New York City Mobility

Problems and Solutions

By

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A project by the Hyperloop Corporation

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Contents

Abstract

Along with a constant growth of population, employment, and tourism in New York City, demographic and mobility trends affect the multimodal transportation network and rise a series of concerns about the sustainability of transportation operations in urban area.

Based on the commuting purposes, choices, travel time, travel patterns, parking behaviors, and attitudes on transportation, it is urgent to reconsider how to modernize the urban transportation system, how it is planned, designed, and operated. It is time to face squarely the crisis of public transportation in New York City and develop a methodology that provides commuters an alternative transit mobility system in order to balance the growing demands on current transportation capacity in the most equitable, sustainable, safe, and efficient way. This proposal offers and describes an attractive and more ideal method to review a new public transit service in New York City.

Introduction

According to U.S. Census Bureau population estimates, New York City's population increased from 8,175,133 in April of 2010 to 8,622,698 in July of 2017 [1]. This is an increase of about 448,000 residents over the 2010 mark, or 5.5 percent [1]. Among five boroughs, Brooklyn, Queens, and Manhattan increased the most. Staten Island only occurred a slow growth. Compare to other major cities, New York City has the highest density in US. Overall, 26,403 people live in each square mile, and in Manhattan, that number is over 66 thousand per square mile [2]. Based on recent projections, New York City's population will be expected to reach 9 million by 2040 [2]. The boomed dynamic population represents the long characterized of this city – the fluidity. As this dynamism, it provides a vast amount of opportunities for people seeking for a better life.

However, the limited public transportation capability slows down and obstructs the city developments.

Metropolitan Transportation Authority 2017 Annual Report shows that the subway system in New York City spans 472 stations and 665 miles of track, that offers 24/7 service across four boroughs in New York City [3]. But nonetheless, it has the worst on-time records among all nation's cities. In January 2018, there were 76,287 delayed weekday trains and 18,931 delayed weekend trains [4]. Comparing with 85.7 % on-time performance of Washington's Metro system, 95 % of Chicago's L-train system and 96.7 % of Atlanta's Marta rail system, New York City subway system only had 58.1 % on-time for all weekday trains and 64.7 % for weekend trains [4]. The public transit system supposed to help pumping up the city's economy to grow. Yet the massive subway delays caused by signal malfunctions, power breakdowns, water damage, track fires, and police activities, are pushing the system and commuters to a breaking point. Specifically, it comes at a cost personally and financially. A construction worker Major Stevenson lost his job because he was stuck underground for more than an hour. For Alexis Roman, even though her bosses were understanding, but only to a point. "You're either here or not," she said [5]. In addition, a study explicitly showed that the cost of subway delays during a typical morning rush was equivalent $864,000 a day, multiplying that figure by all nonholiday weekdays in a year, it resulted in about $307 million in annual losses in work time [5].

On the other hand, $2.75 per ride and $121 for an unlimited monthly pass, the cost of public transportation in New York City is almost double the national average of $67 and significantly higher than other major metros like Chicago or San Francisco, where the cost of a monthly transit pass is $105 and $94, respectively [7]. More worrisome, the fares keep on rising, but the service is not getting any better.

The travel speed of ground transportation across the city had also declined consistently due to traffic, accidents, and so forth. New York City Mobility Report on June 2018 indicated that citywide bus speeds declined marginally in 2016, down 0.4% since 2015 and 2.6% since 2010, the average speeds dipped from 7.47 mph in 2015 to 7.44 mph in 2016 [6]. In Manhattan Central Business District (CBD), travel speeds were down by 21% since 2010, in the range between 6 and 9 mph [6].

To avoid delays, the increasing of household vehicle registrations and for-hire vehicle registrations is arising some other issues consequently. New York City has the highest rates for rides Uber or hailing a cab in the country referring to the traffic and gas prices. Meanwhile, the parking spots are quite expensive because of Manhattan Core regulations in limiting the provision of new parking and the decline in the number of spaces [8].

All the data reveal the gravity of the overall situation of New York City Mobility. It urges to invest a new mass transportation system that could help commuters underground, as well above the ground.

