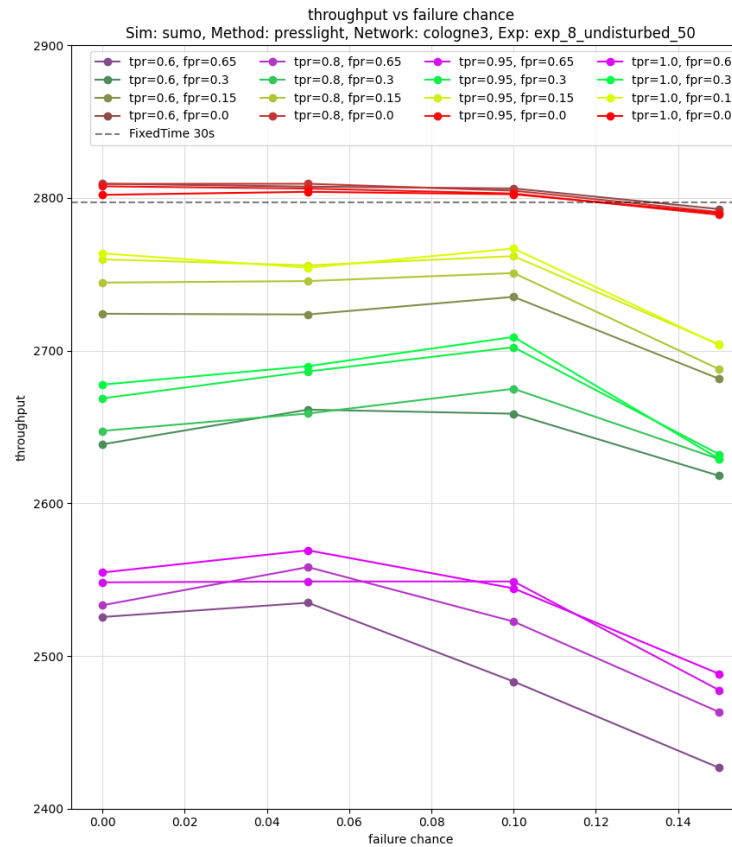
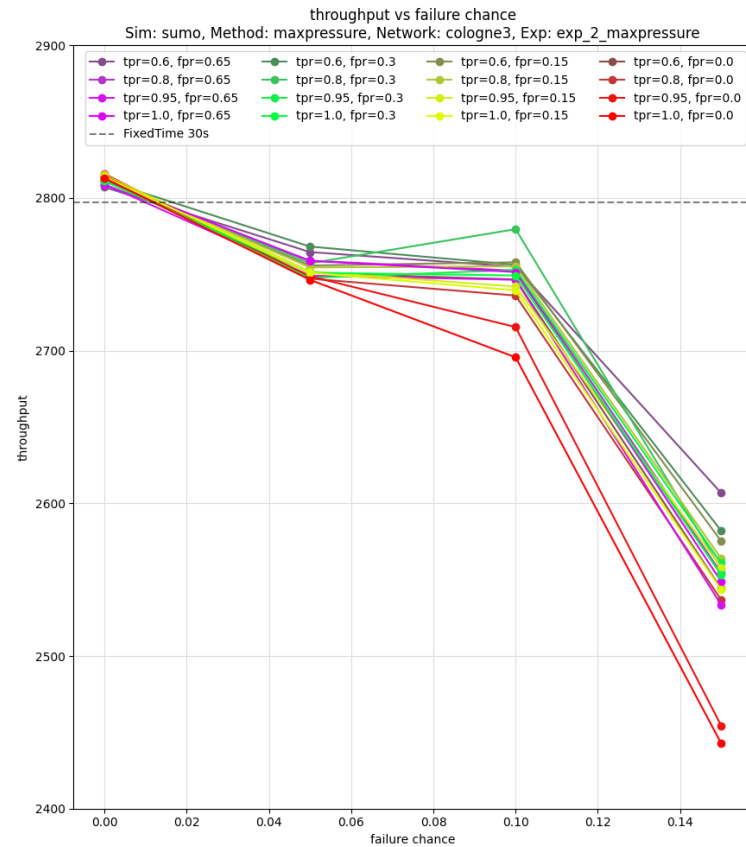
# Results – travel time vs. true positive rate (detection rate)



