Northeast Region
Ride Sharing Analysis

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Executive Summary

In this document we analyse the ridesharing potential of the Northeast Region of the United States. The foundation of the analysis is the NN files, a set of files that represent every individual person within our region and the exact sequence of trips they take on a daily basis. For our population of almost 70 million residents, there are 203 million individual trips originating within the counties.

The entire United States is 'pixelated' into 0.5 mile by 0.5 mile squares, and we seek to provide a ride-sharing solution for a defined level-of-service. Ride-sharing opportunities exist when more than one person is going from approximately the same origin, to approximately the same destination, at approximately the same time. We processed all 200 million trips into individual aTaxis, which is our 5-capacity autonomous vehicle, the basis for our system.

We found that there is genuine ridesharing potential in the northeastern united states. In terms of person-miles-travelled and vehicle-miles-travelled, we were able to achieve an average vehicle occupancy (AVO) of over 1.40. Extremely dense urban areas did very well in achieving high occupancy, as would be expected. However, even rural areas saw ride-sharing potential, which seems contrary to common sense. The cause of this may simply be that in less-dense areas, there are just not that many different destinations to visit for work, or for pleasure.

The implications of this analysis on the environment, economy, and politics are more nuanced than this. Demand and supply of vehicles varies at different locations throughout the day, and in order to satisfy all of the demand, repositioning of empty vehicles is a necessity. We establish a lower bound of fleet size at 6.5 million, and an upper bound at 12.6 million. The lower bound is assumptive of instantaneous repositioning of vehicles, a naive approach. The upper bound is assumptive of only a single repositioning at midnight, a lazy approach. The ideal fleet size and repositioning strategy lies between these two extremes, and should be the focus of further analysis.

We also performed a simple business analysis to look at the capital requirements for investors and desire to consumers, finding that even under conservative assumptions, there is the potential to provide return to investors whilst affordable service to citizens.

Introduction

Our job through this assignment was to assess ride-sharing for the entire Northeast. The Northeast here is defined as Connecticut, Washington D.C., Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, Virginia, Vermont and West VIrginia. As the Northeast is the most densely populated part of the United States, this network of people and their respective trips is quite extensive. In order to fully assess the possibilities of a ride-sharing network in this area, there were several steps we had to take. While the Northeast is generally very densely populated, there is still a broad range in population across states and it is this combination of rural and non-rural areas that makes ride-sharing quite interesting. First we looked at the NN Files provided to get an idea of the Population totals, geographic distribution of the counties, PersonTrip totals and geographic distribution of the PersonTrips and average PersonTrip Lengths. Next we assessed the trips originating in the region based off of the NationWide Trip Data provided. This included AVO analysis and creating aTaxi Trip files as well as assessing supply and demand for the SuperPixels. Lastly, we assess the business case for the region and the potential profit there may be from implementing this. Through our assessment, we can conclude that this implementation has the potential to make substantial money.

Assessment of Population Served

The Northeast is the most densely populated region in the country, about 2.5 times more populated than the second-most populated region, the South. With many metropolitan areas, the population tends to be quite concentrated.

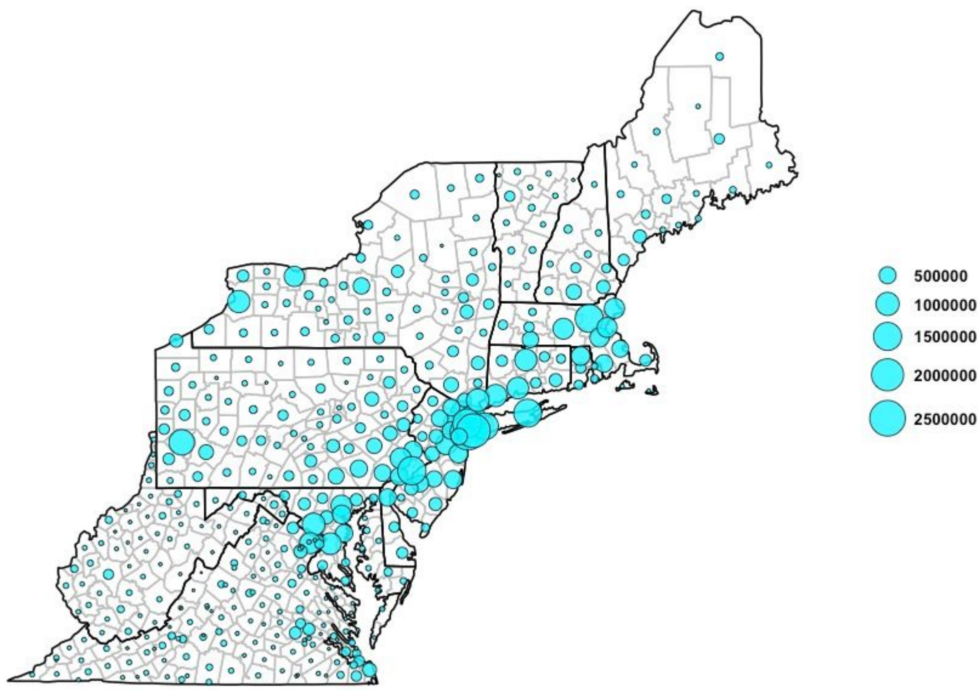
Population: 69,843,652

Major Cities in Each State:

- Connecticut: Bridgeport, New Haven
- DC
- Delaware: Wilmington, Dover
- Maine: Portland, Lewiston
- Maryland: Baltimore, Frederick
- Massachusetts: Boston, Worcester
- New Hampshire: Manchester, Nashua
- New York: New York City, Buffalo
- Pennsylvania: Philadelphia, Pittsburgh
- Rhode Island: Providence, Warwick
- Virginia: Virginia Beach, Norfolk
- Vermont: Burlington, Essex
- West Virginia: Charleston, Huntington

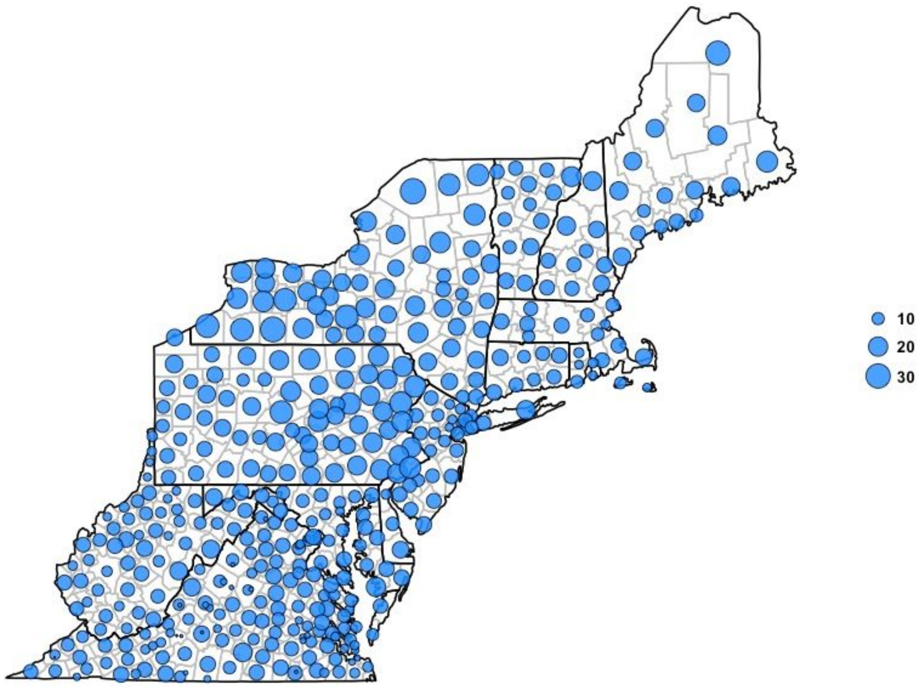
The economy of the Northeast is quite diverse. The economy is fueled by a variety of jobs including agriculture, finance and manufacturing.

