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January 9, 2018

Bill de Blasio
Mayor
City Hall
New York, NY 10007

Re: A intersection control system for future self-driving vehicles in New York City

Dear Mr. Blasio,

I am writing to you to inform you of a proposal to help improve the traffic situation in New York City and reform the road system for the next generation of self-driving vehicles. This proposal will suggest a modern intersection management system to improve the congestion in 5th Avenue(from 120th Street to 40th Street), which can cooperate with the Data Mining System at New York City Department of Transportation to manage the road transposition of the whole city. I am hoping that the City can provide funding for the plan in this proposal. As the mayor of NYC, you opinion would strongly help me to reach out the intersection management system to the City's government.

The traffic congestion has always been a major crisis for not only New York City but also all other metropolis around the whole world. Manhattan always leaves an impression of heavy traffic and symphonic honks to each visitor. According traffic analysis firm INRIX's report of 2016, people in New York City spent 13% of driving time in congestion, 89.4 peak hours in congestion and get 17.4 INRIX Congestion Index, which ranks third out of 1064 cities in the world, which means the third worst traffic situation in the world. The proposed plan for this problem involves the incoming wide spread of self-driving vehicles. The intersection management system is based on several theatrical models which applies to all intersection conditions in New York City. The City's government has tried variety of ways to solve this problem in the past, but the rank of New York City in INRIX was always at the top level. It should be the time to try think out of the box and lead a revolution of road system and stand the City out as a successful model of solving congestion with the plan in my proposal.

Lastly, I would like to thank you for attending my presentation and taking the time to read this proposal. If you have any questions, please feel free to contact me.(7323104177, miheng@me.com)

Sincerely,

Huaheng Yu

Huaheng Yu

Improving the Congestion on 5th Avenue in Manhattan, New York City

With An Intersection Management System

Submitted By:
Huaheng Yu

Submitted to:
Bill de Blasio
Mayor
City Hall
New York, NY 10007

January 9th, 2018

Prepared for:
Scientific and Technical Writing

Abstract

Congestion has always been a major problem of New York City. The city has been on the top three of most congested city in United State for 10 years according to INRIX's reports. Although in 2016, New York City is the third on the rank, it still has the lowest overall congested speeds, 8.23 mph, versus 11.07 and 11.54 in Los Angeles and San Francisco respectively. The city's governments tried many ways trying to solve this problem, but study shows that the whole city is getting slower and slower. However, with the incoming self-driving cars, the city may have the chance to have some critical improvement.

This proposal suggests a intersection management system, which takes the place of signal and stop sign and uses computer algorithm to arrange the cars to pass through each intersection. This system is constructed with several theatrical methods of intersection managements, which can improve the passing speed by 20% to 80%. This system can achieve the maximum improvement in an ideal environment with all cars on road self-driving, but it still can improve the congestion significantly in a mixed environment(both traditional cars and self-driving cars on road), as all theatrical methods are traditional car friendly. This proposal will discuss the plan and the budget of implementing the system on each intersection around Manhattan. If successful, this proposal would become the pioneer of revolution of modern city transportation system.

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Introduction

Traffic congestion has always been a major issue in New York City, as well as all around the world. This section will begin with the discussion of current traffic situation of New York City, and then followed by the background information of self-driving vehicles.

Traffic in New York City

With a population of 8,537,673 (Bureau, U.S. Census, 2017) distributed over a 303.2 square miles land, New York City is the most densely populated city in the United States with a density of 28,188 persons per square mile. Although the city has one of the largest subway systems in the world, which provides approximately 5.7 million daily rides on weekdays (MTA, 2015), the city's road transportation system still has to undertake 2.1 million of registered vehicles (NYCDOT, 2016). This huge population density brings the city the most challenging traffic problem in the United States (Figure 1).

