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Improving the traffic situation by shifting the turn and adjusting the traffic lights

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Abstract. The article deals with the problem of the formation of a traffic jam on the one of the street Krasnoyarsk cities. According to statistics, the largest set of accidents occur when turning the vehicle. For convenience and traffic priority, traffic lights are set up and additional signals or sections of traffic lights are introduced. In Europe, additional lanes are added, designed separately for turning, where cars can continue to wait for their turn, but if there are a lot of cars, then the additional lane ceases to cope with the flow of cars and begins to load the lane. Another option, when all left turns are prohibited, you need to turn right, where there is one-way traffic, look for a place to turn around and return from another street in order to drive straight to the opposite side of the road where the turn was prohibited. These manipulations can affect the ecology near residential areas and overload small streets, where there is already 1 lane for traffic. The paper proposes the option of transferring the turn to the supermarket to the next intersection in order to increase throughput at large traffic flows, and also uses analytical optimization methods to minimize travel time and maximize passing cars per hour. Keywords: Model, optimization, crossroad, traffic light.

1 Introduction

The purpose of this study was to find the possibility of unloading the interchange without economic investment and with an effective growth rate. In the evening, after work, the population of the city moves home from work, including stopping at supermarkets, which are usually located near transport roads. It is not always convenient for visitors to enter the supermarket. It is necessary to wait at the traffic light for their turn through the oncoming lanes, which makes drivers nervous after a working day and make mistakes. A study by modelling a real interchange showed that there is a way to increase the capacity of the interchange by moving the turn to the next intersection in the direction of travel that is not fully used, without affecting the number of cars turning. The following tools were used: AnyLogic programming environment, Java object-oriented programming language, OptQuest optimizer. To optimize the phases of traffic lights, the following methods were

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used: minimizing the time of crossing the intersection and maximizing the number of cars passing by in 1 and 2 hours of time. Usually, high car traffic lasts about 1 or 2 hours in the evening.

2 Materials and Methods

The problem at the next intersection is that there are 2 traffic lanes in each direction. And to turn to the supermarket, you need to take the extreme lane and wait for the signal to turn (the intersection is highlighted in red). It turns out that at this moment one lane starts to work worse, some of the cars are rebuilt in the next lane and also slow down the general movement.

Fig. 1. Model of an intersection with a turn to the supermarket.

It is proposed to consider the possibility of a U-turn at the following intersections. The next intersection is the junction of the entrance and exit of the bridge, where traffic jams are also usually created due to the increase in evening traffic between the banks of the city. As you can see, there is no opportunity to turn around at this intersection.

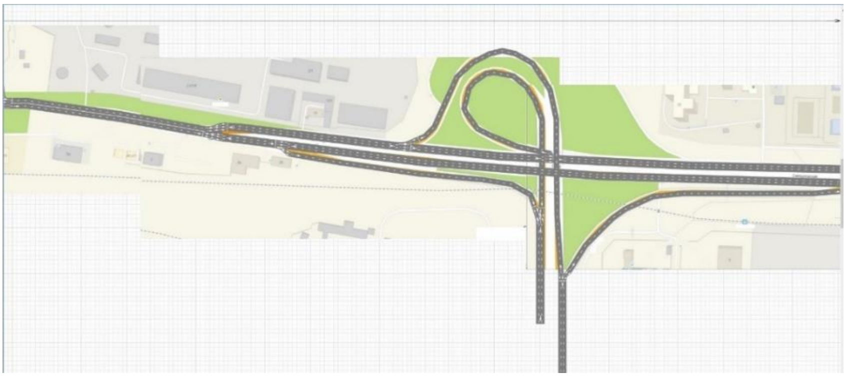

Fig. 2. Model continuation of the transport road.

If we look at the next intersection, we can see that the road narrows after this intersection (highlighted in blue). The lane (highlighted in yellow) can be used for waiting and then turning around, currently it is used only to increase capacity with subsequent narrowing. There is a pedestrian crossing at the blue intersection, so when the phase of crossing the intersection is prohibited, it is possible to make a U-turn of vehicles. The distance between the red and blue intersections is 1.3 kilometres.

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Fig. 3. The end of the transport road model.

Further, stage-by-stage optimization of traffic lights of interchanges was made, which can also affect the traffic situation of this section of the road.