# Results – travel time vs. false positive rate (misdetection rate)

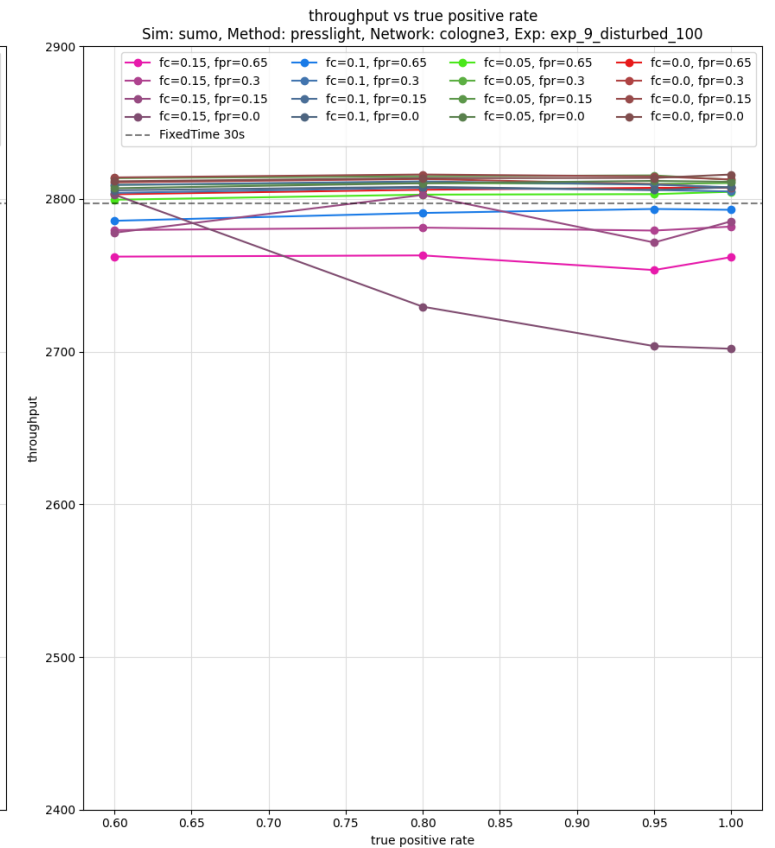