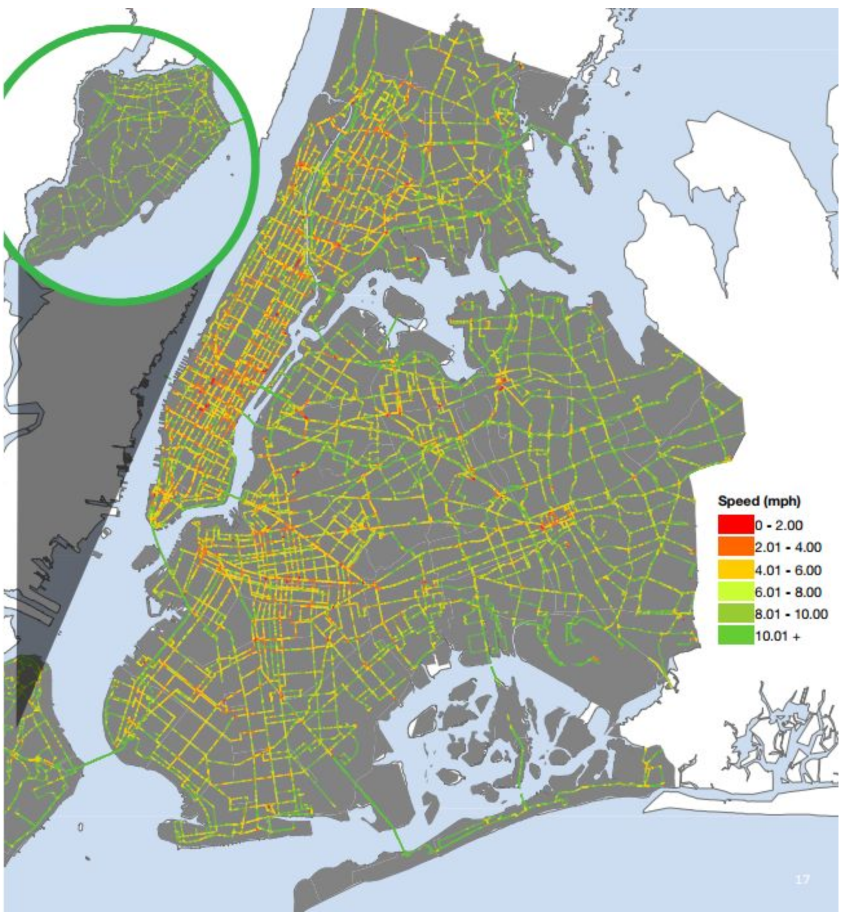


Figure 1 (NYCDOT, 2016)

Figure 1 shows the NYCT bus speeds in weekdays from 4PM to 6PM. The data of this map is based GPS data from MTA Bus Time Program, which gives a clear reflect of how traffic looks like during that time. As the map illustrates that on most of roads in New York City, the average speeds are between 4 - 8 mph, and the slowest speeds are in commercial districts like Midtown Manhattan, Downtown Brooklyn, and Jamaica Queens, where the average speeds are under 2 mph.

	PEAK IN/ OUT	PEAK WITHIN	DAY IN/ OUT	DAY WITHIN	LATE IN/ OUT	LATE WITHIN	WEEK END	OVERALL
Congestion Rate	16%	21%	9%	15%	4%	12%	12%	13%
Congested Speed (mph)	11.68	6.86	10.00	5.52	9.56	5.59	8.37	8.23
Uncongested Speed (mph)	45.28	25.31	52.48	27.22	57.86	31.97	40.70	40.12
Speed Differential (mph)	33.60	18.44	42.48	21.71	48.30	26.38	32.33	31.89
% Reduction in Speed during Congestion	74%	73%	81%	80%	83%	83%	79%	79%

Figure 2 City Dashboard - NYC (INRIX, 2017)

According to INRIX's 2016 traffic report, a global SaaS and DaaS company which provides a variety of Internet services and mobile applications pertaining to road traffic and driver services, New York City had the third worst traffic condition in the world with 13% of total driving time was spent in congestion and 89.4 peak hours was spent in congestion. 4 of the top 10 worst US corridors are in the New York City, and 5th Avenue from 120th Street to 40th Street is the only un-highway corridors in the top 10. As you can see in Figure 2, during the daytime of weekdays, the congested speed inside the city is only 5.52 mph, which is the normal jogging speed of young people, and the figure also shows that the overall congested speed in New York City is 8.23 mph, comparing to Los Angeles with 11.07 and San Francisco with 11.54.