Population Distribution (NN Files)



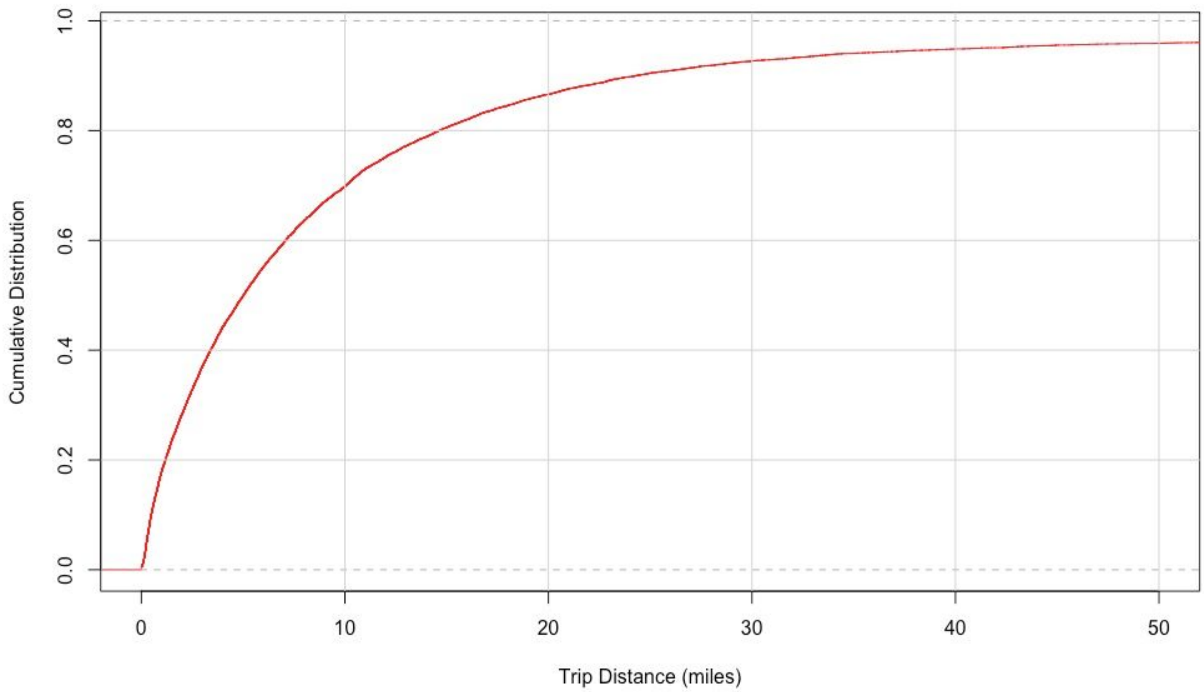
This graph shows very clearly how densely populated the Northeast Megalopolis is. This are includes the following major cities: Boston, Providence, Hartford, Bridgeport, New York City, Philadelphia, Wilmington, Baltimore and Washington, D.C. This area is almost a direct line and gives us a good idea of where most of the trips will be concentrated as people live and work in these cities and their respective suburban zones.

Mean Trip Length by County (NN Files)



Here we see that in more rural areas, the trip lengths tend to be larger. This makes sense because looking at the state of Pennsylvania, the more northern counties have a lower population and therefore the trips are longer. For the state of New York, the same thing applies as the north-most parts are less populated and once again the trips are longer.

Trip Length Distribution (NN Files)



This trip length distribution is based on the NN files provided. It shows how more than half of the trips are under well under 10 miles and very few of the trips are greater than 20 miles. This is very consistent with what you would expect in such a densely populated area, as travelling to work or home or to commercial areas can never be that far generally.

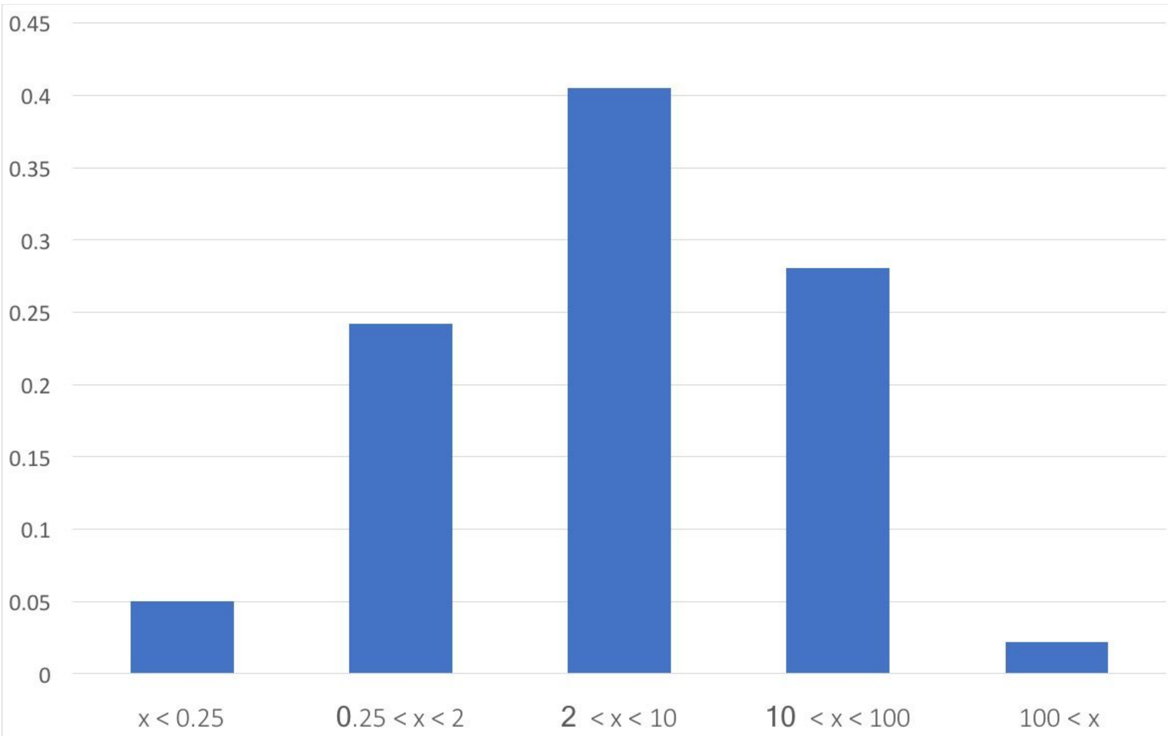
Ride Sharing Analysis

In order to perform our ridesharing analysis we processed the modal trip files for our region. This consisted of all person trips originating within our region that were long enough to be unwalkable, but short enough so as to not be more effectively mode via transit. In order to process these trips and place them in aTaxis, we needed to define a level-of-service (LoS) that we wanted to provide:

Min Distance (Miles)	**Max Distance (Miles)**	**Maximum Wait-Time**	**Destination Super Pixel**
0.25	2	300	2x2
2	10	420	3x3
10	100	600	5x5
100	N/A	1200	10x10