Hyperloop is a revolutionary high-speed transportation technology, which is the perfect innovation and infrastructure to replace current public transportation system. Compared to the alternatives, it should ideally be: safer, faster, lower cost, more convenient, immune to weather, sustainably self-powering, resistant to earthquakes, not disruptive to those along the route [9]. Especially, it is the right solution for the specific case of high traffic city pairs that are less than about 1500 km or 900 miles apart [9]. More beneficial, with the right geometry, the sonic boom noise on the ground would be no louder than current airliners [9].

Plan of Work

How Hyperloop Works

The Hyperloop consists of several distinct components, including:

- Capsule:
    I. Sealed capsules carrying 28 passengers each that travel along the interior of the tube depart on average every 2 minutes from one station to another (up to every 30 seconds during peak usage hours).
    II. A larger system has also been sized that allows transport of 3 full size automobiles with passengers to travel in the capsule.
    III. The capsules are separated within the tube by approximately 23 miles (37 km) on average during operation.
    IV. The capsules are supported via air bearings that operate using a compressed air reservoir and aerodynamic lift.
- Tube:
    I. The tube is made of steel. Two tubes will be welded together in a side-by-side configuration to allow the capsules to travel both directions. The tubes will also be able to run back and forth.
    II. Pylons are placed every 100 ft (30 m) to support the tube.
    III. Solar arrays will cover the top of the tubes in order to provide power to the system.
- Propulsion:
    I. Linear accelerators are constructed along the length of the tube at various locations to accelerate the capsules.

II. Rotors are located on the capsules to transfer momentum to the capsules via the linear accelerators.

- Route:

I. There will be a station at major business, commercial, and residential hubs. Several stations along the way will be possible with splits in the tube.

II. The majority of the route will follow major roads, and the tube will be constructed in the median or underground.

A small description of each component is given below:

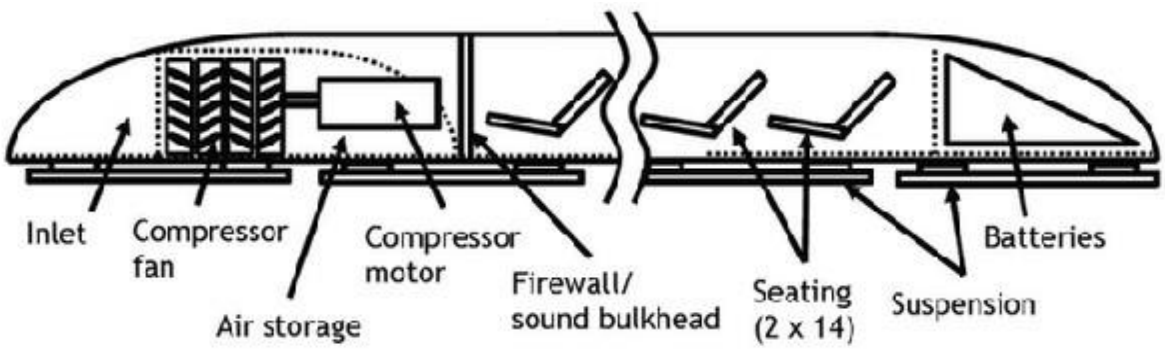
<u>Capsule</u>

For travel at high speeds, the greatest power requirement is normally to overcome air resistance. Aerodynamic drag increases with the square of speed, and thus the power requirement increases with the cube of speed. For example, to travel twice as fast a vehicle must overcome four times the aerodynamic resistance, and input eight times the power.

Just as aircraft climb to high altitudes to travel through less dense air, Hyperloop encloses the capsules in a reduced pressure tube. The pressure of air in Hyperloop is about 1/6 the pressure of the atmosphere on Mars. This is an operating pressure of 100 Pascals, which reduces the drag force of the air by 1,000 times relative to sea level conditions and would be equivalent to flying above 150,000 feet altitude [10]. A hard vacuum is avoided as vacuums are expensive and difficult to maintain compared with low pressure solutions. Despite the low pressure, aerodynamic challenges must still be addressed. These include managing the formation of shock waves when the speed of the capsule approaches the speed of sound, and the air resistance increases sharply. Close to the cities where more turns must be navigated, capsules travel at a lower speed. This reduces the accelerations felt by the passengers, and also reduces power requirements for the capsule. The capsules travel at 760 mph (1,220 kph, Mach 0.99 at 68 ºF or 20 ºC) [10].

