Master Thesis Final Presentation

Reinforcement Learning in traffic control for Automated Connected Vehicles

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25/09/2020

AGENDA

01 | INTRODUCTION
Background, Timeline, First Steps

02 | SINGLE AGENT
Details on the approach, tested cases , results.

03 | MULTI AGENT
Details on the approach, tested cases , results.

04 | CONCLUCSION
Final remarks and future thoughts.

01

INTRODUCTION

SUMO Scenario, Reinforcement Learning, Timeline

Traffic Management Scenario

- 2 way Highway of 5km
- 2.5 km Autonomous Driving (AD) Zone
- RSU: Road Side Unit ()

- CAV : Connected Automated Vehicles
- CV : Connected Vehicles
- LV : Legacy Vehicles

Traffic Management Scenario

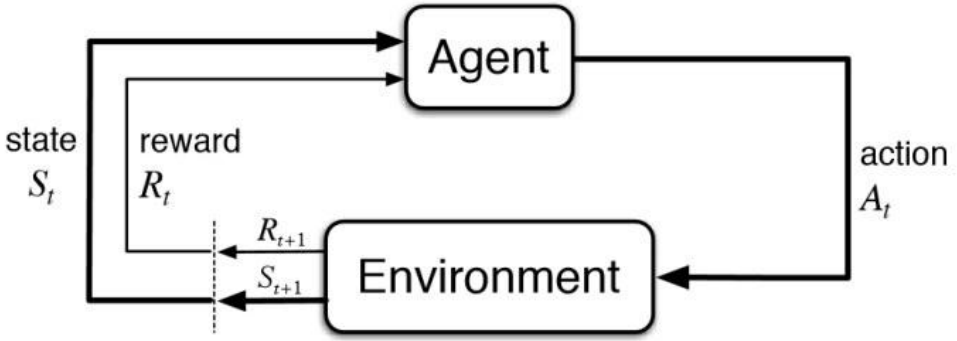
- C(A)Vs approach the no AD zone .
- RSU unit sends take-over request (ToR) messages to C(A)Vs.
- C(A)Vs should perform take-over of control (ToC) before the end of AD zone.

TRANSAID

TRAFFIC MANAGEMENT:

- An already implemented traffic management solution.
- Useful to get insight of the scenario.
- Part of the code has been used in our solutions.
- Operates as the baseline model.

REINFORCEMENT LEARNING



A RL agent:

- Observes the environment.
- Take action on that.
- Receive a reward for this action.
- Continues until reach the final goal.

WHAT WE WANT TO ACHIEVE

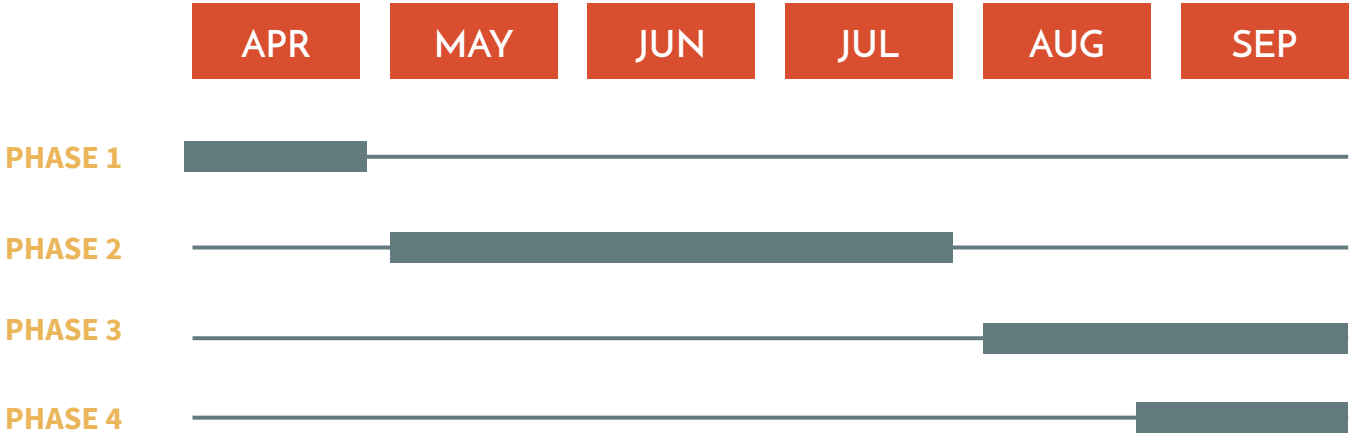
DISTRIBUTE TOC

- Without disrupting traffic flow.
- Without congestion in AD zone.

KEEP AUTONOMOUS

mode for as long as possible.

THESIS TIMELINE



PHASE 1

Introduction to scenario, its purpose and goals.

Experimentation with available frameworks (**FLOW**).

Decision the develop our own custom Reinforcement Learning Framework.

PHASE 2
Single Agent

Set Up the framework (Tensorflow & Stable Baselines & DQN).

Adjust the original TransAID code.

Research, Experimentation, Evaluation.

PHASE 3
Multi Agent

Set Up the framework (Tensorflow & Rllib & DQN).

Adjust previous developed Code.

Research, Experimentation, Evaluation.

PHASE 4

Thesis Writing.

02

SINGLE AGENT

Implementation and Evaluation.

BACKGROUND

Some Details:

- Tensorflow, Stable Baselines and GYM.
- Deep Q-network.
- Research in similar projects
- 30-40 Trainings of the models.
- Model for bad traffic management.
- Automation and Scalability of processes.

INDICATORS

AVG CAV Distance

Covered distance until the moment of issued ToR.

Congestion - Waiting Time

The time in which the vehicle speed was below 0.1m/s.

TravelTime

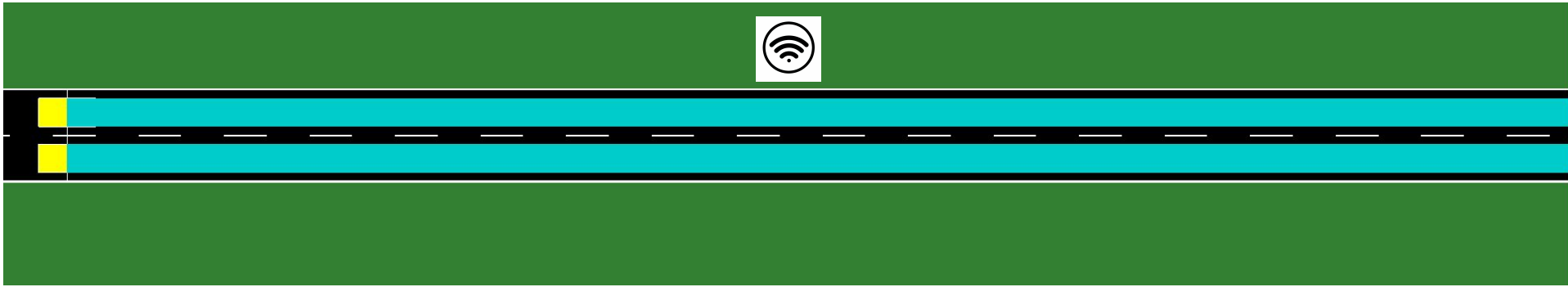
The estimated travel time in a lane.

MeanSpeed

The mean speed of vehicles in a lane.

STRATEGY 1

2 lanes

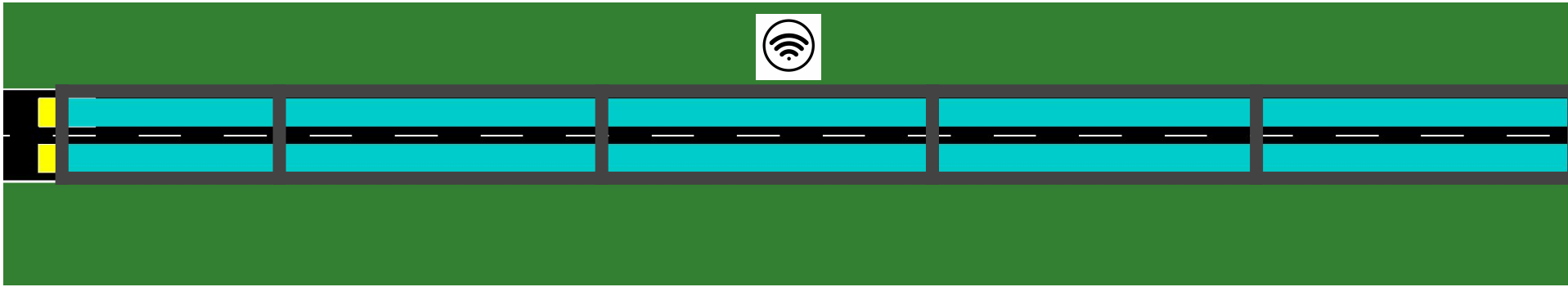


We tried to achieve:

- Maximum Mean Speed.
- Minimum Travel Time.
- Distribute ToR messages based on Density.

STRATEGY 2

10 cells

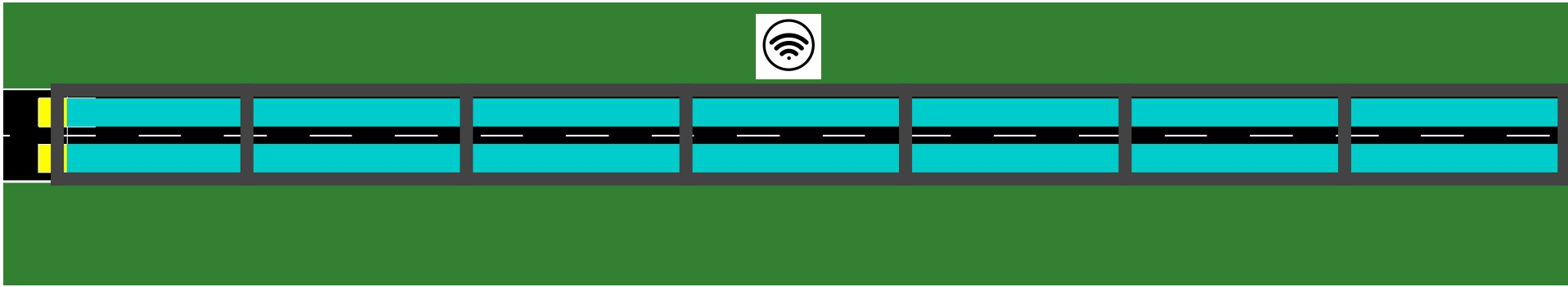


We tried to achieve:

- Better distribution of ToR messages.
- Minimize Congestion of vehicles.
- Keep balanced traffic flow.

STRATEGY 3

14 cells



We tried to achieve:

- Maximum covered distance of C(A)Vs.
- Stable traffic flow.
- Eliminate Congestion Incidents.
- Try to predict congestion by observing speeds.

CHECKLIST

	STRATEGY 1	STRATEGY 2	STRATEGY 3a	STRATEGY 3b
REDUCE TRAVEL TIME	✗	✓	✓	✗
MINIMIZE CONGESTION	✗	✗	✓	✓
INCREASE AVG CAV DISTANCE	✗	✓	✓	✓

EVALUATION METHOD

STEP 1

Run 10 simulation per trained model.

