

# Route Choice Behaviour in a Three Roads Scenario

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**Abstract** We present results of three simple three roads scenarios, which were simulated with an extended Nagel–Schreckenberg CA model. We studied how the global travel times of cars could be optimised by simple routing or distribution strategies. Besides the well-known methods as shortest path, travel times and equal distribution we tested alternating loads and present two strategies based on a remaining road capacity. The strategies were applied only to 25% of the cars, whereas the remaining cars and trucks were distributed over the three roads as a fixed proportional load. The first scenario contains three different road lengths of 20, 22 and 24 km length and the fixed load is evenly distributed. In the second scenario, all three roads have a length of 20 km, but the fixed load is distributed unequally. The third scenario combines the different road length with an unequally distributed load.

## 1 Introduction

This research was part of the project DiNav—Dynamics in Navigation [7], to improve the efficient usage of road networks and to lower travel times. Former studies [6] as well as recent results [1–3] also based on the Nagel–Schreckenberg CA model [5] have led us to the idea to investigate simple routing or distribution strategies on a more complex three roads scenario. In this case, more complex means simulating with two vehicle classes on three roads each with two lanes and overtaking rules for cars. In addition, this study presents two routing strategies based on the maximum vehicle flow capacity, which was derived as well from the simulation.

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## 2 Simulation

For the simulations we used an extended Nagel–Schreckenberg CA model [5] with two vehicle classes: cars and trucks. Cars have a length of one cell equivalent to 7.5 m and a maximum velocity of five cells per second equivalent to 135 km/h. Trucks have a length of two cells equivalent to 15 m and a maximum velocity of three cells per second equivalent to 81 km/h. Furthermore, we simulated roads with two lanes and asymmetric lane change rules for cars only, according to [4]. Trucks can only use the right lane. The vehicular traffic was split into three fractions. Ten percent of the traffic flow was considered to be trucks. The remaining cars were split into a fixed load (75 % cars) and an additional load (25 % cars). Only this additional load of 25 % of the cars are affected by the routing strategies. The other cars and trucks are distributed by fixed ratios. For the whole network, we wanted a desired traffic flow of 6480 vehicles per hour. The outcome of this are 648 trucks per hour and 4374 cars per hour as the fixed load and 1458 cars per hour as the additional load. We simulated a period of thirteen hours. Every simulation started with empty roads. Each simulation was repeated one hundred times.

### 2.1 *Global Topology*

We presume that the three roads connect one source with one destination. Even though the three roads share the same destination, we assume that there is an infinite outlet capacity. These roads may have different length or not, but share the same characteristics. Each of the three roads has the same bottleneck structure to reduce the flow capacity towards the end. The bottleneck is implemented as a speed limit with two cells per second as maximum velocity. The bottlenecks are about 200 m long and start at 90 % of each roads length.

### 2.2 *Routing/Distributing Strategies*

In this three road scenarios we tested eight routing, respectively, distribution strategies. However, at first, we simulated each scenario without the additional load to determine the travel times under free flow conditions. Besides, we want to be assured that this empty road system is under saturated and behave stable. The investigated methods can be grouped into three categories. The first two methods, shortest path and equal distribution, are static methods. Followed by two cyclical approaches, which can be categorised as dynamic. The last group of methods are dynamic and responsive methods with feedback strategies. In the following, we will describe the applied methods in more detail.

**Shortest Path** The shortest path algorithm routes the whole additional load to the shortest of the three roads. In the scenarios with different road length this would be road A. It is easily predictable that this will lead to an over saturated system and to a breakdown in the vehicular flow. We will look at the results here nevertheless.

**Equal Distribution** Here, the additional load is split evenly by one third. This method is independent of road or scenario differences.

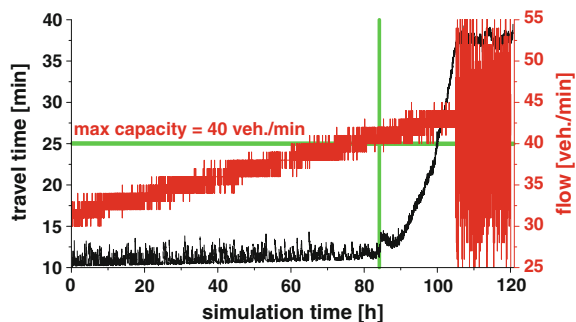
**Alternating Roads** Rather than splitting the load evenly, this method will route the respective cars cyclical on the roads. Each minute the extra load will be directed to another road.

**Travel Time** This is the first method with a feedback strategy, assuming that the travel time of each vehicle can be measured. It prefers the road with the shortest mean travel time. Those travel times are measured from all cars, which left the road within the last minute. Each minute the mean travel times are recomputed for each road. In case the current mean travel time could not be calculated, the mean travel time under free flow conditions will be used instead.

**Travel Time Additional Load** In this case the mean travel times on a road are calculated only from cars of the additional traffic load. This is based on the assumption that only cars which can be influenced in their routing decisions are able to send travel times to a central service. Again without current travel time information, the free flow value acts as substitute.

