Effects of Marathon Road Closures on Taxi Service Times in Manhattan

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1. Introduction

In a busy city such as New York City, efficient and smooth flow of traffic is a critical infrastructural problem that is central to efficient running of the city and its constituent businesses. Disruptions to the road networks, can have a crippling effect on businesses that rely on the roads such as deliveries and taxi services. In between smooth traffic flow and disruptions is the case of pre-planned disruptions. This could take the form of pre-announced road closures for special events such as the TCS New York Marathon that takes place annually.

The TCS New York Marathon attracts approximately 55,000 runners and many more tourists who come to watch the race every year. As a road race, the TCS New York Marathon takes place on roads usually meant for vehicular traffic. On average, over 40 stretches of roads are closed annually to facilitate the race. This creates considerable inconvenience for taxis and often results in increased service times for passengers.

This project aims to develop a methodology and a preliminary tool that is capable of modelling movement of Yellow Taxis in Manhattan under full road availability and partial road closure scenarios. It is envisaged that this may inform planners of the TCS New York Marathon and act as a planning aid in the organization of the race logistics.

2. Data

Data was collected from the TLC yellow-taxi trip data, which includes the location and time of pick-up and drop-off points, estimated distance, number of passengers, amount paid and payment method of each trip. Trips on four specific Sundays in November, 2019 (2019-11-03,2019-11-10,2019-11-17,2019-11-24) were selected since November 3rd is the race day with the rest as controlled days. Some insights could be drawn from the initial exploration of the data.

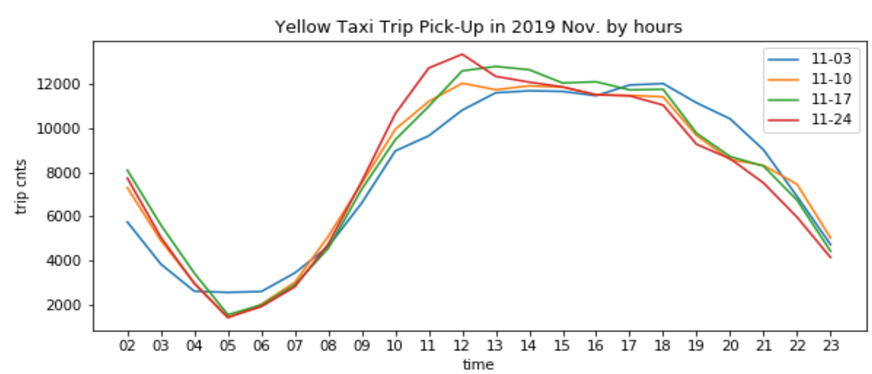


Figure 1 Number of Yellow Taxi Pickups by hours

Figure 1 shows the number of pick-ups from 2am to 23pm on four Sundays. Compared with normal Sundays, the volume on race day was lower from 2am to 4am with some roads starting to be closed. There is an early increase in volume from 5am to 7am as marathon candidates set off for the race. Pickups from 10am to 13pm were obviously less than normal Sundays while as the marathon ended, there was a higher number of pickups after 18pm.

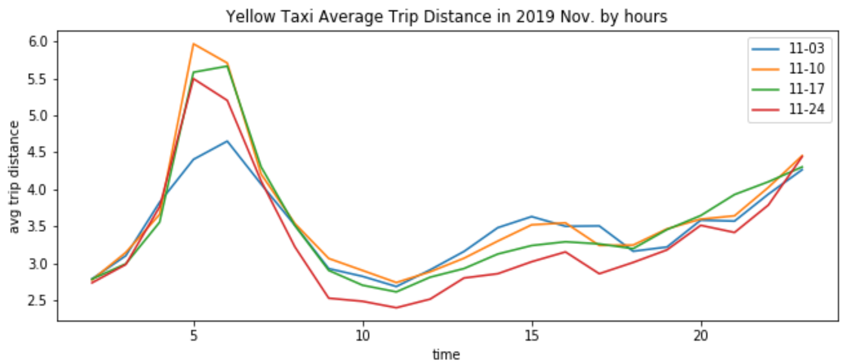


Figure 2 Average Travel Distance of Yellow Taxi Trips by hours

In terms of average travel distance, there was a significant drop from 5am to 7am. The reason might be that marathon candidates took a taxi to the nearest scheduled station to take the official transportation tools.