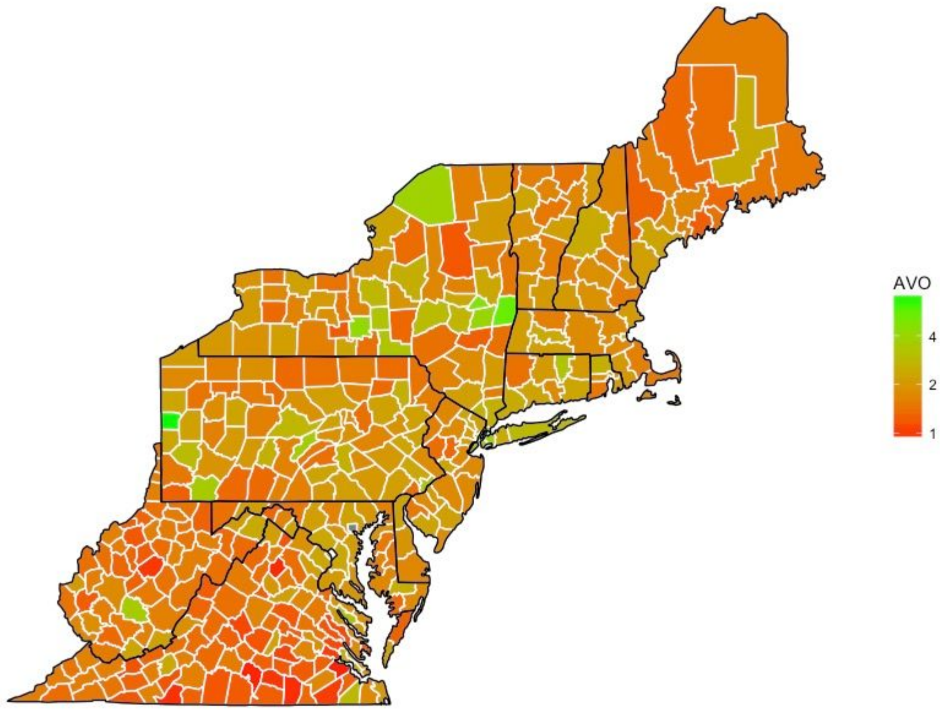
Each trip length bin has an associated wait-time, the maximum amount of time the 'first' passenger is willing to wait before the departure of the aTaxi. We only put passengers originating from the same pixel in the same aTaxi. However, depending on the trip length, there is a 'superpixel' of destinations that passengers in the same aTaxi may be going to. The larger wait times a super pixels for longer trips indicate a passengers more lenient approach when travelling further distances, and also ensures no significant loss in vehicle occupancy due to circuity loss. We process our 203 million trips into vehicles, and show further analysis in subsequent sections.

Trip Length Breakdown (Walk and aTaxi Trips)



The above displays the breakdown of the trip lengths including walking trips and aTaxi trips. Note that trips that need to be rerouted to transit are absent from this distribution. As expected, the range with the most trips are 2 to 10 miles long because most trips that people take on a daily basis are not very long, especially in densely populated areas and the Northeast is the most densely populated part of the country.

AVO Analysis (Unlimited Occupancy)



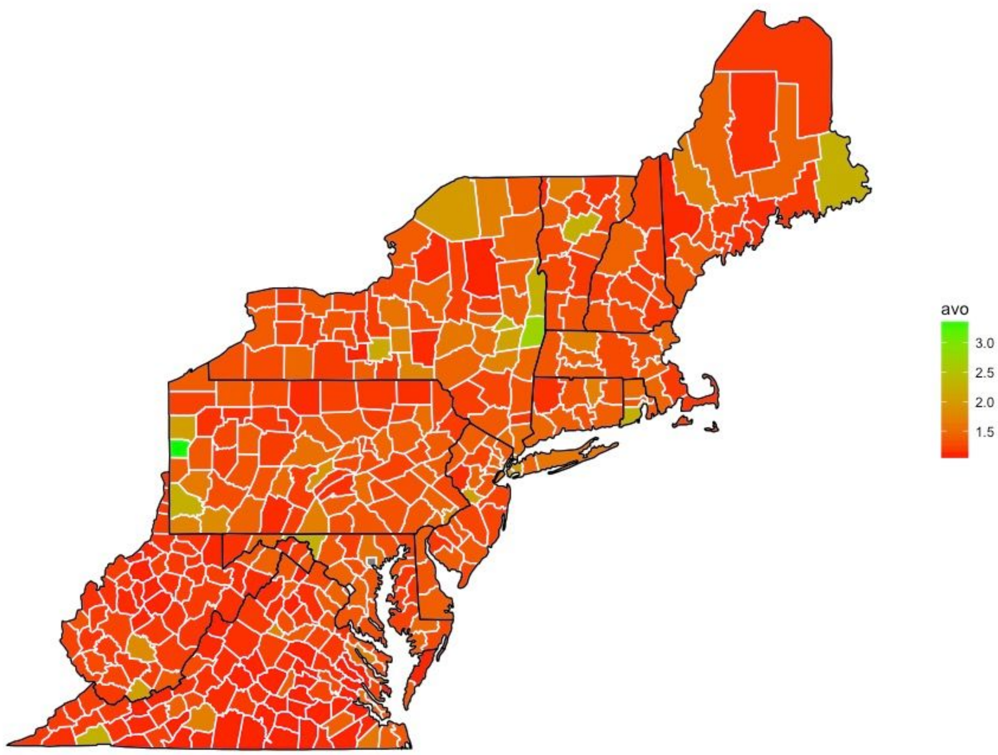
This AVO analysis does not show any particular trends. Perhaps this means that in fact ride sharing is possible and would be effective in rural areas. AVO does not consistently get that much lower in more rural areas, but rather the distribution across counties is somewhat inconsistent.

Top 6 Counties by AVO (Unlimited Occupancy)

FIPS	Metro Area	aTaxis	PMT	AVO
36083	Albany, NY	321,936	44,643,328	4.39
36093	Albany, NY	272,110	16,671,474	3.33
42125	Pittsburgh, PA	459,655	47,938,179	3.05
36109	Ithaca, NY	190,774	21,327,195	2.78
36005	Bronx, NYC	649,543	33,975,009	2.66
36001	Albany, NY	648,313	463,36,163	2.6

The above are the FIPS codes with the highest AVOs when occupancy is unlimited. It is interesting to note that these areas are somewhat rural areas. One reason for such a high AVO in more rural areas could be that since there are fewer places to go in rural areas and trips tend to be longer, people might be going to more or less the same destinations. If people are leaving areas with fewer offices, the commute may be to the same nearest commercial/corporate area.

AVO Analysis (5-Occupancy Limit)



Here we see that with occupancy limited, the graph just shifts to have overall much smaller AVO values.

Top 10 Counties by AVO (5-Occupancy Limit)

FIPS	Metro Area	aTaxis	PMT	AVO
36083	Albany, NY	368,414	44,643,328	2.73
36093	Albany, NY	340,899	16,671,474	2.32
42125	Pittsburgh, PA	530,280	47,938,179	2.25
36109	Syracuse, NY	203,190	21,327,195	2.18
36005	Bronx, NY	959,579	33,975,009	2.17
36001	Albany	713,496	46,336,163	2.08

It is interesting to note here that the AVO decreases much more drastically for the counties in Albany, a more rural area, than in the Bronx, a densely populated area. This makes sense because in the more rural areas, with unlimited occupancy there are many more giant taxis created since so many people are going to such similar places, like the nearest commercial or corporate location. In the Bronx, since there are many more destinations nearby for people to go, there were already many more smaller aTaxis even when occupancy was unlimited so limiting the occupancy to 5 would not decrease the aTaxi sizes very much so the AVO does not go down drastically.

