

Analysis on a road closure in Paris

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Project Report

January 2019

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1 Introduction

This work focuses on the analysis of the traffic behaviour before and after a change in the infrastructure. The initial position is the idea to close a heavy loaded road next to the Seine in the centre of Paris. This work will now analyse the influence of this change. To simplify the analysis only cars were considered, because the closing is only valid for the motorized individual traffic.

This work deals with two different questions. First, the question is answered, what this means for the individual road users. Some users have to choose a different route and thus the travel time increases. The work analyses the impact of the chosen route and the change in travel time. The second question is how the load on the other roads increase. The closure of the road leads to fewer possible routes for the users. Therefore, the users will spread to other roads and the load will increase. It must be proved whether such an increase is possible.

2 Method

2.1 Overview

We simulated the impact of the planned road closure using the agent-based traffic simulation framework MATSIM. For computational efficiency it is assumed that agents use their car for every trip they undertake. Additionally, we assume that agents complete a fixed set of activities at predetermined locations and depart for their trips at fixed times. That is, we assume that their choice of activity and departure time is not informed by the traffic situation. As an added benefit, this approach allows for a one to one mapping of trips across different simulation runs. We later use this fact to investigate in detail how the road closure affects individual trips.

2.2 Calibration

We calibrated the network parameters “flowCapacityFactor” and “storageCapacityFactor” such that a reasonable amount of congestion is observed during the simulation. Here we assume that the actual travel speed observed in a congested metropole like Paris is on average about half the speed agents could achieve if the city was completely empty. That is, we attempted to set the mentioned parameters such that the actually observed travel times of agents are roughly

twice as long as the free-flow times. By setting the flowCapacityFactor to 0.02 and the storageCapacityFactor to 0.2 we achieve the desired behaviour as illustrated in Figure 1. Figure 1a shows a histogram with the frequency of absolute travel times that agents would observe for their trips if the city was completely empty. Figure 1b shows a histogram for the frequency of actually observed travel times with congestion. It can clearly be seen that activated congestion shifted the distribution to the right. Specifically, the median trip duration increased from 8.2 minutes (without congestion) to 17.8 minutes (with congestion). Thus, as intended, the level of congestion results in roughly doubled travel times compared to an empty city.

Furthermore, we compute for each individual trip the ratio travel-time-with-congestion / travel-time-without-congestion, to get an idea of how individual trips are affected by congestion differently. It can be seen that the travel time for most trips only increases slightly as a result of congestion.