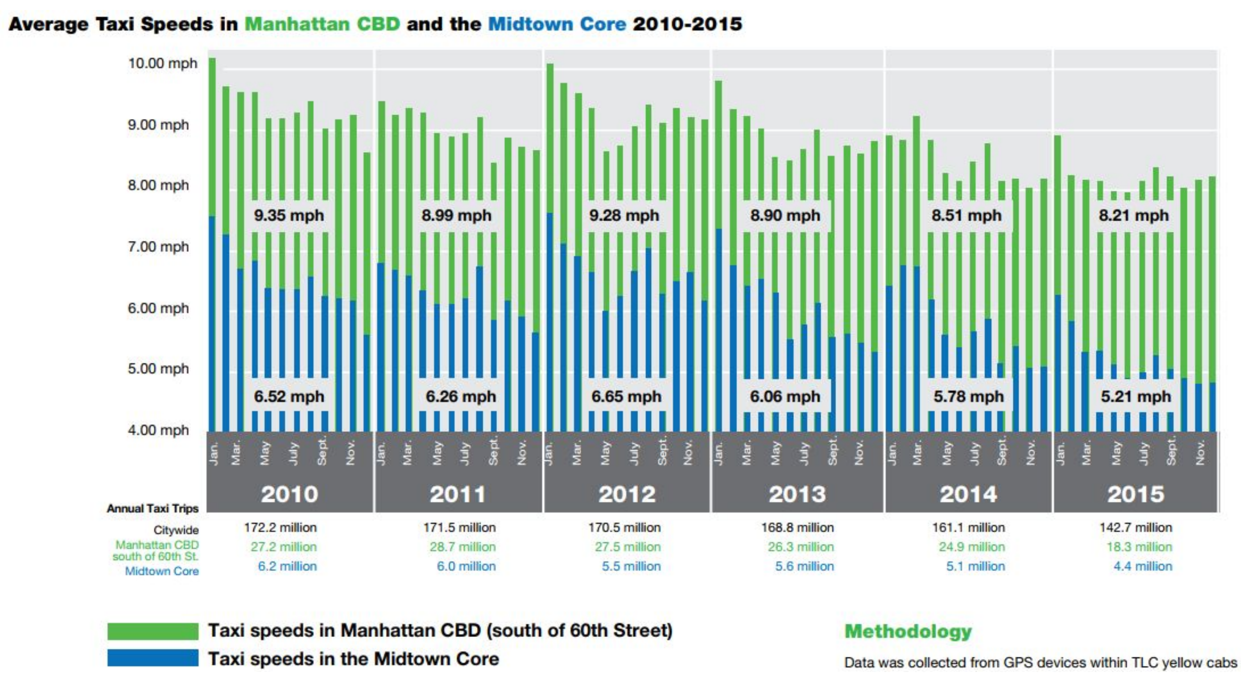


Figure 3 (NYCDOT, 2016)

The traffic crisis concerns every citizen of New York City as well as the City's government. From public records, city's administration along with department of transportation has tried, for a long time period, variety of ways to solve this problem, like THRU Streets Program, Congestion-Pricing Program and also Green Light for Midtown Project. Unfortunately, these program doesn't seems to work very well. Figure 3 shows that, during 2010 to 2015, the average travelling speed of taxi was declining. In Manhattan CBD (south of 60th Street), the average travelling speed decreased from 9.35 mph to 8.21 mph. Respectfully in Midtown Core, it decreased from 6.52 mph to 5.21 mph. The whole Manhattan is becoming slower and slower.