Ride Sharing Summary

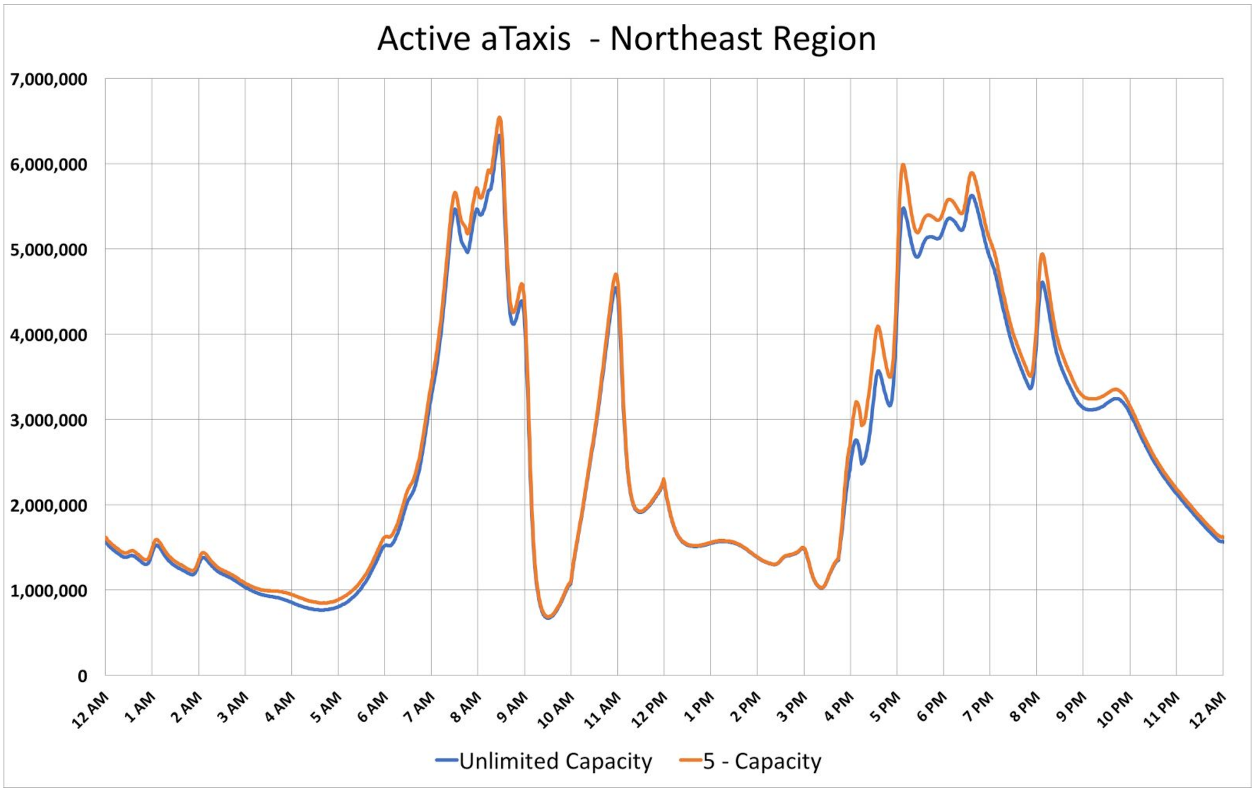
Total Number of Person Trips:	203,625,263
Person Miles Travelled:	2,563,407,492
Total Number of aTaxi Trips:	
Unlimited Occupancy:	123,331,904
5-Capacity Occupancy:	130,389,600
Vehicle Miles Travelled:	
Unlimited Occupancy:	1,752,074,658
5-Capacity Occupancy:	1,829,868,479
Average Vehicle Occupancy:	
Unlimited Occupancy:	1.464
5-Capacity Occupancy:	1.401

Fleet Size Implications

The more important question to environmental activists, political advocates, financial backers, and technological firms is the infrastructure and capital investments required to make this system a reality. The first major question in addressing this issue is fleet size. We have processed the trips and placed them into theoretical, ride-sharing aTaxis, but due to the massive range of departure and arrival times and locations, solving the problem of providing adequate vehicles is challenging. In this section we look to determine an appropriate fleet size to meet our LoS.

In the subsequent sections we establish both a lower and upper bound for the fleet size, and then discuss further how to find the ideal middle ground.

Active aTaxi (Naive) Approach - Minimum



The above graph shows the number of 'active' aTaxis at any given time throughout the entire region. This can be defined by examining the time of departure and arrival of each aTaxi and increment all intermediate minutes by one. Included is the number of active aTaxis when allowing for unlimited capacity vehicles and 5-capacity vehicles. Going forward we are going to focus more specifically on 5-capacity vehicles as it is a practical constraint we should consider.

Examining this graph allows for a lower-bound to be created for the fleet size. In order to completely satisfy the demand dictated by our level-of-service, we must be able to meet the peak number of active aTaxis. The largest number of aTaxis occurs at approximately 8:30 AM (the morning rush hour), at approximately 6.5 million.

The examination of active aTaxis has determined that the fleet size required to service the northeast region is ~6.5 million. However, this approach is naive in that it does not consider the geographic locations of the departures and arrivals of each aTaxi. In order to fully satisfy the demand, aTaxis would need to be able to be instantaneously repositioned from the location it drops off its final passenger to the location it picks up its next passengers. This is not possible, repositioning an aTaxi takes both time and resources. In the next section, we take these considerations into account to establish a better estimation for fleet size.

Supply and Demand Approach - Maximum

In order to take into consideration the geographic distribution of our aTaxis throughout the day, we can look at the departures and arrivals at each pixel throughout the day. In our first approach we make the following simplifications:

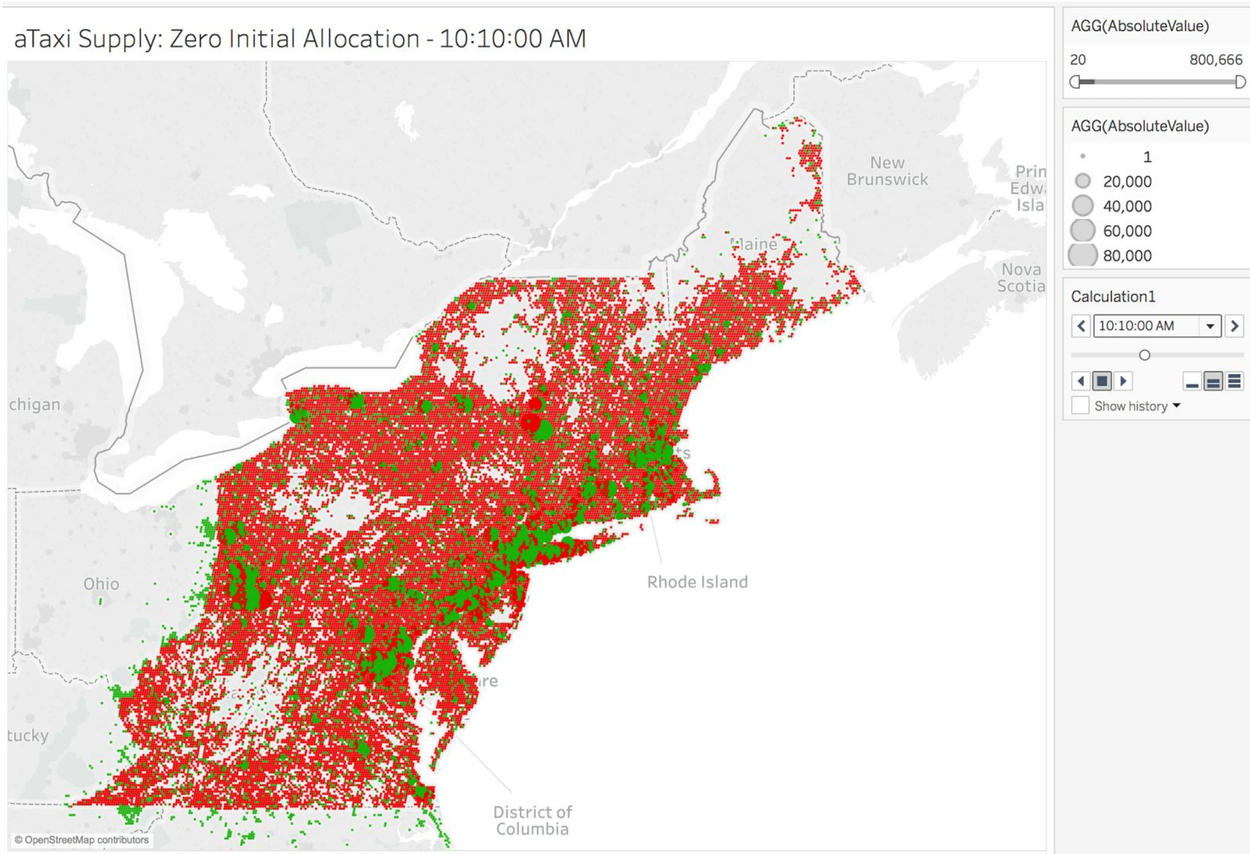
1. The times are simplified from seconds (of departures and arrivals) bucketed into minutes, for a total of 1440.

2. The origin and destination pixels are reduced to 5x5 'SuperPixels' (this analysis can be done for individual pixels and for 10x10 'SuperDuperPixels' but we need to rerun the computations for this and will be reported on at a later date).