3. Network Development

Without relevant data, developing a network that covers the entire of New York State or even Manhattan would require significant amounts of manual data entry and therefore could not be achieved for this project. In lieu of this, a network of Manhattan was developed by segmenting Manhattan into zones. The zones were decided as per the official TLC Taxi Zones in Figure 3.

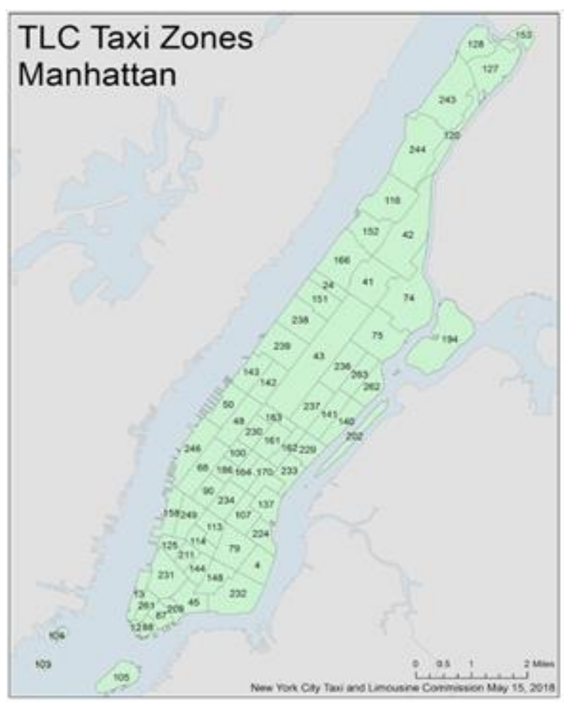


Figure 3 TLC Taxi Zones

The network was derived as follows. First, a list of nodes corresponding to Taxi Zones was extracted from the data. Therefore, all Taxi Zones where there was at least one taxi ride either originating or terminating are included in the list of nodes. A total of 27 nodes were identified. Second, a list of edges was extracted from the data. The list was derived by identifying a list of unique trips between zones present in the data, resulting in a total of 54 edges. Though there were instances of within-zone trips, these were excluded from the analysis on the basis of a lack of granularity with regards to the available data used to construct the network resulting in no meaningful analysis that can be conducted on within-zone trips.

Weights for the edges w_{ij} were approximated from the data by finding the mean travel time $t_{ij,k}$ of all trips between a particular set of nodes.

$$w_{ij} = \frac{1}{n}\sum_{k=1}^{n} t_{ij,k}$$

The aforementioned procedure yielded the following network in Figure 4.

