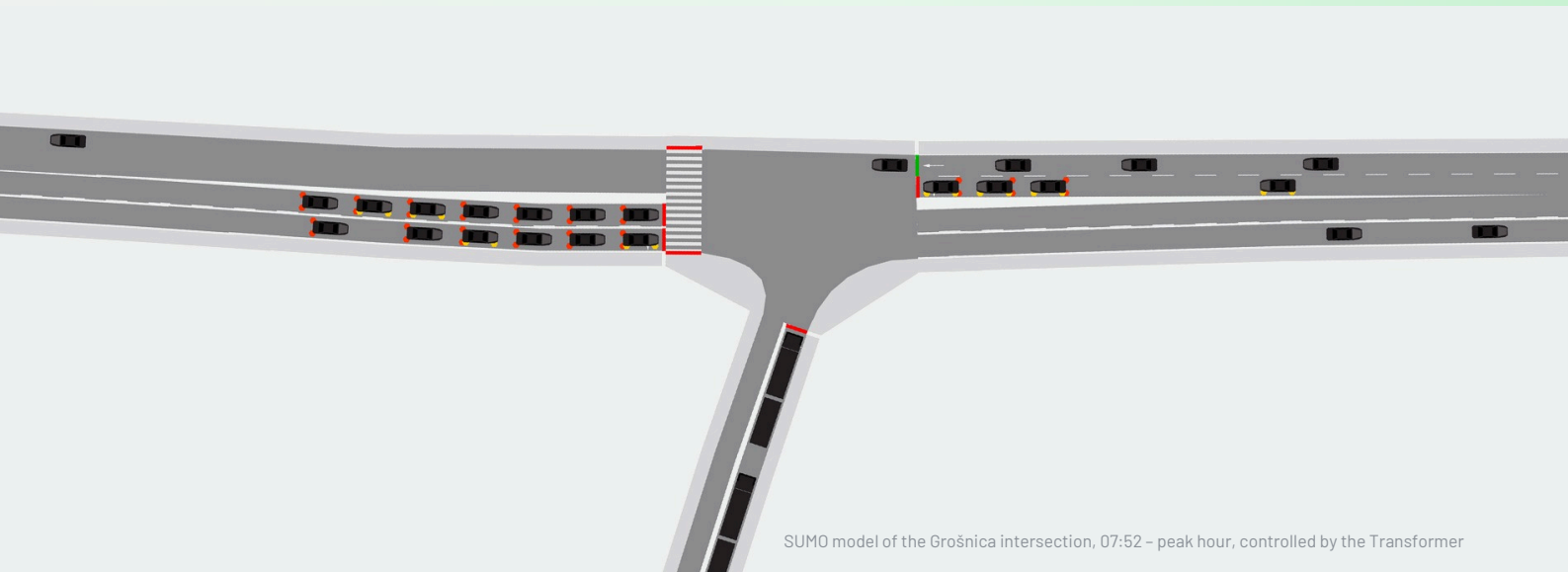


INTERSECTION CONTROL USING ARTIFICIAL INTELLIGENCE

THE TRAFFIC LIGHT THAT LEARNS BY ITSELF - TRANSFORMER AND REINFORCEMENT LEARNING



SUMO model of the Grošnica intersection, 07:52 - peak hour, controlled by the Transformer

Methods

FUZZY

Compares the number of vehicles in the lanes of the active and conflicting phases. Based on 25 predefined rules, it decides: **extend the current phase** or **move to the next one**.

Every hour **5-8%** less delay than the baseline algorithm

TRANSFORMER

A special neural-network architecture. Every second it analyses the state of all lanes and decides: extend or end the current phase. It trains itself inside the simulation.

In daytime **7-12%** less delay than the baseline algorithm



Learns by itself,
in simulation



Every second: extend
or end the phase



Safety defined
by the signal
plan



0.23 ms on
ARM Cortex-A72



New intersection -
same system

 artificial intelligence

When to move to the next phase?

FUZZY - 25 rules written by an engineer

CURRENT \ NEXT	empty	low	medium	high	full
empty	0.2	0.4	0.6	0.8	1
low	0	0.2	0.4	0.6	0.8
medium	0	0	0.2	0.4	0.6
high	0	0	0	0.2	0.4
full	0	0	0	0	0.2

Weighted average $> 0.55 \rightarrow$ switch

Similar shape - it switches when many vehicles are waiting and few are in the active phase. One map was defined by an engineer, the other was **learned by the network itself**. The Transformer has different rules for each phase.

TRANSFORMER - learned the rules by itself

CURRENT \ NEXT	0	1	2	3	4+
0	0.36	0.71	0.90	0.94	0.95
1	0.08	0.22	0.25	0.37	0.55
2	0	0	0	0	0.26
3	0	0	0	0	0.25
4+	0	0	0	0.01	0.26

Switching weight > 0.5 .