For comparison, first, the model is run with real values of the phases of traffic lights at a red intersection. Movements on the side number 1 are as follows:

- 100 cars per hour enter the supermarket to parking (side number 2);
- 400 cars per hour come to the bridge (side number 3);
- up to 1200 cars per hour are created to drive to the side number 4, from the number 1. The movement of cars from the side number 4 is identical to the movement on the side number 1. Movement from the parking (side number 2), 100 cars per hour move to the side 1 and 100 cars to the side 3. From the side 3, 150 cars per hour leave to the side 4 and 300 cars to the 1 side. The sides are highlighted in red in the illustrations.

Phases of traffic lights at a red intersection: p-moves straight 80 seconds, p1 (15seconds) - turn from the supermarket towards the bridge, p2 (15seconds) - turn to the supermarket.

A few explanations of the icons for building model: the first circle icon (values show how many cars were created during the model). The second icon square indicates where the created objects are moving and the third circle show removes cars from the model (values indicate how many cars managed to exit the system in a time period). V1 is a dynamic parameter, that collects all the cars that left from the system.

With real values of the phases of the traffic light of the intersection, without optimization, the result is 3104 cars pass through the model per hour.

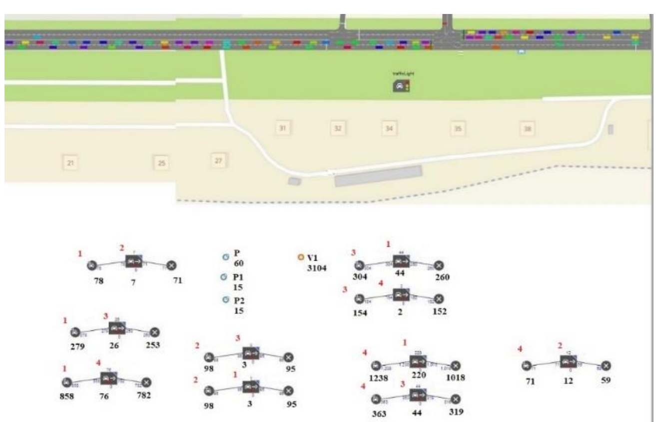

Fig. 4. The end of the transport road model.

After that, the traffic light phases are optimized to maximize the value of cars that pass through the system, where the model must pass the maximum number of cars with changing parameters of the traffic light phases. The optimizer finds the best traffic light phase parameters to maximize the number of passing cars per hour. The value of parameter p varies from 40 to 90 seconds with 5 second step. The value of parameters p1, p2 varies from 10 to 25 seconds with 5 second step.

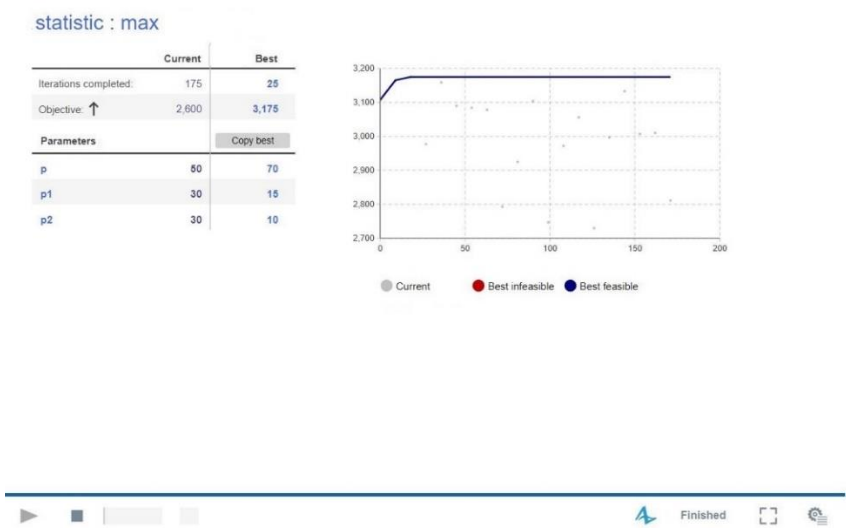

Fig. 5. Optimization of traffic light phases at a red intersection.

Further, the obtained parameters of the phases of traffic lights are substituted into the model. p-moves straight (70 seconds), p1 (15 seconds) - turn from the supermarket, p2 (10 seconds) - turn to the supermarket. The result of running the model is shown in figure 6. After running the model, we get an almost identical result in 3159, which means that the traffic light phase optimization gives identical results.