Rising of Connected and Autonomous Vehicles

The traffic is slowing down due to the nature of traditional cars. Human drivers need a certain response time for safety issues, and the increasing of population which makes the declining unavoidable and hard to control. Recently, there is a key change of human road transportation that would be the game changer of traffic problem, the connected and autonomous vehicles (CAVs a.k.a. Self-driving vehicles). CAVs introduce all sorts of different benefits, from dramatic reduction of crash rates and congestion to concerns about security, safety and privacy, and negative economic consequences associated with transition to vehicle automation (Schoettle and Sivak, 2014; Fagnant and Kockelman, 2015; National Highway Traffic Safety Administration [NHTSA] 2013). To most of people, CAV seems still a fancy future idea, but the truth is these CAVs are coming very soon. Figure 4 shows the prediction of vehicles with technology in United States in the two scenarios with highest possibility. As you can see, in 2025, 89% of vehicles on road would equipped with connectivity, around 6% with L3 automation (hands-off and heads-off for some conditions) and around 14-20% with L4 automation (hands-off and heads-off for most conditions). This is a prediction of whole United States, with a higher income rate and higher interests in technology, the percentage would be much higher in New York City.

Table 12
Percentage of vehicles with technologies in scenarios 7 and 8.

Technology	Scenario 7: *10% rise in WTP, 5% drop in tech price, and regulations*							Scenario 8: *10% rise in WTP, 10% drop in tech price, and regulations*						
	2015	2020	2025	2030	2035	2040	2045	2015	2020	2025	2030	2035	2040	2045
Electronic stability control	24.3	89.7	98.1	99.8	100	100	100	24.3	89.1	98.8	99.9	100	100	100
Lane centering	4.4	10.8	25.5	42.1	55.1	78.1	90.3	4.4	13.5	32.8	51.2	79.0	94.0	97.9
Left-turn assist	3.8	11.6	26.5	43.0	65.1	83.6	95.0	3.8	14.1	34.1	60.9	87.3	96.4	98.4
Cross traffic sensor	10.9	15.6	30.8	48.3	65.4	84.6	95.0	10.9	18.2	39.3	63.6	87.0	96.6	98.5
Adaptive headlights	10.2	11.4	25.0	42.3	58.5	81.3	92.5	10.2	13.4	32.8	55.8	81.4	95.5	98.2
Pedestrian detection	3.7	12.9	28.8	45.8	67.9	84.6	95.3	3.7	15.3	37.6	63.7	87.9	96.8	98.7
Adaptive cruise control	13.3	18.0	31.7	49.1	62.5	82.8	92.8	13.3	20.3	40.4	60.2	83.2	95.4	98.2
Blind-spot monitoring	11.7	18.5	35.6	54.6	67.7	85.4	94.0	11.7	20.5	45.5	66.4	85.9	96.3	98.6
Traffic sign recognition	2.0	9.0	23.2	39.0	62.0	82.6	94.9	2.0	10.9	30.0	57.9	86.4	96.4	98.4
Emergency automatic braking	5.6	13.9	32.9	52.1	72.4	88.0	96.4	5.6	16.6	41.5	68.4	90.0	97.3	98.9
Connectivity	0	41.8	89.1	98.3	99.7	100	100	0	41.3	89.4	99.0	99.9	100.0	100.0
Self-parking valet	0	10.5	25.5	41.6	57.6	82.4	92.9	0	12.6	32.9	54.6	80.3	96.0	99.4
Level 3 automation	0	2.5	5.9	8.3	8.2	26.5	25.5	0	3.5	6.0	7.7	27.7	11.6	2.9
Level 4 automation	0	4.7	13.8	25.5	36.4	44.3	59.7	0	5.5	19.4	33.8	44.2	74.7	87.2