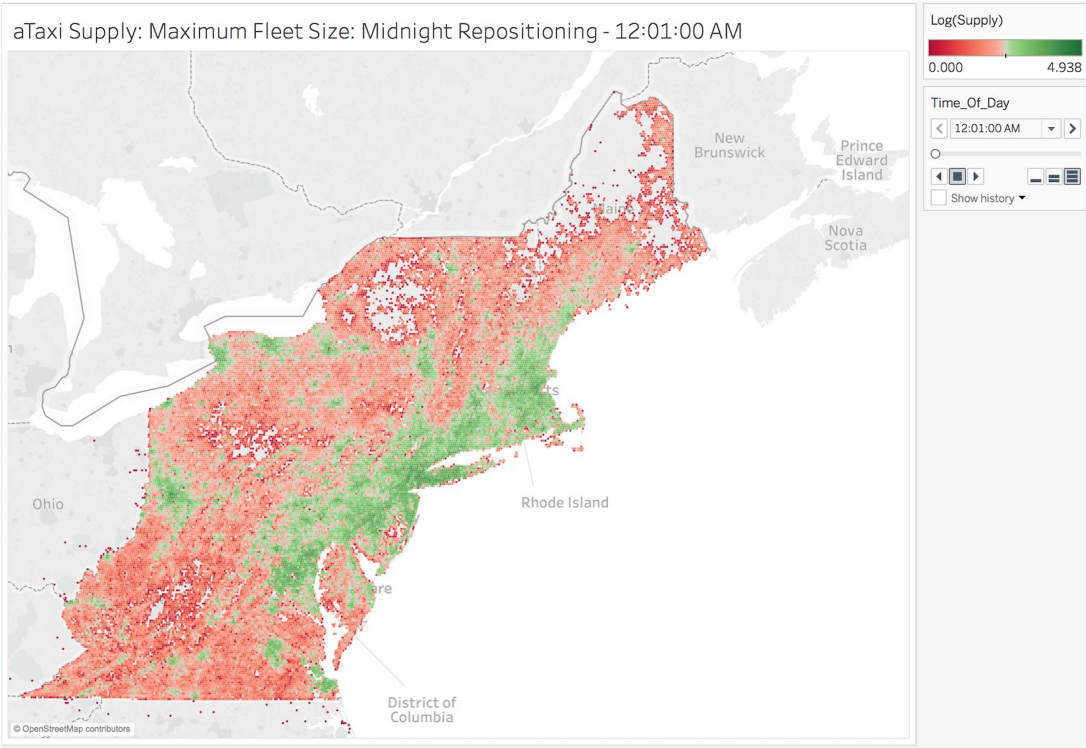
3. There is a single, instantaneous repositioning of aTaxis will occur at 12AM.

By applying these conditions to the entire set of aTaxis for the region, at any moment we can see the 'net supply' of aTaxis at that superpixel cumulative through the day. The 'net supply' is set to 0 at midnight, and is defined at time *t* as the cumulative number of arrivals minus the cumulative number of departures for a given pixel.

We can use the information to place an upper bound on the fleet size. We want to determine how many taxis must be located at each pixel at 12AM in order to ensure that the net supply is always greater than zero. For any given pixel, there is some time *t* in which the net supply is most negative, and that is the number of aTaxis we would need to place there in order to ensure we can meet the level-of-service. Summing this number over all pixels will give us a maximum fleet size.