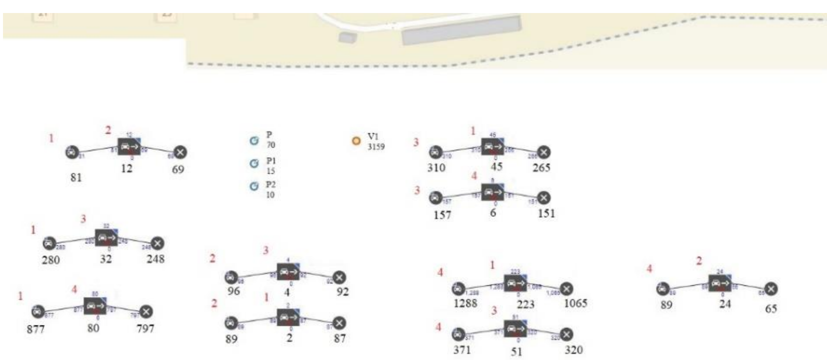

Fig. 6. The result of substitution of the obtained values.

After that, the transport model is reconstructed, it is forbidden to turn left at the red intersection and transferred to the blue intersection. Which in turn removes 1 phase at a red traffic light. We get the throughput of the site in 3746 cars per hour. The traffic light phase parameters are:

- P - Move straight on the red intersection (70 seconds);

- P1- Turn from the supermarket (15 seconds);
- P2 - Move straight on the blue crossroad (70 seconds);
- P3- U-turn at blue crossroads + crosswalk (10 seconds).

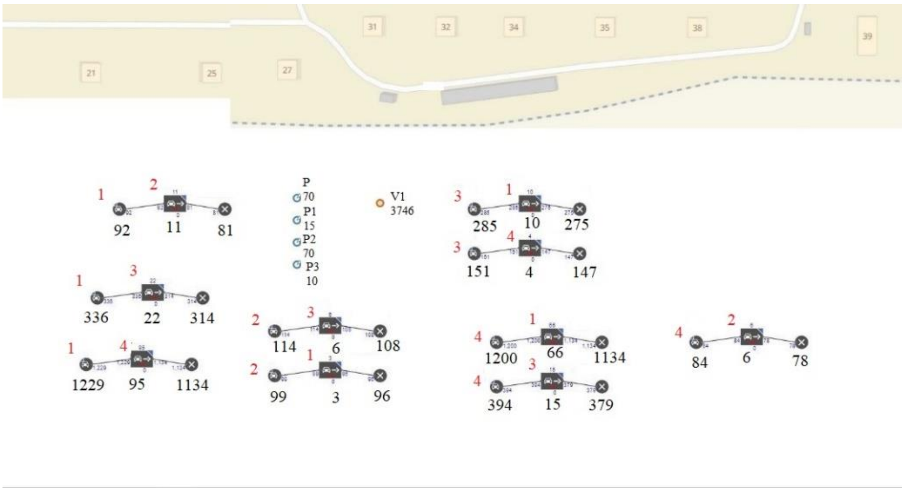

Fig. 7. Values after transfer to another crossroad.

Traffic light phases are optimized to identify the best traffic light phases at two intersections to maximize model throughput.

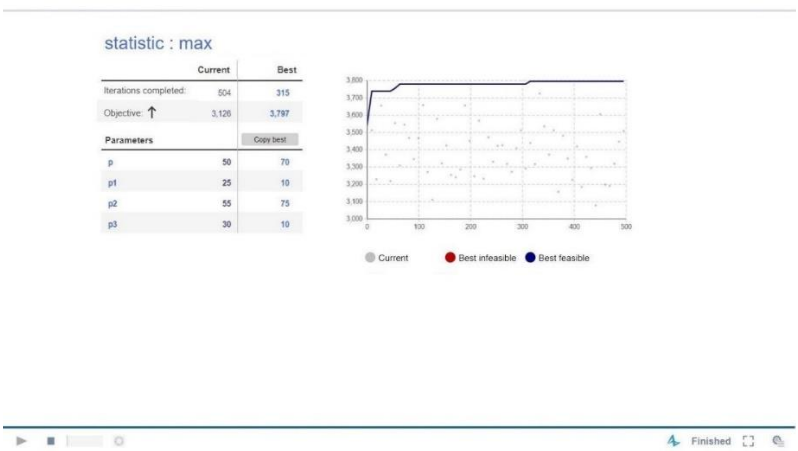

Fig. 8. Optimization of traffic light phases at 2 intersections.

Traffic light phase optimization data is inserted into the model. According to the results, the passage of 3774 cars per hour is obtained.

