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Model of the influence of weather conditions on car traffic (using the example of weather conditions in Siberia)

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Abstract. The purpose of the study is to build a model of the influence of weather and climatic factors on the throughput of various types of roads and intersections. Weather conditions affect the acceleration, braking and stability of a vehicle on the road. The results show that the weather affects traffic intersections of streets, which need to be optimized depending on the current road and transport situation. As a result, a model of the influence of rain, snow and ice on road situations was simulated and built.

1 Introduction

Vehicle traffic conditions and road capacity during periods of adverse weather conditions deteriorate significantly. Weather and climatic factors [1] make significant adjustments to the quality and safety of roads. In areas of Siberia, the weather can change by 30 degrees in a day, and if the temperature changes from positive to negative temperatures and include precipitation, then many motorists face transport and road problems. When precipitation falls on the road surface, a layer of water, snow or ice forms at low temperatures, which directly affects the grip of the car with the road. It is quite difficult to calculate the acceleration of a car, the technical characteristics are very different and the data on the acceleration of cars specified in the documentation were obtained under ideal conditions. In addition, all cars are different, drivers accelerate differently, and the influence of front or rear wheel drive is not taken into account.

2 Problem statement

According to statistics, the braking distance on wet asphalt increases by 2 times, on icy roads by 4 times, and on icy conditions with snow by 8 times [2]. Weather conditions affect the acceleration dynamics of the car, grinding and slipping of the wheels occurs, which reduces the acceleration of the car [3]. For research the problem in the simulation model, it is possible to change the acceleration and braking parameters of the vehicle.

Based on the described situation, the following questions were posed for solution:

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- How do weather conditions affect traffic flows?
- Which intersections are more resistant to weather and traffic changes?
- How does the speed limit affect traffic flows?

3 Methods

In this work, the model is built in the Anylogic program version 8.5.2 [4,5].
Implementation of the model. The following road models were taken for analysis:

1. 1 lane 750 meters long, at a distance of 600 meters from the beginning of the path there is a traffic light with phases of 40 seconds green for cars, 3 seconds delay yellow and 20 seconds green for pedestrians (Figure 1).
2. 2 traffic lanes 750 meters long, at a distance of 600 meters from the beginning of the path there is a traffic light with phases of 40 seconds green for cars, 3 seconds delay yellow and 20 seconds green for pedestrians (Figure 1).
3. 3 lane of traffic 750 meters long, at a distance of 600 meters from the beginning of the path there is a traffic light with phases of 40 seconds green for cars, 3 seconds delay yellow and 20 seconds green for pedestrians (Figure 1).

Fig. 1. Parallel roads with different numbers of lanes and traffic lights.

1. An intersection with 4 adjacent roads, 2 lanes in each direction, cars move only in opposite directions, no turns or U-turns, traffic light phases are 45 seconds for each direction. The length of each lane is 500 meters until the intersection. The model is presented in Figure 2.

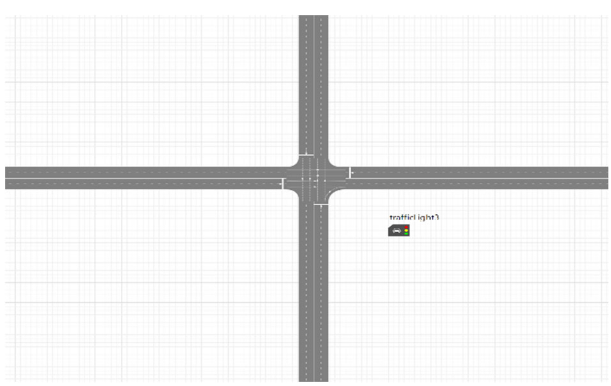

Fig. 2. Intersection model.

2. Ring traffic, cars approach from 4 sides, each road has 2 lanes and one-way 2-lane traffic on the ring. The length of each lane is 400 meters before the roundabout. The model is presented in Figure 3.

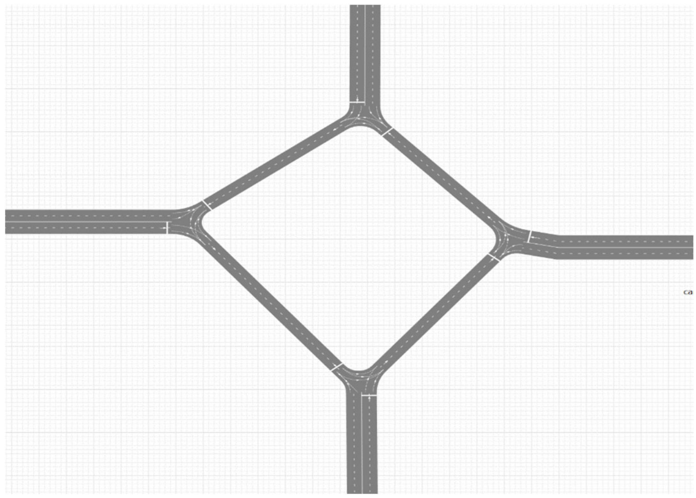

Fig. 3. Roundabout model.