STEP 2

Collect data from tripinfo.xml.

STEP 3

Collect data saved during the simulation.

STEP 4

Compare the models and produce the plots.

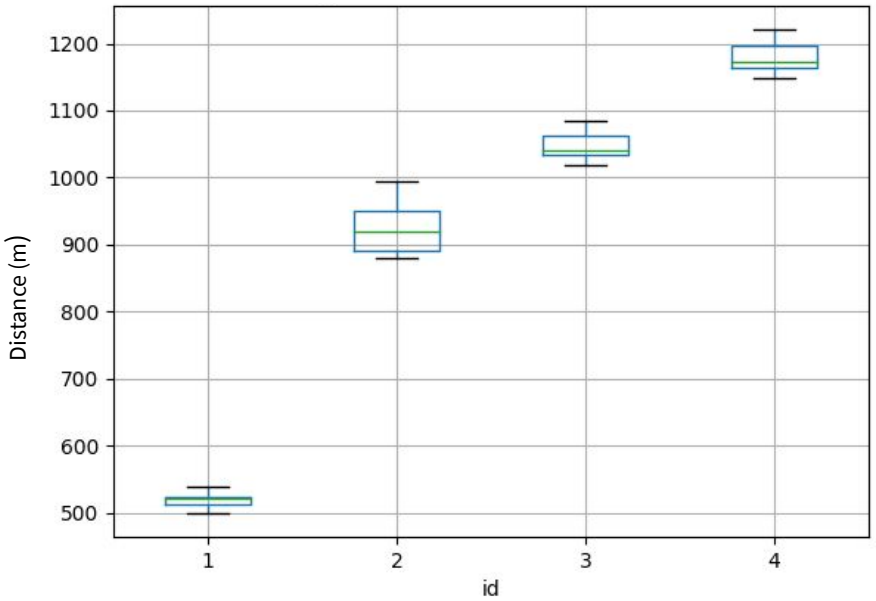
Boxplot of Average covered distance by C(A)Vs in Meters.

TransAID — ID 1

Strategy 2 — ID 2

Strategy 3a — ID 3

Strategy 3b — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

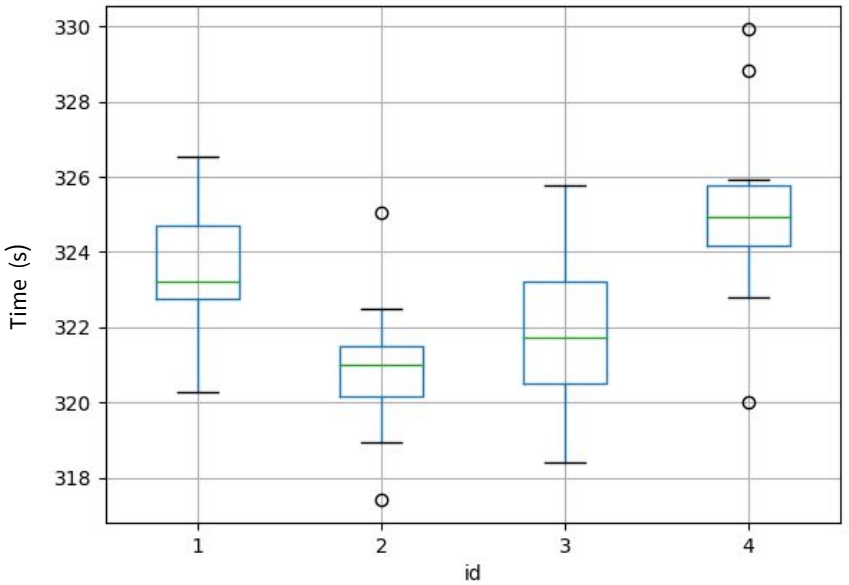
Boxplot of TravelTime sum for both lanes in Seconds.

TransAID — ID 1

Strategy 2 — ID 2

Strategy 3a — ID 3

Strategy 3b — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

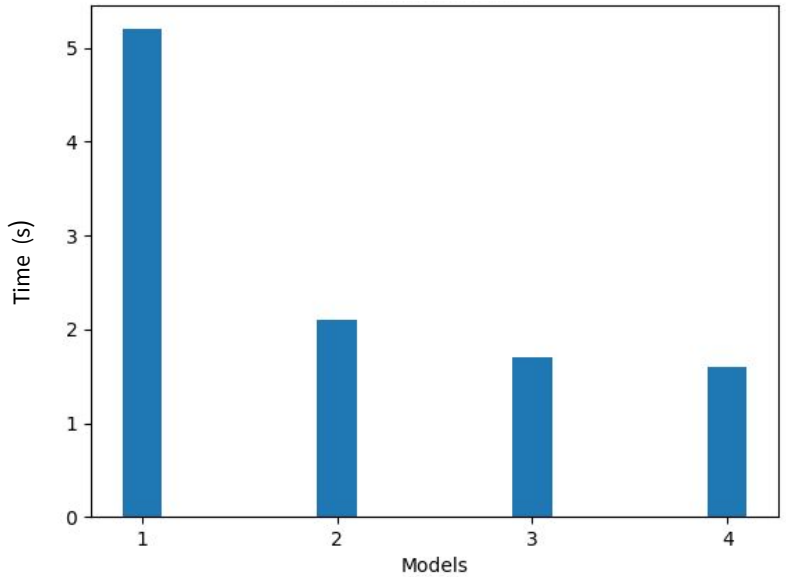
Plot of Total Waiting-Congestion Time in Seconds.

TransAID — ID 1

Strategy 2 — ID 2

Strategy 3a — ID 3

Strategy 3b — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

03

MULTI AGENT

Implementation and Evaluation.

BACKGROUND

Some Details:

- Tensorflow and Rllib.
- Deep Q-network.
- 30-40 Trainings of the models.
- Research in similar projects
- Automation and Scalability of processes.
- 2,3,6 Agents -> 3 Agents

INDICATORS

AVG CAV Distance

Covered distance until the moment of issued ToR.

Congestion - Waiting Time

The time in which the vehicle speed was below 0.1m/s.

TravelTime

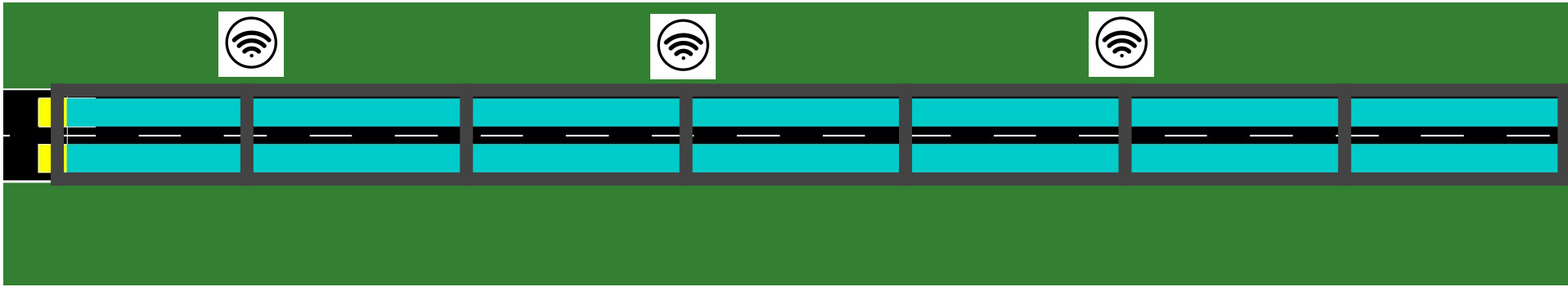
The estimated travel time in a lane.

MeanSpeed

The mean speed of vehicles in a lane.

STRATEGY A

14 cells

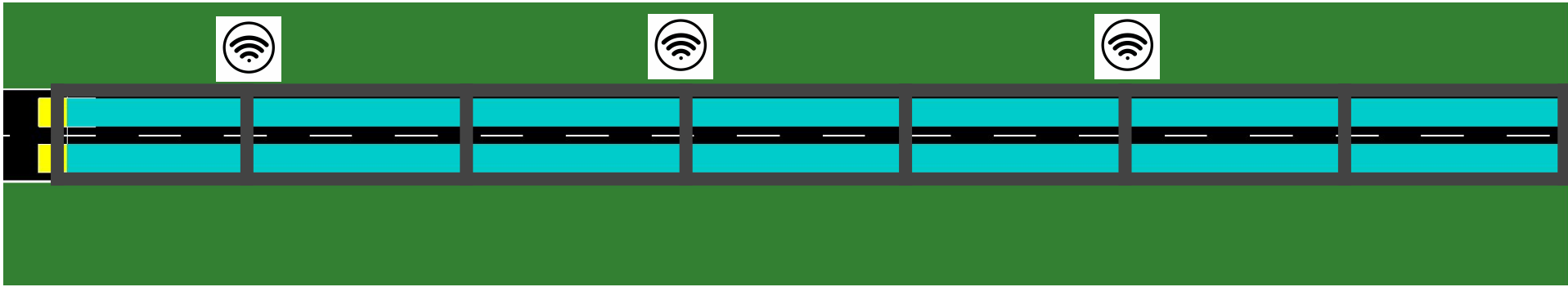


Our goal was to achieve:

- Transform Single Agent Strategy 3 to MultiAgent
  - Maximum covered distance of C(A)Vs.
  - Stable traffic flow.
  - Minimum Congestion Incidents.

STRATEGY B

14 cells



Our goal was to achieve:

- Increasing ToR distribution.
- Increase covered distance of C(A)Vs..
- Minimum Congestion Incidents.
- More manipulation on First Agent.

CHECKLIST

	STRATEGY A	STRATEGY B1	STRATEGY B2
REDUCE TRAVEL TIME	✓	✗	✗
MINIMIZE CONGESTION	✗	✓	✓
INCREASE AVG CAV DISTANCE	✓★	✓★	✓★

EVALUATION METHOD

STEP 1

Run 10 simulation per trained model.

STEP 2

Collect data from tripinfo.xml.

STEP 3

Collect data saved during the simulation.

STEP 4

Compare the models and produce the plots.

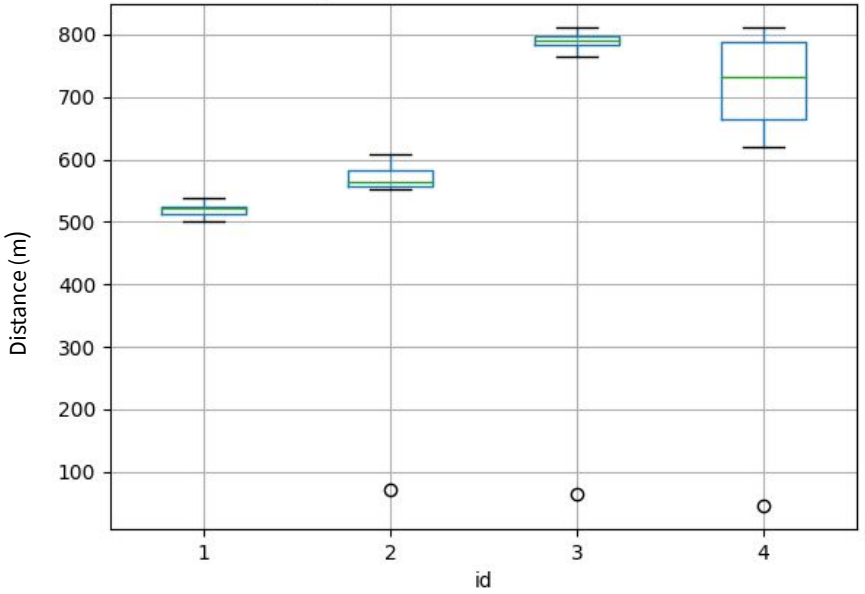
Boxplot of Average covered distance by C(A)Vs in Meters.