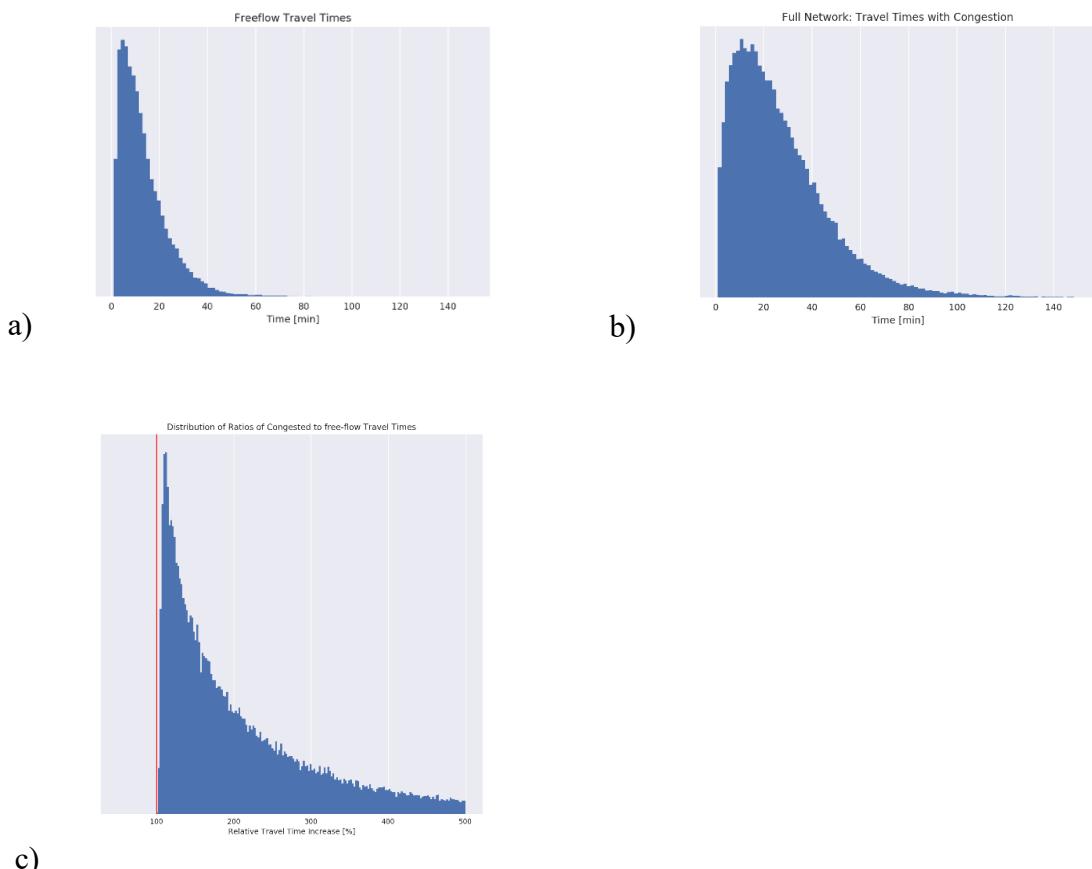


Figure 1: (a) Histogram of the distribution of trip travel times in the full network (i.e. before the road closure) without congestion. Mean travel time: 10.6 minutes; Median travel time: 8.2 minutes. (b) Histogram of the distribution of trip travel times in the full network with congestion. Mean: 22.1 minutes; Median: 17.8 minutes. (c) For each trip the ratio of free-flow travel time to travel time with congestion is computed. This subfigure shows the histogram of the distribution of these ratios. The travel time of the average trip increased by 250%. The median increase is 184%.

2.3 Road Closure

Two simulations were run with these parameters. First, we run a simulation over 100 iterations with the original network, to obtain an estimate of the state of traffic before the road closure. Then we run a second simulation with a modified network that implements the planned road closure. To this end, we identified the links that correspond to the road closure plans and removed them from the network. Additionally, we cleaned the network by also removing links that turned into dead ends. Further, we had to modify the synthetic population since agents could not reach activity locations anymore that were located on the now deleted links. Here we assume that agents would drive by car to the location on the road network that is closest to the activity location and then walk the final meters. However, we do not explicitly model the walking section, since pedestrians are not affected by congestion. Hence it is reasonable to assume that the walking leg is part of the activity which now takes place at the new location. We implemented this by moving all activities, that are located on a deleted link, to the still existing link with the smallest distance to the activity location.

3 Results

3.1 Difference in overall travel times

Figure 2 shows the travel times after the closure and the distribution of the ratios of travel time before and after the road closure. If the road closure has a system wide effect, we would expect all travel times to increase heavily. Comparing the travel times before (Figure 1b) to the travel times after the road closure (Figure 2a) shows that this is not the case. Both distributions of the travel times look similar. A comparison of the characteristics showed only a small extension of travel times. Specifically, the average trip duration only increased by approximately 1 minute from 22.1 minutes to 23.1 minutes.