Everywhere the initial speed = 0, it is assumed that the cars are moving away from the traffic light. The cars are approximately 2.7m long.

4 Results and discussion

The following indicators change in the model:

1. 1.Speed. The maximum speed is set at 60 km per hour and 80 km per hour for comparison; on the city roads it is possible to accelerate to 80 km per hour.
2. 2.The number of cars appearing on the road per hour. Values from 600 to 800 and 1000 cars per hour were taken, the value is supplied simultaneously to each road, the values per hour can be slightly more or less than the specified value if a traffic jam is not created in the model. So that everything is identical.
3. 3.The acceleration and braking coefficients of cars change, that is, depending on the road surface (dry, wet, ice, snow + ice).

We find u - this will be our braking acceleration; if we substitute the speed data from the first three lane models, we can get values for different weather conditions [6]

1. 1.u1 = 4.1 m/s (dry asphalt);
2. 2.u2 = 2.2 m/s (wet asphalt);
3. 3.u3 = 1 m/s (ice);
4. 4.u4 = 0.5 m/s (ice with snow),

The remaining values are derived by the analogy indicated above, that the braking distance increases depending on the conditions; in icy conditions, the braking distance is 8 times higher.

Calculating car acceleration is quite difficult, all cars are different, drivers accelerate differently, and the influence of front or rear wheel drive is not taken into account. The basis is a Volkswagen polo car with a 1.4 85 hp engine, acceleration to 100 km in 14 seconds, if you accelerate to 60, you will need 8 seconds of quiet acceleration on dry asphalt. Wet surfaces will increase acceleration to 10 seconds, icy conditions to 12 seconds, and in icy conditions with snow there may still be severe slippage, which will increase to 14 seconds [7]. Therefore, we obtain the following acceleration coefficients:

1. Dry acceleration 7.5 m/s
2. Acceleration on wet asphalt – 6 m/s
3. Acceleration on ice – 5 m/s
4. Ice with snow - 4.6 m/s

The model was run with various coefficients for 1 hour.

An example of the result of the model is presented in Figure 4. Where z is the number of cars created in the system on each road per hour, s is the maximum speed value that the car can reach, apl is the acceleration value, amin is the braking value. R1 – model with 1 lane, r2 – model with 2 lanes, r3 – model with 3 lanes, p1,2,3,4 – intersection passage values on each road (in the table this indicator will be combined into a single value), c1,2,3,4 - the values of the ring passage on each road (in the table this indicator will be combined into a single value) [8]. The results are presented in Figure 4.

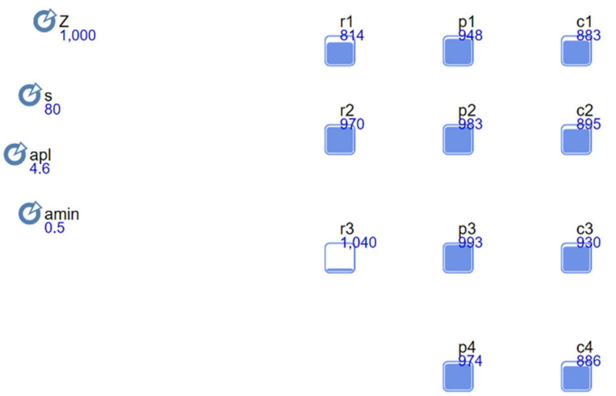

Fig. 4. Result of the model in Anylogic.

The results of the experiments are shown in the table 1 below.

Table 1. Experimental results of the developed models.