TransAID — ID 1

Strategy A — ID 2

Strategy B1 — ID 3

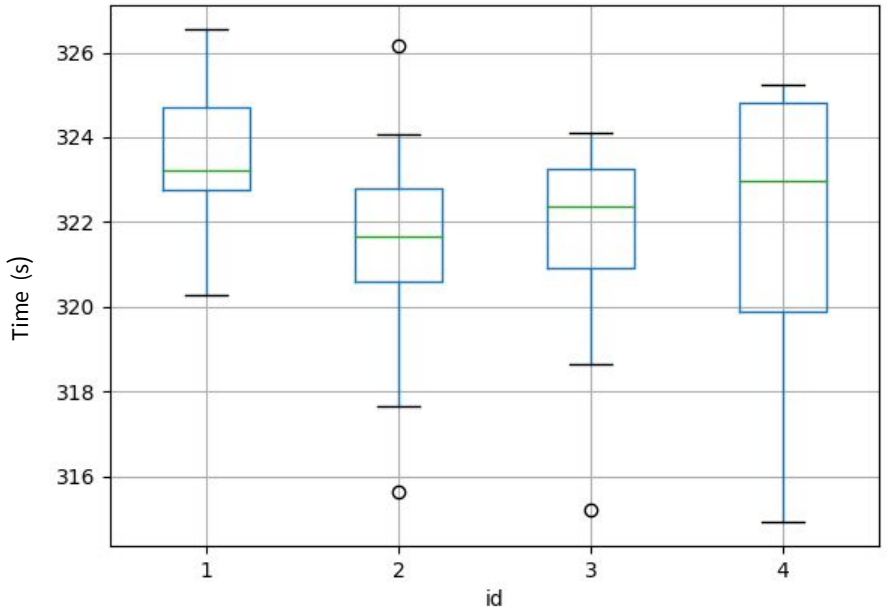
Strategy B2 — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

Boxplot of TravelTime sum for both lanes in Seconds.

TransAID	ID	1
Strategy A	ID	2
Strategy B1	ID	3
Strategy B2	ID	4



Boxplots of values gained from 10 simulations rounds for every model.

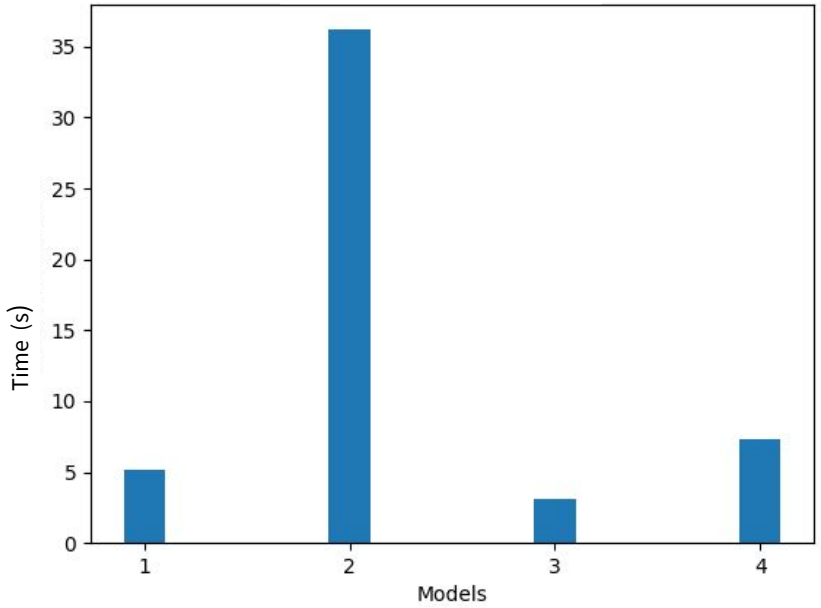
Plot of Total Waiting-Congestion Time in Seconds.

TransAID — ID 1

Strategy A — ID 2

Strategy B1 — ID 3

Strategy B2 — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

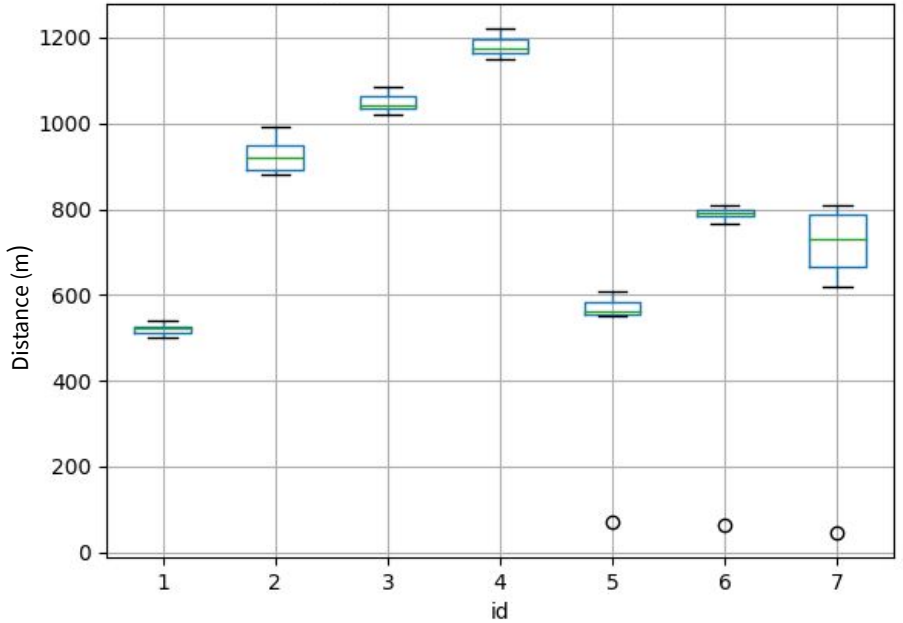
04

Conclusion

Final Thoughts, Future steps.

Boxplot of Average covered distance by C(A)Vs in Meters.

TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

Boxplot of TravelTime sum for both lanes in Seconds.

TransAID	ID 1
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Strategy 3a	ID 3
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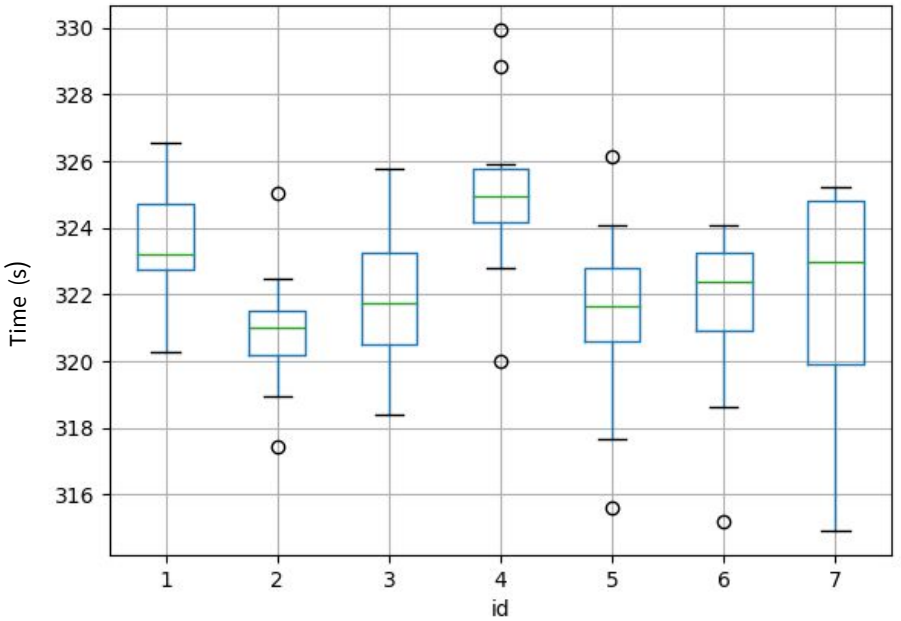
Strategy B2	ID 7



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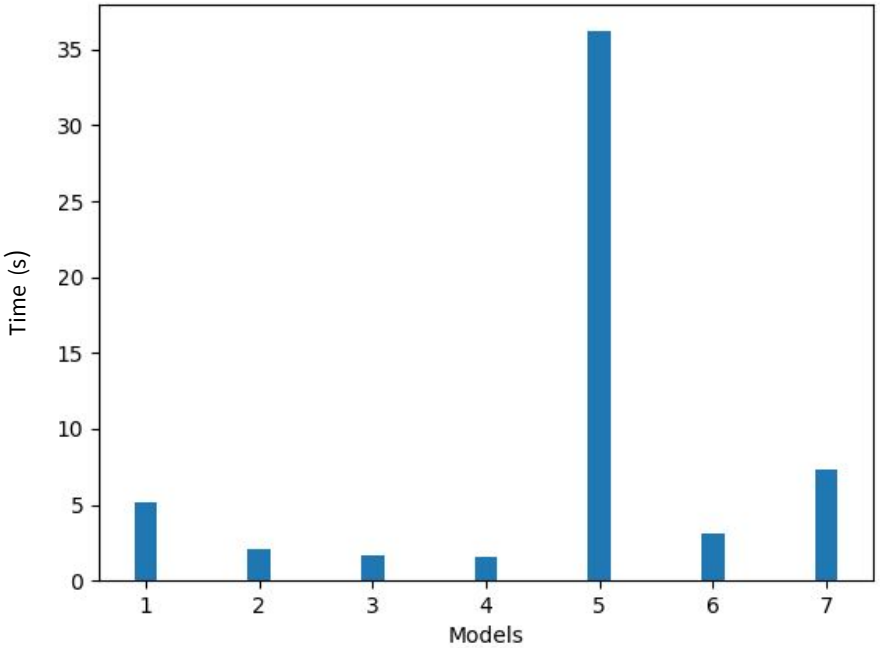


Boxplots of values gained from 10 simulations rounds for every model.

CONCLUSION

SUMMARY:

- The Single Agent approach has better results.
- The Multi Agent approach needs more investigation.
- The appearance of Congestion-Waiting Time is possible.
- More time on training should be allocated.
- Increase of CAV AVG leads to Increase of Travel Time.

PROBLEMS:

- First Agent Symptom in Multi Agent
  (More Agents, Bigger Problem).
- Stability issues - Robustness.

FUTURE WORK

SOME THOUGHTS:

- More research on Multi Agent approach.
- Explore different approach (no cells).
- Improve the Robustness of the models.
- Longer training processes.

THANK YOU

Do you have any questions?