**Remaining Road Capacities** We came up with the idea to use a remaining road capacity as feedback strategy. Therefore we identified the flow capacity for the roads in our scenarios. This was done by simulations a single road with the same road and traffic characteristics. However, in this special test case, we started with a low traffic flow which was then increased in small steps over time. The result of one of those simulations is shown in Fig. 1. This simulations indicate that a flow of 40 veh./min is the appropriate maximum capacity for the roads used in our simulations. The actual traffic flow is measured with a virtual loop detector at the beginning of each road and aggregated over 1 min. The remaining road capacities are calculated for each road by subtracting the current flows from the maximum road capacity. Negative

**Fig. 1** Simulating one road with slowly increasing vehicle flow (red) to determine maximum road capacity. With flow up to 40 vehicles per minute the travel times (black) increases proportional, but above travel times become unstable and rise exponentially. In the end the whole system collapses



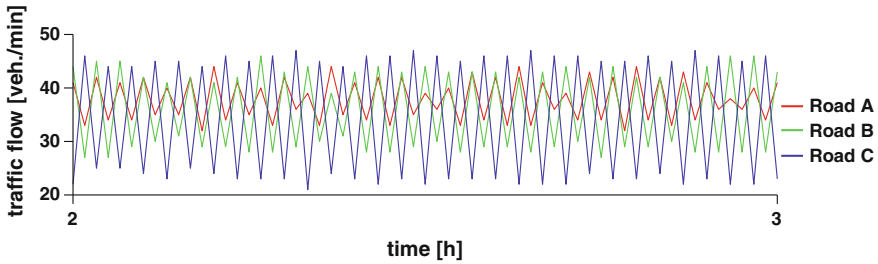


Fig. 2 Resulting traffic flow per minute within scenario II and the remaining road capacity strategy

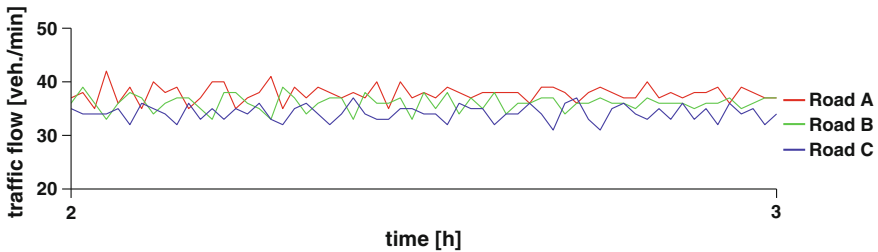


Fig. 3 Resulting traffic flow per minute within scenario II and the mean remaining road capacity strategy

remaining capacities are neglected. These results are then standardised to generate a distribution formula for the additional load. Figure 2 shows that this method induces a high fluctuation in the traffic flows.

**Mean Remaining Road Capacity** To enhance the former method the mean remaining capacities over 3 min generate the adapted distribution formula. This last method leads to more stable traffic flows as shown in Fig. 3.

### 3 Scenarios and Results

The three scenarios differ regarding to the road length and the distribution ratios for the fixed load. Below, each scenario is explained and the respective results are discussed. To calculate the mean travel time for each method and scenario the first and last half an hour of all simulations were discarded. To compare the distribution strategies in each scenario the results are presented in tables. The first table lists the distribution strategies in their tested order and shows the average road use for each road and strategy. The second table lists the travel times for all cars and for cars of the additional load. The strategies are in order of the increasing average overall travel time.

### 3.1 Scenario I

In the first scenario the three roads have different length. Road A has a length of 20 km with the bottleneck between 18.0 and 18.2 km. Road B is 10 % longer, therefore has a length of 22 km with the bottleneck between 19.8 and 20.0 km. Road C is the longest with 24 km length (20 % longer than road A) and has the bottleneck between 21.6 and 21.8 km. The fixed load is equally distributed. This results in a desired vehicle flow of 1458 cars and 216 trucks per hour on each road (Table 1).

We can summarise that all methods were able to reach the desired vehicular flow rates, besides the shortest path algorithm, which could only reach about 62 % of the additional vehicular flow. In this scenario, all strategies which utilised the roads more or less equal achieve an average global travel time about six to eight percent above free flow conditions, as Table 2 shows. Both strategies considering the travel times shift the additional load from road C to road A and perform less in reference to the average travel times.

### 3.2 Scenario II

The second scenario has three roads with the same length. Roads A, B and C have the length of 20 km with the bottleneck between 18.0 and 18.2 km. But in contrast to scenario I, the fixed load is now distributed uneven. The desired fixed vehicle flow on road A is raised by 20 % to 1750 cars and 259 trucks per hour. That is 40 % of the fixed traffic load. Road B remains at a third of the fixed load with the vehicle flow of 1458 cars and 216 trucks per hour. The main vehicle flow on road C is lowered by 20 % to 1166 cars and 173 trucks per hour equal to 26.67 % of the fixed load. The shortest path algorithm was excluded here, because of the missing difference in road length (Tables 3, 4, 5 and 6).