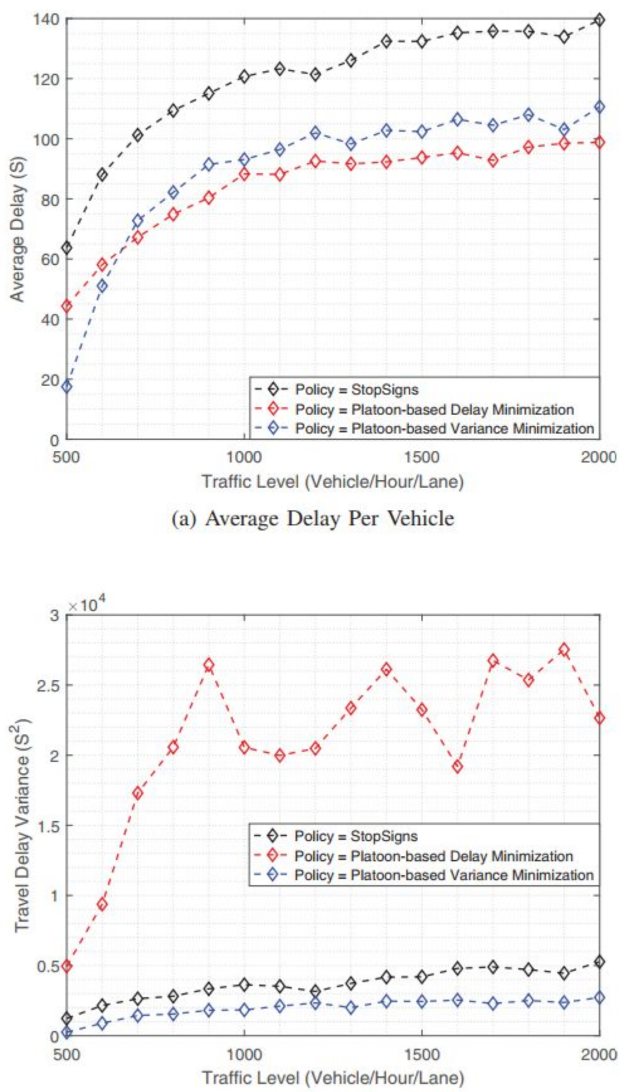
Figure 4 (Prateek Bansal, 2016)

Literature Review

Overview

The traffic congestion problem of Manhattan, New York is a major crisis and is getting worse and worse. However, with incoming of CAVs, a new way of how cars are passing through the intersections can help solving this problem, which is the modern intersection management system (MIMS). This section of proposal will explain three theoretical models that providing a solution to increase the passing speed of intersections.

A Platoon-Based Intersection Management System



(a) Average Delay Per Vehicle

(b) Delay Variance

Figure 6 (Masoud Bashiri, Cody H. Fleming, 2016)

Algorithm 1 Autonomous Intersection Manager

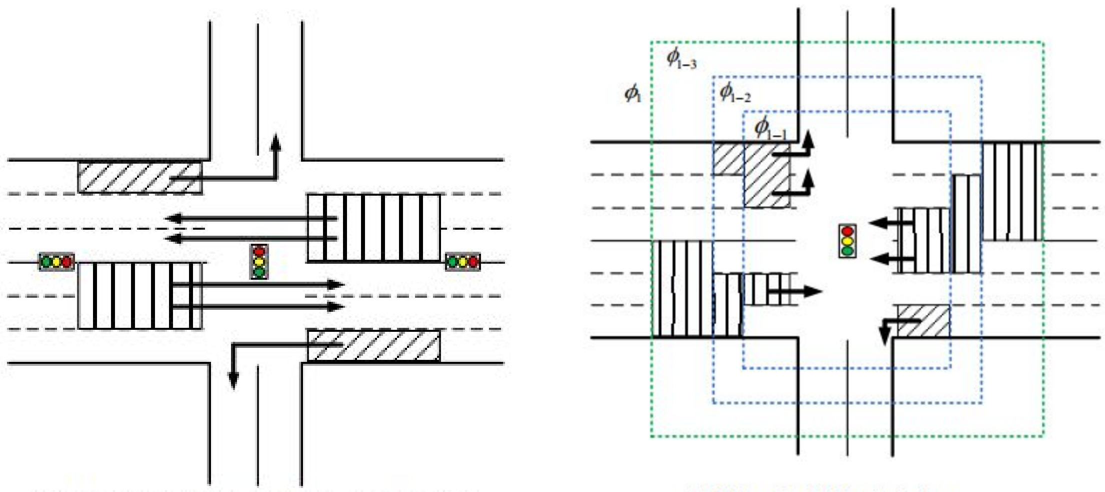
```
function INTERSECTIONMANAGER(s)^a
    while True do
        P = getRequests() ^b
        sort(P)^c
        pool = selectCandidates(P)
        if !pool.isUpdated() then
            continue ^d
        end if
        if s = 1 then
            [platoons, schedule] = PDM(pool)
        else if s = 2 then
            [platoons, schedule] = PVM(pool)
        end if
        i = 1
        for platoon in platoons do
            update(platoon, schedule_i)
            i++
        end for
    end while
end function
```

