

# AURIEL

Making walking safe and accessible for all.

**PACE**  
UNIVERSITY

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Challenge Based Innovation | 2022/2023

Team

**FUSION**

# ABSTRACT

Road traffic accidents are a major public health concern resulting in approximately 1.35 million deaths and 50 million injuries worldwide annually [World Health Organization 2022]. In addition, 273 people, 50% of them pedestrians, died in road traffic accidents in New York City in 2021 [Transportation Alternatives 2022]. Target 3.6 of the United Nations Sustainable Development Goal #3, Good Health and Well-being, aims to halve global deaths and injuries from road traffic accidents by 2030 [United Nations 2023]. Likewise, a New York City initiative, the Vision Zero program, aims to reduce traffic-related injuries and fatalities in collaboration with government, legislature, industry, and citizens [The City of New York (1)].

We propose a solution for improving pedestrian safety at intersections in New York City while reducing human error and enhancing decision-making for pedestrians. Employing a design-centered approach, our solution is a vehicle-to-network (V2N), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) system called Auriel. The system uses real-time sensor data and provides navigational direction with imagery in the form of pattern-based alerts to increase situational awareness in intersections. Traffic signals and cameras are currently the most common systems utilized at intersections to regulate traffic flow and increase safety. Auriel differs from the punitive systems such as traffic lights and crossing signals that are based on rules and limitations. Monitoring the intersection by collecting object-based data, Auriel alerts pedestrians using screen technology for people to be aware of potential safety hazards in their surroundings, leading to increased situational awareness [Airswift 2023].

Auriel is a state-of-the-art solution that combines multiple advanced technologies to enhance street safety in urban settings. Equipped with a LiDAR-based sensor system, LED screen system, solar power system, and a wireless communication system, Auriel can measure the speed, distance, and velocity of approaching vehicles, and identifies the level of activity from the density of objects in the area. In addition, a high-speed information system, including signal processing, navigation, and AI, is integrated to provide up-to-date traffic analysis and management.

Our proposed solution is expected to reduce traffic injuries and deaths by reimagining intersections that enhance pedestrian safety and create an accessible city that prioritizes people over cars. Auriel strives to improve the well-being of citizens by envisioning a safer, more walkable, and accessible city for everyone by 2030.



Picture: Morton Street crossing at West Village, Manhattan, NY.

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Picture: CERN, The Globe of Science and Innovation at Geneva, Switzerland.



Picture: Team Fusion at CERN Ideasquare in Geneva, Switzerland.

## TEAM MEMBERS



**Susanna Lammervo**

**Master of Science in Human Centered Design**

Susanna is a User Experience Designer with a background in graphic design, business, and aviation. She is completing her master's degree in Human Centered Design at Pace University with a focus in User Research and Product Innovation. As a curious generalist, she enjoys solving urban problems and improving products for personalized, joyful experiences. She thrives from design processes that leverage empathy through research in decision making, with a strong passion for envisioning a better and more sustainable future for society and its citizens.



**Aastha Bhadani**

**Master of Science in Information Systems**

Aastha is a User Experience Designer with a background in architecture. She is pursuing a master's degree in Information Systems at Pace University with a focus in User Experience Design. Aastha has always been fascinated with crafting captivating experiences, and solving complex problems using creativity and innovation. She believes her design superpower is empathy which allows her to truly resonate with the people she is designing for and deliver some groundbreaking designs.



**Sachin Archer**

**Bachelor of Arts in Computer Science**

Sachin is pursuing a bachelor's degree in Computer Science with a minor in Photography at Pace University. Outside of the world of technology, Sachin is also a multi-published photographer who enjoys connecting with others through his work. He believes his ability to connect with anyone from any background allows him to be a refreshing asset in the technological world.



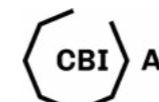
Picture: Ideation session by team Fusion at CERN Ideasquare in Geneva, Switzerland.

# INTRODUCTION

The Challenge Based Innovation (CBI) A<sup>3</sup> project is a Design Factory Melbourne initiative focusing on developing innovative outcomes connecting technologies from CERN, the European Organisation for Nuclear Research, and ATTRACT technology, an innovation project funded by the European Union [CERN 2023; ATTRACT 2023]. The challenge of this project was to explore problem areas framed by the United Nation's Sustainable Development Goal number 3 (UN SDG), Good Health and Well-being, and to design an outcome that addresses a specified problem on a local level of each collaborating Design Factories. Since New York, US is home to the NYC Design Factory that our team is part of, our target was to orientate the problem and define the design solution focused in New York [Pace University 2023].

The problem area selected for this project is to reduce road injuries and deaths, which is a sub-target under UN SDG3, aiming to halve the number of global deaths and injuries from road traffic accidents by 2030 [United Nations 2023]. Our design team is focusing on how our solution might contribute to this target on a local level in New York City.

A proposed indicator to measure the progress of the target is a road traffic death rate per 100,000 population.



# SOCIETAL CHALLENGE

Road traffic accidents pose a major societal problem due to people losing lives and experiencing severe injuries that significantly impact families, communities, and society as a whole. New York City is one of the most densely populated cities in the world with a high volume of vehicles and pedestrians sharing the roads.

Road traffic accidents are globally an existing and serious threat to societies, which too often lead to serious injuries and fatalities [WHO 2022]. In the United States, the most common cause of death for people aged 1-54 is road traffic accidents which are repeatedly reported in large urban areas and busy cities around the country [Centers for Disease Control and Prevention 2023]. In 2020, more than 5,25 million traffic accidents were reported by the US police, of which more than 2,28 million people were injured (varying from mild to severe), and as a result of which up to 38,824 people died. Over the past decade, the number of fatal accidents has seen a substantial growing trend when fatalities increased by more than 20 percent, while reports of accidents made by the police have decreased by almost 7 percent during 2019 and 2020 together. The numbers reported by the National Highway Traffic Safety Administration [NHTSA 2020] conclude today's accidents are more often fatal even when the overall number of accidents had slightly decreased.

In 2021, the road accident death rate in New York was 1.6 percent, which is more than double the same figure in the whole country. Traffic crashes killed 273 people, of which almost 50 percent were pedestrians, people out on the streets running their daily errands. New York has faced a rapid increase in hit-and-runs in just 3 years (2018 to 2021), when cases have more than doubled and only 3 percent of the cases ended up being solved. [Transportation Alternatives 2022.] The number of accidents rises especially during afternoon rush hours when people get off work, and during evenings when daylight turns into darkness [Vision Zero View 2023].



Figure: Traffic data from NY and the US [NHTSA 2020; Transportation Alternatives 2022]

## Why injuries happen?

When the amount of traffic and people is high, the probability of accidents also increases. Millions of people walk the streets of New York every day making each of them a potential target of a serious accident. Even though the city has added pedestrian plazas and bike lanes to improve road safety, pedestrian deaths, and injuries have still continued to rise.



# PROBLEM SPACE

Based on secondary research, we recognized three main problem areas which are repeatedly connected to traffic accidents: intersections, decision-making, and situational awareness. Our leading research question that defines the problem, highlights the importance of minimizing human error while enhancing decision-making at intersections.

## Intersections

Intersections are fundamental parts of connecting people and transportation from one route to another. Despite the usefulness of intersections, they cause situations where accidents and close-call accidents often happen leading to severe and life-threatening conditions and trauma. Even though the busiest intersections are signalized with traffic lights that control the flow, drivers speeding through yellow and red lights are a common sight in New York City. One of the reasons why drivers fail to perceive traffic signals is when they are distracted by cell phones or other electronic devices and miss up to 50 percent of the information in their surroundings. [NYC Department of Transportation 2022.]

## Decision-Making

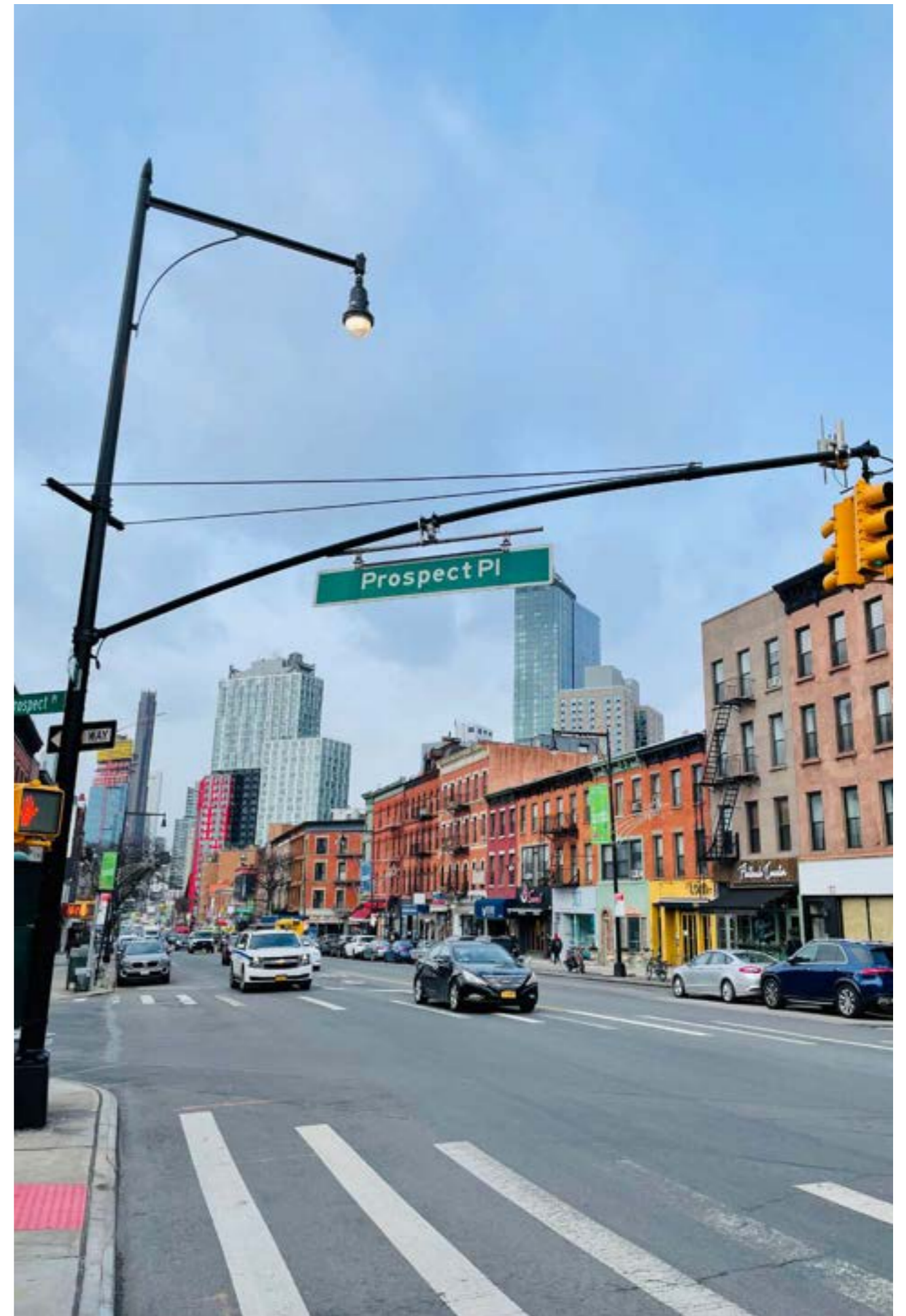
Human decision-making is another factor that plays a significant part in most traffic accident cases. When approaching an intersection, drivers typically either make a decision to cross an intersection or choose to give space for an oncoming vehicle or a road-crossing pedestrian. In addition, fast driving and phone occupancy are also decisions that drivers make while sitting behind the wheel. Drivers may also feel hesitant, or on the contrary overconfident, in a crowded street where visibility may be limited through blind spots or not noticing the traffic light status, which requires looking up instead of keeping eyes on the road level. [Marti et al. 2015]