The proposed capsule geometry houses several distinct systems to reside within the outer mold line (figure 1)

Figure 1: Hyperloop passenger capsule subsystem notional locations



[10]

<u>Tube</u>

The main Hyperloop route consists of a partially evacuated cylindrical tube that connects several stations in a closed loop system. The tube is specifically sized for optimal airflow around the capsule improving performance and energy consumption at the expected travel speed. The expected pressure inside the tube will be maintained around 0.015 psi (100 Pa, 0.75 torr), which is about 1/6 the pressure on Mars or 1/1000 the pressure on Earth. This low pressure minimizes the drag force on the capsule while maintaining the relative ease of pumping out the air from the tube. The efficiency of industrial vacuum pumps decreases exponentially as the pressure is reduced, so further benefits from reducing tube pressure would be offset by increased pumping complexity.

In order to minimize cost of the Hyperloop tube, it will be elevated on pillars which greatly reduce the footprint required on the ground and the size of the construction area required. Thanks to the small pillar footprint and by maintaining the route as close as possible to currently operated highways, the amount of land required for the Hyperloop is minimized.

The Hyperloop travel journey will feel very smooth since the capsule will be guided directly on the inner surface of the tube via the use of air bearings and suspension; this also prevents the need for costly tracks. The capsule will bank off the walls and include a control system for smooth returns to nominal capsule location from banking as well. Some specific sections of the tube will incorporate the stationary motor element (stator) which will locally guide and accelerate (or decelerate) the capsule. Between linear motor stations, the capsule will glide with little drag via air bearings.

In order to keep cost to a minimum, a uniform thickness steel tube reinforced with stringers was selected as the material of choice for the inner diameter tube. Tube sections would be pre-fabricated and installed between pillar supports spaced 100 ft (30 m) on average, varying slightly depending on location. This relatively short span allows keeping tube material cost and deflection to a minimum [11].

The steel construction allows simple welding processes to join different tube sections together. A specifically designed cleaning and boring machine will make it possible to surface finish the inside of the tube and welded joints for a better gliding surface. In addition, safety emergency exits and pressurization ports will be added in key locations along the length of the tube.

<u>Propulsion</u>

The propulsion system has the following basic requirements:

1. Accelerate the capsule from 0 to 300 mph (480 kph) for relatively low speed travel in urban areas.
2. Maintain the capsule at 300 mph (480 kph) as necessary, including during ascents over the mountains surrounding Los Angeles and San Francisco.
3. To accelerate the capsule from 300 to 760 mph (480 to 1,220 kph) at 1G at the beginning of the long coasting section along the I-5 corridor.
4. To decelerate the capsule back to 300 mph (480 kph) at the end of the I5 corridor.

The Hyperloop as a whole is projected to consume an average of 28,000 hp (21 MW). This includes the power needed to make up for propulsion motor efficiency (including elevation changes), aerodynamic drag, charging the batteries to power on-board compressors, and vacuum pumps to keep the tube evacuated [11]. A solar array covering the entire Hyperloop is large enough to provide an annual average of 76,000 hp (57 MW), significantly more than the Hyperloop requires [10].

The Hyperloop uses a linear induction motor to accelerate and decelerate the capsule. This provides several important benefits over a permanent magnet motor:

1. Lower material cost – the rotor can be a simple aluminum shape, and does not require rare-earth elements.
2. Lighter capsule.
3. Smaller capsule dimensions

Route

The Hyperloop route should be based on several considerations, including:

1. Maintaining the tube as closely as possible to existing rights of way.
2. Limiting the maximum capsule speed to 760 mph (1,220 kph) for aerodynamic considerations [11].
3. Limiting accelerations on the passengers to 0.5g [11].
4. Optimizing locations of the linear motor tube sections driving the capsules.
5. Local geographical constraints, including location of urban areas, mountain ranges, reservoirs, national parks, roads, railroads, airports, etc. The route must respect existing structures.