[a]Where s is an integer in {1,2}
[b]Where P is a map of platoons paired with their respective request information
[c]Sort the platoon list based on their arrival time to make the candidate selection run faster
[d]Skip this iteration if the selection pool has not changed

Figure 5 (Masoud Bashiri, Cody H. Fleming, 2016)

This system is mainly deployed on a infrastructure, a control computer, on each intersection replacing a stop sign. The system will communicate with each incoming cars towards this intersection, and the system will calculate the platoon size from each way and provide a crossing plan for each way, when to pass and how many cars to pass this time, with platoon-based intersection scheduling algorithm. The whole algorithm is shown in Figure 5, where PDM refers to Platoon-based Delay Minimization and PVM refers to Platoon-based Variance Minimization. By testing both PDM and PVM with random generated traffic simulation data, the outcome is shown in Figure 6. As you can see, the average delay time decreases both with PDM and PVM, but PDM has a better performance when the traffic level increases. With the help of the system, the passing delay for each car is decreased by 60% to 30% comparing to a stop sign. However, in Manhattan, especially in the propsing area, most of the intersections are organized by traffic lights instead of stop signs, thus this method is not totally feasible.

Maximum Capacity inteRsection Operation Scheme with Signals (MCross)



(a) The concept of continuous flow intersection

(c) MCross for CAVs: single phase (at the beginning of sub-phase 1-1)

Figure 7 (Sun, W., 2017)

In this scheme, the system, instead of taking place of traffic signals, cooperate with the traffic signals. The traffic signals would still working as the go sign, but only in two phases. One phase for North and South, and the other for West and East.(Sun, W., 2017) As you can see in the Figure 7(a), the left turn lane has being moved to the most left lane of the road, which was originally the lane for cars coming from the other side. At the same time on the other side, the waiting line for cars on the most right lane are moved backward so the cars would go after the left turn car from the other side. Another feature this scheme offers is the plan of how cars should wait in the waiting area under different level of traffic. Figure 7(b) gives a clear example of how the plan would be make in a normal traffic condition. The traffic from west have more left turns, so there will be more area took from the waiting area of traffic from east. This is not the whole part of the plan, after the traffic in the first phase is gone, the plan requires a lane change of some of the cars in the traffic in order to get minimum passing time for the whole traffic.

However, in the more realistic environment that traditional cars are mixed with CAVs, the line changing process would be hard for normal human, as they need more response time than CAVs which would leads to a unsync movement of certain cars in the traffic and increase the passing time again.

Hybrid-AIM

The hybrid-AIM is designed specifically for a mixed environment of both traditional car and CAVs. Similar to the platoon-based intersection management system, Hybrid-AIM has a central control computer to receive and process CAVs passing request.(Sharon, G., Stone, P., 2017) At the same time, the system also controls how the traffic signals will go. Hybrid-AIM are equipped with cameras and sensors to monitors how the traffic is going on in the intersection and it also detects if there is any car coming to the intersection without sending a request(a traditional car). The system plan the passing off each with FCFS algorithm, which provide a 90% decrease in average delay of a traffic signal in a full CAV environment. (Kurt Dresner, Peter Stone, 2008) The test result of a 4-way intersection is shown in Figure 8.