## Situational Awareness

The situational awareness of drivers and pedestrians is affected by several factors in the environment that they cannot influence or control. A driver may not see a cyclist when taking a right turn due to a blind spot, and a pedestrian may not be aware of a speeding vehicle approaching the same intersection. [NYC Department of Transportation 2022.]. Situational awareness out on the streets could be improved, for instance, with external signals such as road signs, or devices like car side mirrors that help reduce blind spots for drivers [Harvard 2016]. However, these tools are almost always visible or available to drivers and pedestrians, and thus do not seem to be very effective means of raising people’s situational awareness in the middle of busy traffic.

### Problem Statement

*How might we improve safety at NYC intersections for pedestrians to make better decisions through real-time information?*



Picture: Pedestrian crossing at Flatbush Avenue & Prospect Place in Brooklyn.



Picture: Alabama Avenue Station, Brooklyn, NY.

# New York City Zero Priority Map

Type	Share of City	Citywide	% of the City	Share of Ped KSI	Total Ped KSI	% of Total Ped KSI	% of Total Ped Fatalities
Priority Corridors	531 miles	6012	9 %	2513	-	51 %	50 %
Priority Intersections	303 intersections	41078 intersections	1 %	782	-	16 %	18 %
Priority Areas	67 sq. miles	302 sq. miles	22 %	2682	-	52 %	43 %
<b>Combined Total</b>				<b>3,520</b>	<b>4,936</b>	<b>71%</b>	<b>67%</b>

Data from years 2017-2021

## NYC INITIATIVE – VISION ZERO

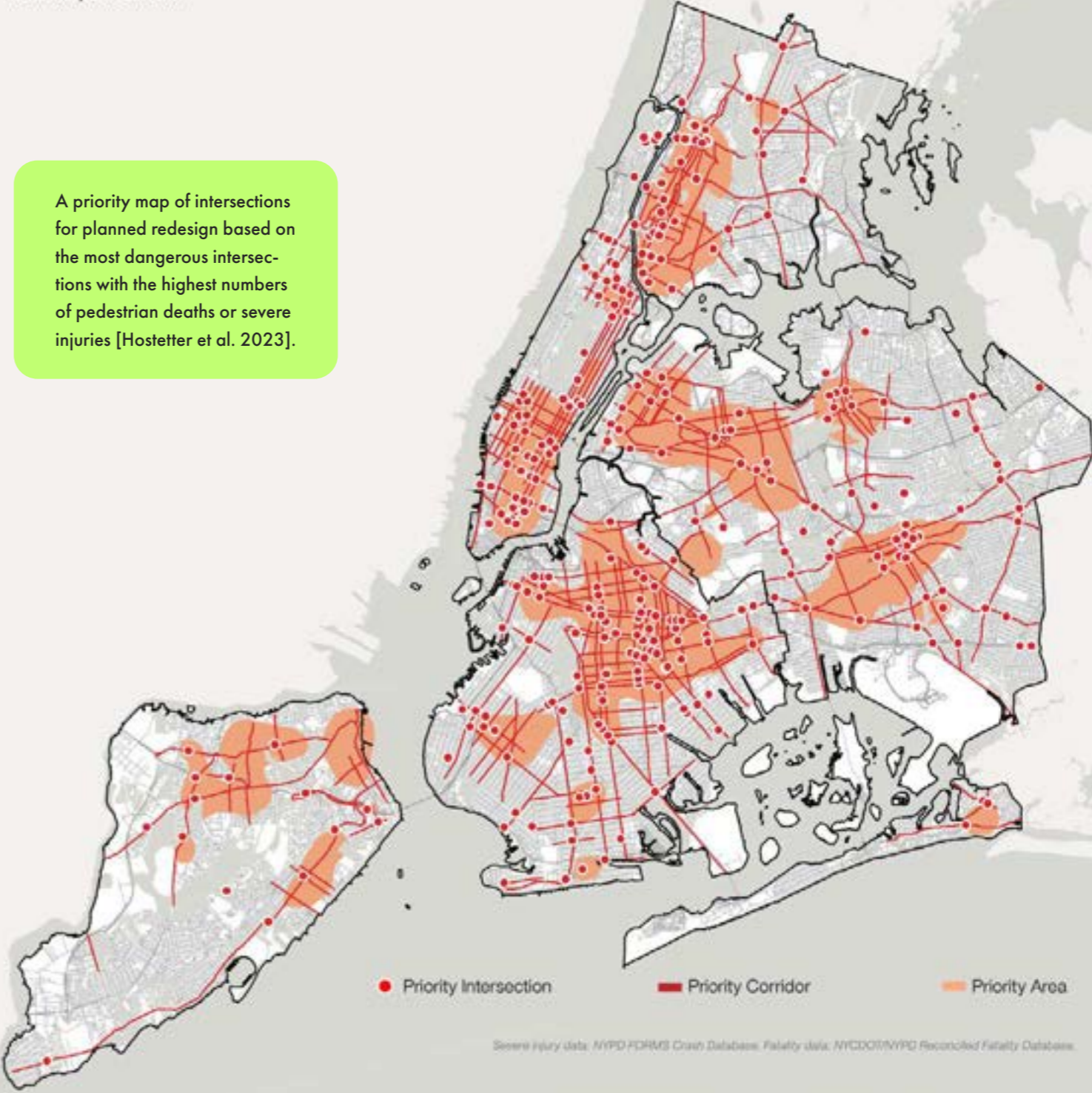
NYC Vision Zero is a road safety initiative launched by the City of New York in 2014 that aims at completely eliminating traffic related fatalities and injuries. The program is one of the main initiatives the city currently takes action through to reach this goal via a combination of design, engineering, education, and enforcement efforts. Despite the program changes applied to the streets, a greater number of crashes has been one of the existing challenges since the program began. [The City of New York 2023.]

The NY Vision Zero program strategy consists of reducing vehicle speeds, improving infrastructure for pedestrians and cyclists, promoting public awareness, and increasing traffic regulations. [The City of New York 2023] The NY Department of Transportation (DOT) has recently made expanded efforts to redesign 1,000 intersection areas where fatalities and serious injuries have mostly occurred. Modifications have been made for pedestrian crossing signals to provide "head-starts" to enter before vehicles are permitted to turn. In 2022, construction work was announced to raise some crosswalks for better accessibility while serving as speed bumps to slow drivers, and

the number of bicycle racks that are expected to improve visibility for drivers, cyclists, and pedestrians, while preventing drivers from turning too quickly [The City of New York (2) 2022].

In 2021, the City of New York placed a new rule for drivers to stop until a pedestrian has completely crossed an uncontrolled intersection that has no stop sign or a traffic light [The City of New York (3) 2021]. A public awareness campaign called "Stop. Let Them Cross" was created to promote the change and the enforced consequences of rule violations [The City of New York (4) 2022].

A priority map of intersections for planned redesign based on the most dangerous intersections with the highest numbers of pedestrian deaths or severe injuries [Hostetter et al. 2023].



Severe injury data: NYPD FORVIS Crash Database. Fatality data: NYCDOH/NYPD Reconciled Fatality Database.



# NYC INITIATIVE – PLANYC

In 2007, the City of New York launched a PlaNYC program to initiate comprehensive sustainability measures and combat climate change while enhancing the quality of life for New Yorkers. The program aims to mitigate the negative impacts of climate change but also bring about positive changes in people’s daily lives through cleaner air, improved mobility, safer homes, and the creation of green jobs and businesses. The program’s future vision is to achieve a more equitable, healthy, and resilient society for the city residents.