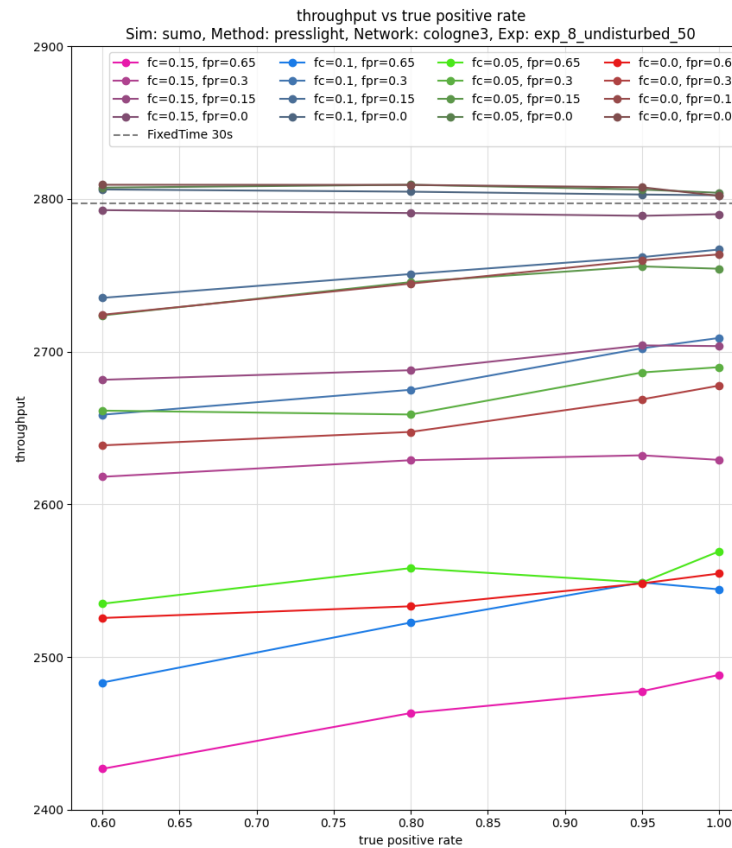
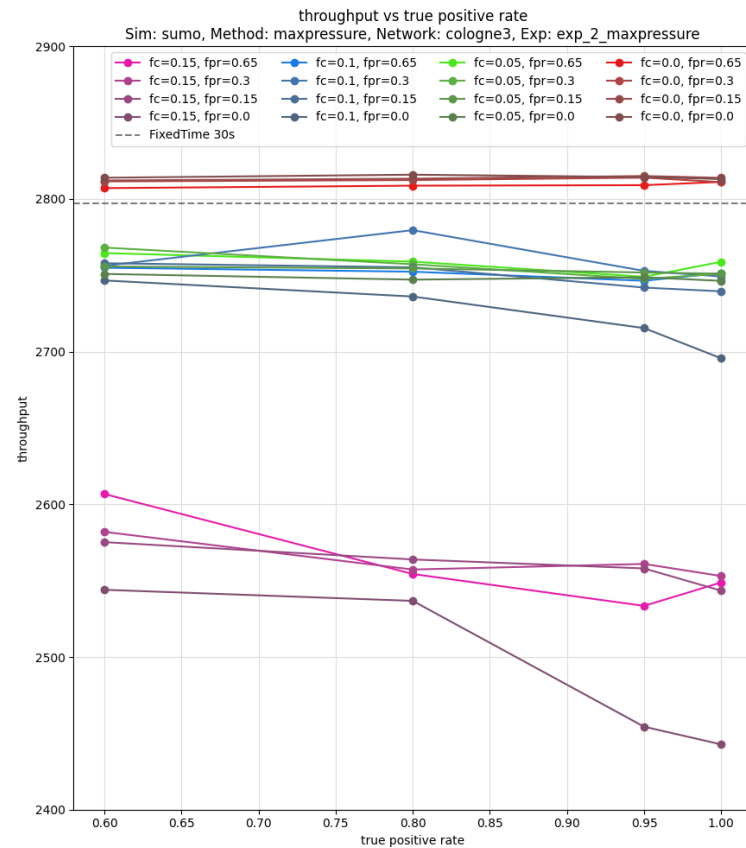