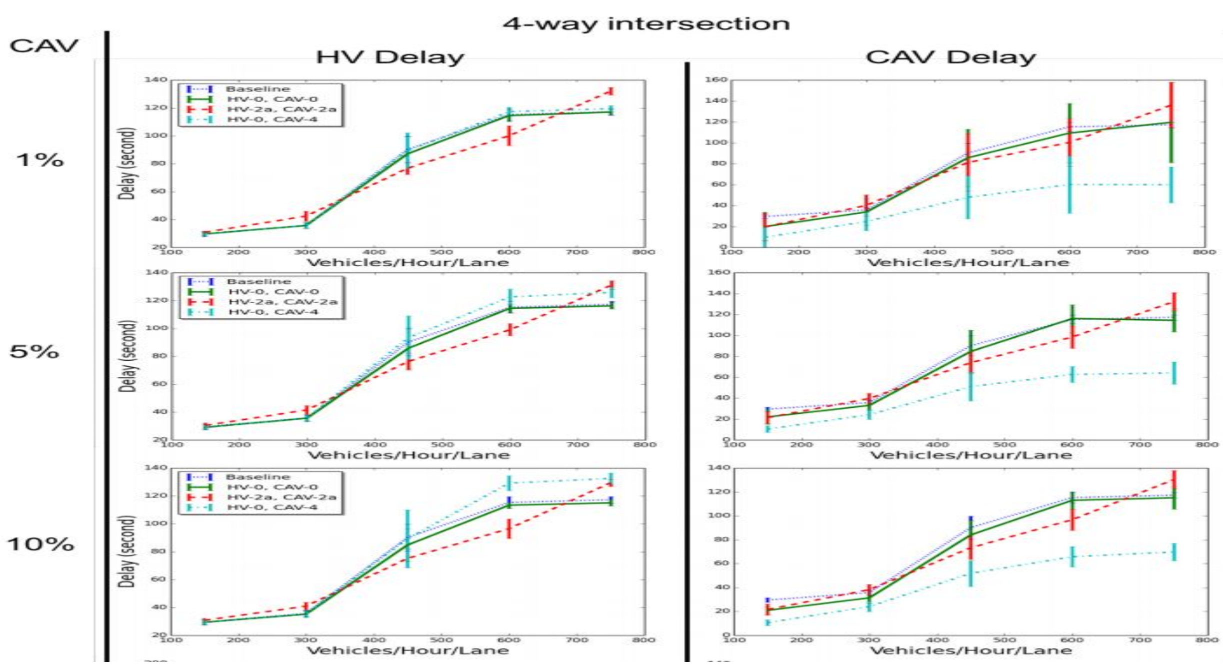


Figure 8 (Sharon, G., Stone, P., 2017)

In Figure 8, the red line indicates the performance of using “flexible” policy, and the blue dot line indicates the performance of FCFS only. This shows that, in a traffic volume around 400-600 vehicles per hour per line which is the day time volume in 5th Ave (NYCDOT, 2016), Hybrid-AIM can achieve around 20% improvement of the passing performance when using “flexible” policy when there is only 5%-10% of cars are CAVs.

After reviewing variety of methods of using intersection management system to improve traffic condition, it is noticeable that Hybrid-AIM provide the most decreasing of delay time for passing through intersection; it is also the most feasible method as the environment will still be a mix of traditional cars and CAVs in the next few decades.

Plan

After reviewing the three theoretical above, the plan will use a intersection management system to solve the congestion in 5th Avenue. The system is based on the communication method of the platoon-based IMS, and the mainframe of Hybrid-AIM algorithm.