## Improving Quality of Life

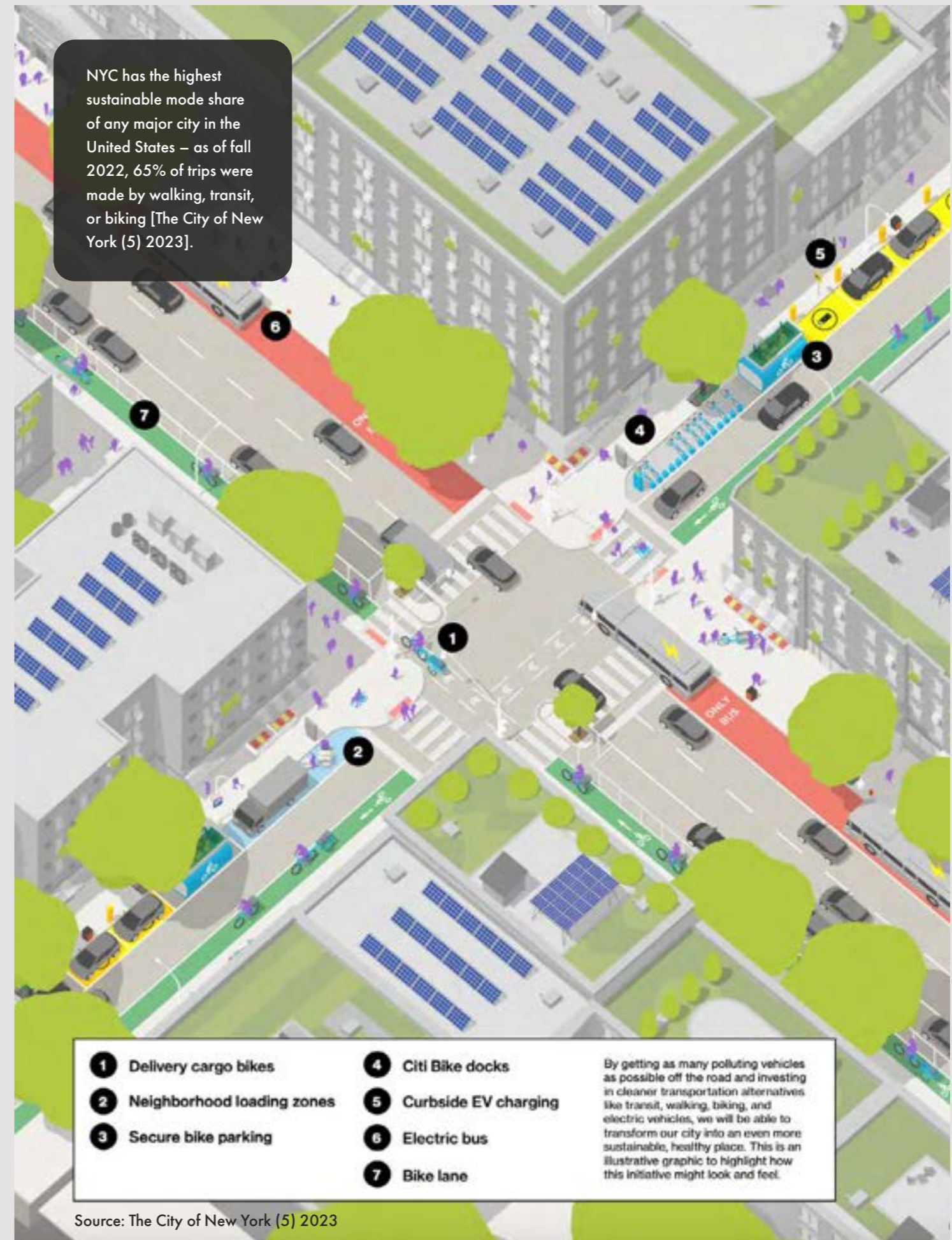
The PlaNYC initiative is committed to ensuring equal access to a healthy and enjoyable urban life for all. It aims to provide high quality of life for New Yorkers through reliable and accessible public transportation, and accessible parks. The city’s safety is particularly sought to be influenced by traffic by paying attention to trucks in the city and increasing the number of electric vehicles. Transportation emissions will be reduced by increasing public transit ridership and making the city more walkable and bike-friendly. [The City of New York (6) 2022.] The city will maintain its partnership with the Metropolitan Transportation Authority (MTA) to implement measures that improve the efficiency and reliability of buses as a mode of transportation. This includes implementing camera-enforced bus lanes, transit signal priority, and redesigning the bus network to ensure faster and more dependable travel options. Congestion pricing in New York imposes tolls on drivers entering Manhattan, and encourages drivers to switch to public transit, walking, or biking while generating revenue to modernize the regional transit system. [The City of New York (5) 2023.] In addition, building a connected network to open spaces will increase access to quality parklands and forested areas [The City of New York (6) 2022].

## Protection from Climate Change

One of the program’s plans is to protect communities from the effects of climate change by reducing high air pollution and heavy use of fossil-fueled energy sources. The city’s carbon footprint will be improved through a low-emission construction industry and by pursuing fossil fuel-free operations executed by the city. In time, New York’s aging infrastructure will be replaced with clean energy resources, in addition to building and homeowners assisted with projects such as green roofs and solar panels. [The City of New York (6) 2022.]

## Building Green Economic Engine

A transition towards the green circular economy is an essential part of the city’s overall transformation for a more sustainable future where the impacts of climate change are mitigated while new jobs are still created [The City of New York (5) 2023]. The city is committed to supporting climate education and training, growing its "green" employment, and endorsing entrepreneurial opportunities through industrial innovations. Recycled materials are reused or manufactured into new products, such as recycled asphalt which can be used in paving the roads and streets. [The City of New York (6) 2022].



Source: The City of New York (5) 2023

# NYC STREET EVOLUTION

New York City's street infrastructure has undergone significant evolution since the 1900s when cars first took over the roads guiding the urban design of the time. Since then, the city has gradually evolved into a more pedestrian-friendly and safety-oriented place for its residents.

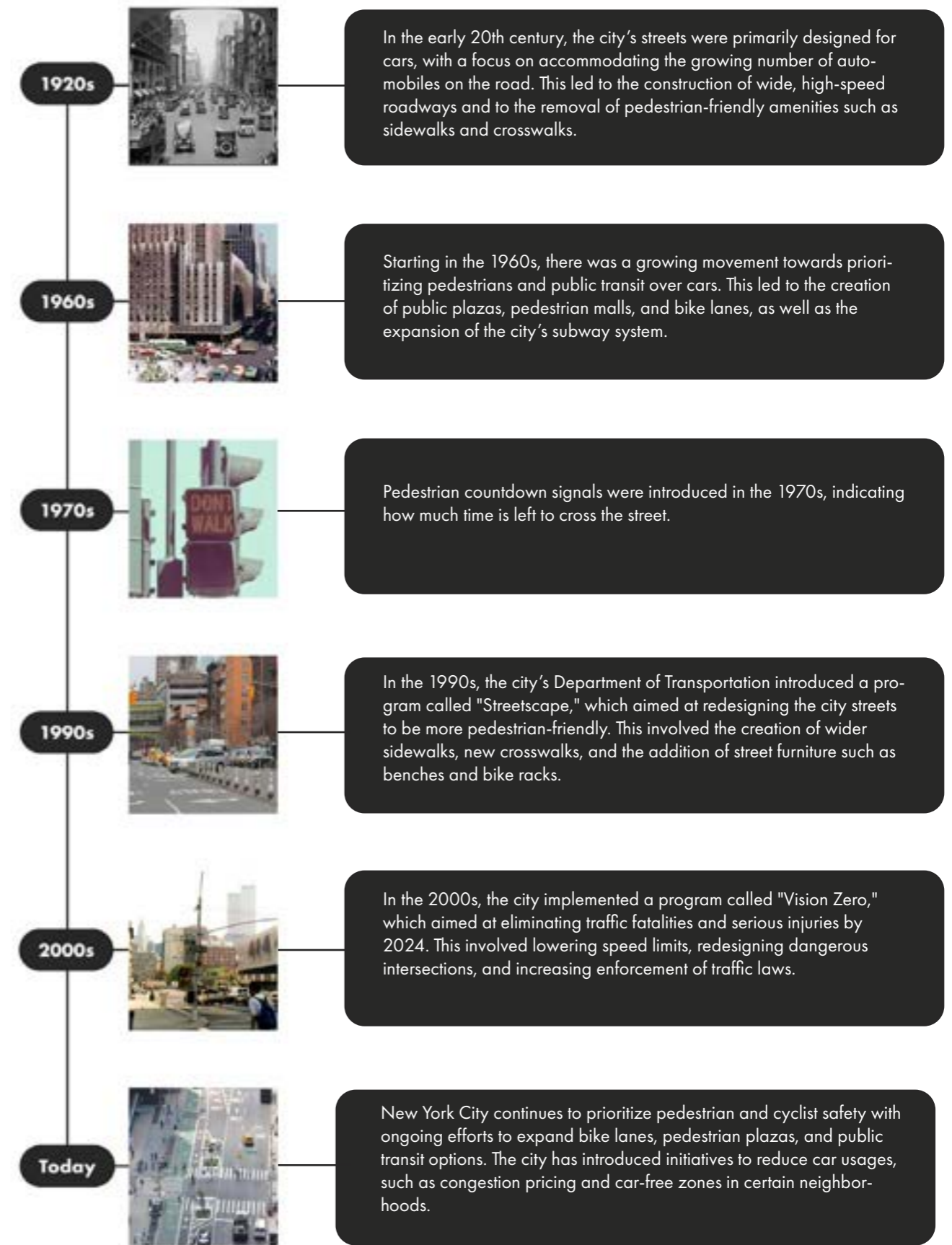
At the start of the 1900s, the five boroughs that operated as separate cities united to create "Greater New York," resulting in a notable shift in the city's demographics. This expansion increased the city area from 60 to 360 square miles and its population from 2 million to nearly 3.5 million. [Ravuri 2021.] Most of New York City's skeletal infrastructure dates from the first part of the 20th century [Madrigal 2014]. In 1915, the installation of the first traffic control devices at intersections in New York City began. These devices were manually operated semaphores with four arms and the words "stop" and "go" painted on them.

The following year, a more elaborate device was introduced. The first traffic tower was erected in the middle of the intersection of Fifth Avenue and 42nd Street in 1916. The tower featured a booth where an operator would stand and control 500-watt lamps positioned on top of the booth. Three of these lamps were colored red, amber, and green, facing north, while three similarly colored lamps facing south. [CWA Local 2023.] A fully automated traffic light system could not have come at a better time as the volume of traffic was about to increase drastically.