Using these assumptions, we find that a fleet size of 12,656,401 will ensure that all demand can be met if we can instantly reposition all aTaxis at midnight. Therefore we set our maximum fleet size at ~12.6 million. On the next page, we show the supply of aTaxis at each superpixel for various times throughout the day. By construction, the supply of aTaxis is always nonnegative.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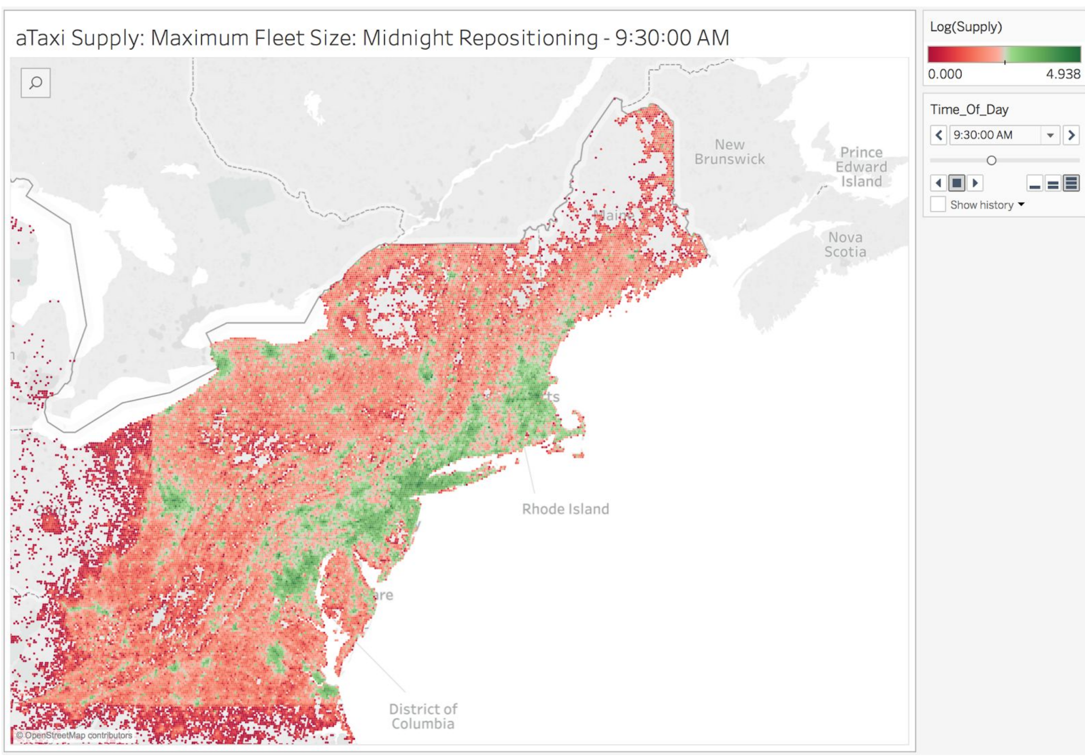
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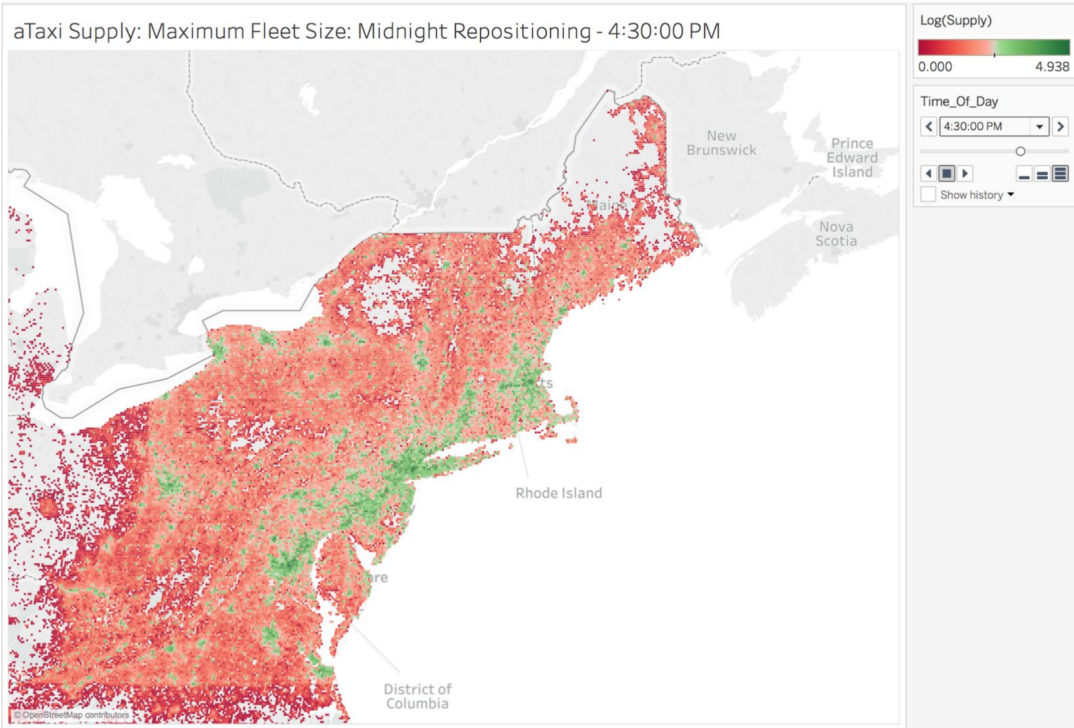
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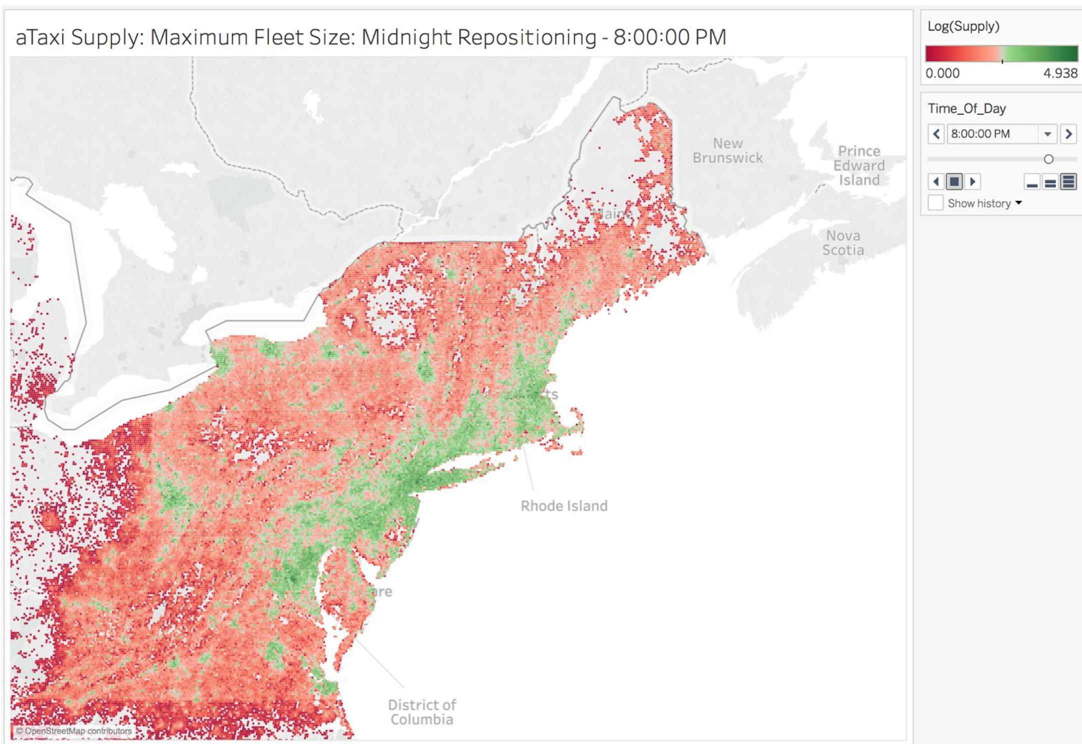
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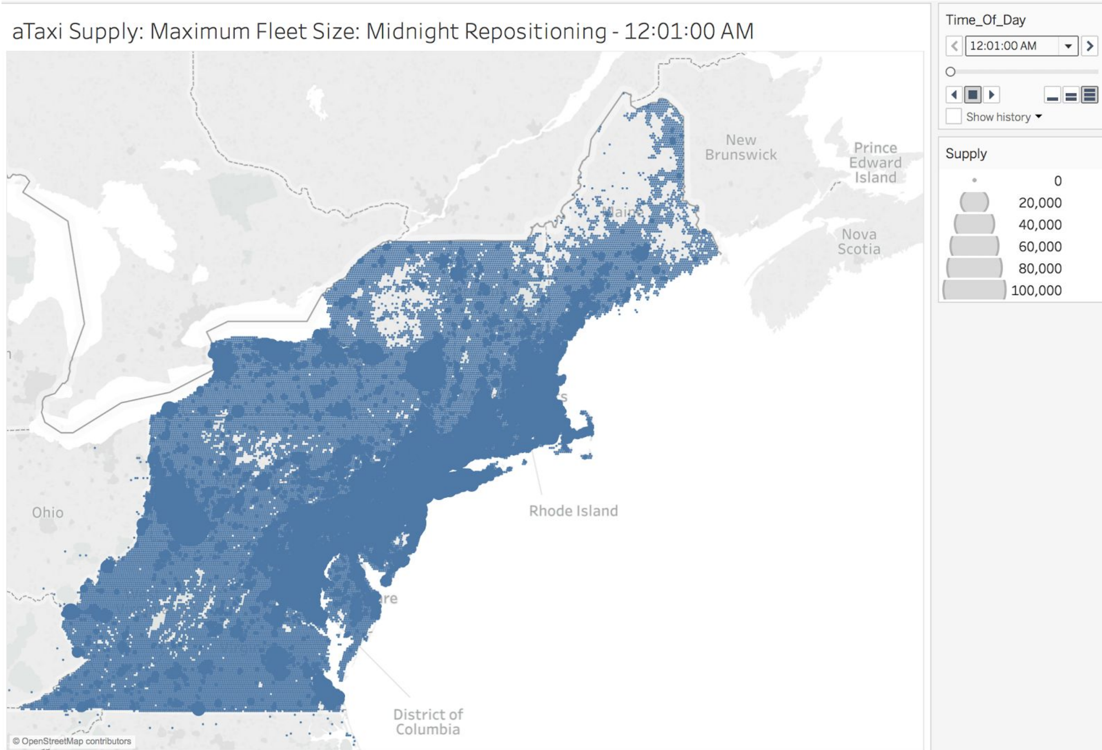
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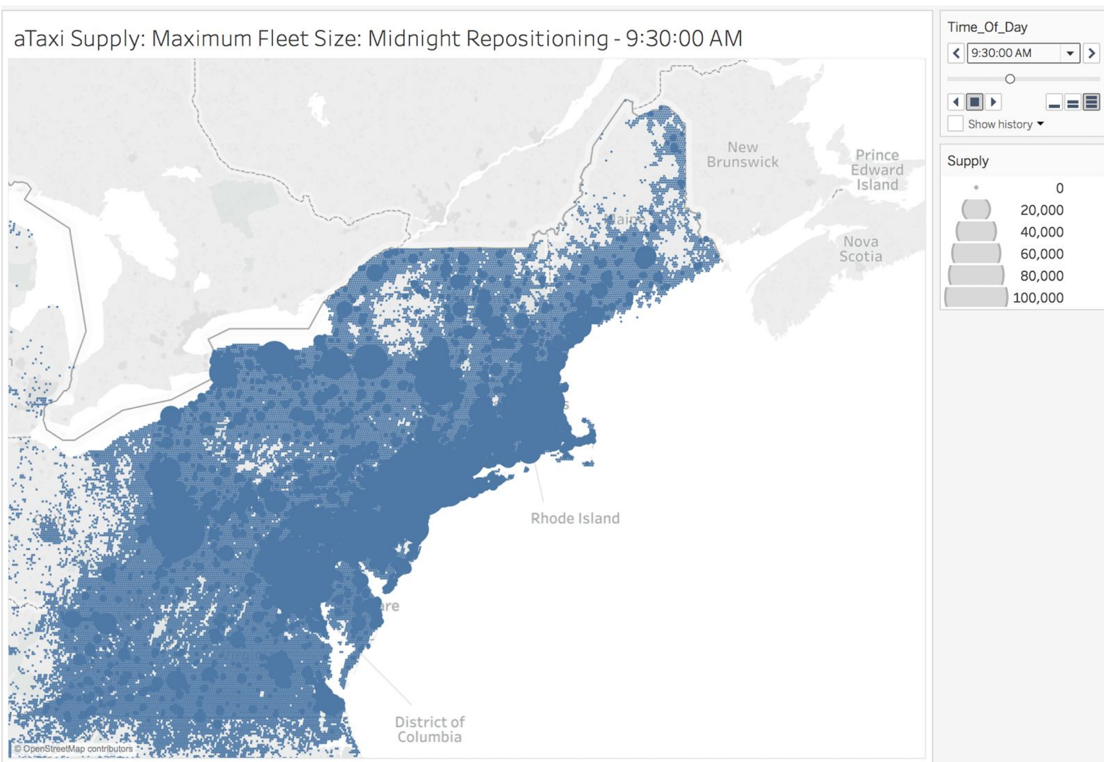
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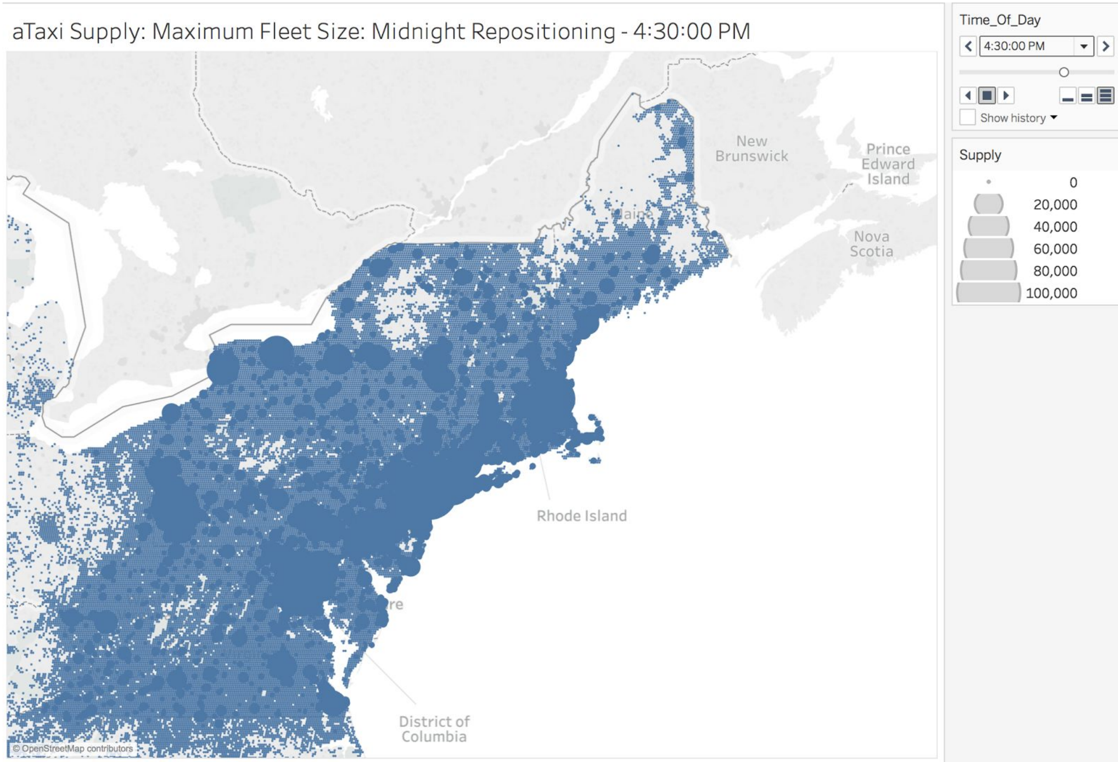
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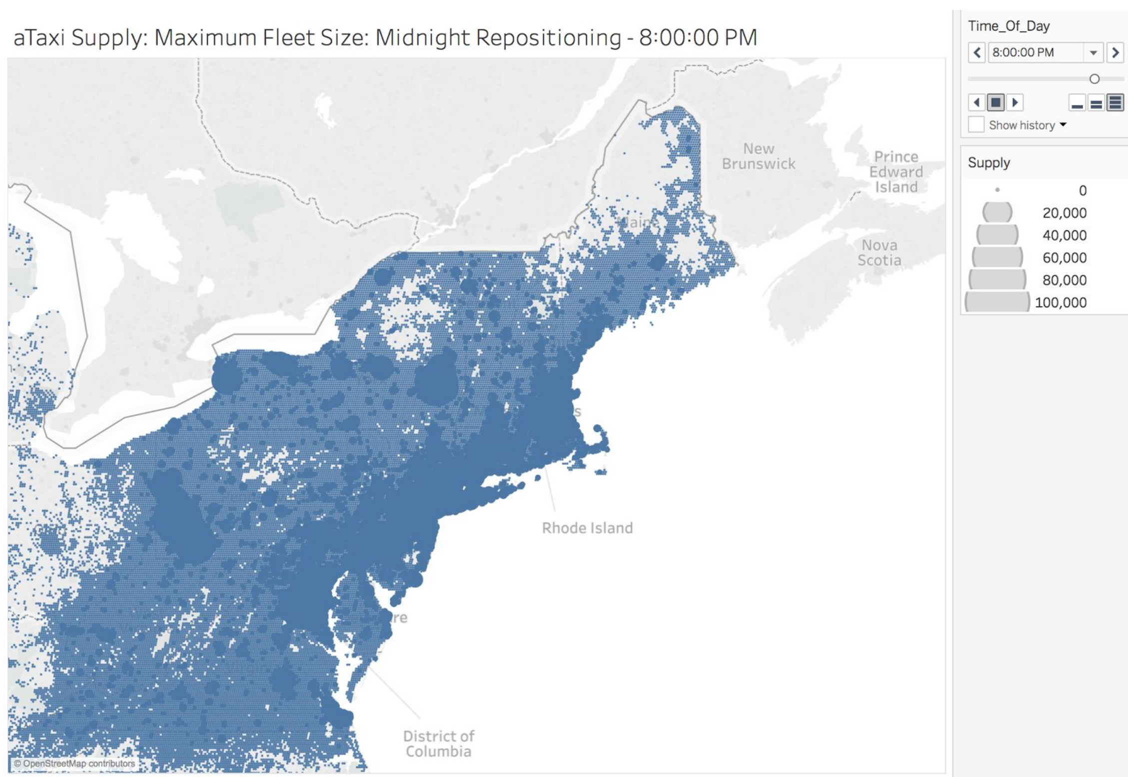
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Alternative Fleet and Reposition Approaches