Step 1: Algorithm Implementing

Although the Hybrid-AIM is the most feasible method in this research, it still needs some improvement. Pedestrian, bike are not in the model provide in the study (Guni Sharon, Peter Stone, 2017), and also when the Police or emergency vehicles are passing through the intersection, the system should give them the priority to pass first. These side feature should be added during the process of algorithm implementing. This process requires approximately about 12 months, so that the full algorithm can be fully tested inside computer, and sensors and cameras can be tested at the same time.

Normally for algorithm implementing, it will be done by a company. But in this proposal, I suggest that it should be done by either an existing government department like Information Technology and Telecommunications under NYCDOT, or a new department. As the system requires cameras installtion on public area, the individual privacy would be a problem if a external company is involved. Besides, there a central control computer connected to every single intersection management system on road. Although the system operates individually, there still be the need of a central computer to monitor the traffic status on each intersection.

Step 2: Real World Testing

A real world testing is always needed before its official implementation. As for the location, recent study(INRIX, 2016) gives a suggestion for best locations of testing CAVs in Manhattan, which includes E 59th-63rd Streets between 5th Avenue and the East River. With its intersection with the propasing area, the 5 intersections, 5th Avenue with 59th-63rd Streets, would be the best location of testing the intersection management system. Before the test, the testing intersection would be closed for 2-3 days for implementing the system, and there should be public announcements about the test so that the public can know about this system and get to learn how to interact with it for pedestrians and bike riders.

Step 3: System Deployment

Between step 2 and 3, there should be a period time for public feedback and revise the system according to the feedbacks, like the priority of bikes and pedestrians when they are crossing the street. Before revising, it is the final official implementation. The whole process will need 80-90 days as it is impossible to close the intersections at the same time which would cause a wrose traffic congestion. After the implementation, there should be post or sign on the sidewalk for pedestrians and bikes to let them know that this is a intersection with intersection management system, especially tourists. More importantly, there should be signs all intersections that are one block away from the proposed area to notify drivers that the next intersection is equipped with intersection management system and act accordingly. If it’s a CAV, the vehicle itself will connect to the system without any response from drive, and if it’s a traditional vehicle, the driver will just follow the traffic lights as they used to do.

Budget

One Time Cost

The one time cost includes the funding for realization of the algorithm, and all equipments as well as the installation cost. All 80 intersections would be equipped with 4 camera and 4 detective sensor for each way and also 4 sign for pedestrian. All intersections that are one block away need 1 sign for each. The total one time cost is shown in Table 1.

Category		Unit Price	Total Cost
Algorithm implementation		$150000	$150000
Equipments	Camera	$100	100* 80 *4 = $32000
	Detective Sensor	$200	200 * 80 * 4 = $64000
	Sign	$50	50 * (4*80 +160) = $24000
			$270,000

Table 1

Continuous Cost

The continus cost includes the maintenance of the whole system, which need a technician team. Based on the size of the system, it would need a team of 2-3 software engineers to maintain the system and deal with errors. The annual salary for a software engineer is around $100,000. So the whole system need $200,000 to $300,000 annual funding to keep it working.

Discussion

As the population keep growing in New York City, the traffic congestion problem will getting worse and worse if there is no effective plan. Citizens have to waste their time just staying in their cars and get angry. As showed previously, CAVs is in their way to everyone and soon in the next few decades most of the vehicles on road would be CAVs. Along with CAVs, my plan is going to reform the roadway system in Manhattan starting from 5th Avenue. If the plan be proved to be effective, is can be easily used in all other intersections in Manhattan and all the other areas of New York City. New York City can be the pioneer of the revolution of roadway system led by the revolution of vehicles.

In order to determine if the plan improves the traffic congestion along 5th Avenue, traffic data would should clearly show it. But drivers need time to get used to it both traditional cars and CAVs, and it take time. 3 months should be a reasonable time period. At that time, around 2020, according to the prediction I mentioned before, there should be 10% of vehicles equipped with L3 or L4 self-driving functions, thus the improvement of traffic congestion should be visible, and become more and more efficient at the rate of CAVs goes up.

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