In 1927, The Holland Tunnel opened, thus increasing the number of cars driving into the city [CWA Local 2023]. In the 1930s, New York City officials began implementing the "Green Wave" traffic signal system, which coordinated traffic lights along major corridors to allow for more efficient automobile traffic flow. This system prioritized cars over pedestrians, as pedestrians had to wait longer for the lights to change. [Gray 2014.]

During the 1950s and 1960s, the city's focus on automobile traffic continued to grow, with the construction of highways and expressways such as the Brooklyn-Queens Expressway and the Cross Bronx Expressway [Kobara 2013]. During the 1960s, Robert Moses, the transportation commissioner of New York City, initiated various urban renewal initiatives that emphasized the importance of automobile traffic at the expense of pedestrian safety. Among these initiatives was the construction of the Lincoln Center for the Performing Arts in the Upper West Side, which was designed to be reachable exclusively by car and had minimal pedestrian access. As a result, a significant portion of the neighborhood was effectively disconnected from the rest of the city. [Sabiha 2018.] The city's implementation of one-way wider driving lanes prioritized cars over pedestrian safety [Zipper 2023].

The rising number of vehicles, and traffic caused by them, has always been an intractable problem in New York City. Over the years, the New York City street infrastructure has resulted in a cityscape that is dominated by a vast network of streets and highways, congested traffic, and air pollution. The infrastructure reflects the needs of drivers over pedestrians and cyclists making it an unpleasant and unsafe environment for those not accessing the road by cars or vehicles. In 2000, to prioritize pedestrians, the city implemented the Vision Zero Program to tackle the rising number of pedestrian fatalities which is an alarming and ongoing national trend in the United States. [Kuntzman 2022; The City of New York (6).]



# FUTURE SCENARIO

Designing for the future requires speculation of different possible scenarios. Thus, we picture a future that centers around greentocracy where environmental concerns dominate the societies and decision-making. The scenario is divided into seven distinct societal categories that help us imagine the future until 2050.



## Social

We speculate that by 2050 the United States will be a country where extreme urban densification is taking more place in the society and a high wealth gap is only getting higher. Only wealthy people can afford good education and people suffer from a new disease called Societal Stress Disorder due to compact living spaces and restricted access to nature. Do everything yourself (DEY) culture is ubiquitous, and repurposing of used items and upcycling have found their place in communities.

## Technological

A shift towards sustainable transportation has made autonomous cars and buses to become the new norm and only chargeable cars are allowed on the roads. We imagine that the high investment boom in climate-friendly commodities has resulted in highly-sensored and technology-based cities that monitor and regulate energy use. Households generate their own power through solar panels leading to a wide availability of affordable and clean energy.

## Economic

A highly regulated economy is part of the greentocracy scenario we envision for the decades to come. Punitive measures will be set for businesses that continue as usual forcing companies to adapt to a circular economy and upcycling, which are at an all-time high. Consumerism is predicted to slow down in low- and middle classes due to carbon taxation and individual allowances. New job types such as cleaning up the environmental pollutants and processing materials for re-use boost the employment levels but create less desirable jobs.

## Environmental

Strict climate action forces every person to contribute to helping the planet to recover from pollutants and climate warming. Extreme ecological regulations have reduced emissions and global mean temperature rise remains below 1.5°C which has resulted in cleaner air, healthier environment, and lower sea level rise. Because access to nature has been restricted for humans, the size of protected land has increased by as much as 70%.

## Political

We also assume that less of global governments will be democratically elected which lowers civil liberties. Planet-first thinking guides global decision-making leading to stringent environmental regulations and therefore causing disillusion among the majority of citizens. Street protests have become a common sight in urban environments.

## Legal

Large countries such as the US have shared more power for scientific advisory boards that influence local legislation. We imagine that pervasive carbon taxation and personal carbon allowances take place in the legislation for which a Global Carbon Xchange will be opened where companies and even individuals trade their carbon quotas.

## Ethical

Overpopulation has led to discussions about global population control through restrictive reproductive rights. Civil liberties have significantly decreased due to lower freedom of expression, and the sounds of nature can only be heard through mobile devices because of restricted access to nature.

## DESIGN SOLUTION



AURIEL

Introducing Auriel, a revolutionary vehicle-to-network (V2N), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) system designed to improve pedestrian safety at intersections in New York City. Utilizing real-time sensor data, Auriel provides pedestrians with alerts to help them make informed decisions about when crossing an intersection is safe.

Contrary to traditional traffic signals and cameras that are based on rules and limitations, Auriel monitors intersections and collects data from its surroundings to alert pedestrians about potential threats such as speeding or turning vehicles, and high-density areas. By prioritizing pedestrian safety, Auriel is expected to reduce traffic-related injuries and deaths in the city creating a safer, more walkable, greener, and accessible city for everyone.



## PRODUCT CONCEPT

Auriel's wireless network, managed by an in-built system, enables event observation and real-time notification. It combines state-of-the-art technology, including a LiDAR-based sensor system, an LED screen system, solar panels as a power source, and a communication system to measure speed, distance, and velocity of approaching objects, in addition to identifying high-density areas of a large number of people or busy traffic.

Auriel, our proposed pedestrian safety solution for intersections in New York City, has been designed to be approximately the same height as the current pedestrian traffic light, or slightly higher. It will be placed on the corner of two pedestrian crossings with each 4-way intersection having 4 Auriels, one on each corner. Though, only one Auriel equipped with a LiDAR sensor is required for each intersection.

Auriel provides visually dynamic alerts about traffic events with the majority of the product consisting of a 3D LED screen area. Positioned on a corner of an intersection, the screens are facing people waiting on the opposite side of the road. Additionally, Auriel emits audio-based alerts that are targeted toward pedestrians standing directly under or near it. The finalized product design mimics a green plant with ecologically acceptable biocomposite being the primary material used for its structure.

Link to a product [video](#).



# TRAFFIC ALERTS

Auriel communicates information with pedestrians in the form of visual patterns and audio alerts in order to inform them about traffic hazards around them. The information received by the data collection point (LiDAR sensors) in Auriel, will use an LED screen to demonstrate visual patterns and Sound-Beam technology to provide on-spot and targeted sound for pedestrians who are in the vicinity of Auriel.

## Visual Alerts

Through visual data storytelling, complicated information will be simplified through the screens in a way that pedestrians can engage with the information provided for them and make critical decisions faster and more confidently [Microsoft 2023]. Data visualization will play a remarkable role in determining how receptive pedestrians are to receiving information about a dynamic traffic scene. It will also help transform boundless amounts of data into something simpler and digestible. Effective visualization helps Auriel streamline the data received and reveal traffic trends, patterns, and findings from an unbiased viewpoint.

The traffic data is visualized in the form of patterns that can be interpreted effortlessly. The design of the patterns will be oriented such that the traffic situation at the intersection is partitioned into distinct quadrants with

the aim of facilitating pedestrian comprehension of the traffic flow and empowering them to make informed decisions. The patterns will be visualized in the form of animated dots that are implemented with the help of machine learning algorithms. The dots will use a data-driven animation concept to form distinct patterns depending on the nature of the danger to alert pedestrians.

## Audio Alerts

On-spot audio alerts will make critical information more accessible for people with cognitive impairments, such as visual and color related, by providing information about safety hazards using a directional loudspeaker. People who are near Auriel and about to cross the road, will only hear the audio alerts from the side of the crosswalk they are about to walk over. [Holosonics 2023.]

## Traffic Scenarios

<p><b>Low-speed vehicles</b></p> <p><b>Case:</b> Few vehicles approach an intersection at low speed.</p>	<p><b>High-speed vehicles</b></p> <p><b>Case:</b> A high volume of traffic approaching an intersection at high speed.</p>	<p><b>A turning vehicle</b></p> <p><b>Case:</b> An approaching vehicle is about to take a turn.</p>	<p><b>No threats</b></p> <p><b>Case:</b> Safe for pedestrians to cross, no threat identified.</p>
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## Visual Alerts

Four (4) different visual animations communicating four different scenarios:

<p><b>1. Low-speed vehicles</b></p> <p>A few dots move <b>slowly</b> to create a pattern.</p> 	<p><b>2. High-speed vehicles</b></p> <p>Several dots move <b>quickly</b> to create a pattern.</p> 	<p><b>3. A turning vehicle</b></p> <p><b>Curved line</b> of dots.</p> 	<p><b>4. No threats</b></p> <p><b>Straight line</b> to show a clear path.</p> 
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## Audio Alerts

Three (3) different audio alerts communicating three different scenarios:

<p><b>1.</b></p>  <p><b>Low-speed vehicles</b></p> <p>A short high-pitched and alarming <b>whistle</b> sound, similar to that of a crossing guard.</p>	<p><b>2.</b></p>  <p><b>High-speed vehicles</b></p> <p>A quick succession of <b>beeps</b>.</p>	<p><b>3.</b></p>  <p><b>A turning vehicle</b></p> <p>A repetitive <b>clicking</b> sound, similar to a car's turning signal.</p>	 <p>Audio Spotlight</p>
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# TECHNOLOGY COMPONENTS

## Motion Sensors & LED lights

Auriel is integrated with energy-efficient lighting sources that use light-emitting diodes (LEDs) to produce lighting for the streets by utilizing a combination of sensing, computing, and lighting technologies. The motion sensors detect motion and the presence of pedestrians at a crossing, and then activate the LEDs. The lights consist of a microcontroller that receives input from the motion sensors and uses the information to activate the LED lights. The lights are programmed to adjust the brightness depending on the weather conditions, traffic flow, and other factors to enhance safety and increase visibility at intersections. [LEDMy-Place 2023.]

## LED Screens

To provide pedestrians with safety alerts, Auriel uses shaped LED displays with low energy consumption to display visual cues based on the data collected in real-time [Unit LED 2021]. These alerts will be in the form of patterns translating the data into perceived information to help pedestrians in decision-making.