For aerodynamic efficiency, the speed of a capsule in the Hyperloop is typically:

- 300 mph (480 kph) where local geography necessitates a tube bend radii < 1.0 mile (1.6 km) [12].
- 760 mph (1,220 kph) where local geography allows a tube bend > 3.0 miles (4.8 km) or where local geography permits a straight tube [12].

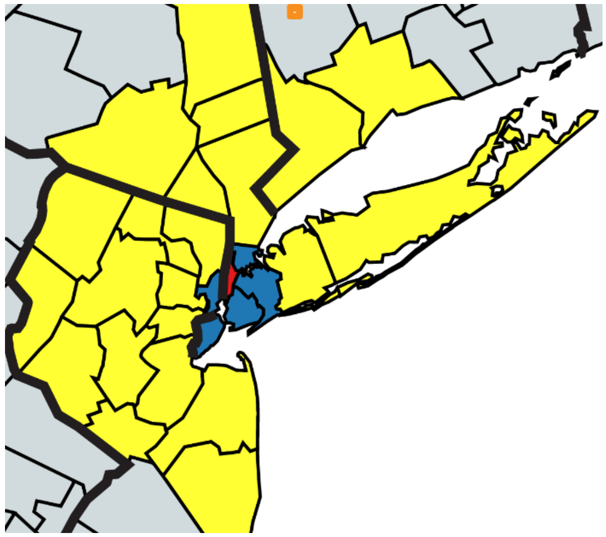
Service Overview

In order to alleviate the many commuting problems facing the New York metropolitan area today, we will construct a network of hyperloops throughout the region to replace many existing modes of transportation. Hyperloop lines will entirely replace New York City Subway, PATH, and commuter railroad lines. This system will also reduce vehicular traffic throughout the region, and provide bus and scooter service as replacement. In particular, cars will be banned from Manhattan, reducing pollution and increasing walkability.

In order to achieve these goals, three major service areas will exist. The first area will be the "Central Business District," consisting of Manhattan Island, which will be the hub of the hyperloop network, with frequent transfer stations. The surrounding "urbanized area" will consist of the Bronx, Brooklyn, Queens, Staten Island, and Hudson County in New Jersey. The hyperloop networks will provide these urbanized areas with local and express service that is more widespread than the current subway and highway system. The third area, consisting of the suburbs, will feature hyperloop routes with local services making frequent station-stops and express services stopping in major commercial areas and areas that are distant from the CBD, thereby replacing commuter rail lines and highways unable to cope with rush hour traffic. This information is shown in Figure 2.

Planned routes will be constructed to minimize disruption to nearby businesses and residents while maximizing their ability to serve every region in the metropolitan area. As a result, hyperloop lines in suburban areas will tend to be elevated, and will be built above or alongside major roads or will recycle commuter rail tracks that this system will render redundant. In more urban areas and the CBD, hyperloop lines will be built in tunnels beneath major streets, reusing subway tunnels where possible to reduce costs. Stations will be built at major destinations along each route, such as hospitals, shopping areas, and business centers, as well as to facilitate hyperloop-hyperloop and multimodal transfers. Stations will be most frequent in Manhattan and decrease in frequency as distance from the CBD increases. Altogether, this hyperloop system will allow for a more interconnected and more sustainable metropolitan region.

Figure 2: Hyperloop Service Areas



Central Business District

The metropolitan area's hyperloop network will be centered on the island of Manhattan. In this area, hyperloops will replace subways, commuter railroads, and major roads. Routes will be arranged as a rough grid following the avenues and major cross streets set out in the Commissioner's Plan of 1811 [13]. In particular, north-south routes will run under Essex St-Avenue A-FDR Drive-York Avenue, Allen St-First Avenue, Chrystie St-Second Avenue, Pearl St-The Bowery-Third Avenue, Lafayette St-Park Avenue, Broadway, West Broadway-Fifth Avenue, Church St-Sixth Avenue, Varick St-Seventh Avenue, Hudson St-Eighth Avenue, Greenwich St-Ninth Avenue, Tenth Avenue, and Eleventh Avenue. East-west routes will run under Wall-Rector Sts, Liberty St, Worth St, Canal St, Delancey-Spring Sts, Houston St, 8th-Christopher Sts, 14th St, 23rd St, 34th St, 42nd St, 50th St, 59th St, 66th St, 72nd St, 79th St, 86th St, 96th St, 106th St, 116th St, 125th St, 135th St, 145th St, and 155th St. This information is summarized in Figure 3.