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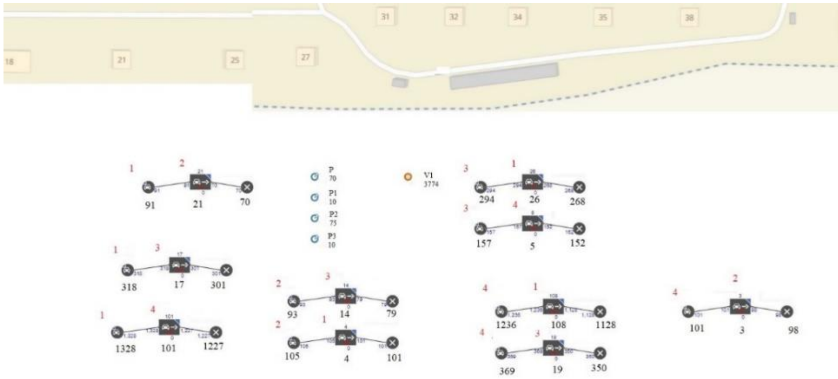

Fig. 9. Model result after optimization.

To compare the work of the method of maximizing the number of passing cars, the optimization method is used to minimize the time of crossing intersections. To do this, additional variables are created that collect statistics on the travel time of cars from the stage of their creation in the system until they leave the system. The optimizer finds the minimum value of the objective function based on the crossing time in minutes.

Fig. 10. Model travel time minimization optimization.

After optimization, the model was run according to the obtained optimization results, as a result, 3643 cars per hour were obtained. It turns out that different optimization systems produce similar results of the model.

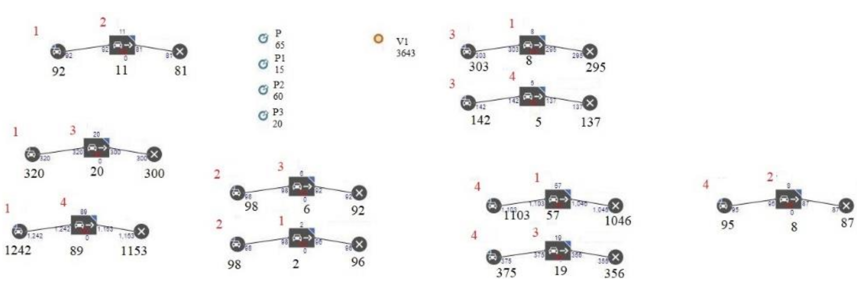

Fig. 11. Model result after optimization the minimization of travel time.

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For comparison, according to the best obtained values of the phases of traffic lights, the model was run for 2 hours to make sure that the model will continue to function after a longer time and will give a positive result.

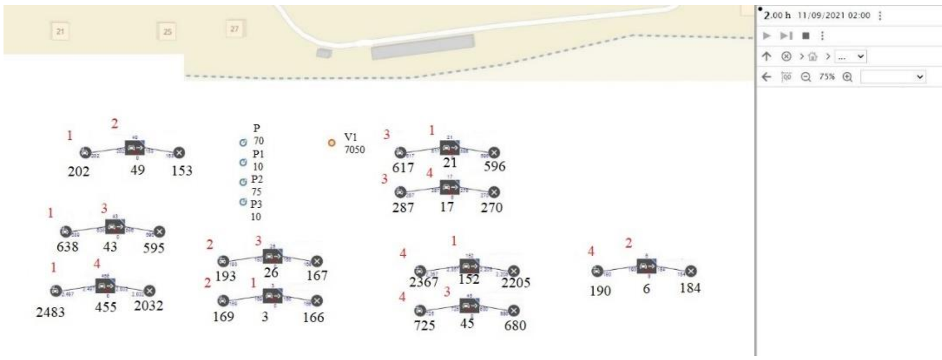

Fig. 12. Model result in 2 hours.

After 2 hours of running the model, there is no traffic jam in this section and the values are 7050 passing cars per hour.

3 Results

Based on the modernization and optimization carried out, it can be concluded that the throughput will increase significantly and will not affect the turning cars to the supermarket in any way. In this case, optimization will no longer greatly affect the result. The results are given below:

Table 1. Model results.

Model	**Real values**	**Actual values after traffic light phase optimization**	**Values after transfer to another crossroad**	**Optimization of traffic light phases after turn transfer**	**Values after optimization to minimize travel time**	**Model result in 2 hours**
Amount of cars passed	3104	3159	3746	3774	3643	7050
Improvements relative to the real value	-	1,0177	1.2	1.216	1.17	7050/3104*2=1.14
Ratio (%)	-	+102%	+120%	+121,5%	+117%	+114%

Adjusting the phases of traffic lights gives an increase of several percent. Transferring the turn itself to another intersection increases traffic capacity by up to 120%.