## Wireless Communication

Auriel will have a 6G-V2X (vehicle-to-everything) connection in order to establish communication throughout the network. 6G will provide an ultra-reliable high-rate V2X communication in high-mobility environments. [M. Noor-A-Rahim et al. 2022.]



## Audio Spotlight

Auriel utilizes a revolutionary SoundBeam technology to provide pedestrians with a multi-sensory innovation for receiving safety alerts. It creates sound in a narrow beam with a directional loudspeaker to provide high-quality, precisely targeted sound that can help pedestrians with cognitive impairments. The audio output works on a motion sensor trigger that is used to raise attention among pedestrians and increase Auriel's effectiveness. [Holosonics 2023.]



## Solar Thin-Film Panels

Auriel operates independently with the help of renewable sources of energy through its solar panels. The panels produce clean and emission-free energy helping to power various components of Auriel, thereby reducing costs and carbon footprints while increasing its operative reliability and resilience. Organic photovoltaic (OPV) panel uses conductive organic polymers, or small organic molecules, in order to produce electricity. In these photovoltaic cells, several layers of thin organic vapor solutions are placed between two electrodes to carry an electrical current. Solar thin-film panels offer flexibility and mobile solar technology. [LaBerge 2023.]

## Natural Vegetation

Natural vegetation can improve the air quality in the city by absorbing pollutants and releasing oxygen. Plants will act as natural air filters helping to reduce the amount of particulate matter and other pollutants in the air. They will also contribute to reducing the urban heat island effect that is caused by a high concentration of buildings and other infrastructure in an urban environment. [NYC Department of Environmental Protection 2022.]

## Responsive Planter

Auriel has an origami-inspired responsive planter equipped with sensors that could display air quality information (AQI) in an interactive and playful manner. With the help of Auriel, it is possible to track the AQI and identify areas with high levels of pollution and take necessary actions to reduce emissions and improve air quality. A water reservoir collects rainwater for drip irrigation to water the plants from inside the planter.

## Battery

Auriel's main power source is a battery that is located inside the responsive planter. The battery stores the energy generated by solar panels that are used to power the battery [Shaikh et al. 2017]. It will function independently even though tied to a utility grid as a backup power source.

# DEEP TECHNOLOGY

## ATTRACT Technologies



### Hyger equipped LiDAR

Auriel is integrated with an optical remote sensing LiDAR technology that serves as a data collection point. It acts as a rangefinder device that measures the speed, distance, and velocity of the vehicles approaching the intersection in real-time. [Hasan 2022.] Auriel uses Hyger, an Attract technology, that consists of a highly efficient infrared detection unit based on high-purity black germanium technology [ATTRACT Hyger 2022]. This helps to create a three-dimensional model of a dynamic traffic scene with a 360-degree view using scanning technique. Auriel functions in both daylight and in complete darkness as it is equipped with an active illumination sensor present in LiDAR technology.

### Micromechanical Bolometers

Auriel uses H-cube's micromechanical bolometers to detect the presence and movement of vehicles and pedestrians in real-time. The H-cube technology addresses the emerging need for low-cost, portable solutions for hyperspectral imaging in the terahertz (THz) region of the electromagnetic spectrum. H-cube will help in remote monitoring and inspection of infrastructure and environment, thus complementing satellite information with 'ground truth' data. [ATTRACT H-cube 2022.]



## CERN Technologies



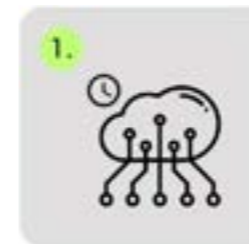
### Central Intelligence

Auriel's "brains" consist of CERN's Remus technology which is responsible for providing supervisory control and data acquisition (SCADA). With the help of Remus, Auriel can independently detect and gather data on the surrounding environment through its instrumentation [CERN Remus 2023]. Auriel will be an important component of the Intelligent Transportation System (ITS), where the archived and real-time measurements and events recorded by the REMUS system will be accessible by traffic control rooms for better traffic management in

### Singular Light

Auriel uses CERN's Singular Light technology for vehicle-to-infrastructure communication to transmit data between vehicles and ITS infrastructure [CERN Singular Light 2023]. The single-mode laser converter will provide high-bandwidth communication with low latency, making it suitable for use in real-time applications such as in Auriel to enhance pedestrian safety.

## What makes Auriel unique?



### Real-time monitoring

Auriel monitors traffic in real-time delivering accurate and up-to-date information that is communicated with pedestrians through a V2P network system.



### Pedestrian routing

Auriel provides pedestrian routing based on real-time data on pedestrian movement and traffic hazards to help them navigate the city more safely and efficiently.



### Pedestrian detection

Auriel detects pedestrians, alerts drivers, and connects vehicles to pedestrians, enabling real-time communication to reduce accidents caused by inattention or poor visibility.



# SYSTEM ARCHITECTURE

Auriel’s design and function are based on a complex system which architecture is built on four different system layers that outline the technological components, interactions, and the system’s overall organization. A system like Auriel also requires an active security system due to its reliance on technology, big data, and information.

## Sensing Layer

Auriel is equipped with sensors and actuators. The immediate goal of sensors is to collect data and pass it to a central cloud management platform. Actuators allow Auriel to act – send alerts [Syed et al. 2021].

## Network Layer

Auriel’s network layer is responsible for providing connectivity and communication among its components. 6G connectivity delivers real-time access to data, and REMUS serves as a central intelligence unit for Auriel.

## Data Processing Layer

Auriel’s data processing layer includes the software and hardware components that are responsible for collecting, analyzing, and interpreting data from the sensors. Auriel utilizes a cloud-based service, like Amazon Web Services, to process and analyze large volumes of data. This service also provides tools for data cleaning, data transformation, and data analysis, as well as visualizations and dashboards for data monitoring. A field gateway acts as a bridge between sensors and the cloud. [Amazon Web Services 2023.]

## Applications Layer

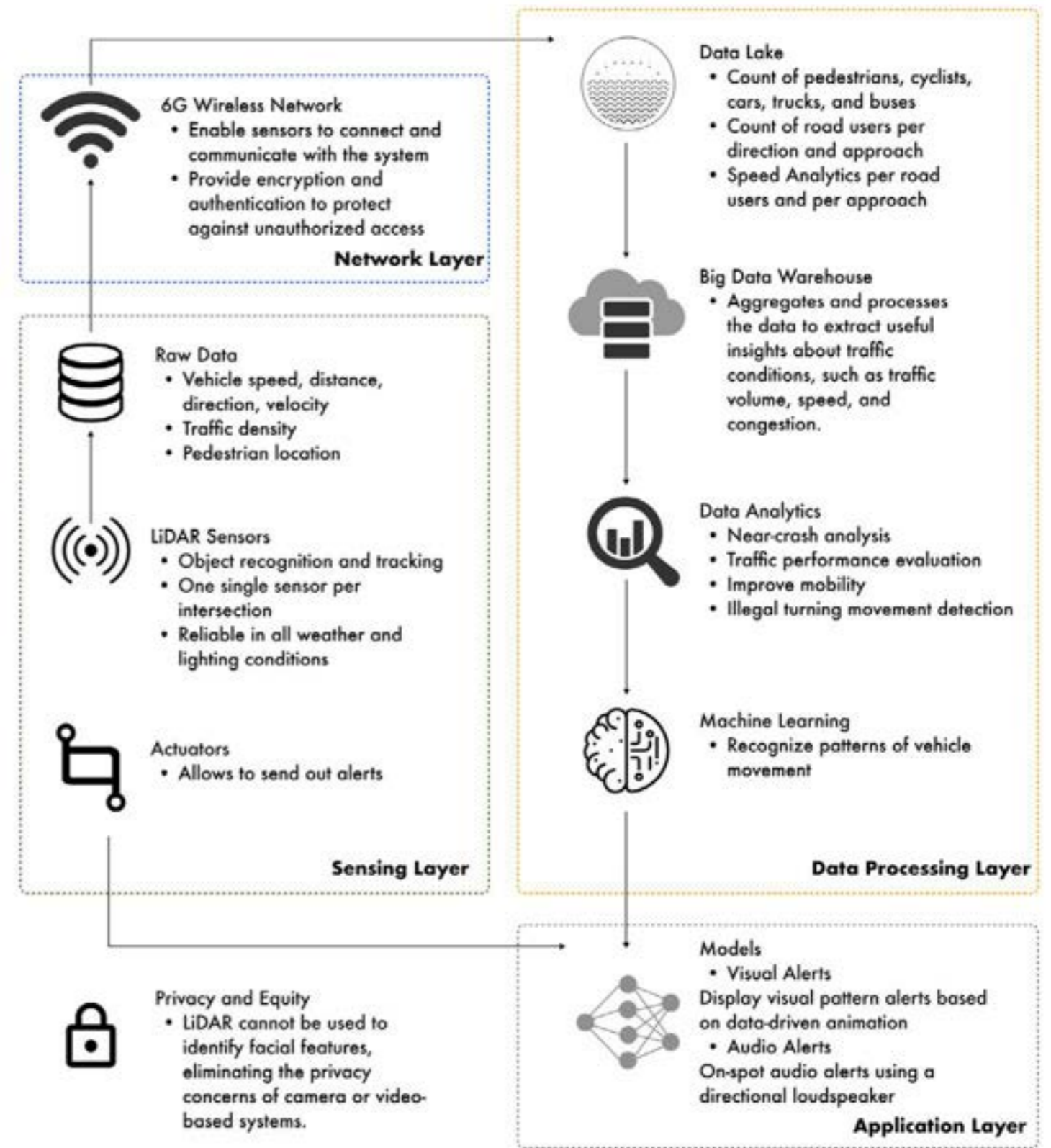
Auriel’s application layer, on top of the IoT architecture, communicates directly with pedestrians. With the help of data visualization tools, Auriel communicates information in the form of visual patterns and audio alerts to inform pedestrians about traffic hazards around them.