# Results – throughput vs. failure chance

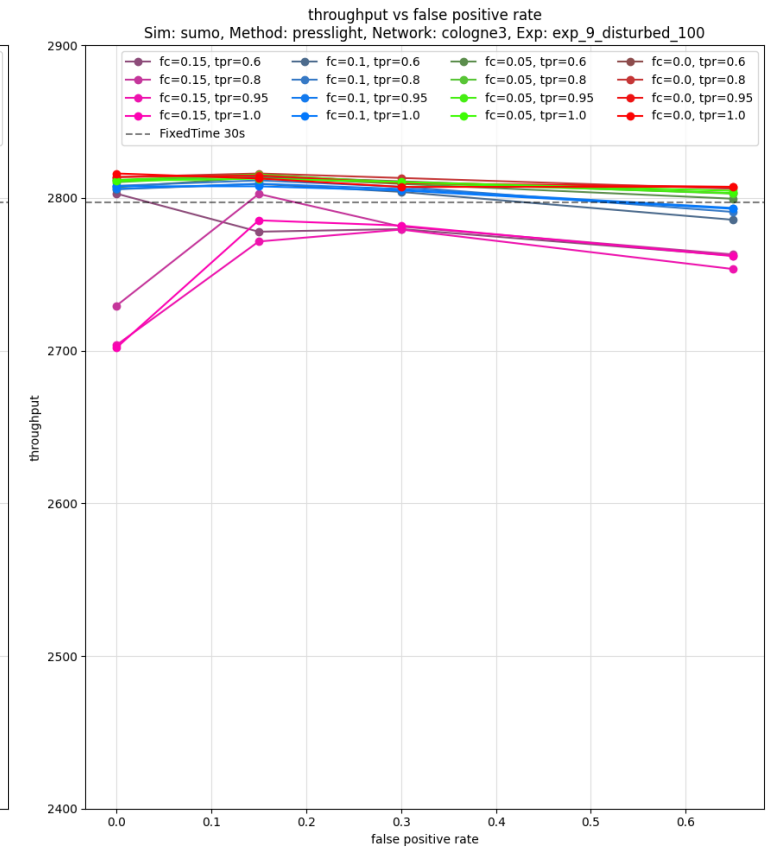
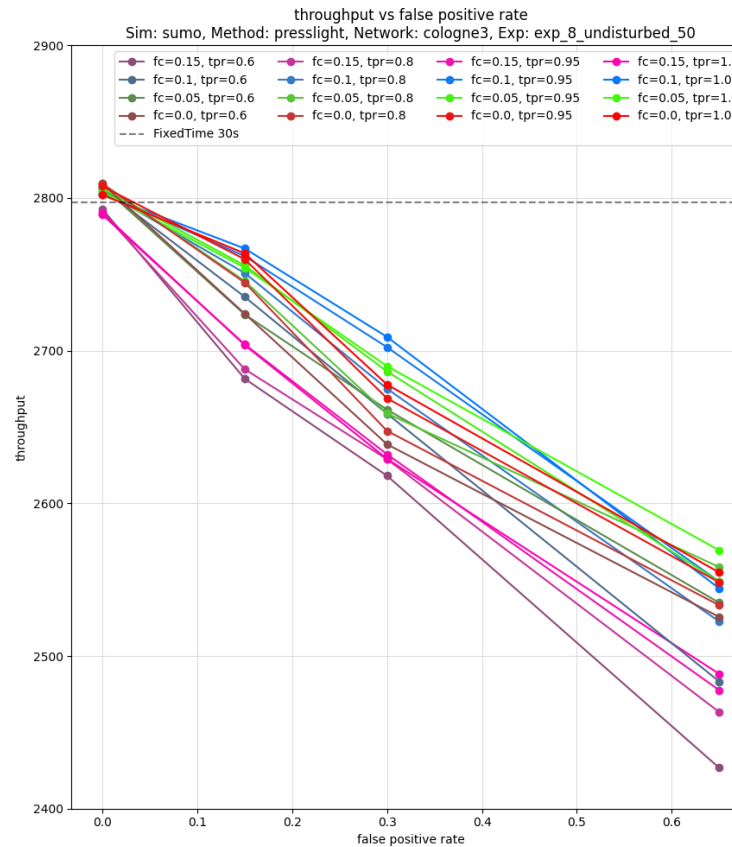
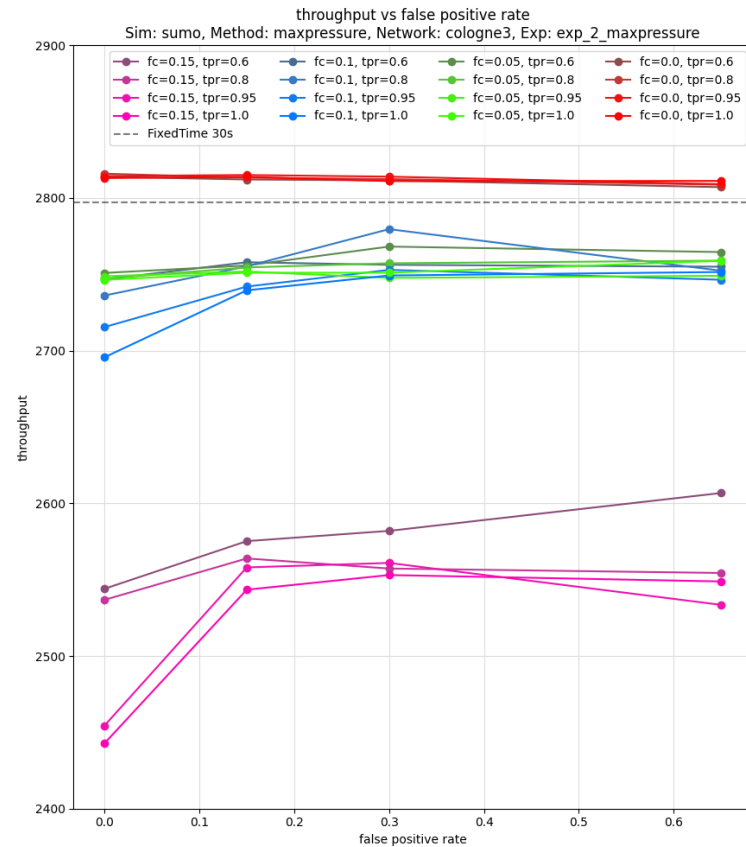