RESULTS IN CALIBRATED SUMO MODELS

5 to 8%

Less delay with **Fuzzy** than the baseline algorithm at Grošnica, every hour (23 to 52% vs. Fix LISA)

7 to 12%

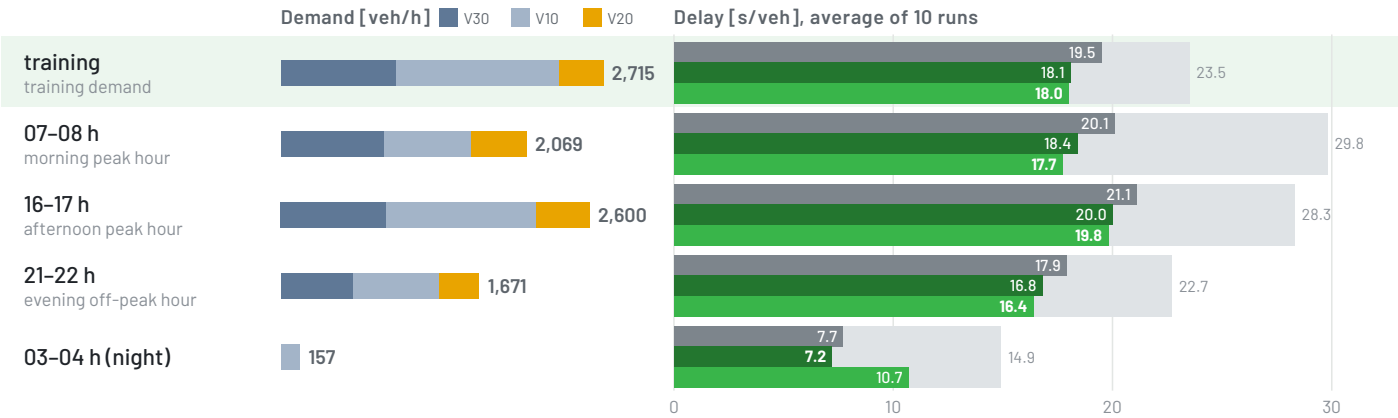
Less delay with the **Transformer** than the baseline algorithm at Grošnica in daytime (24 to 41% vs. Fix LISA)

0.23 ms

is how long a Transformer decision takes on an ARM Cortex-A72 processor – a whole second is available

Grošnica, Kragujevac – demand and delay

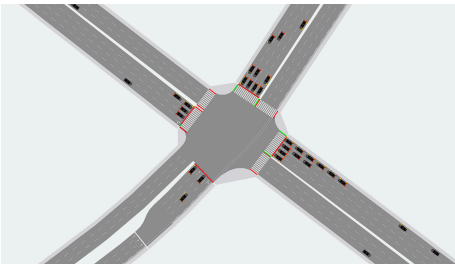
Fix LISA Algorithm Fuzzy Transformer



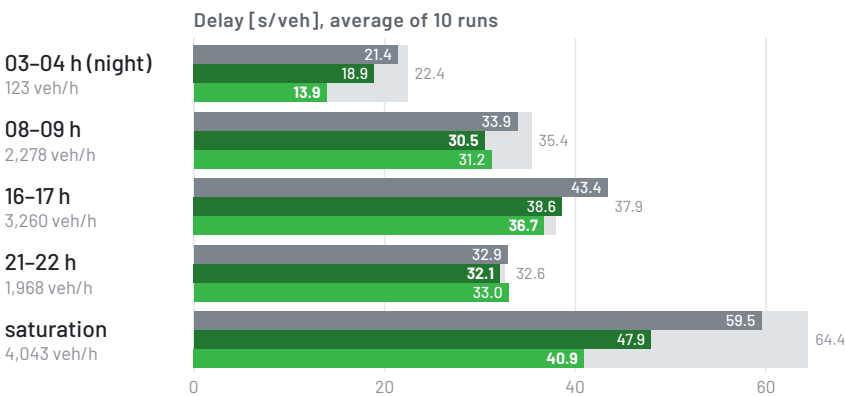
GENERALISATION TO NEW DEMAND

The Transformer learned only on the **training demand** (2,715 veh/h, volume randomly varied by 0.05–2× in each episode). It is best in three real hours, with different volumes and directional splits, that it has **never seen**. At the second intersection it was trained on 08–09, 16–17 and 21–22 h, and it is also best in two scenarios outside its training: night and saturation.

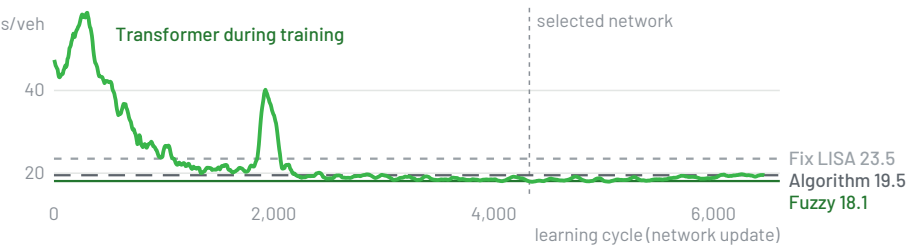
Bulevar Vudroa Vilsona / Nikolaja Kravcova, Belgrade – second intersection [s/veh]



The Transformer was retrained from scratch with 24 input parameters instead of 8. It is best at night (35% vs. the baseline algorithm), at 16–17 h and under saturation (31%). Fuzzy uses the same rules and threshold as at Grošnica, without any tuning – and stays better than the baseline algorithm in every hour.



How it learns



Reinforcement learning (PPO): ≈ 4,300 learning cycles, ~15 h of autonomous computing. The system only chooses the **moment of switching** between phases.

Required: a detector on every lane and a good SUMO model.