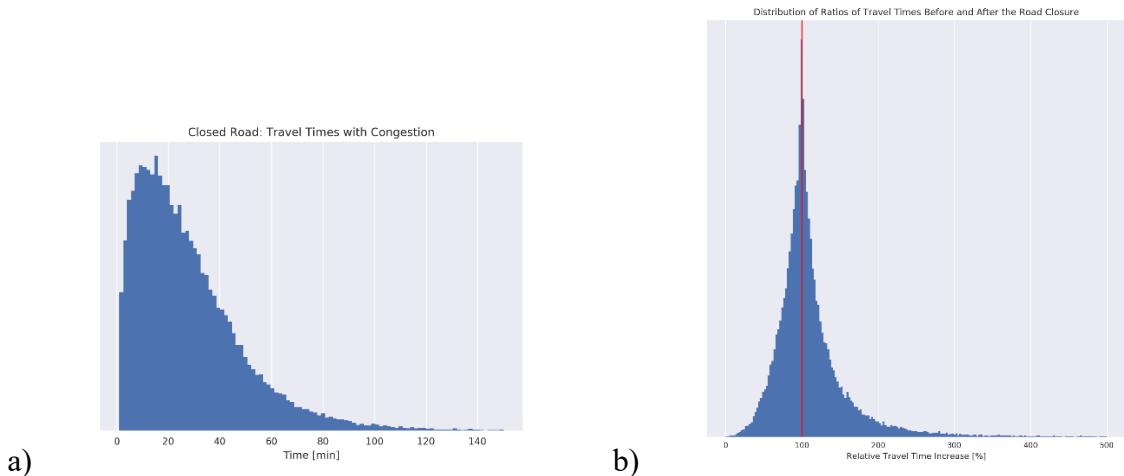


Figure 2: (a) Histogram of the distribution of trip travel times after the road closure. Mean: 23.1; Median: 18.2.
 (b) Histogram of the ratios by which trip travel times increased after the road closure. Mean: 113%; Median: 101.4%.

Figure 2b further illustrates this point. Here, we computed for each trip the relative amount by which the travel time increased after the road closure and plotted their distribution. On average, the travel time increased by 13%. This, however, is due to the long tail of the distribution. The median increase in travel time only amounts to 1.4%. Note, that due to the randomness of the co-evolutionary algorithm some agents might have found a better route during the second simulation compared to the first. This effect is completely independent of the road closure. Hence, the considerable number of trips that actually decreased in travel time.

3.2 Difference in travel times for affected trips

Next, we only consider trips that were actually affected by the road closure. I.e. trips that incorporated at least two of the deleted links. 2.3% of all trips made by agents in the synthetic population fulfil this criterion and for this subset of trips we observe a much larger impact on travel times. Figure 3 shows the distribution in travel times before and after the closure, and the relative increase in travel time. Here, the average travel time increased by 10 minutes from 42.5 minutes to 52.2 minutes. This corresponds to a median increase in travel time for individual trips by 19%. Thus, the minority of people that is affected by the road closure, will, in fact, observe a quiet noticeable increase in travel time.