Q&N SLIDES

DQN

PARAMETERS:

- **Learning_rate** : learning rate for adam optimizer
- **Buffer_size**: size of the replay buffer
- **Batch_size**: fraction of entire training period over which the exploration rate is annealed
- **Exploration_fraction**: fraction of entire training period over which the exploration rate is annealed
- **Target_network_update_freq**: update the target network every target_network_update_freq steps.

TRAINING

DETAILS:

- Train on random seeds (1024-2024).
- 30-60 trains give fair results.
- Tensorboard support to visualize training.
- Keep a training record for the variations.

EVALUATION

DETAILS:

- 10 simulation with 10 given seeds .
- Boxplots helps in tracing the outliers.
- Csv file :
  - AVG CAV Distance
  - TravelTime
  - MeanSpeed
- Tripinfo.xml
  - WatitingTime
  - Timeloss, DepartDelay,Duration, etc

FLOW CASE

DETAILS:

- Couldn’t load our xml files.
- Our flows definition were using more sophisticated type distributions.
- Patch over patch led to a mess.

SOFTWARE

TOOLS:

- Python
- Anaconda
- Tensorflow, TensorBoard
- OpenAI Gym
- Stable Baselines
- Rllib

MORE RESULTS

EXTRA INDICATORS

TimeLoss

The time lost due to driving below the ideal speed.

departDelay

The time the vehicle had to wait before it could start his journey.

waitingCount

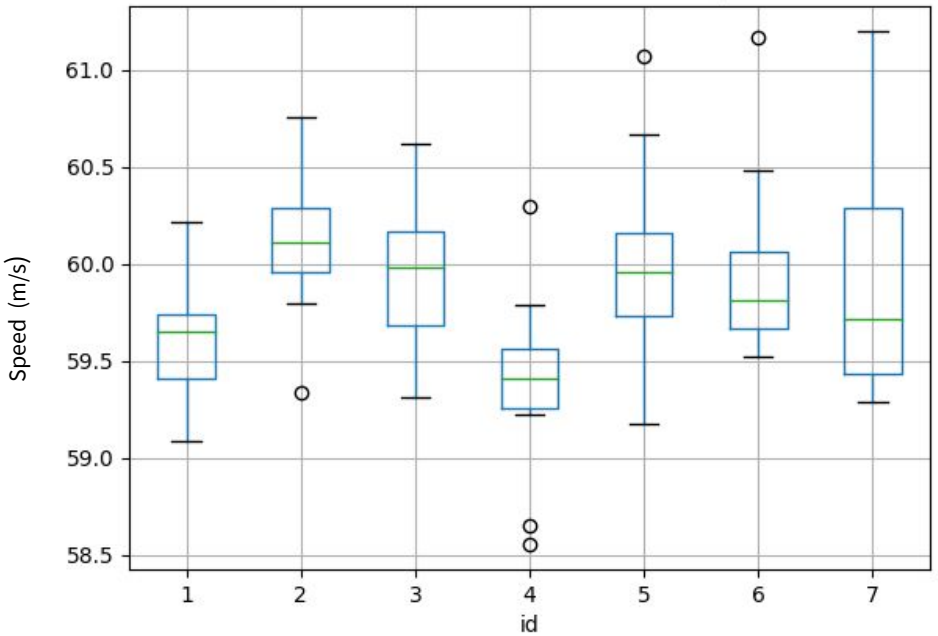
Number of waitingTime episodes.

duration

The time the vehicle needed to accomplish the route.

Boxplot of MeanSpeed for both lanes in m/s.

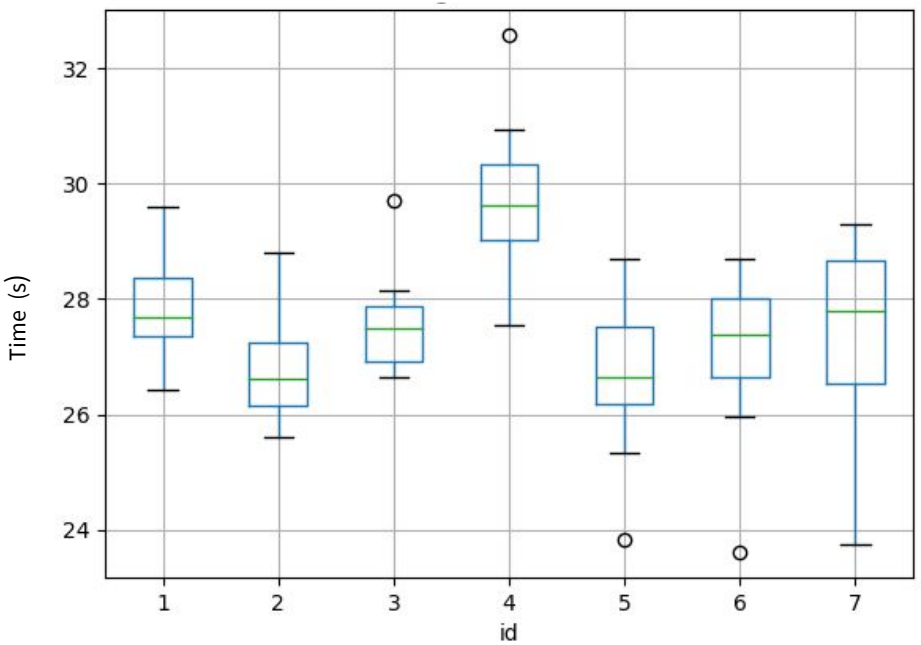
TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

Boxplot of TimeLoss for both lanes in Seconds.

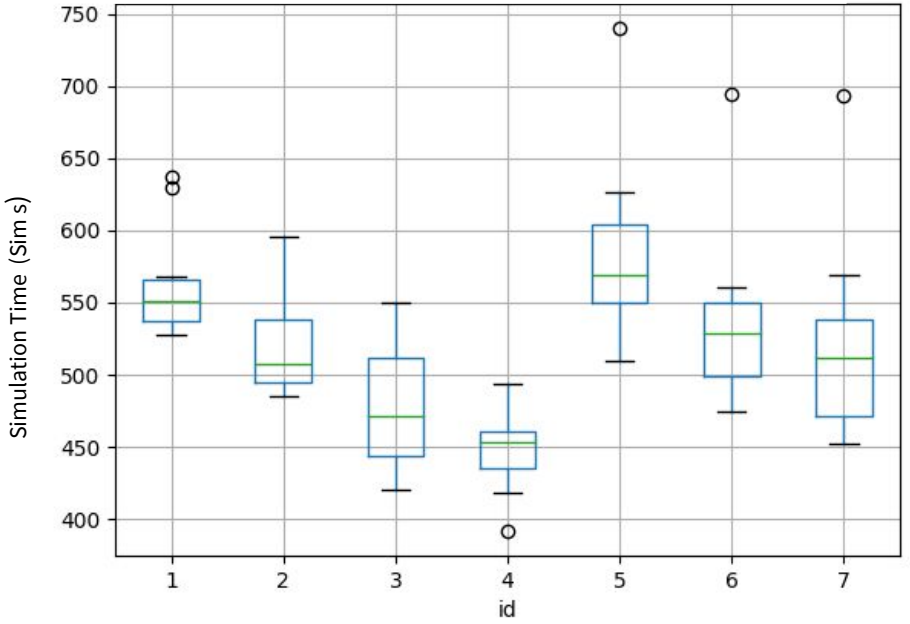
TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

Boxplot of DepartDelay for both lanes in Seconds.

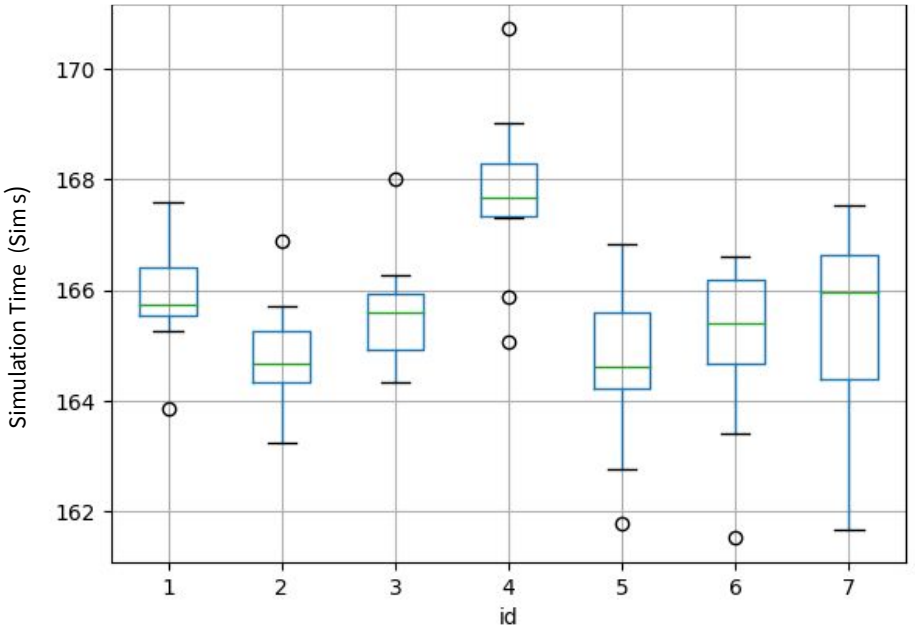
TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

Boxplot of Duration for both lanes in Seconds.

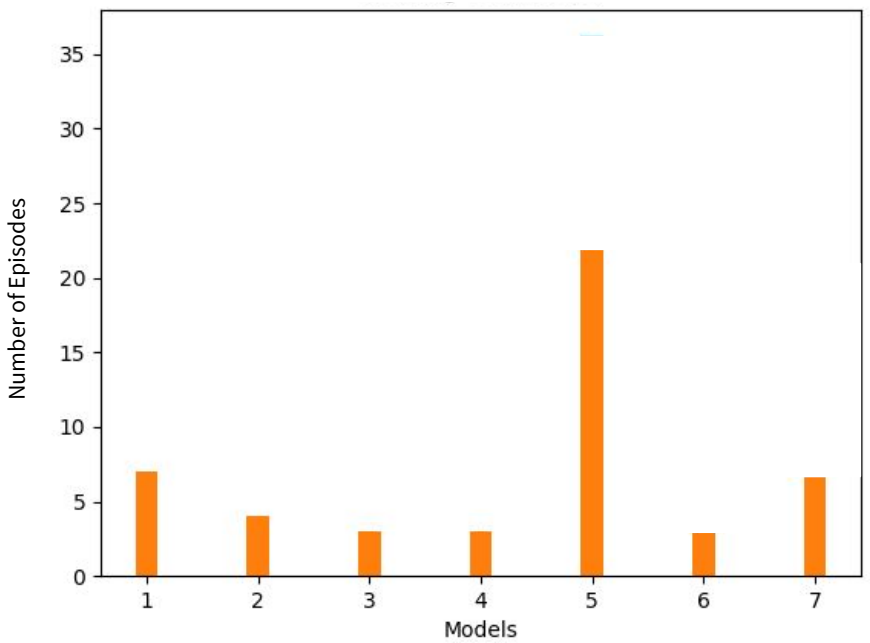
TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

Plot of Total Waiting-Congestion Episodes.