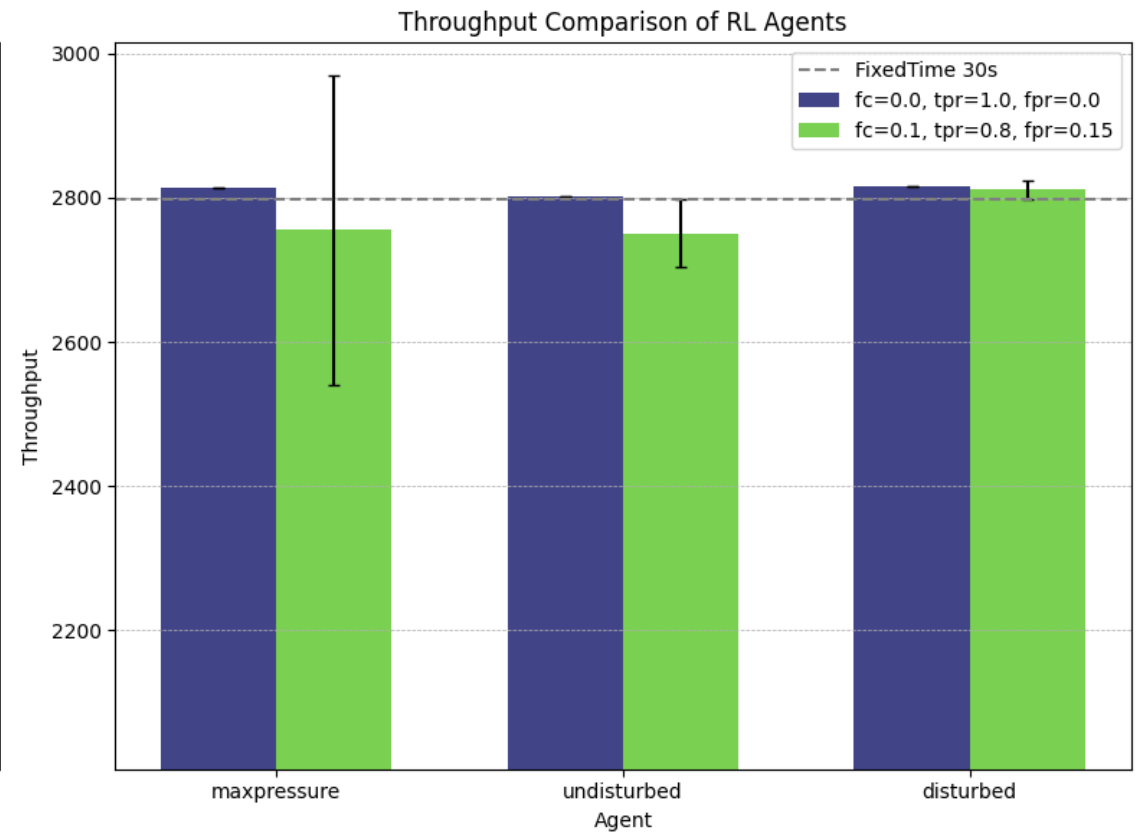
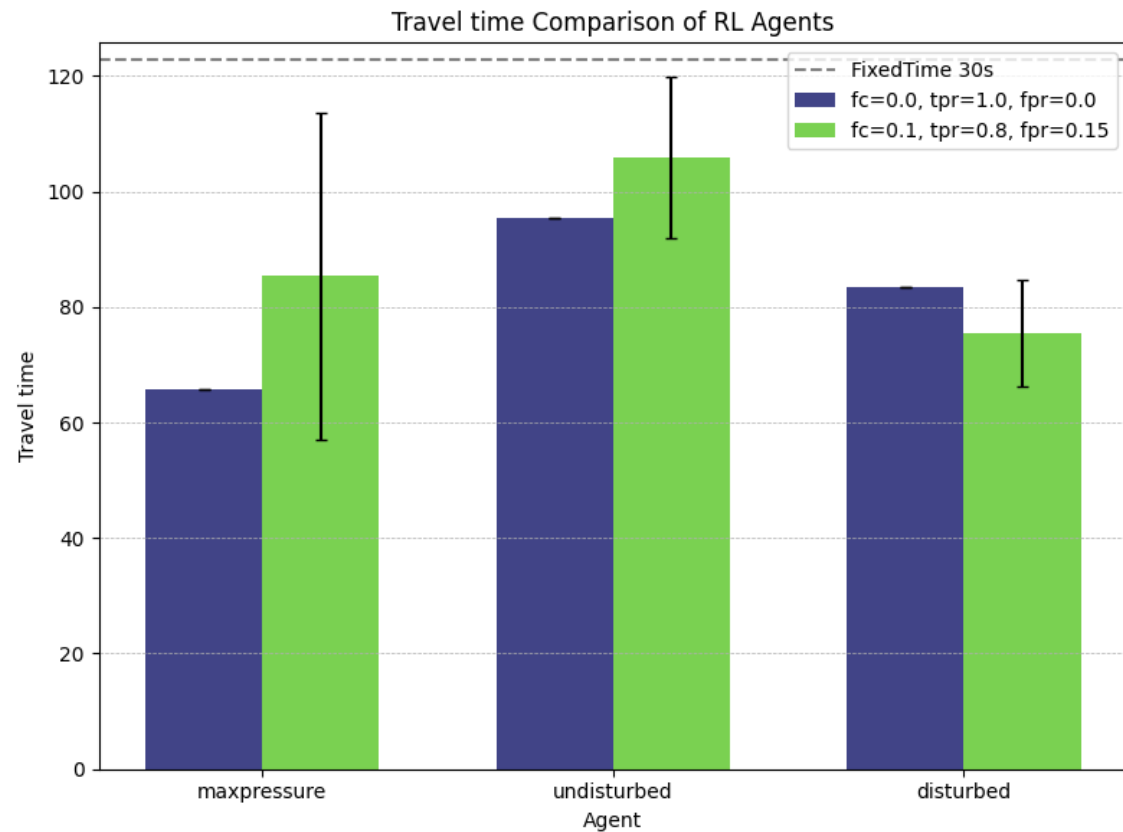
# Results – throughput vs. true positive rate (detection rate)