The two prior sections have given us a lower bound of ~6.5 million and upper bound of ~12.6 million aTaxis to service the Northeast region. This already appears to be a massive improvement over today's standards, indicating one aTaxi for every 5 to 10 people in the most densely populated section of the country.

Our lower bound approach assumed instantaneous aTaxi repositioning, an idealized approach that is physically impossible. Our upper bound approach assumed a single repositioning at midnight, a lazy approach that means even at peak demand barely 50% of our aTaxis are being utilized, and at lowest demand, less than 8%.

There are many ways to approach this problem in a more reasonable way. Under the assumption of a single repositioning, we could modify the time from midnight to the time of day when the least number of taxis are active (around 4AM) to bring the upper bound down more. Similarly we could reposition at more times throughout the day.

Business Model Analysis

To make the ride-sharing opportunity a reality, we need to not only demonstrate the demand and the ability for our ride-sharing network to meet this demand, but also demonstrate a viable business model, that is both financially realistic and compelling. That is, it needs to make profit, while still being being realistically capital intensive so as to secure financing. Below, we present this, albeit simple, business model.

Costs/Liabilities

To begin, we will start with our costs, as these are easier to account for and will give us a baseline which we must surpass to break even.

Our greatest expense is our initial outlay of cash for the 7.5MM $60K vehicles that we need to adequately respond to the mobility demands of the North East. These vehicles have approximately a $150K lifetime before they are fully depreciated. Because every car travels 240 miles a day, they depreciate on average $97/day, we need to replenish our fleet about once every 614 days. This initial financing will come from a loan which we repay over a

The next expense is the cost to actually operate the aTaxis which includes maintenance, road tax, operational costs, etc. This expense was calculated to be about $0.45/VMT ($0.25/VMT + $0.15/VMT for operations, maintenance, & insurance + $0.05/VMT for road tax). Multiplying this number by the the number of VMT/day for the entire fleet gives us the travel/operation costs per day for the business.