## Security

Systems like Auriel can be vulnerable to attacks by malicious actors such as cybercriminals or nation-states. To mitigate the risk of a possible intrusion or attack, Auriel’s system activities will be continuously monitored for malware, insider threats, denial of service, and other technical or physical deficiencies. With the help of activity logs, all software and hardware, including operating systems, network devices, and other intelligent programmable devices, will be kept up-to-date, monitored, and managed for security compliance. [Sajid et al. 2016.]

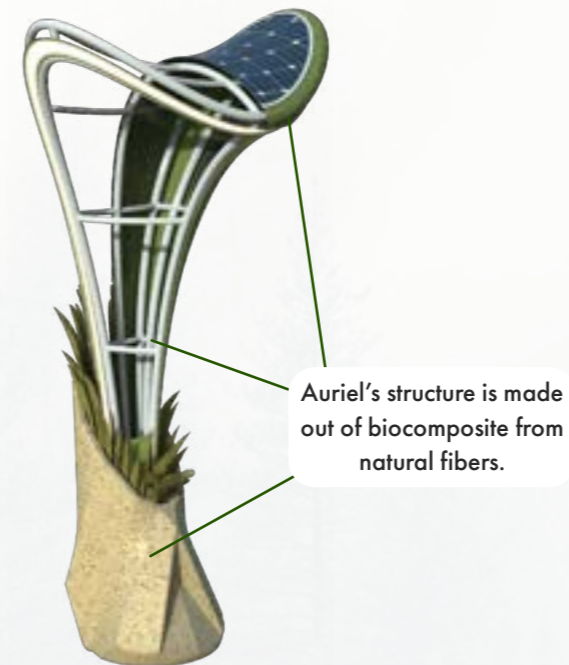
Checksum methods, which will be supported by host-based detection systems, will help with identifying harmful files (black lists) and allowed files (white lists) to validate the integrity of the system. Auriel will be equipped with antivirus software that will protect against attacks or breaches on the system. Auriel’s IoT system component will be regularly updated and patched to avoid any arbitrary code execution by cyber threat actors thereby keeping the system secure. Unknown errors in the cloud system will be easily discovered by continuous monitoring and vulnerability testing. To strengthen Auriel’s security, proxy solutions will be used to protect its most vulnerable components. These solutions will perform filtering and inspections, implement access control, and limit the range of instructions sent to the network. [Sajid et al. 2016.]

# System Architecture Layers



# PRODUCT MATERIAL

Environmental concerns are at the core of our solution. Therefore Auriel’s structure is based on sustainable, environmentally-friendly material solutions as much as possible. Biocomposite is an environmentally-friendly material made out of natural fibers which will be used as one of the main materials in Auriel.



## Biocomposite

One of the components that are part of Auriel’s state-of-the-art properties, are the sustainable and environmentally-friendly materials that contribute to our vision of the circular economy and green infrastructure [Vigneshwaran 2021]. The biocomposite used in Auriel is a 100 percent biobased material that doesn’t only reduce CO2 emissions but has a negative impact due to its ability to capture and store carbon in its bioplastic and wood-based fibers. The biocomposite used in Auriel is made of biodegradable polymers and FSC-certified wood from sustainably managed forests, which makes the material biodegradable. [Stora Enso2023.] Unlike materials such as metal or plastic, biocomposite is made out of renewable resources that reduce the environmental impact of production and the disposability of the product [Zwawi 2021].



Picture: Biocomposite material manufactured by Stora Enso (Finland).

Because of its resilience in moisture, ability to bear temperature changes, and to withstand the sun’s ultra-violet light, biocomposite offers a strong and durable structure for Auriel [Masek 2021]. This makes Auriel a prime option for the New York streets where the weather conditions can vary from very hot to extreme coldness. Use of such material will raise awareness among pedestrians about the importance of using eco-friendly materials, and also add aesthetic value to the green streets.

# IMPLEMENTATION PLAN

Launching and deployment of Auriel-equipped intersections will take place in three phases. The 1st phase covers the busiest intersections in Manhattan, the 2nd phase covers the busiest intersections in the entire city, and the 3rd phase covers the busiest intersections in the metropolitan area. The busiest and most dangerous intersections will be selected based on mapping done by the NYC Vision Zero program.



Figure: The three deployment phases.

- Phase 1: Neighborhood deployment
- Phase 2: City wide deployment
- Phase 3: Metropolitan deployment

	Social	Technological	Economic	Environmental	Political	Legal	Ethical
<p><b>2030</b></p> <p><b>Phase 1: Neighborhood Deployment</b></p> <p>The first traffic alerting detectors will be introduced and deployed to the busiest neighborhoods in Manhattan, such as Lower East Side, Midtown, and Upper East Side.</p> <p><b>Area: Manhattan</b></p>	<p>Living space is getting smaller and people have less freedom in choosing their living options due to rising costs and increasing wealth gap.</p>	<p>The city's public lighting is based on ultra-efficient LEDs and smart occupancy sensors.</p>	<p>Certain punitive measures for businesses that don't take action on climate change.</p>	<p>Traffic congestion is priced and used to promote environmental justice.</p>	<p>Democracy no longer the most popular form of government.</p>	<p>Legislation highly affected by the science and scientific advisory boards.</p>	<p>Freedom of expression has gradually started to be restricted.</p>
<p><b>2035</b></p> <p><b>Phase 2: City Wide Deployment</b></p> <p>The introduction of Auriel will be extended to the busiest and most dangerous intersections in all five boroughs of the city; Manhattan, Brooklyn, Queens, Bronx, and Staten Island.</p> <p><b>Area: The 5 boroughs</b></p>	<p>People's mental health and well-being is starting to take a toll because of the rise in a regulated society.</p>	<p>Solar energy becomes the main source of energy for urban housing and infrastructure in New York City.</p>	<p>Trading at Global Carbon Xchange begins.</p>	<p>The city's tree canopy has grown by 30% due to new buildings being required to offer green spaces for their residents.</p>	<p>Street protests become common in urban settings.</p>	<p>Individual carbon taxation begins.</p>	<p>People start to forget how the real sounds of nature sound like.</p>
<p><b>2040</b></p> <p><b>Phase 3: Metropolitan Deployment</b></p> <p>Auriel equipped intersections extend metropolitan wide, and the safety level of the deadliest intersections in New York, New Jersey, Connecticut, and Pennsylvania will be upgraded.</p> <p><b>Area: Tri-State</b></p>	<p>Citizens exercise their right to protest out on the streets.</p>	<p>Nearly all the traffic is autonomous and streets are highly censored.</p>		<p>The city is mainly optimized for public transportation, bikers, and pedestrians. Sidewalks are wider, cleaner, and greener.</p>	<p>Decision-making is strictly based on planet-centric guides.</p>		<p>Population control begins due to overpopulation.</p>

Sources: Arup 2019, The City of New York (5) 2023



2030

**Phase 1: Neighborhood Deployment**

In 2030, one of the most visible changes would be the expansion of the city’s infrastructure to protect the most vulnerable road users (VRUs) which include bicyclists, pedestrians, and motorcyclists [Zeeger et al. 2012]. There would be a comprehensive network of protected bike lanes throughout the city, making it easier and safer for cyclists to get around [The City of New York (5) 2023]. To enhance decision-making among pedestrians and reduce human errors, Auriel is introduced as a cutting-edge and future-focused system at bustling intersections across the neighborhoods of Manhattan to improve pedestrian safety.

Auriel will be a revolutionary Vehicle-to-Network (V2N) and Vehicle-to-Infrastructure (V2I) system that utilizes real-time sensor data to provide pedestrians with alerts that will be broadcasted on the screens in the form of patterns. To use a multi-modal form of communication with

the pedestrians, Auriel will use audio spotlights to alert pedestrians with the help of audio output.

The PlaNYC and Vision Zero initiatives in New York City made significant progress in improving air quality, reducing greenhouse gas emissions, increasing the use of public transportation, and creating new parkland, among other sustainable achievements. [The City of New York (5) 2023; Hostetter et al. 2023.] The city is home to a world-leading climate solutions centered on the 172-acre island in the heart of New York Harbor that focuses addressing the global climate crisis [Pace University (2) 2023]. By continuing to invest in sustainable infrastructure and implementing policies to reduce emissions, increase renewable energy use, and improve air and water quality, New York City is setting an example for other cities around the world to follow.

Figure: Deployment phase 1 in orange, Manhattan >





2035

**Phase 2: City Wide Deployment**

In 2035, New York City would have significantly reduced its dependency on fossil fuels with a goal of phasing out all gasoline-powered vehicles [Kolodny 2021]. Auriel will coexist with the growing number of autonomous vehicles (AVs) as well as electric vehicles (EVs) by enabling smarter and more responsive interactions between vehicles and pedestrians. Instead of traffic lights that were previously used to monitor the traffic flow, the LiDAR sensors will now be able to communicate real-time information to nearby AVs and EVs.

To establish a V2I, V2N, and V2P network, AVs and EVs will be integrated with cameras and other sensor technology that will allow them to detect pedestrians in their immediate vicinity. To further improve pedestrian safety, cars

will be able to automatically adjust their speed, route, and behavior upon receiving the information from the LiDAR sensors to avoid any pedestrian injuries or accidents.

Pedestrian plazas and green spaces would be another key aspect of the city's greentocracy vision for 2035. The city would have created more public spaces that prioritize pedestrians and limit car traffic, such as the popular pedestrian plazas at Times Square and Union Square. These plazas would be filled with greenery, seating areas, and art installations, creating a welcoming environment for people to relax and enjoy the city. [NYC.GOV 2023.] The shift towards electric and hybrid vehicles would reduce air pollution and create a quieter, more pleasant environment for pedestrians.