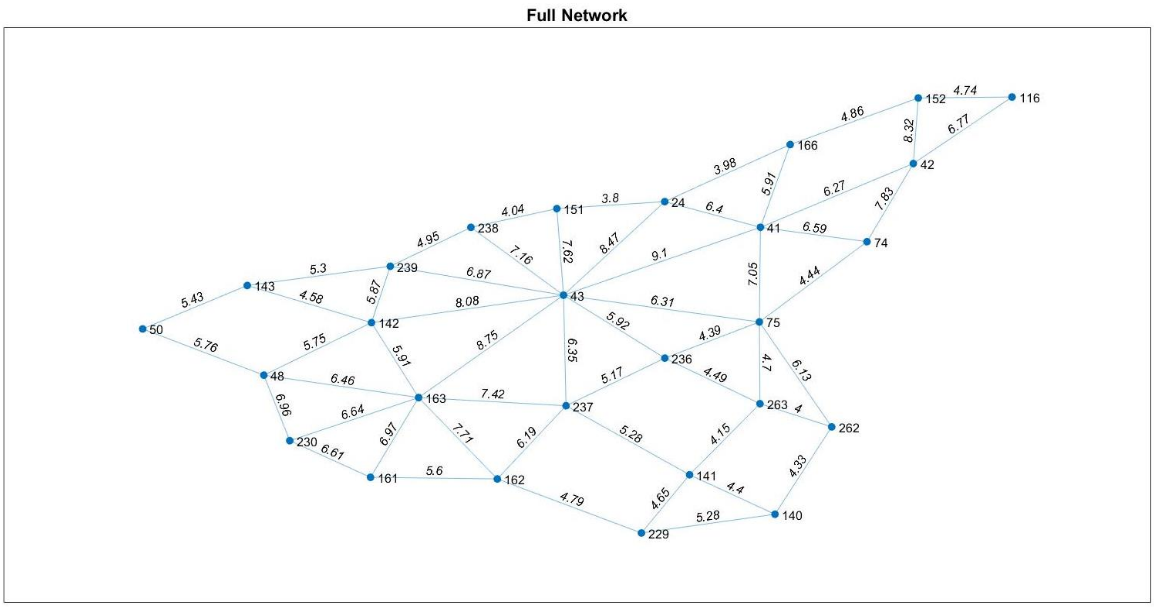


Figure 4 Visualization of Manhattan Road Network

4. Modelling Road Closures

The approximately 42 road closures that occurred in the 2019 TCS New York Marathon resulted in the closure of approximately 9 miles of road in Manhattan, including large swaths of 1st Avenue, 5th Avenue and roads surrounding and within Central Park. Ideally, our network should have edges corresponding to the exact roads that are closed. However, due to the constraints described in section 3, this is not possible. As an approximation, entire zones corresponding to the closed roads are removed from the network to simulate no-go zones where vehicular traffic cannot pass. The corresponding zones are detailed in Table 1.

Table 1 Taxi Zones Corresponding to Road Closures

Closed Road	Zones
Central Park & Surrounding Roads	43
1st Avenue	140, 262
5th Avenue	74, 75, 236, 237

Removing these nodes from the full network results in the following networks in Figure 5.