Other costs include the costs of acquiring land and solar power, and the cost of installing solar power, which we build above the parking lot. While renting land for parking is perhaps cheaper in the short-term, long-term it is less expensive to construct the parking spaces ourselves. This also means that parking is a fixed expense, rather than a variable cost that could change over time, which makes us less susceptible the risks that are inherent of variable costs.

The cost per foot for constructing a parking space in the North East is approximately $90. For each aTaxi we need about 200 square feet, which means we are paying approximately $18K per parking space. We approximate we need to have the space to park 6.5MM aTaxis at any given time since, at any given time, only 1MM aTaxis will be in operation. The cash for this will come in the form of a loan which we will service over a 20yr period, thus making it affordable for us and giving us a reasonable amount of time for which to pay it off.

Like parking, our solar installation fees will also be paid for by loan which will be repaid over a 20yr period. The reasoning for this is akin to the reasoning for the financing of the parking lot construction. The solar installation fee is a function of the TVM, kWh needed for the TVM, the amount of kWh that each square foot of solar panel produces, and the cost of a square foot of material needed to construct a solar panel. Intuitively, this is a rather large expense, which necessitates the use of a loan to finance this construction.

These solar panels produce the energy that we need to operate our fleet. Our daily energy consumption and costs is a function of TVM, cost/kWh, and kWh/mile. Because we are using solar energy to power our fleet, we didn't need to add the extra $0.05 for fuel in the operating costs that Kornhauser calculated. Interestingly, our cost of solar energy per TVM is slightly cheaper than Kornhauser calculated, sitting at $0.03/TVM.

After all expenses are accounted for, our total liabilities/costs amount to $678.5Bn/year. If we also include other miscellaneous costs, such as wages and such, ours costs increase by less than $500MM. These costs are marginal compared to the other considerable expenses listed on both the income statement and balance sheet.

Loan Structure

Our description of the terms of these loans has been somewhat lacking, and, as such, needs to be expanded upon. The current interest rate environment features historically low rates that will most likely not continue and a FED that seems content on raising rates. Thus, due to both the current economic environment and the lengthy duration of the loan, a variable loan rate equal to some LIBOR rate plus however many basis points will most likely not be favorable to our bottom line and our business. With this being the case, it would perhaps be better to either lock in some fixed forward rate, try to cap the interest rate (which would entail paying a premium on the loan amount), or employing a blended type strategy where we take advantages of both a fixed and variable interest rate structure, which will protect us from the risks of rising interest rates and paying more now for a fixed rate.

Revenue/Assets

To begin, our projected earnings per day is approximately $2 trillion and our projected earnings per year is approximately $770 trillion, making this a high revenue industry**.** These earnings will give us an operating margin of approximately 11.7%. Sophisticated pricing mechanisms has to be made in order to account for the projected values and to also make it attractive to consumers of our product. This mechanism will be explained in the next paragraph.

Firstly, it is important to know in addition to the price/mile rate, we also included a price/minute rate because for a place like the Northeast, there is a lot of traffic in certain regions so it makes sense to add that rate because it does not make sense to obtain revenue for a journey that is 10 miles but takes about one hour to get there without a price/minute rate. Thus, the total revenue per aTaxi is gotten from the base fee of ~$0.75, a price/minute rate of ~$0.23, and a price/mile rate of ~$0.45. The next paragraph will explain how we got those rates.
For our base fee, we came up with $0.89 by multiplying $0.75 by the square root of the AVO which is 1.41. Our logic was that if we had an AVO of about 4 passengers, the base fee will $1.5 which is higher than $0.75, and thus means more revenue for us. However, the 1.5 wil be split among 4 passengers

making each one pay a base fee of approximately $0.375 which will incentivize them to ride share with other passengers. So we used this logic to come up with similar formulas for the price/minute rate (which is $0.23 * square root of AVO) and for the price/mile rate ($0.45 * square root of AVO). The income statement of our business can be found on the next page.

Our total revenue, after account for everything, sums to ~$769Bn/year. Much of the revenue depends on how much we charge per mile and per minute, so even with a $0.01 increase in any of these prices, our revenue increases dramatically (just interesting to note).

Profit and Operating Margin

Our total profit is ~$90Bn, which gives us an operating margin of ~11%, which is reasonable. As was said before, our revenues and costs are dramatically influenced by $0.01 changes to our prices/costs, so this margin can be both increased and decreased depending on the business climate going forward.

Income Statement

Attached below is our income statement.

Revenue	Day	Year 1
Single passenger		
Base fee per ride	$ 0.89	
$/mile	$ 0.53	
$/minute	$ 0.27	
Revenue from mileage	$ 130.37	
Revenue from time	$ 133.27	
Total revenue per taxi (mileage and time)	$ 263.64	
Total revenue	$ 2,105,904,626	$ 768,655,188,328.60
		$ 678,532,196,614
Costs		
Cost per taxi	$ 60,000.00	
# of taxis	7500000	
Total fleet cost	$ 732,899,022.80	$ 267,508,143,322
Cost per mile	$ 0.45	
Total miles traveled	243.9824639	
Total travel costs per taxi	$ 109.79	
Total travel cost per day	$ 823,440,815.55	$ 300,555,897,676
Acquisition Costs		
Solar Installation	$ 228,984,226.79	$ 83,579,242,778
Parking Lot Construction cost per foot	$ 90.00	
Land	$ 16,027,397	$ 5,850,000,000
Solar Power Generation	$ 57,640,857	$ 21,038,912,837
Profit	**$ 246,912,306**	**$ 90,122,991,715**
Operating Margin	**11.72%**	**11.72%**

Pro Forma Balance Sheet

Attached below is our prospective balance sheet.

Assets ($ in Billions)		**Liabilities ($ in Billions)**	
Ride Sharing Revenue	$ 769	Annualized Vehicle Acquisiton Costs	$ 268
		Annual Solar Installation Fees (up until 20 yrs)	$ 84
		Annual Operating Fees	$ 301
		Annual Parking Costs (up until 20 yrs)	$ 6
		Annual Energy Generation Costs	$ 21
Total Assets	**$ 769**		
Cash	**$ 90**	**Total Liabilities**	$ 679

Further Analysis

Based on our analysis, an aTaxi system for the Northeast region of the United States seems both effective and profitable. With an estimated $90 billion in profit, the potential is great. One of the most important realizations from this analysis is that ride-sharing in rural areas can actually be very useful. Despite fewer people and larger travel distances, the AVO is very high in the more rural areas. It makes even more sense for ridesharing in these sorts of places because people tend to be going to similar areas and therefore can easily ride-share.

In terms of next steps, repositioning is a major component of implementing this system of ride-sharing. There are a few options for what may be realistically the best way to go about repositioning. One possibility is to reposition the vehicles at a time of day where the fewest cars are on the road. The second option is to repositioning at multiple points throughout the day, perhaps proportional to the amount of cars on the road at those specific points. In this way, the number of cars being repositioned and used would be optimized. Depending on location, these times may be different as well because in different parts of the region there are different times that are busier and not busier. For example, in a major city in the Northeast, roads may need cars at times that rural areas will not really need them

Fleet size itself is also very important. The range that we have is 6.5 to 12.5 million, but this is still quite a large range. While we do not the cars to be underutilized, we also do not want the cars to be overused. There is give and take to this aspect of ride-sharing and it is necessary to analyze exactly how sturdy the cars are, how much of the day they should ideally be on the road and what is the most profitable way to go about it. There must be a balance so that cars are used to their full capacity without breaking and needing to be replaced too often.

There are many environmental implications to this implementation as well. As expected, an aTaxi system will have a major positive impact on the environment because fewer cars will be on the road. However, will the cars automatically be electric? Will infrastructure need to immediately change, gradually change or not change at all?

The political implications of this system are extremely important to consider as well. There are a few major questions to answer: Will the government be responsible for setting this up? Could people pay taxes for the system? Will the state governments be involved or will this be a national system? What sorts of regulations will be imposed? Who will regulate?

Lastly, there are major business implications because so much money is involved. Who will invest? What will incentive be for investors? What types of people will invest?