TransAID	ID 1
Strategy 2	ID 2
Strategy 3a	ID 3
Strategy 3b	ID 4
Strategy A	ID 5
Strategy B1	ID 6
Strategy B2	ID 7



Boxplots of values gained from 10 simulations rounds for every model.

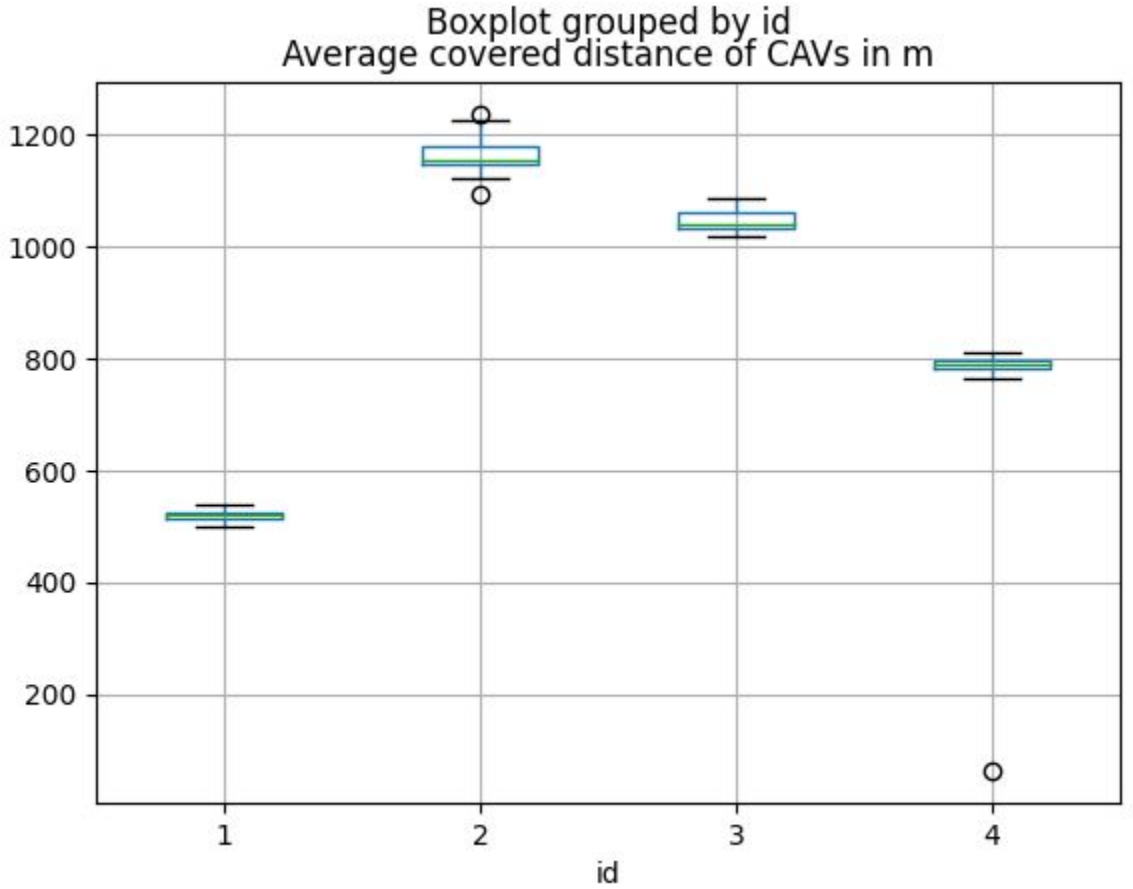
BAD MODEL

TransAID — ID 1

Bad model — ID 2

Strategy 3a — ID 3

Strategy B1 — ID 4



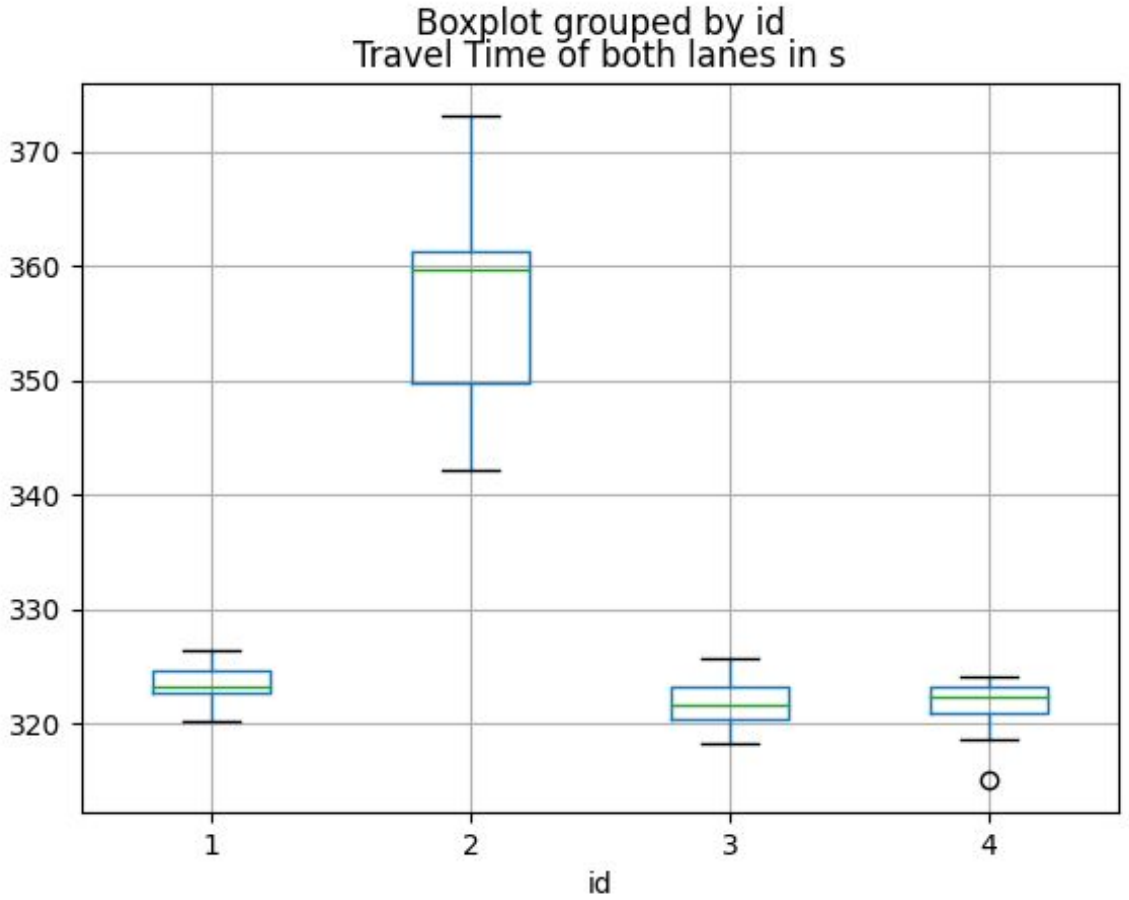
Boxplots of values gained from 10 simulations rounds for every model.

TransAID — ID 1

Bad model — ID 2

Strategy 3a — ID 3

Strategy B1 — ID 4



Boxplots of values gained from 10 simulations rounds for every model.

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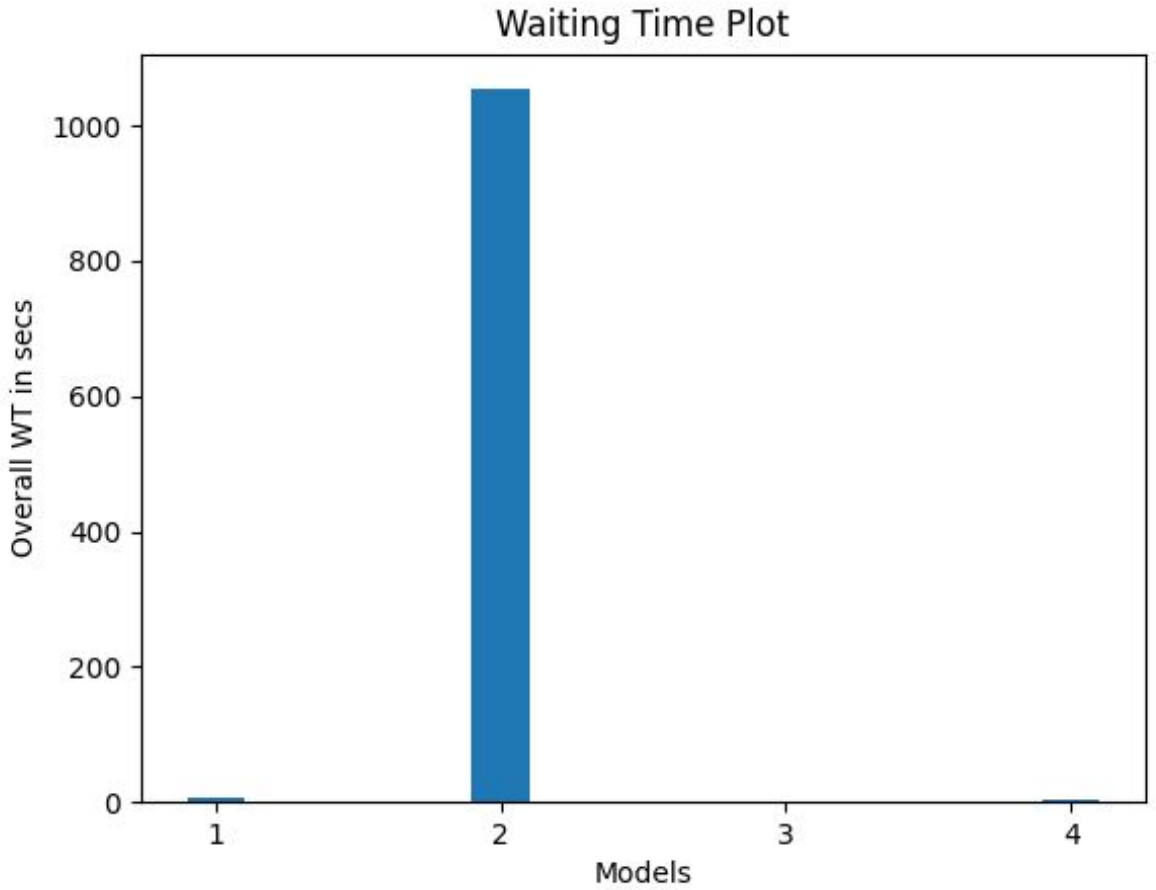