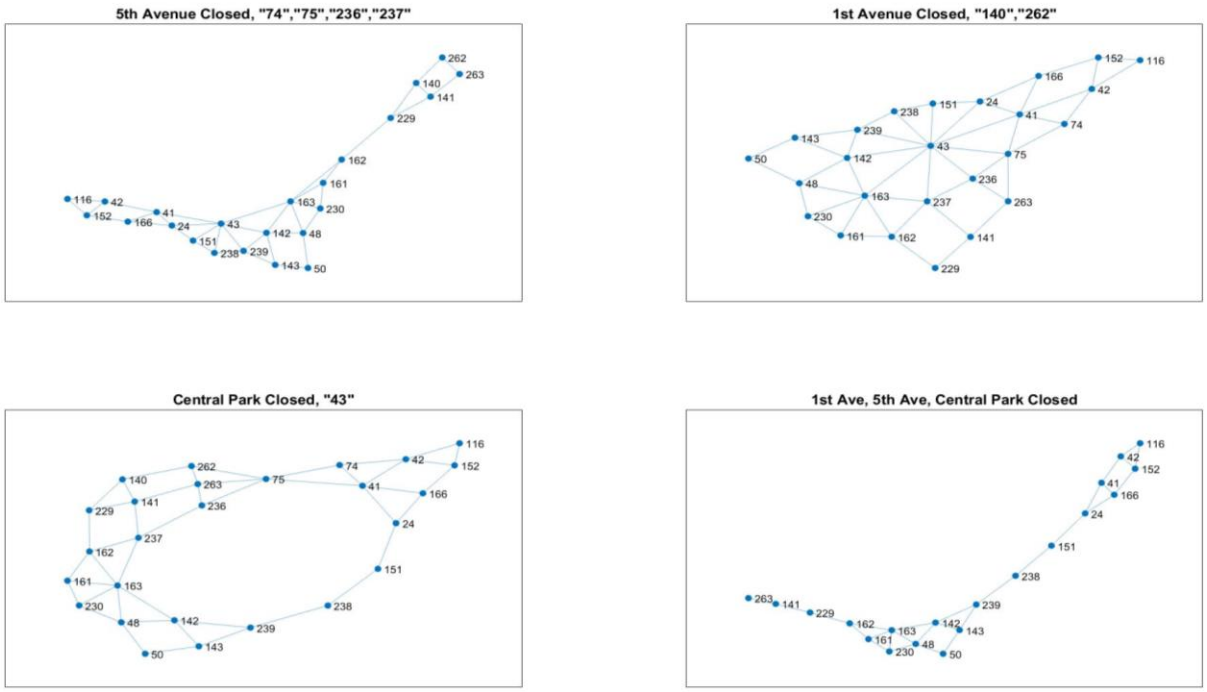


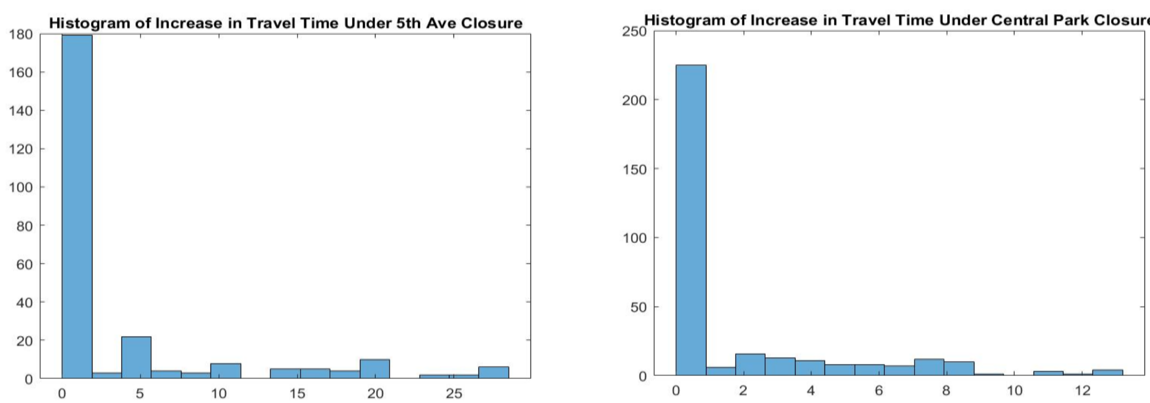
Figure 5 Visualization of Reduced Networks (Top Left: 5th Ave Closed, Top Right: 1st Ave Closed, Bottom Left: Central Park Closed, Bottom Right: 1st Ave, 5th Ave, Central Park Closed)

5. Finding Travel Times

a. Increase in Travel Time by Route

The baseline travel times were found by setting up shortest path problems and solving them for each possible pair of nodes in the full network described in section 3. Following which, the travel times for each of the 4 reduced networks in section 4 was computed similarly. The travel time t_{ij} was then compared and the increase in time δt_{ij} was calculated.

Figure 6 (continued on the next page) shows the increase in travel time across all possible trips in the respective networks.



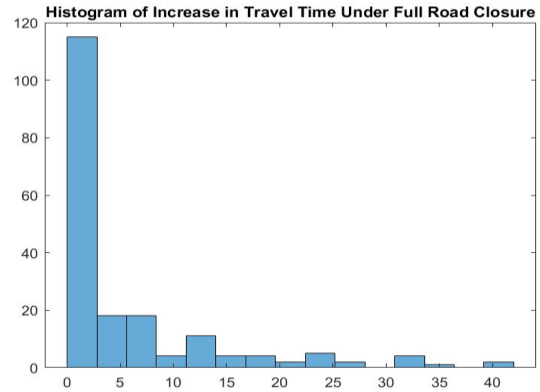


Figure 6 Increase in Travel Time Due to 1st Ave, 5th Ave and Central Park Road Closures

The histogram corresponding to the 1st Ave Closures was not presented as there was no change to all the travel times. This can be attributed to the nodes representing 1st Ave (Nodes 140, 262) residing on the periphery of the full network and therefore affecting very few, and in this case none of the shortest paths.

As expected, the majority of travel times were unaffected by the closure of a few nodes, particularly as the nodes are often adjacent to each other. However, 32.4% of routes were impacted by closure of 5th Avenue, 33.2% of routes were impacted by closure of Central Park and surrounding roads and 47.4% of routes were impacted by the combined closure of 1st Ave, 5th Ave and Central Park.

b. Estimating Demand

To obtain a holistic understanding of the global impact of road closures on travel times, it is important to consider the distribution of demand across the different zones as well. Using the data, estimated demand rates $\lambda_{i,t}$ were derived for several times, corresponding to peak and non-peak hours. These can be accessed in Appendix 1. The demand rates used were obtained as the average number of taxis demanded in each zone per hour over all datapoints in the data.

c. Global Time Increase Due to Road Closures

Due to limitations with the data size, a simplifying assumption is made such that the demand for each route starting from a particular zone is uniformly distributed amongst all other remaining nodes. This allows us to calculate the mean increase in travel time for each zone δt_i.

$$\delta t_i = \frac{1}{n} \sum_{j \neq i} \delta t_{ij}$$

Multiplying the mean increase in travel time for each zone with the demand for each zone in each time period gives the global hourly service time increase for each time zone. This is shown in Figure 7.