# Results – throughput vs. false positive rate (misdetection rate)



# Results – comparison



# Research questions – answered

**RQ1: Impact of different sensor failure modes on RL TSC agent performance**

**-> varies by agent**

**RQ2: Impact of different sensor noise levels on RL TSC agent performance**

**-> varies by agent**

**RQ3: Does training on noisy data improve robustness?**

**-> yes, quite significantly!**

# Noise impact on agents

<div>Noise</div> <div>Agent</div>	Failure chance	TPR	FPR
MaxPressure	high	low	low
Undisturbed	low	moderate	high
Disturbed	low	low	low

# Power consumption



60 – 150 W



10 – 20 W



1 – 2 W



Raspberry Pi 4

<6 W



Traffic camera

1-10 W  
solar powered

~12-20 / intersection

~1 / 20 intersections

~4-8 / intersection

Traffic lights 1 and 2: <https://www.semanticscholar.org/paper/Safety-Evaluation-of-Converting-Traffic-Signals-to-Srinivasan-Carter/844679009108df4458a571b5da4c9511b975024d/figure/0> (removed frame)

1W traffic light: [https://assets.new.siemens.com/siemens/assets/api/uuid:6a00415b-7e0f-4158-8d26-cf5941888ac0/width:4320/im2016040420mo\\_300dpi.jpeg](https://assets.new.siemens.com/siemens/assets/api/uuid:6a00415b-7e0f-4158-8d26-cf5941888ac0/width:4320/im2016040420mo_300dpi.jpeg)

Raspberry Pi 4: [https://www.berrybase.de/media/image/9a/6a/c8/ID\\_76878\\_orig\\_600x600@2x.jpg](https://www.berrybase.de/media/image/9a/6a/c8/ID_76878_orig_600x600@2x.jpg)

Traffic camera: <https://www.milesight.com/security/product/4g-solar-powered-traffic-sensing-camera>