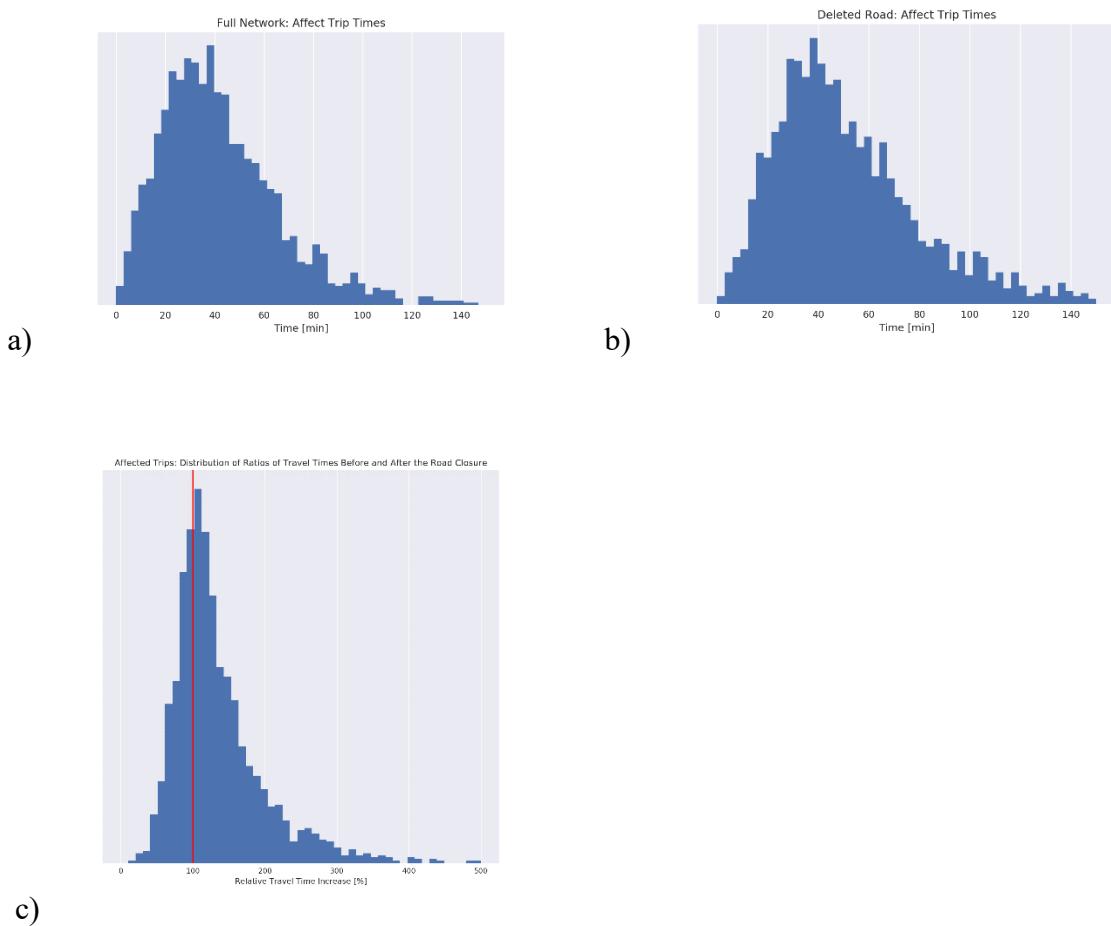


Figure 3: (a) Histogram of the distribution of travel times before the road closure, for affected trips only. A trip is considered to be affected if it incorporated at least two of the deleted links. Mean: 42.5 minutes; Median: 38.2 minutes. (b) Histogram of the distribution of travel times after the road closure, for affected trips only. Mean: 52.2 minutes; Median: 45.9 minutes. (c) Histogram of the factors by which trip travel times increased after the road closure, for affected trips only. Mean: 143%; Median: 119%.

It can also be seen that the proportion of smaller travel times is lower in comparison to the overall travel time distribution. Considering that every trip is affected in this distribution, the proportion with smaller travel times is large. The shorter travel times can be a result of the moved activities. It's possible that the chosen route to the moved activity is faster. But the walking leg is not considered. It's also possible that the shorter travel time results of the changed route of all agents. The chosen route can be less affected by other agents and that leads to a decrease of the congestion and a decrease in travel time. There could be more explanations, but the smaller travel times do not affect the congestion and therefore it will not be considered further.

3.3 Example of route changes

Finally, we present some examples of how exactly individual agents deal with the road closure. The following Figures show the route before the closure (red) and the route after the closure (green) for exemplary trips. Figures 4a and 4b present two trips that were affected by the road closure. In both cases the travel time increased heavily. In figure 4a, the increase in travel time is a result of the large detour. The agent has to go around the city. In the figure 4b, the new route has almost the same distance. The additional travel time comes from a lower travel speed. The cause can either be a higher traffic volume or lower allowed speeds.



Figure 4: Examples of route choices before (red) and after (green) the closure – Increase the travel time

Figure 5 shows an example of a trip where the agent could compensate the closed road by avoiding the city centre all together. This route only takes slightly longer than the original one.