This grid system, with parallel and equally-spaced routes, is the most efficient arrangement of the hyperloop network, because it allows for all residents of Manhattan to be within walking distance of stations [14]. Additionally, stations would be placed to maximize the number of transfers at the expense of lower speeds. Nevertheless, speeds would still be faster than delayed subways and the 9 mph at which traffic currently travels in Manhattan [6]. Furthermore, it would allow any commuter throughout the metropolitan region to require only one hyperloop-hyperloop transfer to get to any destination. Furthermore, this gridded arrangement directly replaces all major streets and also subways, which only run under streets anyway. In addition, this would allow many subway tunnels to be repurposed for hyperloop use, thereby reducing construction costs.

There will also be other major transportation network changes on the island of Manhattan. Though the entire island will be served by hyperloops, shuttle buses will be routed throughout the island in order to make more localized stops originating from hyperloop stations. Additionally, a public scooter program will be implemented to assist in local travel. Some of these scooters would be self-driving.

Altogether, this network of hyperloops and shuttle buses will render cars obsolete in Manhattan, and non-emergency vehicles would be banned from entering the island. For Manhattan residents who would wish to sell their cars as a result of this measure, a government buyback program would be instituted. Meanwhile, for Manhattan residents who would wish to keep their cars, parking garages would be built in the Bronx, Brooklyn, Queens, and New Jersey. Commuters from the urbanized area and suburbs will not be allowed to use these garages, thereby reducing the traffic around them and encouraging use of the hyperloop system.

Additionally, streets would be converted to have much larger pedestrian areas, with one lane in each direction for buses and several lanes for scooters and bicycles.

Figure 3: Hyperloop Routes in the CBD

<u>Widespread Service in Urbanized Areas</u>

In other urbanized areas, such as Brooklyn, Queens, the Bronx, Staten Island, and Hudson County, the hyperloop network will expand high frequency service to many areas that currently lack it, while bus service will be reorganized to provide feeder service to hyperloop stations and to connect secondary destinations. Hyperloop routes will primarily serve to improve transit from these areas to the CBD and major local hubs, such as Downtown Brooklyn, Flushing, and Jersey City. As a result, the New York City Subway and PATH system would be completely replaced by the hyperloop system, while traffic on infamously slow expressways, such as the Brooklyn-Queens Expressway and the Cross Bronx Expressway, would be significantly reduced [15]. Altogether, this system will eliminate overcrowding on the area's struggling bus and subway systems and will significantly increase public transportation options in many areas, including much of Queens, Staten Island, Hudson County, and Southeast Brooklyn.

Routes will be constructed as originating from Manhattan and then following each borough or county's street layout. For instance, in lines in Queens and northern Brooklyn will be orientated southwest-northeast, following roads such as Northern Boulevard, the Long Island Expressway, and Union Turnpike [16]. These routes would serve major hubs, including Flushing and Jamaica. Meanwhile lines in southern Brooklyn will be oriented north-south, along routes such as Ocean Parkway, New Utrecht Avenue, and Nostrand Avenue [16]. Lines in Hudson County will be arranged east-west, due to Manhattan being to the east of this area and to allow for lines to continue on to suburban areas of New Jersey [16]. Some routes from Brooklyn and Hudson County will serve Staten Island, and will be north-south to minimize curves [16]. The western Bronx will have a full grid system, due to both north-south and east-west lines entering this area from Manhattan. However, the eastern Bronx will tend to have southwest-northeast routes [16].