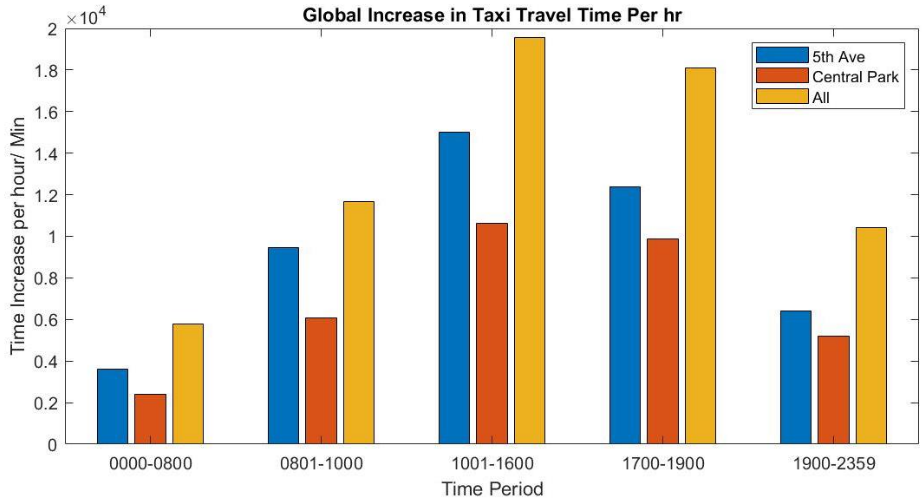


Figure 7 Ride Time Increase by Time Zone

Interestingly, the global increase in ride time in the morning peak hour (0801-1000) is lower than that of the afternoon hours. This suggests that road closures which are often in effect till noon would have a significant impact on the overall travel time.

The above analysis allows us to find the mean time increase per ride under the 3 scenarios of a 5th Ave closure, a Central Park closure and an overall closure which is presented in Table 2.

Table 2 Mean Increase in Travel Times

Closed Road	Mean Time Increase
Central Park & Surrounding Roads	1.15 min/ ride
5th Avenue	1.94 min/ ride
1st Avenue, 5th Avenue, Central Park	2.94 min/ride

6. Conclusion

This project has proved that road closures have a significant impact on the global travel time of all taxis operating in Manhattan. It is predicted that the closure of roads during the New York Marathon impacted 47.4% of all taxi rides within Manhattan, at a cost of an increase of 2.94mins/ride. This project has also provided insights into planning considerations that when taken into account, have the potential to limit the impact of road closures. They are:

1) Closing roads near the boundary of Manhattan such as 1st Avenue over roads that are located in the middle of the city.
2) Reopening roads by 10am would reduce the number of commuters affected by the road closures as well as reduce the average increase in travel time.

However, a critical limitation of this project remains a lack of resolution of the network developed due to the use of zones as nodes instead of road intersections. As a result, the results presented in this report should be viewed as worst case scenarios.

Appendix

Appendix 1: Table of Demands

Demand values are in number of taxis demanded per hour $\lambda_{i,t}$ within the stated time range.

Time	**00:00-08:00**	**08:01-10:00**	**10:01-16:00**	**17:00-19:00**	**19:00-23:59**
Node	**Non-Peak**	**Peak**	**Non-Peak**	**Peak**	**Non-Peak**
24	10.00	38.50	42.43	36.33	18.80
41	20.67	54.33	54.48	45.00	24.33
42	9.33	25.17	18.67	12.50	6.60
43	19.50	115.33	290.48	180.17	77.00
48	241.67	204.83	318.86	369.67	331.00
50	67.71	110.83	105.95	86.33	63.73
74	22.67	40.00	43.10	37.17	20.73
75	28.21	87.00	86.14	68.67	36.73
116	7.67	12.50	10.71	6.67	6.47
140	37.54	118.33	181.67	160.00	81.47
141	91.08	189.17	327.57	273.33	155.73
142	73.33	193.67	425.90	549.50	236.80
143	20.50	119.17	180.10	140.33	60.53
151	20.96	98.17	160.81	114.17	51.20
152	5.29	6.67	9.19	9.33	4.60
161	84.67	173.33	454.38	481.50	244.53
162	69.17	178.00	333.90	369.17	197.67
163	99.75	157.17	344.48	336.50	208.80
166	15.79	41.50	60.90	57.33	31.27
229	69.04	135.33	225.52	183.33	117.13
230	189.00	250.50	398.43	457.33	361.87
236	50.04	279.33	550.71	440.00	183.13
237	74.92	223.33	560.33	532.83	235.40
238	46.67	232.67	302.05	247.50	108.67
239	64.75	236.83	472.19	373.83	174.07
262	23.54	139.17	180.29	119.83	43.60
263	90.25	161.00	260.14	220.83	124.40