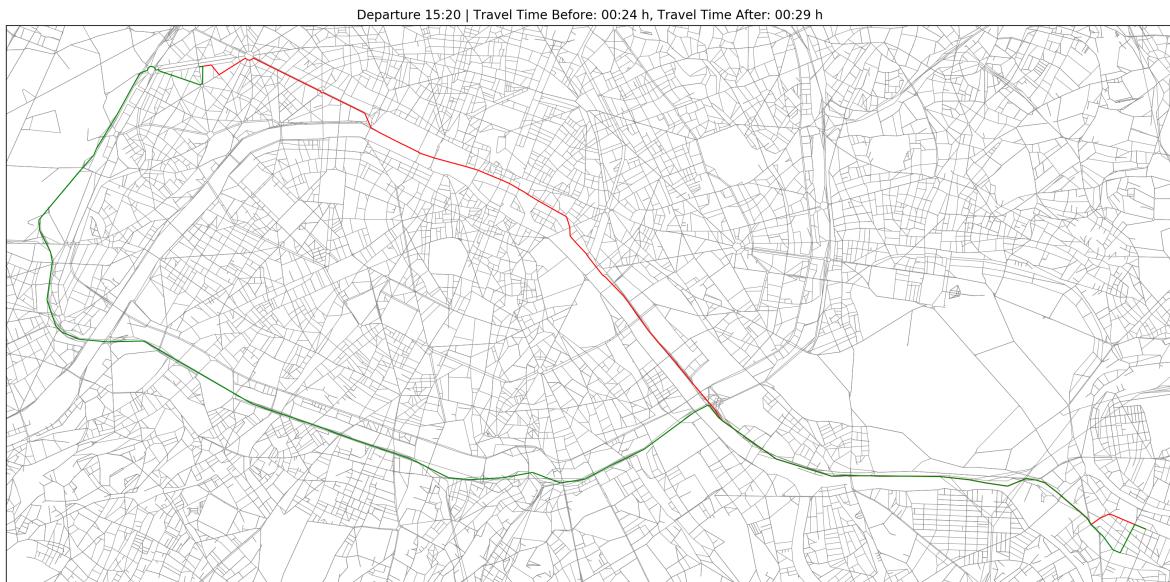


Figure 5: Examples of route choices before (red) and after (green) the closure – small increase in the travel time

Finally, Figure 6 shows a trip that seems to have been positively affected by the road closure. This, however, is a result of the previously mentioned randomness of the co-evolutionary algorithm. That is, the algorithm (by chance) computed a suboptimal route choice for the agent during the first simulation.

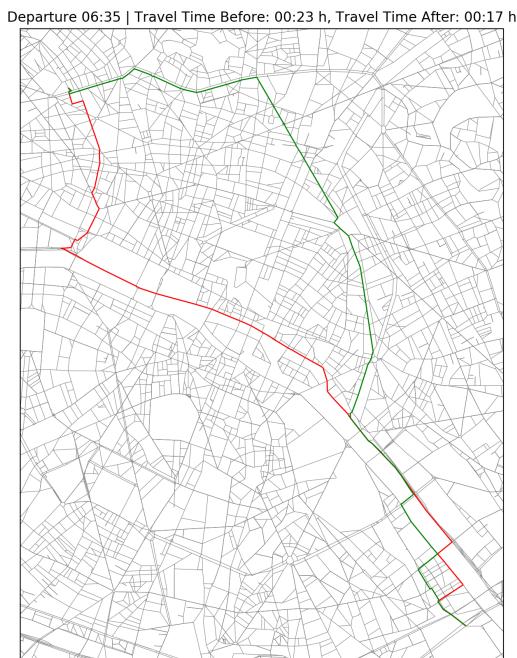


Figure 6: Examples of route choices before (red) and after (green) the closure – decrease in the travel time

3.4 Difference in the load of the Roads

The closed road leads to a new distribution of the chosen routes. To compare the load before and after the change, the traffic volume per hour was calculated for each link from the events file. The traffic volume was determined for the simulation before and after the closure of the road. The result is the count data of the study area.

The total sum of all counted cars increases by 0.57%. Since the length of each link was not considered, this value says nothing about the additional travel time or distance. It shows the additional required capacity of the road network. The cars use more roads on average, because they choose other routes. This leads to a higher load in the road network. The 0.57 percent correspond to 31'000 cars. If they spread across the whole network, the increase will not be a problem. But it is reasonable to assume that the affected cars choose a similar substitute route. Consequently, it must be proved which roads have the highest increases and if the capacities are sufficient.