<u>High-speed Suburban Network</u>

In suburban areas, a key goal of the planned hyperloop network is to replace commuter railroads and reduce road traffic. As a result, the hyperloop will serve Nassau and Suffolk Counties in Long Island to replace the LIRR [17]; Fairfield and New Haven Counties in Connecticut and Dutchess, Orange, Putnam, Rockland, and Westchester Counties in New York to replace Metro-North [18]; and Bergen, Essex, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Passaic, Somerset, Sussex, Union, and Warren Counties in New Jersey to replace New Jersey Transit [19]. Hyperloop capsules will run at speeds of hundreds of miles per hour, greatly shortening commute times and allowing people from more distant suburbs to be much better connected to the CBD. Besides connecting suburbs to Manhattan's CBD, this network will also connect suburban commercial and employment centers to one another, which the current commuter rail network fails to achieve [20]. This will also alleviate capacity issues these railroads face in with having termini in Manhattan, because while trains must switch tracks at a terminal, delaying all other trains on the line, hyperloops would remain in one tube, with no interruption to the service of other hyperloops [21]. In these areas, hyperloops are expected to operate at speeds up to several hundreds of miles per hour [22].

Though present throughout the New York metropolitan region, Long Island in particular faces major congestion on its railroads and highways due to its elongated east-west geographic orientation, forming bottlenecks for commuters [23]. As a result, the hyperloop system will have 8 east-west routes constructed on Long Island to replace these systems. These will include routes along Northern Boulevard, the Long Island Expressway, Hillside Avenue and the Jericho Turnpike, the Southern State Parkway, and the Sunrise Highway [24], as well as converting the Long Island Railroad Main Line, Montauk Branch, and other lines to hyperloop standards, among other routes [25]. Stations will exist at major urban areas such as Freeport, Hempstead, Long Beach, and Valley Stream [26].

In Upstate New York, major north-south routes experience high volumes of cars [27], while Metro-North, the commuter railroad serving the region, has been plagued with safety issues and derailments in recent years [28]. As a result, the hyperloop system will have several north-south lines east of the Hudson River, including ones along Broadway, the Saw Mill

Parkway, the New York State Thruway, Bronx River Parkway, the Hutchinson River Parkway, and the New England Thruway [27], as well as converting the Metro-North Harlem, Hudson, and New Haven Lines to hyperloop use [29]. Routes in the easternmost part of Westchester County would be extended to Connecticut. Altogether, these routes would extend to major jobs centers such as Mount Vernon, New Rochelle, Poughkeepsie, White Plains, Yonkers, Bridgeport, and New Haven [26], [30].

West of the Hudson River, almost 42% of New Jersey's main roads are above or approaching capacity [31]. Meanwhile, New Jersey Transit railroads are facing major employee shortages, resulting in frequent train cancellations and the closures of some lines [32]. Planned hyperloop routes will parallel major roads, such as the Garden State Parkway, Interstate 78, Interstate 80, Interstate 278, the New Jersey Turnpike, and the Palisades Interstate Parkway [33]. Additionally, most New Jersey Transit and Metro North tracks west of the Hudson River would be redeveloped to be used by hyperloops [34]. This will include service to Newburgh in New York and Clifton, Elizabeth, Newark, Passaic, Paterson, and Trenton [26], [35].

Implementation Schedule

The construction of the hyperloop system will be divided into four phases, in order to stagger construction and make sure that transit options remain available for commuters while the hyperloops are being built.

- Phase 1: The goal of this phase is to supplement the current transit system, solving urgent transit problems while establishing the foundations for the rest of the hyperloop network. Additionally, because hyperloop is still a new technology, construction techniques will be tested, including constructing new tunnels and recycling older ones for hyperloop use. This phase would be complete by 2023.

I. A new tunnel would be built under Third Avenue in Manhattan, removing the need to continue building the extremely expensive Second Avenue Subway [20]. This would allow testing of tunnel construction techniques.
II. The current 14th Street Line tunnel, serving the L train, would be renovated for hyperloop use. The MTA intends to shut down the 14th Street Line to carry out repair work after Hurricane Sandy; instead, this tunnel will be repaired and then converted to hyperloop standards, allowing testing of techniques for converting existing tunnels for hyperloop use [36].
III. Under 34th, 86th, and 125th Streets, in order to improve crosstown travel.

- Phase 2: The goal of this phase is to begin large-scale construction of the hyperloop network and begin serving all three service areas. This phase would be complete by 2032.