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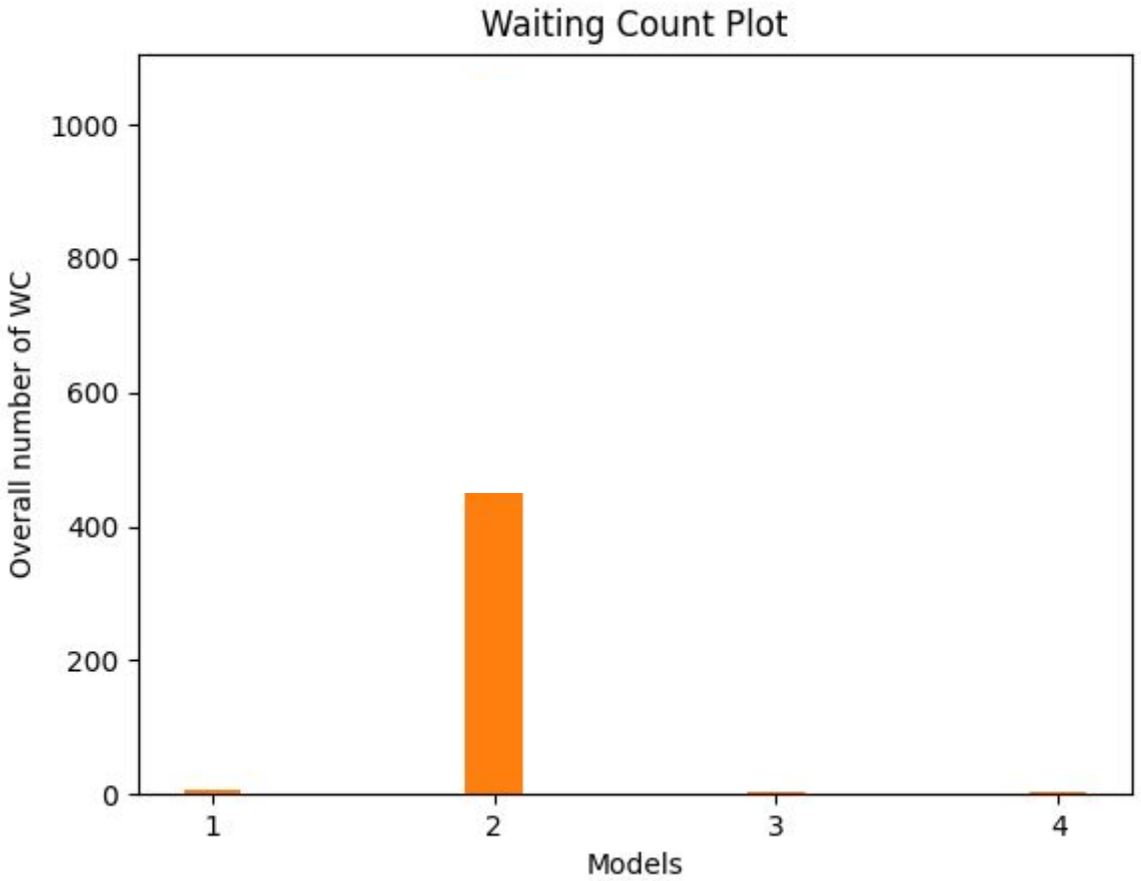

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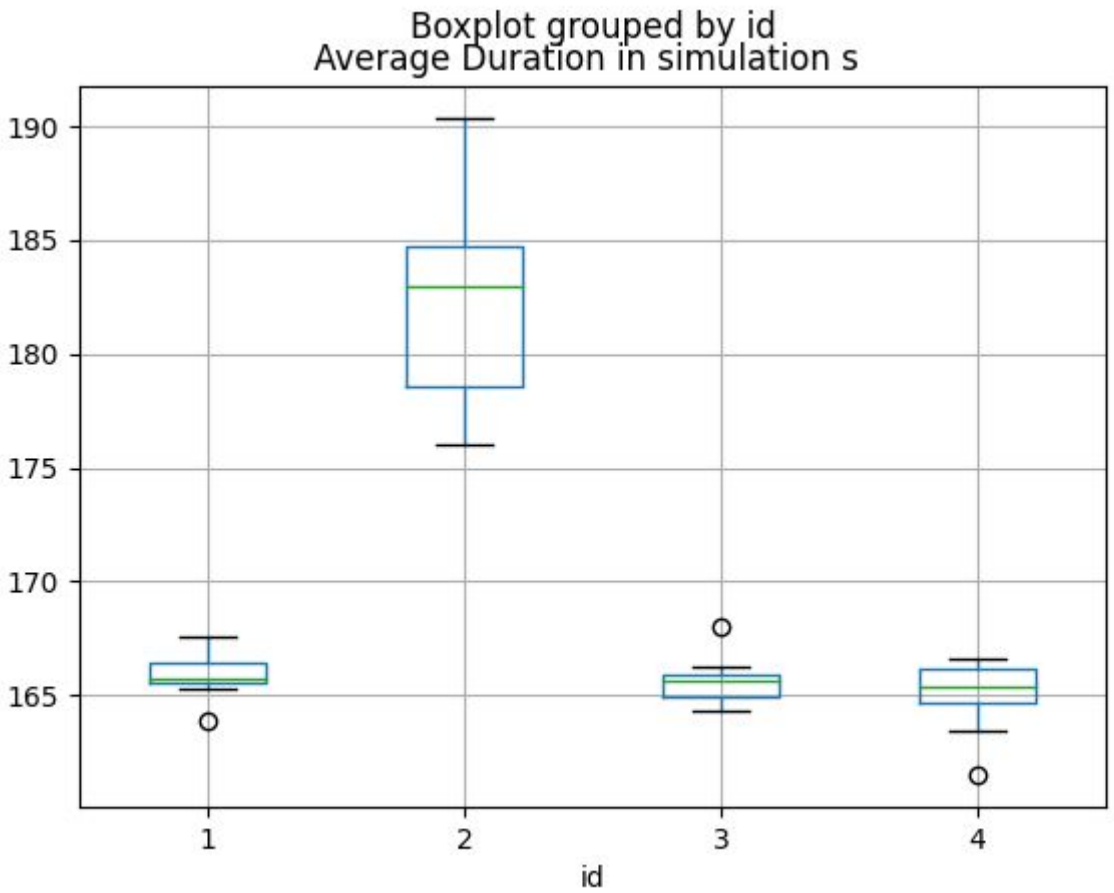


Boxplots of values gained from 10 simulations rounds for every model.

RESULTS
BOXPLOTS

TransAID — ID 1

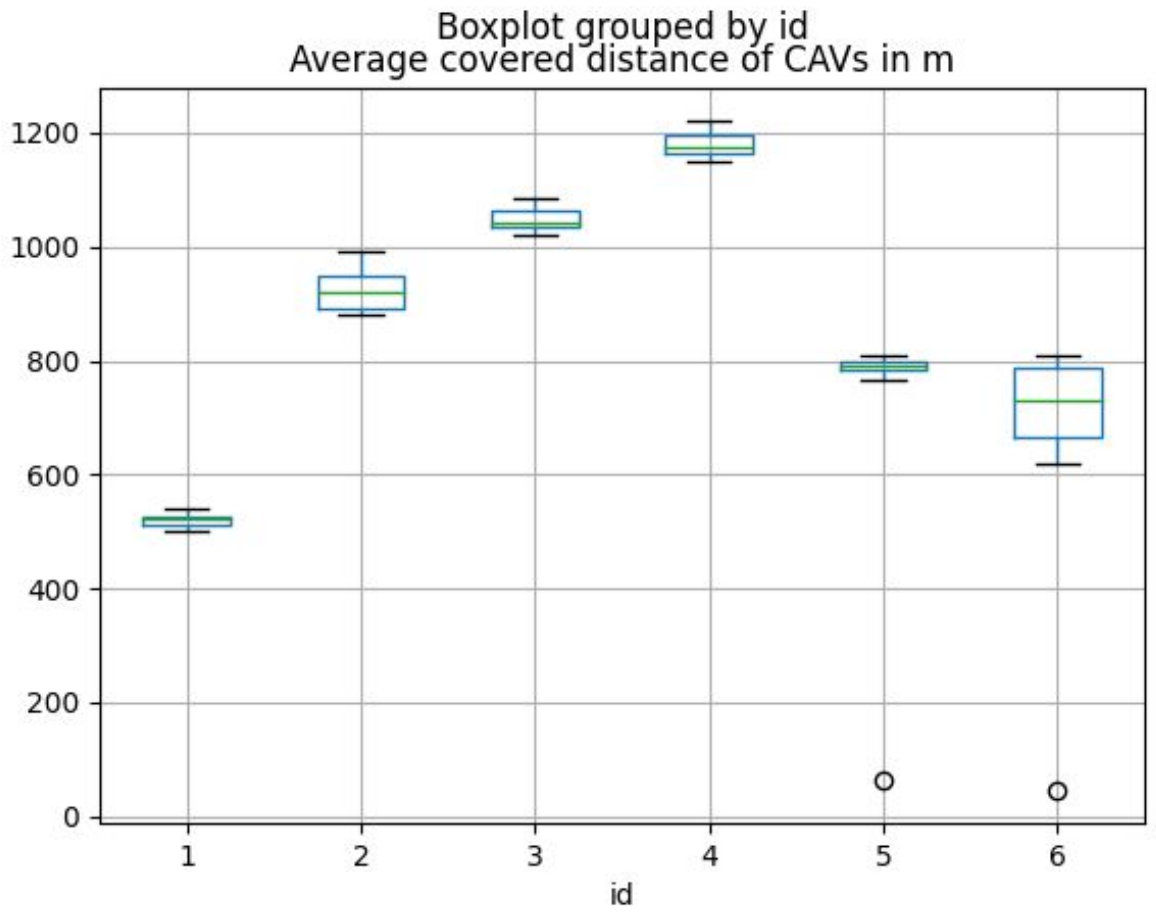
Strategy 2 — ID 2

Strategy 3a — ID 3

Strategy 3b — ID 4

Strategy B1 — ID 5

Strategy B2 — ID 6



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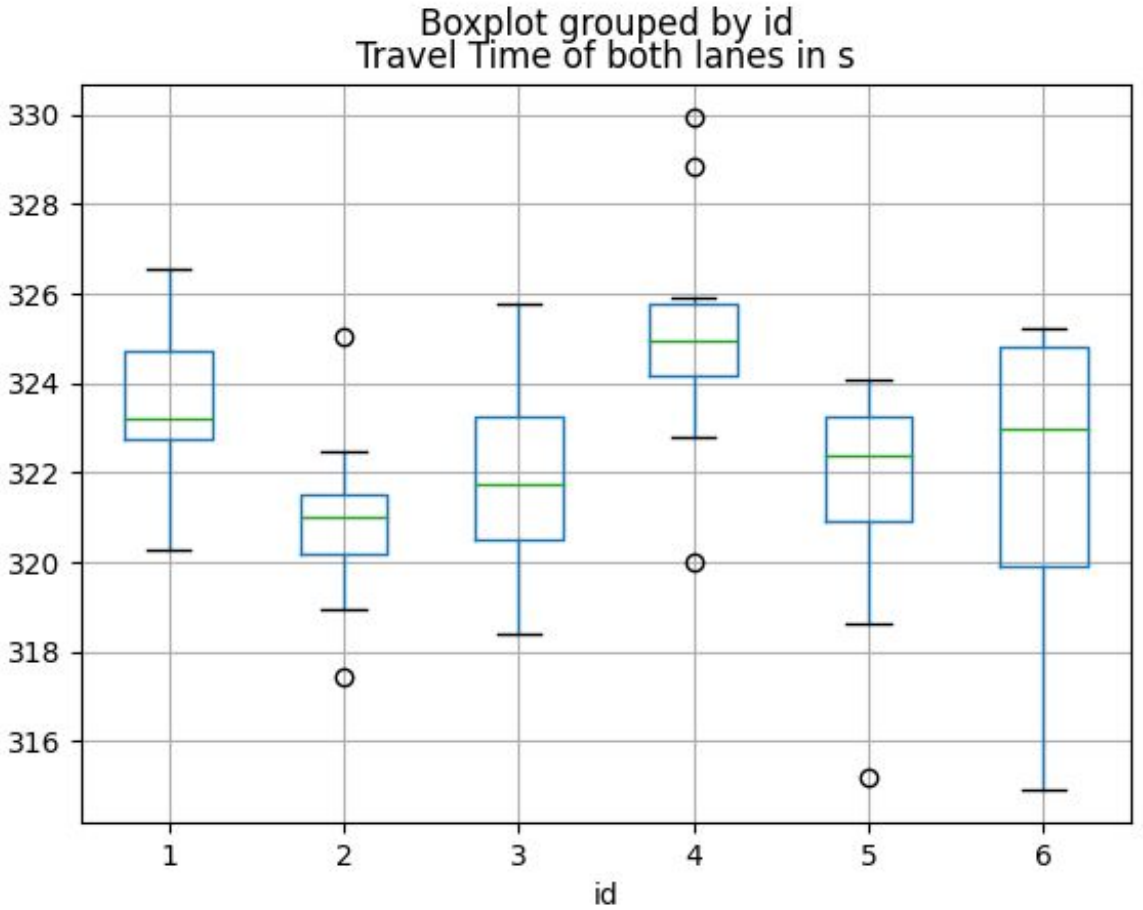