Only the links can be compared, which have a traffic load before and after the closure. There are some links which have a load only before the closure and some links have only a load after the closure. There are over 6'000 links, which have a load only after the closure. The maximum total amount of cars per day and per link of these 6'000 links is nine cars. This amount can be neglected. Therefore, these 6'000 links were not considered in the analysis.

The comparison of the relative increase has shown that certain links have an increase of more than 1000%. This is because many links have a very low load of 1 to 2 cars per day before the closure. After closure, they have a traffic volume of 10-20 cars per day. That's an increase more than 1000 percent. But the total amount of cars is negligibly small. Therefore, only the difference in the number of cars was considered for the analysis.

Figure 7 shows the difference in number of cars per day. It can be seen that the majority of the links have only a small increase. An increase of 50 cars per day means an average increase of 2 cars per hour. This small additional load should not be a problem, but it will be proved in the next section.

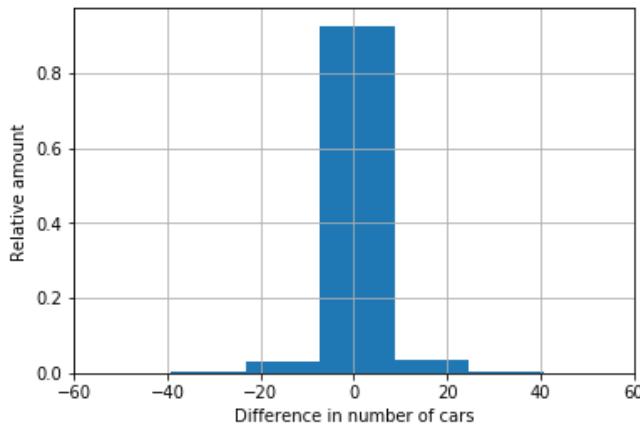


Figure 7: Difference in numbers of cars after the closure

Figure 7 does not show that there is a small amount of links, with an increase of more than 50 cars. Figure 8 shows all links with an additional load more than 60 vehicles per day (blue) and the deleted links (red). It is noticeable, that all these links concentrate around the closed roads. They are all in the city centre. Consequently, no large detours are driven. Available capacities outside the city centre are not utilized to compensate the closed roads.

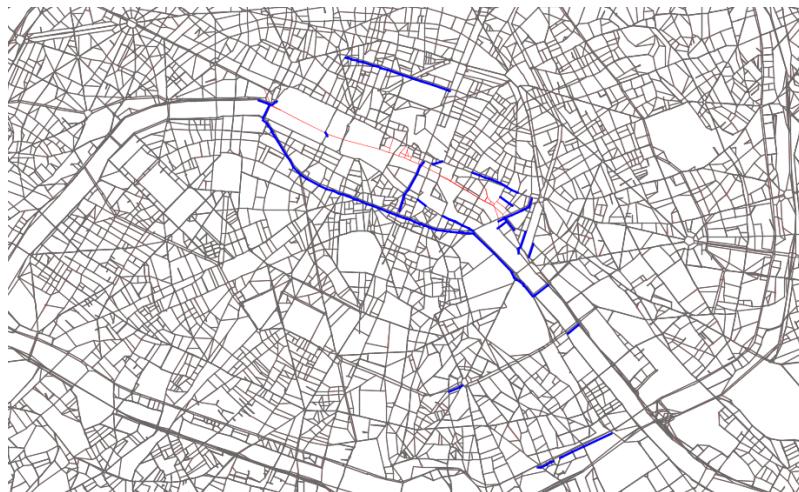


Figure 8: Links with an increase in traffic volume more than 60 vehicles per day (blue) and deleted links (red)

Figure 8 approved the assumption that the affected cars choose a similar substitute route. Most of the blue links are important connections to avoid the closed roads. Consequently, the cars change from the closed route to these routes. From the point of view of traffic planning, it should be proved, if such an increase on the roads can be accepted.