4 Conclusion

After applying the upgrades and optimizations, we can conclude that the transfer of this queue helps to get a throughput increase of up to 120%, and both optimization methods show identical results that do not greatly affect the result of the model. Thus, if we consider subsequent intersections, we can find an intersection at which cars can turn around so as not to slow down the general traffic in both directions. Based on the results obtained, it can be said that such actions can increase traffic capacity without the economic cost of widening the street. The optimization system is useful when you do not want to spend money on increasing roads if you are not sure about their operation, as well as for optimizing traffic light intervals based on statistics that can be changed depending on the traffic flow. But as the study shows, optimization methods can´t always increase the throughput of the intersection.

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References

1. M. Abolghasemian, A.G. Kanafi, M. Daneshmandmehr, A two-phase simulation-based optimization of hauling system in open-pit mine (2020) DOI 10.22059/IJMS.2020.294809.673898
2. H.X. Chen, X.J. Huang, H. Li, H.B. Zhang, Coordinated timing of multiple intersections based on Anylogic (2021) DOI 10.53136/979125994383518
3. D. Chu, S. Wei, Y. Lin, Application of Pedestrian Microscopic Simulation Technology in Researching the Influenced Realm around Urban Rail Transit Stations (2015) DOI 10.1061/9780784479384.406
4. E. Shibareva, Imitation modeling of transport linkages Kubovaya- Kedrovaya city of Novosibirsk (2019) DOI: 10.33764/2618-981x-2019-7-99-106
5. A. Ghorbanian, S. Aramesh, Multi-objective optimization for a complex intersection using design of experiments and simulation (2020) DOI 10.18280/jesa.530605
6. A. Ikidid, A. Fazziki, M. Sadgal, A fuzzy logic supported multi-agent system for urban traffic and priority link control (2021) DOI: 10.3897/jucs.69750
7. Lu Kai, Tian Xin, Optimization model of intersection signal timing based on ring barrier phase (2020) DOI: 10.1080/15472450.2020.1795847
8. D. Kuzmin, V. Baginova, 14th International Scientific Conference on Precision Agriculture and Agricultural Machinery Industry, INTERAGROMASH (2021) DOI 10.1007/978-981-16-3844-2_29
9. S. Masoud, S. Kim, Y.J. Son, Integrated dual toll pricing with network design for hazardous materials transportation (2015)
10. G. Merkuryeva, V. Bolshakovs, Vehicle schedule simulation with AnyLogic (2010) DOI 10.1109/UKSIM.2010.38
11. M.-D. Pop, Decision Making in Road Traffic Coordination Methods: A Travel Time Reduction Perspective (2020) DOI 10.1109/EnT48576.2020.00014
12. H. Rachih, F.Z. Mhada, R. Chiheb, Simulation optimization of an inventory control model for a reverse logistics system (2022) DOI 10.5267/j.dsl.2021.9.001
13. X.M. Song, Y.N. Zhang L. Ma, Journal of Transportation Systems Engineering and Information Technology (2020) DOI 10.16097/j.cnki.1009-6744.2020.06.016
14. H. Shengneng, J. Zhen, Y. Anping, X. Kui, H. Guoqi, Evaluating the Sustainable Traffic Flow Operational Features of U-turn Design with Advance Left Turn (2022) DOI 10.3390/su14116931.

15. A.O. Stupin, V.V. Kukartsev, V.S. Tynchenko et al, Management modelling of the natural resources extraction station by agency modelling means (2020) DOI: 10.1088/1742-6596/1661/1/012196
16. A.O. Stupin, L. Kazakovtsev, A. Stupina, Control of traffic congestion by improving the rings and optimizing the phase lengths of traffic lights with the help of anylogic (2022) DOI 10.1016/j.trpro.2022.06.113
17. L. Sun, J. Tao, C. Li, S. Wang, Z. Tong, Microscopic Simulation and Optimization of Signal Timing based on Multi-Agent: A Case Study of the Intersection in Tianjin (2018) DOI 10.1007/s12205-018-0528-2
18. Z. Weibo, C. Xiawei, T.S. Kuang, Research on Traffic Lights Timing Optimization and Simulation (2022) DOI 10.13203/j.whugis20200029