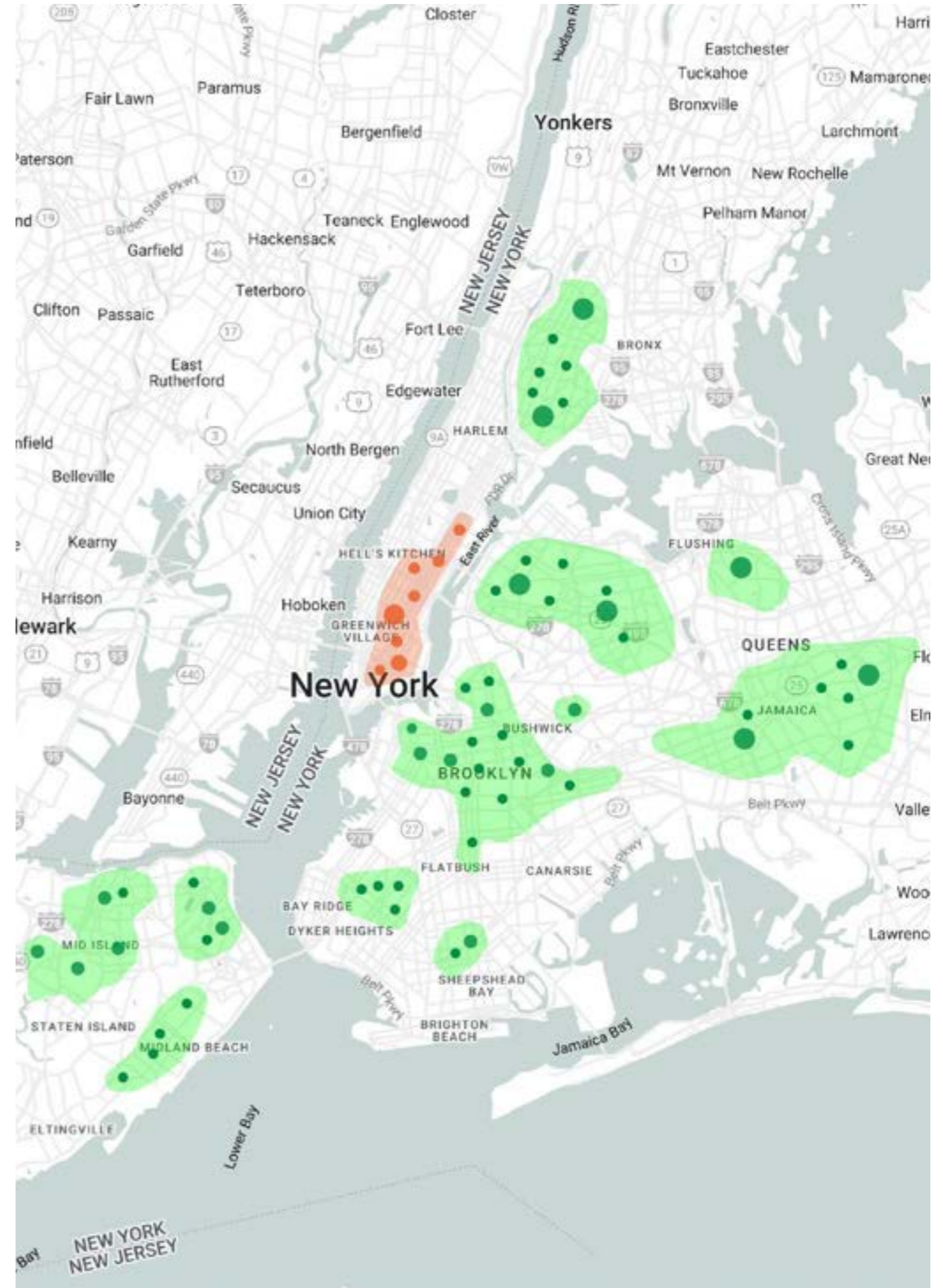


Figure: Deployment phase 2 in green, the five boroughs >



2040

### Phase 3: Metropolitan Deployment

In the year 2040, New York City has undergone a radical transformation and is now a shining example of greentocracy. The city has begun to revolve around the people again whilst prioritizing the sustainability and well-being of New Yorkers. The city has made significant strides towards greentocracy that prioritizes pedestrians. The first step towards this vision was the complete phasing out of fossil fuels, which was achieved by 2035. There is an addition to public transit with the launch of hyperloops that has significantly reduced the widespread use of personal vehicles. [NBC New York 2019.] Electric buses and trains are on the rise. The city's streets have become more walkable, bikeable, and accessible to everyone, creating a safer and more pleasant environment for pedestrians.

Instead of deploying Auriel as a physical product, it will now be embedded in the infrastructure as a part of the intelligent transportation system (ITS). Auriel will no

longer display alerts on screens, but will rather have a laser holography technology that will project alerts about potential hazards to both pedestrians and drivers. The system will use machine learning algorithms to detect when a pedestrian is about to cross a busy street. Auriel will then provide an alert to the driver to warn them of the potential collision by creating a holographic projection of the pedestrians from the information gathered through the LiDAR technology in real-time.

One of the most significant changes in the city was the adoption of a circular economy model [NYC.GOV (2) 2023]. The city has drastically reduced its waste by prioritizing reuse, repair, and recycling and became a beacon of hope for a more sustainable future that is not only environmentally responsible but also a pioneer for utilizing state-of-the-art technologies to improve livability standards in the city.

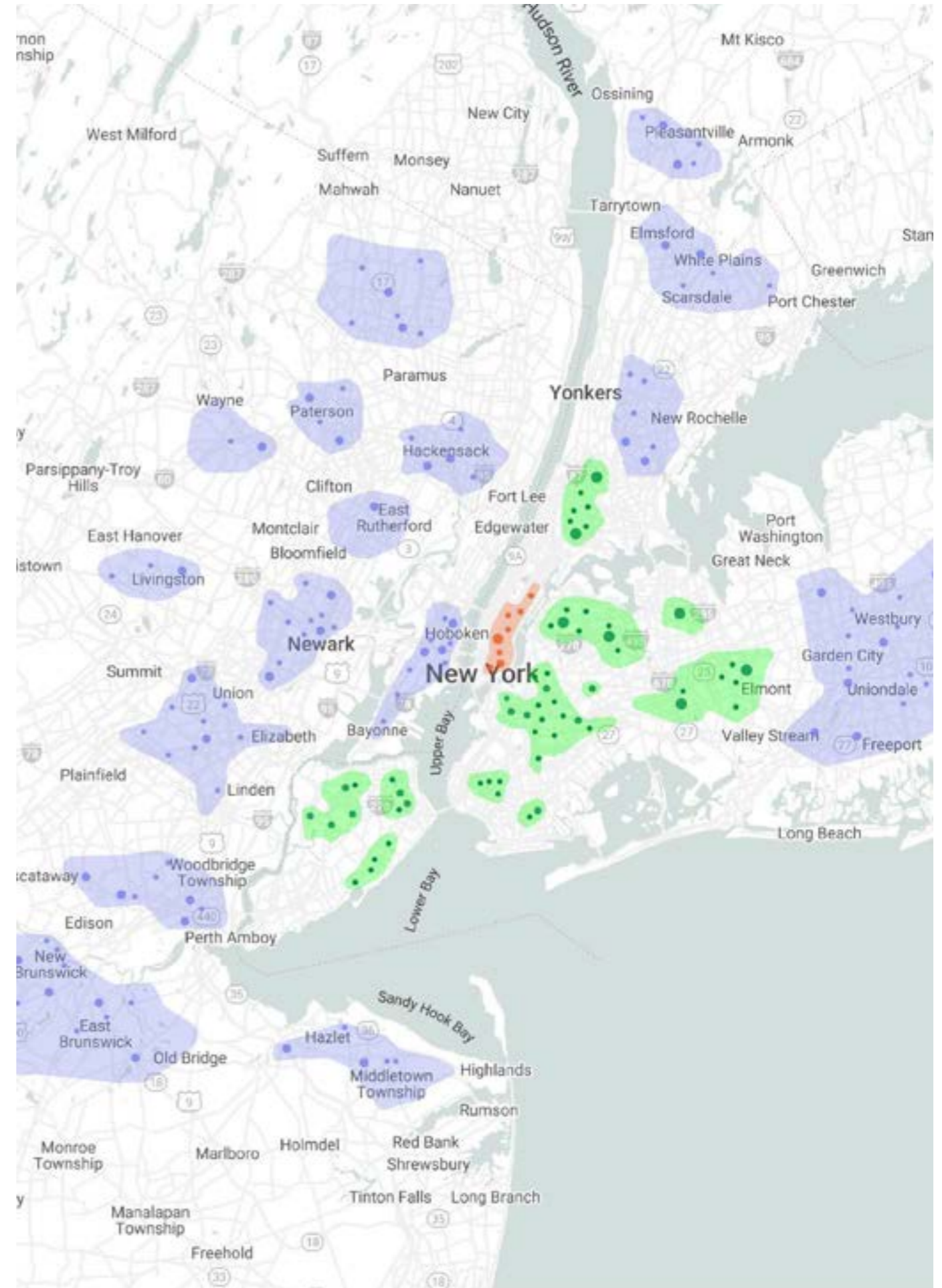


Figure: Deployment phase 3 in blue, Tri-State area >

# STAKEHOLDERS

Stakeholders that affect Auriel vary from street users to city and state departments that can substantially influence different deployment phases. Identifying opportunities and expectations that different stakeholder groups may have, is crucial for the success and acceptance of Auriel before becoming part of the urban streets.

Just like in most cities, streets constitute public property which the city is responsible for taking care of. The stakeholders of Auriel include several entities varying from immediate street users (pedestrians, cyclists, and drivers) to city departments and government officials. The most significant and notable officials are the City of New York representatives, such as the Office of the Mayor of NYC and the NYC Department of Transportation (NYCDOT) [Office of the Mayor of New York City 2023; Department of Transportation 2023]. When implementing Auriel to be part of the city's newest infrastructure components, it is highly important to collaborate and be involved with the city and state representatives.