Boxplots of values gained from 10 simulations rounds for every model.

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Strategy 3a — ID 3

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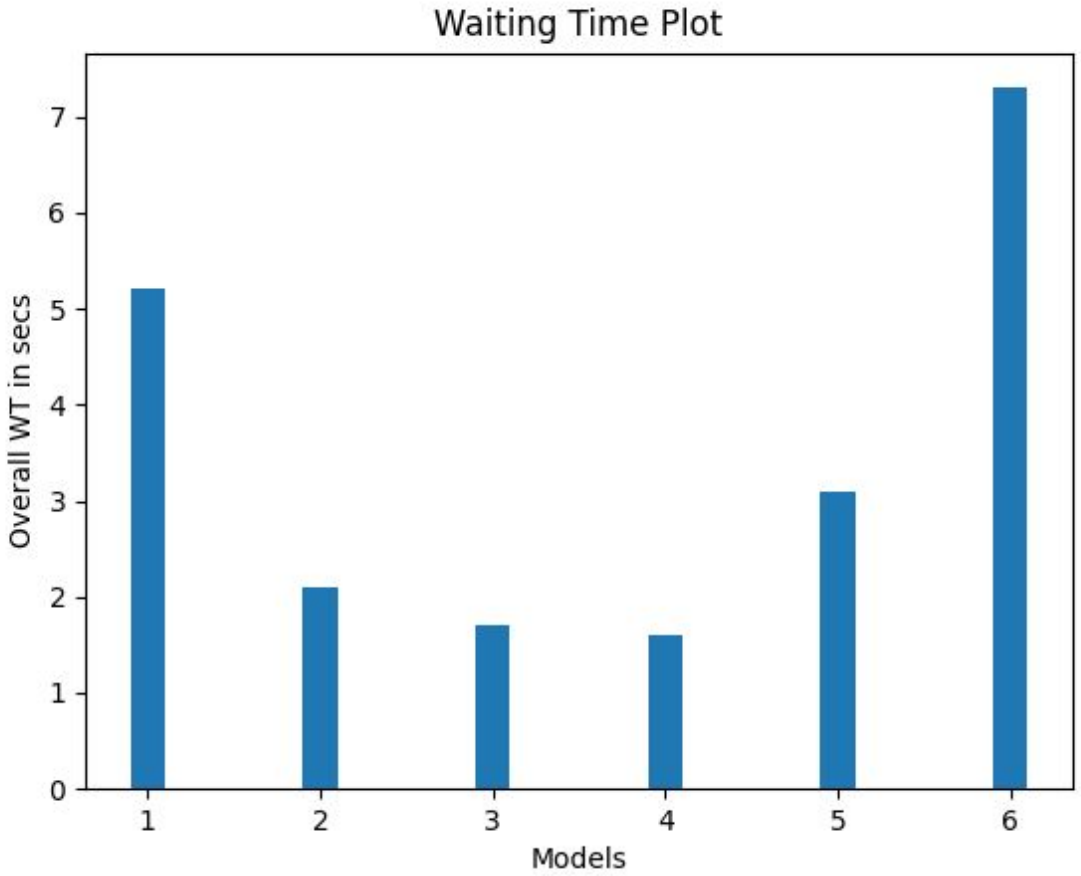

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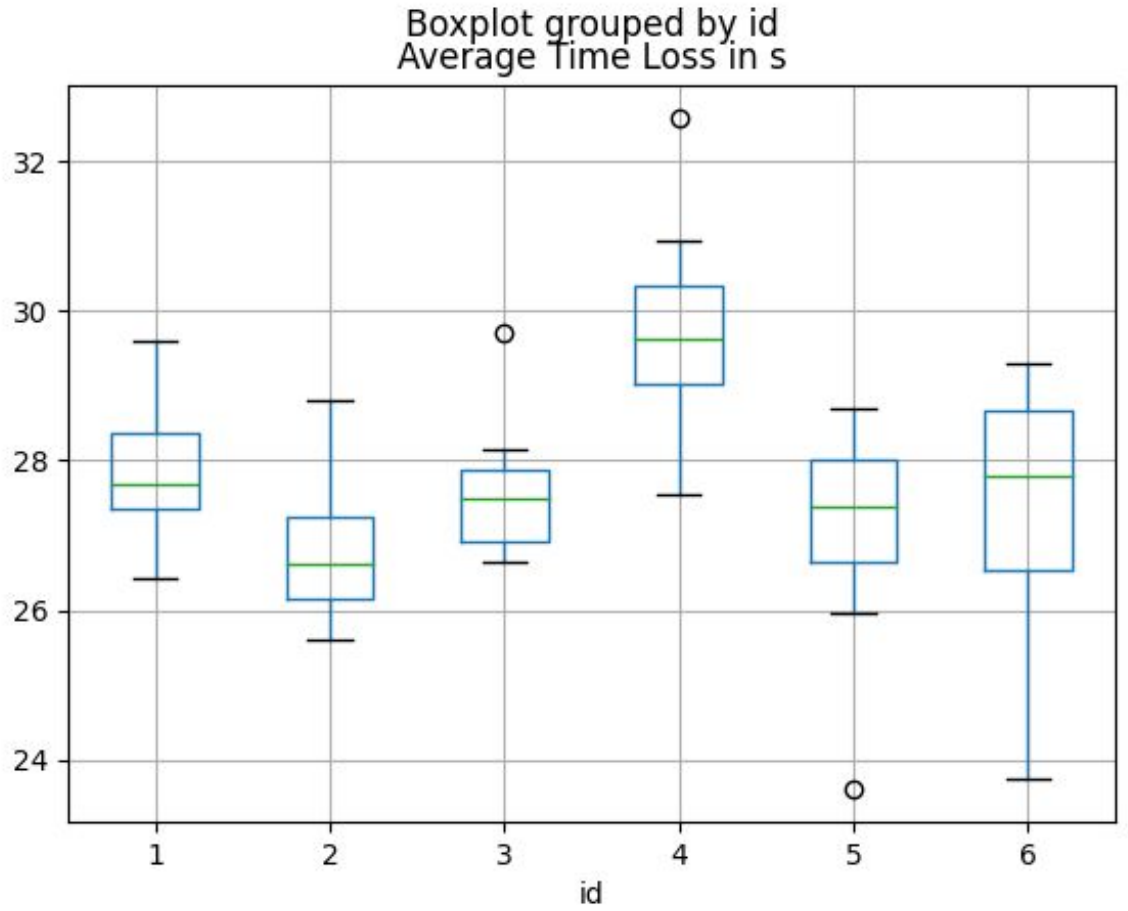
Strategy B1 — ID 5

Strategy B2 — ID 6



Boxplots of values gained from 10 simulations rounds for every model.

TransAID — ID 1

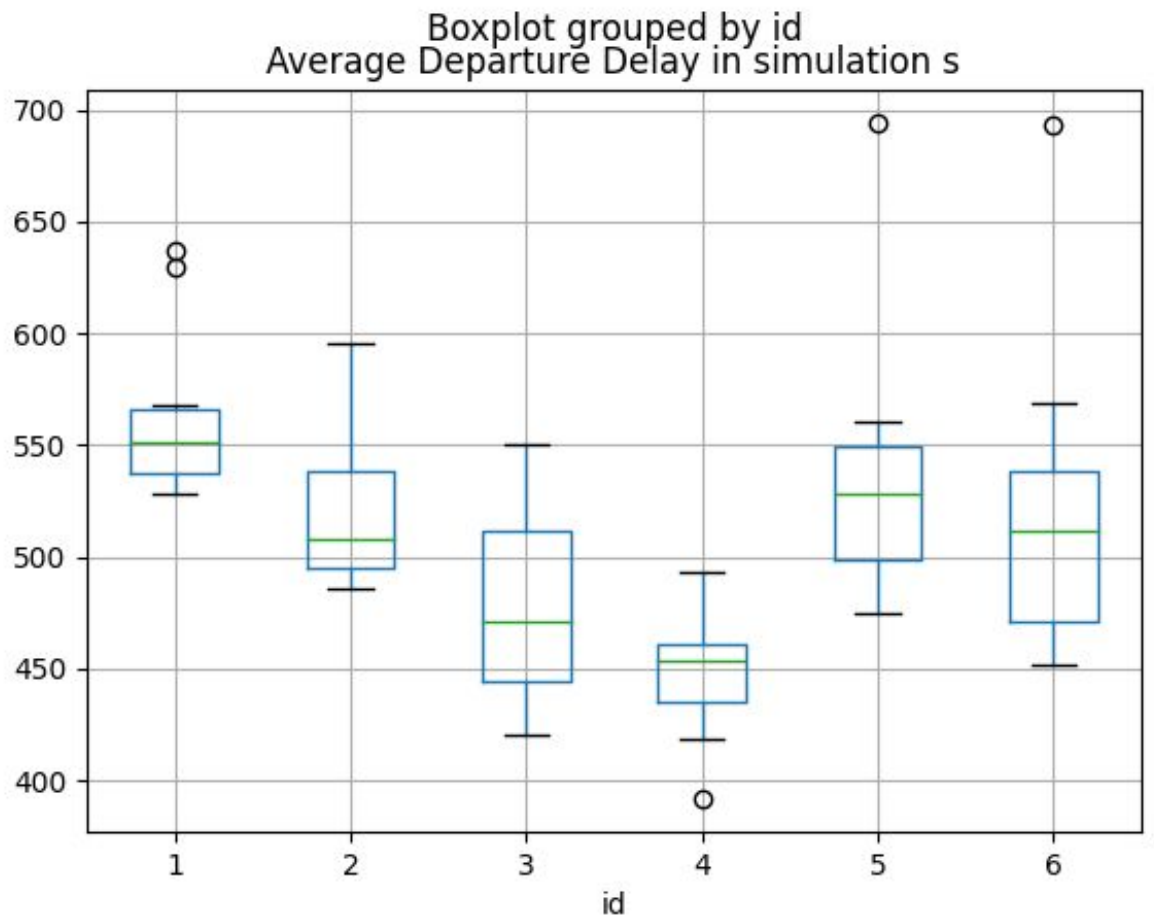
Strategy 2 — ID 2

Strategy 3a — ID 3

Strategy 3b — ID 4

Strategy B1 — ID 5

Strategy B2 — ID 6



Boxplots of values gained from 10 simulations rounds for every model.