3.5 Degree of capacity utilization after the road closure

The additional load of the roads can lead to problems with the capacities. This section proves the degree of capacity utilization of all roads. It also considers the roads, which were neglected in the last section. It ensures that no roads are neglected, which can lead to bottlenecks.

The capacities of the links were compared with the maximum hourly traffic. The highest calculated degree of capacity utilization after the closure is around 4%. The traffic demand in this simulation is much lower than the available capacities. Therefore, it is unnecessary to perform more analysis about the degree of utilization. The question is why this value is so low. Such a small value seems unrealistic for a city like Paris.

The input population data is limited to the Ile de France region. A synthetic population has been created for this region. A degree of utilization of 4% shows that this population contains too few agents for a realistic simulation.

3.6 Temporal change in traffic volume

This section proves the temporal distribution of the traffic volume. Figure 9 shows the temporal distribution of the traffic demand of the whole network before (orange) and after (blue) the closure. It can be seen, that the closure does not affect the temporal distribution of the demand.

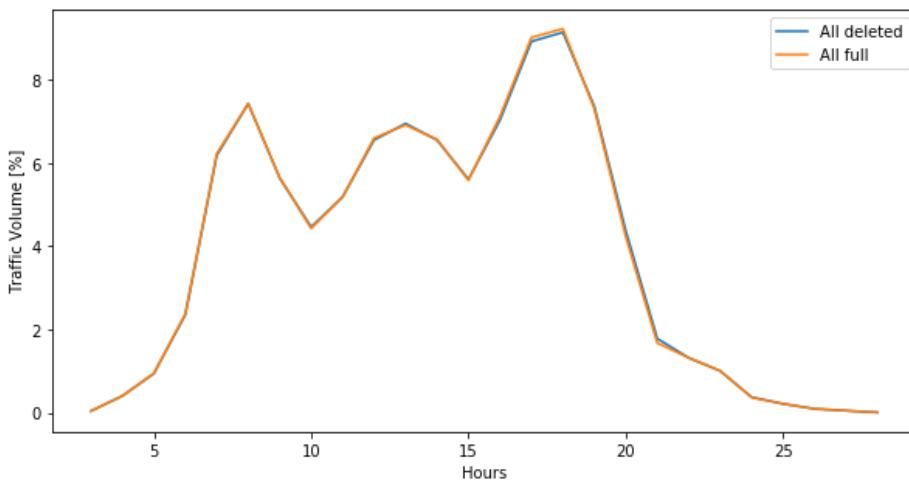


Figure 9: Traffic volume through the day of all links

The peak hours are visible in this figure. There are three peak hours through the day. The maximum peak hour defines the required capacity. If the capacity is adapted to the demand, it will only be satisfied during this peak hour. During the rest of the day, the capacity utilization

remains below capacity. A more uniformed distribution of the demand can use the network more efficiently. It has to be proved, which strategies would reach a more uniformed distribution. However, this is not necessary as long as there are no capacity bottlenecks.

As shown in section 3.4, the amount of links that have larger increase in the load of traffic is very small. A change in the temporal distribution on these links will not be recognizable in figure 9. Therefore, the same figure was created again, which contains only the links, which have an increase of over than 60 cars. Figure 10 shows the temporal distribution of the traffic demand of these links before (orange) and after (blue) the closure.