In this scenario with symmetric roads, but asymmetric fixed traffic loads the performance of strategies with an even distribution dropped. Now, the capacity driven

**Table 1** Distribution of the additional load on the three roads in scenario I

Strategy	Road A (%)	Road B (%)	Road C (%)
No additional load	0.00	0.00	0.00
Shortest path	100.00	0.00	0.00
Equal distributed	33.33	33.33	33.33
Alternating roads	33.30	33.30	33.41
Travel time	42.15	36.45	21.40
Travel time additional load	42.02	36.80	21.17
Remaining capacity	33.28	33.19	33.52
Mean remaining capacity	33.33	33.34	33.33

**Table 2** Simulation results of the mean travel times in scenario I

Strategy	Mean travel time all cars (min)	Percentage (%)	Mean travel time additional load (min)	Percentage (%)
No additional load	11.018	100.00	NA	NA
Equal distributed	11.708	106.26	11.737	100.10
Mean remaining capacity	11.711	106.29	11.725	100.00
Remaining capacity	11.769	106.81	11.835	100.94
Alternating Roads	11.857	107.61	11.948	101.90
Travel time additional load	12.818	116.34	13.427	114.51
Travel time	13.137	119.23	13.912	118.65
Shortest path	23.386	212.25	37.900	323.23

**Table 3** Distribution of the additional load on the three roads in scenario II

Strategy	Road A (%)	Road B (%)	Road C (%)
No additional load	0.00	0.00	0.00
Equal distributed	33.33	33.33	33.33
Alternating roads	33.34	33.29	33.37
Travel time	16.39	35.49	48.13
Travel time additional load	18.25	37.36	44.39
Remaining capacity	17.78	34.34	47.88
Mean remaining capacity	18.29	33.33	48.38

**Table 4** Simulation results of the mean travel times in scenario II

Strategy	Mean travel time all cars (min)	Percentage (%)	Mean travel time additional load (min)	Percentage (%)
No additional load	10.129	100.00	NA	NA
Mean remaining capacity	10.671	105.35	10.623	100.00
Remaining capacity	10.728	105.91	10.733	101.04
Travel time additional load	11.617	114.70	12.172	114.59
Travel time	11.747	115.98	12.405	116.78
Equal distributed	12.056	119.02	11.853	111.57
Alternating roads	12.159	120.04	12.026	113.20

**Table 5** Distribution of the additional load on the three roads in scenario III

Strategy	Road A (%)	Road B (%)	Road C (%)
No additional load	0.00	0.00	0.00
Shortest path	100.00	0.00	0.00
Equal distributed	33.33	33.33	33.33
Alternating roads	33.31	33.29	33.40
Travel time	30.15	32.94	36.29
Travel time additional load	36.78	31.46	31.76
Remaining capacity	17.89	34.21	47.90
Mean remaining capacity	18.36	33.33	48.31

**Table 6** Simulation results of the mean travel times in scenario III

Strategy	Mean travel time all cars (min)	Percentage (%)	Mean travel time additional load (min)	Percentage (%)
No additional load	10.972	100.00	NA	NA
Mean remaining capacity	11.681	106.46	11.974	100.00
Remaining capacity	11.739	106.99	12.085	100.93
Equally distributed	12.948	118.01	12.847	107.29
Alternating roads	13.095	119.35	13.059	109.06
Travel time	13.351	121.68	13.461	112.42
Travel time additional load	16.152	147.21	16.615	138.76
Shortest path	23.777	216.70	37.071	309.60

strategies distributed the additional load in average similar to the methods with the travel time feedback but beat them when the average travel time is concerned. Distributing the additional flow even over the three roads results in a steady rise of travel times on road A, which then dominates the average global travel time. All strategies were able to reach the desired vehicular flow rates.

### 3.3 Scenario III

The third scenario is a combination of the former two. We simulated the three roads scenario with the different road length (20, 22 and 24 km) and the shifted distribution (40, 33.33 and 26.67%) of the fixed traffic load. Again the simulation results are combined within the following tables.

Again all the algorithms except shortest path, were able to reach the desired vehicular flow rates. The shortest path method could reach just about 39% of the additional vehicular flow. The capacity based strategies head the table of the average travel times again, even though a significant load shift towards the longest road C is observed. In addition the travel time strategy with the feedback of only cars of the additional load lead here as well to an over saturated road A which results in a poor performance of the average travel time. We observe that the values for the average distribution is contrary to the results considering the travel times of all cars.

## 4 Conclusion and Outlook

All three chosen scenarios show that a distributing or routing strategy which takes the actual traffic flow and the flow capacity of a road into account can improve the average travel time in a road network. Averaging this method over 3 m stabilises the traffic flow and increases the performance. Both strategies work especially well in systems with asymmetric basic loads. In further studies we want to compare these methods with even more feedback strategies. Also, it is interesting to investigate networks with shorter road length and how these methods perform under time variant dynamic vehicular traffic flows. The same applies for studies with different ratios between the fixed and the additional traffic load.

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