Dry	Speed (km/h)	Acceleration (m/s)	Deceleration (m/s)	Number of cars per hour	Cars passed per hour
1 lane	60	7.5	4.1	600	564
				700	661
				800	700
				1000	899
	80			600	581
				700	693
				800	748
				1000	814
2 lanes	60	7.5	4,1	600	594
				700	697
				800	784
				1000	959
	80			600	593
				700	695

				800	791
				1000	970
3 lanes	60	7.5	4.1	600	563
				700	667
				800	788
				1000	1005
	80			600	588
				700	690
				800	797
				1000	1040
Intersection	60	7.5	4.1	600	582
				700	681
				800	778
				1000	944
	80			600	586
				700	691
				800	790
				1000	975
Roundabout	60	7.5	4.1	600	599
				700	662
				800	771
				1000	795
	80			600	590
				700	702
				800	798
				1000	899
Wet	Speed (km/h)	Acceleration (m/s)	Deceleration (m/s)	Number of cars per hour	Cars passed per hour
1 lane	60	6	2.2	600	549
				700	636
				800	731
				1000	913
	80			600	568
				700	684
				800	792
				1000	937
2 lanes	60	6	2.2	600	560
				700	695
				800	763
				1000	945
	80			600	572
				700	683
				800	788
				1000	973
3 lanes	60	6	2.2	600	580
				700	710
				800	813
				1000	970
	80			600	585
				700	682
				800	803
				1000	980
Intersection	60	6	2.2	600	600

				700	661
				800	709
				1000	772
	80			600	592
				700	673
				800	734
				1000	793
Roundabout	60	6	2.2	600	602
				700	683
				800	650
				1000	740
	80			600	598
				700	690
				800	704
				1000	756
Ice	Speed (km/h)	Acceleration (m/s)	Deceleration (m/s)	Number of cars per hour	Cars passed per hour
1 lane	60	5	1	600	592
				700	634
				800	707
				1000	885
	80			600	590
				700	650
				800	682
				1000	924
2 lanes	60	5	1	600	600
				700	676
				800	760
				1000	945
	80			600	598
				700	691
				800	774
				1000	943
3 lanes	60	5	1	600	596
				700	686
				800	769
				1000	980
	80			600	597
				700	703
				800	759
				1000	1034
Intersection	60	5	1	600	574
				700	639
				800	483
				1000	614
	80			600	595
				700	677
				800	673
				1000	729
Roundabout	60	5	1	600	565
				700	671
				800	520
				1000	694

	80			600	578
				700	676
				800	478
				1000	744
Ice+snow	Speed (km/h)	Acceleration (m/s)	Deceleration (m/s)	Number of cars per hour	Cars passed per hour
1 lane	60	4.6	0.5	600	570
				700	634
				800	721
				1000	890
	80			600	585
				700	662
				800	660
				1000	924
2 lanes	60	4.6	0.5	600	561
				700	659
				800	775
				1000	942
	80			600	584
				700	688
				800	818
				1000	954
3 lanes	60	4.6	0.5	600	582
				700	669
				800	809
				1000	989
	80			600	590
				700	705
				800	829
				1000	998
Intersection	60	4.6	0.5	600	576
				700	564
				800	442
				1000	612
	80			600	580
				700	597
				800	512
				1000	662
Roundabout	60	6	2.2	600	557
				700	677
				800	527
				1000	613
	80			600	561
				700	643
				800	553
				1000	640

If we consider the ratio of passing cars that manage to drive on dry asphalt and in ice and snow, we obtain the following ratios (Table 2).

Table 2. Ratio of passing cars on dry surfaces in relation to snow and ice at the intersection and roundabout.

	Speed (km/h)	Number of cars per hour	Dry	Snow+ice	Ratio %
Intersection	60	600	582	576	1.03%
	60	700	681	564	17.18%
	60	800	778	442	43.19%
	60	1000	944	612	35.17%
	80	600	586	580	1.02%
	80	700	691	597	13.60%
	80	800	790	512	35.19%
	80	1000	975	662	32.10%
Roundabout	60	600	599	557	7.01%
	60	700	662	677	-2.27%
	60	800	771	527	31.65%
	60	1000	795	613	22.89%
	80	600	590	561	4.92%
	80	700	702	643	8.40%
	80	800	798	553	30.70%
	80	1000	899	640	28.81%

Based on the results of the experiment, it was revealed that the influence of weather conditions on traffic capacity is especially great on roads such as intersections and rings [9].

5 Conclusion

Based on the results of the constructed model, we can conclude that:

1. Straight sections of roads with only traffic lights are least dependent on road conditions and always show identical results.
2. Roundabouts and intersections may lose capacity due to congestion caused by high traffic flows and poor weather conditions. The drop in throughput can reach 40% [10].
3. Increasing the speed by 20 km per hour slightly increases the overall road capacity.
4. Icy roads and snow have the greatest impact on transport hubs, where it is necessary to brake and accelerate a lot, especially when there is a large number of vehicles.
5. Over 700 cars per hour begin to accumulate in areas of 500 meters and create traffic difficulties.

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