TransAID — ID 1

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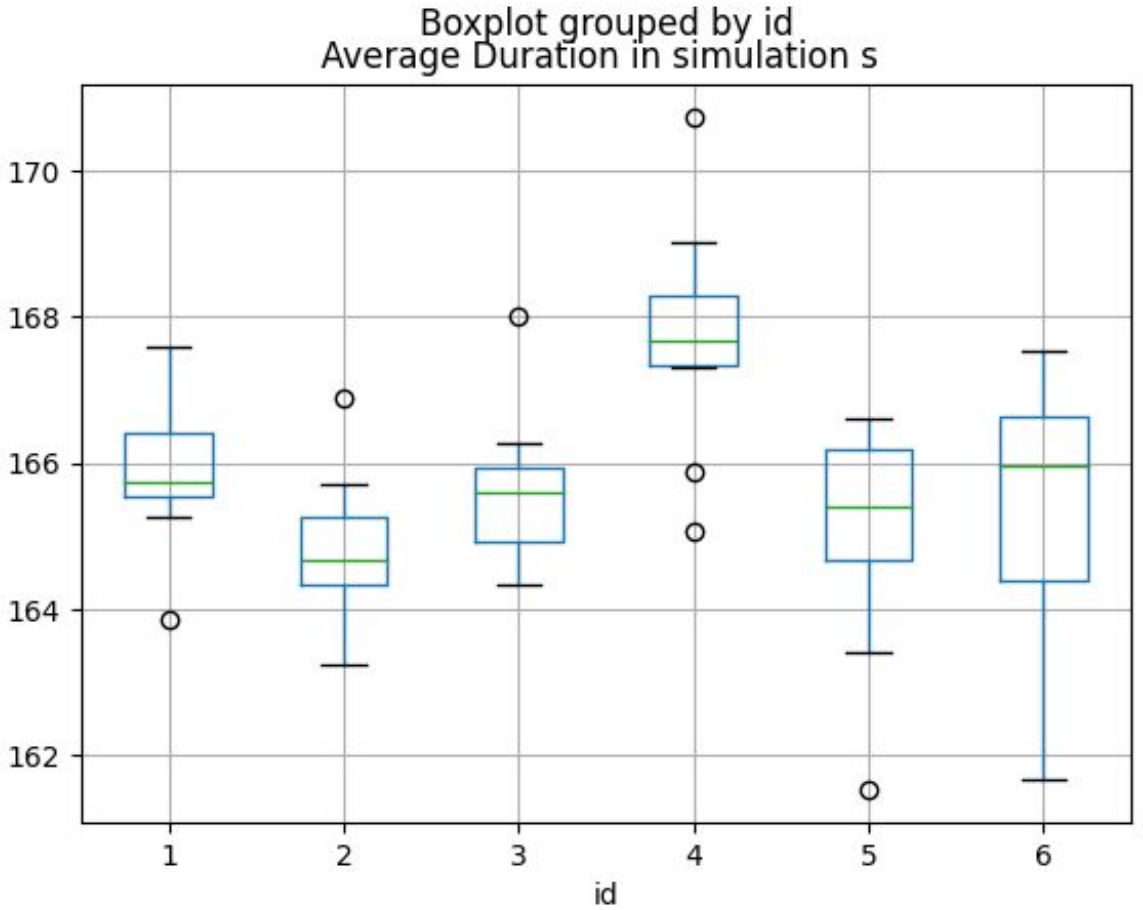
Strategy B1 — ID 5

Strategy B2 — ID 6



Boxplots of values gained from 10 simulations rounds for every model.

TransAID — ID 1

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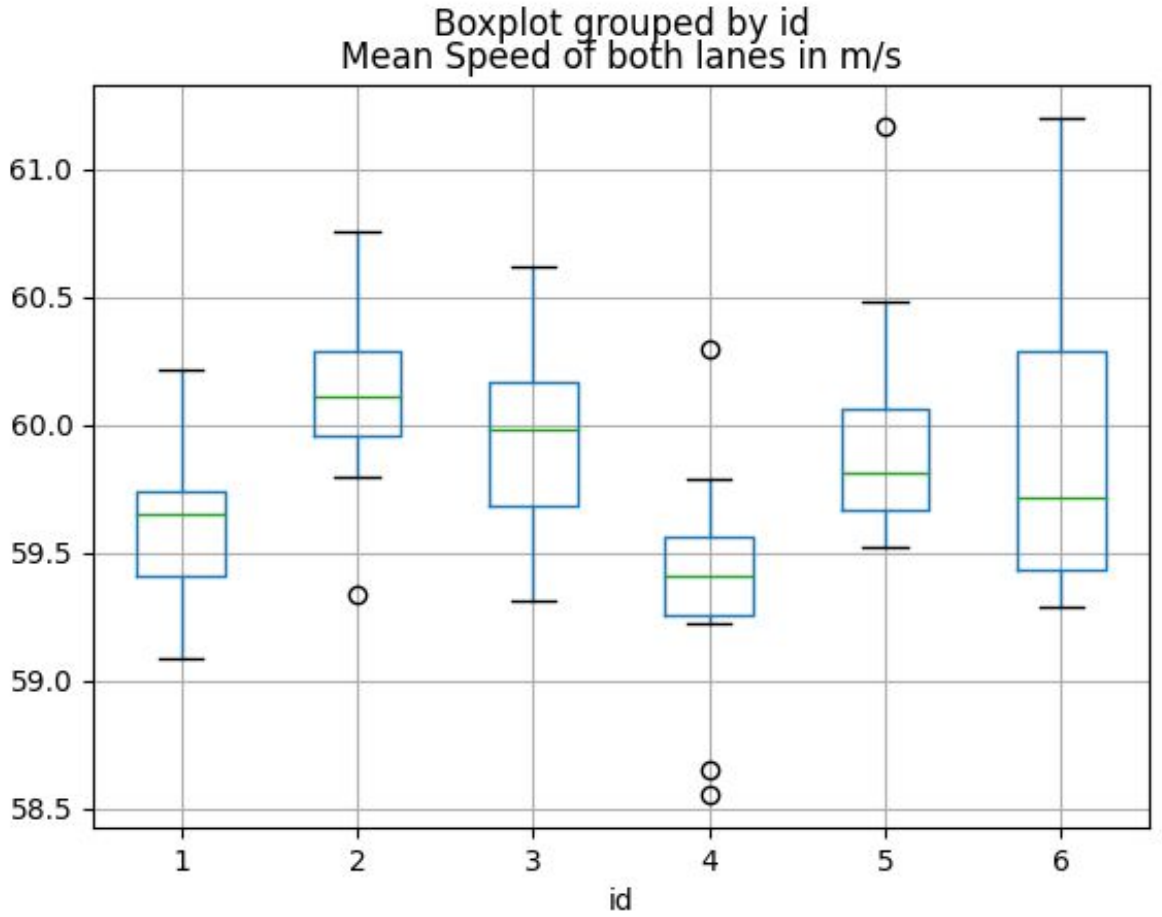
Strategy B2 — ID 6



Boxplots of values gained from 10 simulations rounds for every model.

TransAID — ID 1

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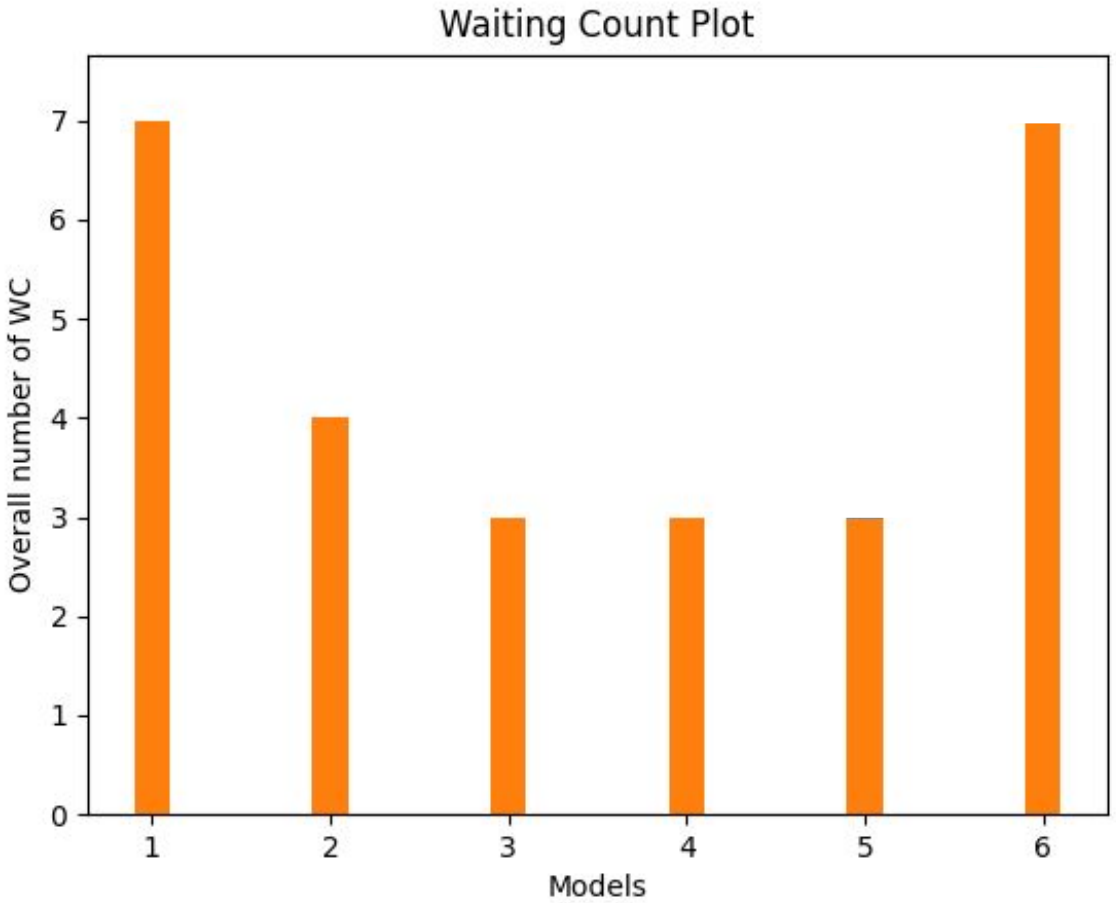

Boxplots of values gained from 10 simulations rounds for every model.

THANK YOU (Again)

Do you have any questions?