I. Phase 1 lines would be extended through the urbanized areas to the suburbs.
II. The current subway tunnels under 7th Avenue, serving the 1 2 3 and N Q R W trains, would be renovated for hyperloop use.
III. New tunnels would be built for lines under 1st, 5th, 9th, and 11th Avenues. Together, these lines under odd-numbered avenues would not affect most subway lines, reducing community impact.
IV. New tunnels would be built under Wall-Rector, Fulton, Canal, Houston, 50th, 72nd, 106th, and 145th Sts. Together with the 14th, 34th, 86th, and

125th St tunnels, these routes would significantly improve cross-town travel speeds.

V. Shuttle bus routes would be launched, and the public scooter program would begin.

- Phase 3: The goal of this phase is to greater increase service to urbanized areas and suburbs while completing all hyperloop lines in the CBD. This phase would be complete by 2040.

I. Phase 2 lines would be extended through the urbanized areas to the suburbs.

II. The current subway tunnels under Second Avenue, serving the Q train; Park Avenue, serving the 4 5 6 trains; Sixth Avenue, serving the B D F M trains; Broadway, serving the 1 2 3 and N Q R W trains; Eighth Avenue, serving the A C E trains; 42nd Street, serving the 7 train; and 59th Street, serving the N R W trains, would be renovated for hyperloop use.

III. New tunnels would be built under York Avenue-FDR Drive, Tenth Avenue, and Liberty, Worth, Delancey-Spring, 8th-Christopher, 23rd, 66th, 79th, 96th, 116th, 135th, and 155th Streets. This would complete the hyperloop network in Manhattan.

IV. The shuttle bus and scooter programs would be expanded, and self-driving scooters would be tested.

V. Parking garages would be constructed near Manhattan, and the government car buyback program would be set up.

- Phase 4 The goal of this phase is to complete the hyperloop system. This phase, and the entire plan, would be complete by 2045.
    I. Phase 3 lines would be extended through the urbanized areas to the suburbs.
    II. The shuttle bus and scooter programs would be completed.
    III. Cars would be banned from Manhattan, and streets would be redeveloped for bus, scooter, and pedestrian use.

Budget

The budget is divided into two phases:

- Making capsule
- Making tube

Table 1 and table 2 represent the cost breakdown for making the capsule and the tube respectively.

Table 1: Crew capsule weight and cost breakdown

Vehicle component	Cost ($)	Weight (KG)
Capsule Structure &	245,000	3100
Interior & Seats	255,000	2500
Propulsion System	75,000	700
Suspension & Air	200,000	1000
Batteries, Motor &	150,000	2500
Air Compressor	275,000	1800
Emergency Braking	50,000	600
General Assembly	1,000	N.A
Passengers & Luggage	N.A	2800
Total/Capsule	1350,000	15000
Total for Hyperloop	$ 54,000,000	

[10]

Table 2: Total cost breakdown for capsule and tube

CAPSULE	54 (40 CAPSULE)
Capsule Structure & Doors	9.8
Interior & Seats	10.2
Compressor & Plumbing	11
Batteries & Electronics	6
Propulsion	5
Suspension & Air Bearings	8
Components Assembly	4
Tube	5410
Tube Construction	650
Pylon Construction	2550
Tunnel Construction	600
Propulsion	140
Solar Panels & Batteries	210
Station & Vacuum Pumps	260
Permits & Land	1000
Cost margin	536
Total	6000

[10]

Qualifications and Experience

This project is initiated and advocated by experienced core members:

1. Rashidul Ikram Summy is the CFO (Chief Financial Officer) of the 'Hyperloop Corporation'. Before that he graduated in Computer Engineering from the City College of New York and completed PhD on Digital Integrated Circuit from the Massachusetts Institute of Technology. He has 3 years experience of working with the Microsoft as a technical evangelist.

2. Steven Toprover graduated from The City College of New York with a BE in Electrical Engineering, followed by graduate school at the Massachusetts Institute of Technology. He has worked at for Parsons-Brinckerhoff and SpaceX before becoming Chief Operating Officer of the Hyperloop Corporation.

3. Jingqian Wang is the Planning and Development Manager of Hyperloop Corporation. She completed her BS degree in Computer Science at The City College of New York, MS degree in Urban Design at UC Berkeley College of Environmental Design, and had 3-year experience as Urban Designer at the Department of City Planning before she joined the company.

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