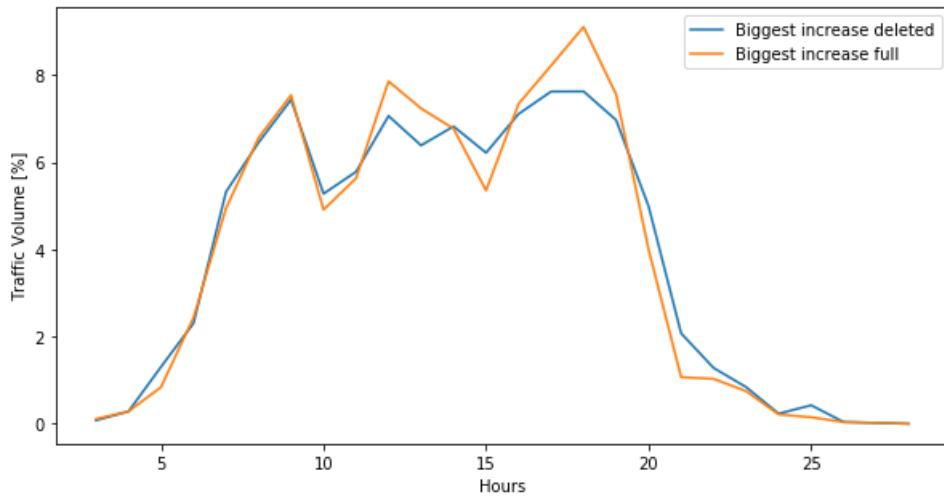


Figure 10: Traffic volume through the day for the links with an increase more than 60 cars

It can be seen that the influence on the temporal distribution at these links is greater than before in Figure 9. The road closure leads to a more uniform distributed traffic demand. The demand has grown, but it is better distributed. The peak hours are lower than before the closure. As a result, less capacity is needed, although the demand has increased.

4 Conclusion

In this simulation, the change due to the closure is small and therefore acceptable. There is only a small extension in the travel time. The dense road network provides many substitute routes. The new routes have on average no big disadvantages compared to the original routes. From the agent's point of view, this closure can be made.

The traffic volume of each link and the temporal distribution of the demand do not change either. The whole network can compensate the closure. A specific look at the city centre identifies a small number of links, which are the most used substitute routes. These links have the biggest changes due to the closure. The demand increases and is more uniform distributed. The more uniform distributed demand uses the capacities more efficiently. The demand is also small compared to capacity. As a result, the closure can be done without any problems due to insufficient capacity.

All results are too less meaningful to evaluate the consequences of this change in infrastructure. The number of agents is too small to simulate the influence of the closure. The closure does not cause any problems, because there are enough capacities left. It can be assumed that in reality the roads are more heavily loaded. In reality, the new selected routes can lead to an overload on other roads. The consequence would be that more other routes may be chosen. The traffic volume will increase over a larger region, because more agents will be affected. The less capacity in the centre is left, the larger becomes the radius of the influence of the closure. In the end, it also leads to a greater increase in travel time.

The simulation runs with a very small demand and ignore these consequences completely. The simulation only identifies the most chosen substitute routes. Thus, only the links are determined, which leads first to bottlenecks.

5 Discussion

5.1 Limitations

The simulation is characterized by various simplifications, which lead to limitations. The biggest simplification is that only the cars were considered. As a result, many factors were not considered. The city of Paris is a big city with a dense road network. On this road network are other modes of transport, which can affect the cars. There are pedestrians, the public transport, cyclist and more. That means the simulations run under perfect operating conditions for the cars. All capacities in the city centre are available only for the cars. The different modes of transport concentrate normally in the city centre and need the capacity too. In this case, it could be possible, that a large detour around the city centre is a better choice than through the city centre.

In addition, the road network has a high density of intersections. All modes of transport have to pass these intersections. The intersections are normally signalized and reduce the capacity for the cars. Signalized intersection can lead to long queues and an increase in travel time. The routes through the city centre are therefore too attractive. A proper study of the effects of closure is not possible without taking these factors into account. It's just an indication of what's going to happen.

5.2 Future work

The future work will be to capture more important factors, which can affect the simulation. A realistic demand can improve the results. The demand should be extended by the traffic demand from other purposes. The demand, for example, should be extended by the demand from outside the region, city logistics, other modes of transport and tourists.

Another important point is the modeling of possibilities. The agents can only choose the routes. As a result, they do not have many options to respond to the closure. The most important options would be the choice of different means of transport or the departure time. It is possible, that the agent is faster, if he takes the bus or walk. He can also be faster, when he drives outside the peak hours. More possibilities allow the agents to reduce the disadvantages of the closure better.