The NYCDOT provides funding opportunities for transportation safety-related innovative projects, which could include pedestrian safety enhancement projects like Auriel. Since Auriel is a system that contributes to pedes-

trian infrastructure and the safety of the streets, a grant program called Transportation Enhancement Activities could offer proper funding for product development and installation to implement Auriel to become part of the city's pedestrian focused infrastructure. [New York State 2023; Federal Highway Administration 2017]

To meet the needs of the locals, it is important to interview and observe pedestrians for research purposes throughout Auriel's system implementation phases. The feedback and input from pedestrians and local community members will help to identify areas of concerns and issues that still need revision during the initial implementation phase. Throughout the different phases, the system will be monitored and evaluated to ensure that it is meeting the needs of pedestrians and improving the safety of the intersections that are equipped with Auriels.



Picture: New York City Hall building in Manhattan.



Picture: Street users on Broadway in Lower Manhattan.

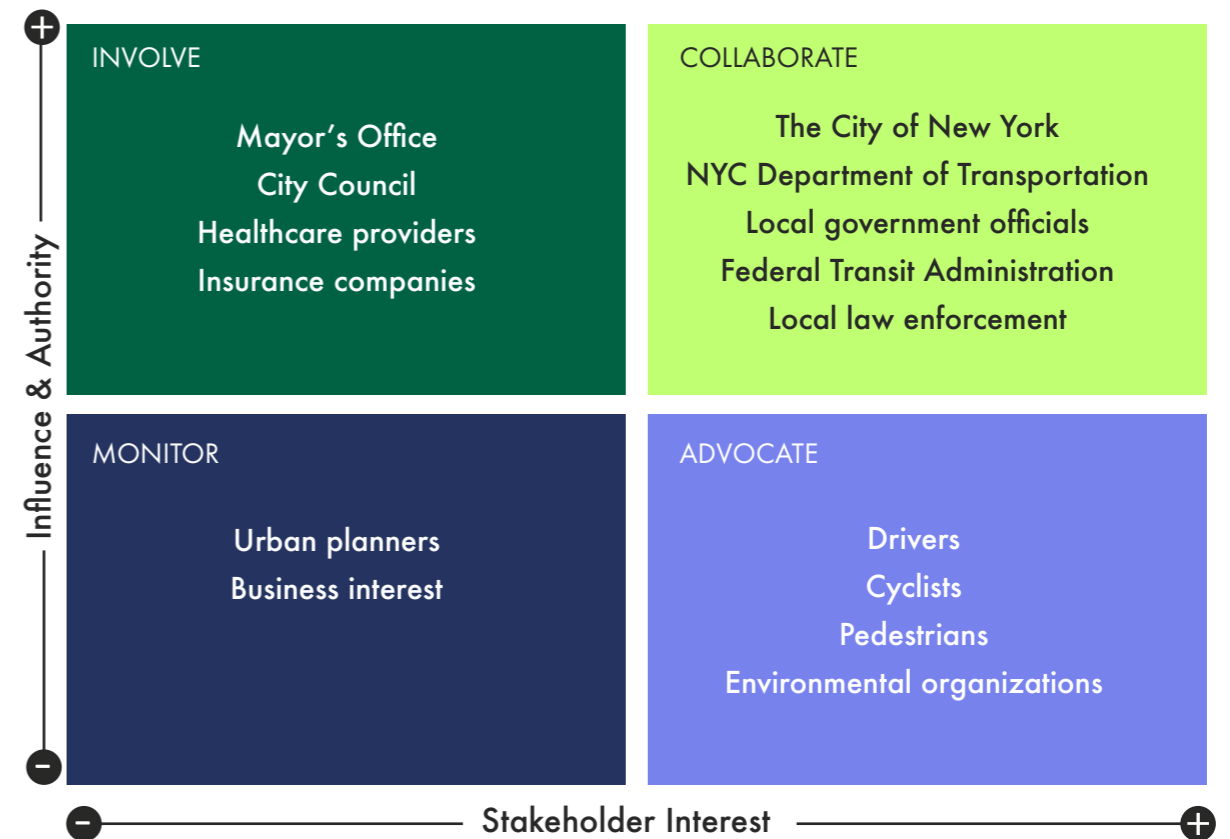


Figure: A stakeholder map representing the affecting parties for Auriel's implementation

# VALUE PROPOSITION

Societies centered around urban settings can benefit from Auriel’s presence in a number of ways. Creating a real-time responsive environment increases street safety when people are less often injured and therefore lowers the need for medical treatments. In addition to the increased effect on societal health and well-being, the network system promotes climate-friendly and sustainable infrastructure through its design and material choices.



### Real-time Responsive Environment

As a system, Auriel creates a real-time responsive environment with the help of sensory-based detection technology transforming the analyzed data into visual and audio alerts. Detecting the presence and movement of vehicles and pedestrians in real-time, Auriel allows people to be better aware of their surroundings and avoid potential safety hazards. Real-time wireless system communication provides opportunities for cities to integrate Internet of Things (IoT) technologies and improve intelligent infrastructure. Auriel’s system increases traffic management as its deployment phases develop and Auriel is adapted to the urban street scene.



### Increased Street Safety

Increased global population has led to growing and densely populated cities where people are constantly exposed to severe traffic injuries due to vehicle driving being prioritized for the past several decades. To address these issues, Auriel prioritizes pedestrians over drivers creating a safe space for them to cross a road that otherwise could put them in a dangerous situation, where most of the accidents currently happen. Auriel’s citywide network system provides navigational guidance for street walkers to be better informed and aware of what is happening around them. Real-time information thus helps them make better decisions when traveling on lively streets and reduces the risk of making detrimental and severe decisions.



### Pedestrian Behavior Change

During Auriel’s commissioning, its first goal is to familiarize and engage pedestrians with the system for paying attention to the alerts on its screens about possible dangers in nearby traffic. The first crossings equipped with Auriel may arouse some interest and attention due to people facing novel objects in new places (intersections). We expect people to be interested in Auriel’s playful alerting signals, and thereby learn to recognize how Auriel can help them make better-informed decisions before crossing a street at an intersection.



### Societal Health & Well-being

Traffic accidents pose an enormous threat to the health and well-being of societies, as serious injuries can cause disabilities and lifelong trauma. Medical treatments can often cause financial troubles and even personal bankruptcies to follow families, specifically in the U.S. where medical treatment and insurance costs are a complicated and costly issue. Because Auriel is a system that is strongly linked to the reduction and prevention of traffic accidents, its societal value therefore lies in improving the health and well-being of the people living in the city, and thus promoting socio-economic development.



### Climate-friendly Infrastructure

It is crucial to invest in urban areas that prioritize pedestrian safety without forgetting the ongoing climate change crisis and sustainability issues. Auriel is a solution that prioritizes pedestrian safety around sustainable infrastructure through its natural fiber-based material choices in the product structure and self-producing power through its lightweight solar panels. Auriel creates a more enjoyable living environment through the planters which bring a piece of nature to the city that is otherwise built of stone and concrete. Its environmentally friendly design promotes the attitude of city dwellers and visitors towards sustainable and climate-friendly solutions.





# AURIEL

## CONCLUSION

With Auriel rolling out, we can combat the problem of rising pedestrian injuries and deaths in New York City. The future of pedestrian safety holds great potential with the integration of Internet of Things (IoT) technologies in the infrastructure. Auriel leverages many interconnected data-driven systems to enhance the protection and well-being of vulnerable road users (VRUs). Auriel's LiDAR sensors contribute to traffic management and pedestrian safety by providing accurate and reliable data for real-time monitoring, adaptive traffic control, and enhanced communication in autonomous vehicles. By providing real-time data about pedestrian movements, positions, and interactions with vehicles, Auriel can help enhance the safety of intersections and urban environments. Our aim to reduce pedestrian fatalities and make the city more livable coexists with on-going New York City initiatives like Vision Zero, PlaNYC and many more. With the implementation of Auriel, the city rethinks and reimagines the future of pedestrian safety.

# References

Airswift. 2023. Situational awareness. URL: <https://www.airswift.com/about/safety/situational-awareness> [Accessed April 27, 2023]

Amazon Web Services. 2023. AWS IoT Analytics. URL: <https://aws.amazon.com/iot-analytics/> [Accessed May 18, 2023]

Arup. 2019. 2050 Scenarios – Four plausible futures. London, UK. URL: [foresight.arup.com](https://foresight.arup.com) [Accessed April 23, 2023]

ATTRACT. 2021. Home page. URL: <https://attract-eu.com/> [Accessed April 27, 2023]

ATTRACT Academy. 2022. H-cube – Technology Card archive.

ATTRACT Academy. 2022. Hyger – Technology Card archive.

Centers for Disease Control and Prevention. Road traffic injuries and deaths – A global problem. January 10, 2023. URL: <https://www.cdc.gov/injury/features/global-road-safety/index.html> [Accessed April 20, 2023]

CERN. 2023. Home page. URL: <https://home.cern/> [Accessed April 27, 2023]

CERN. 2023. Remus. URL: <https://hse.cern/content/remus-supervision-control-and-data-acquisition-systems-radiation-and-environmental> [Accessed April 25, 2023]

CERN. 2023. Singular light: Integrated single mode laser converter. URL: <https://kt.cern/technologies/singular-light-integrated-single-mode-laser-converter> [Accessed April 25, 2023]

CWA Local. 2023. History of traffic. URL: <https://local1182.org/about-us/history-of-traffic/> [Accessed April 27, 2023]

Department of Transportation. 2023. The City of New York. URL: <https://www.nyc.gov/html/dot/html/home/home.shtml> [Accessed April 25, 2023]

Federal Highway Administration. June 27, 2017. Transportation Enhancement Activities. URL: [https://www.fhwa.dot.gov/environment/transportation\\_enhancements/](https://www.fhwa.dot.gov/environment/transportation_enhancements/) [Accessed April 25, 2023]

Gray, C. May 16, 2014. A history of New York traffic lights. The New York Times. URL: <https://www.nytimes.com/2014/05/18/realestate/a-history-of-new-york-traffic-lights.html> [Accessed April 2, 2023]

Harvard. 2016. Curbing distracted driving with "situational awareness." School of Public Health. URL: <https://www.hsph.harvard.edu/news/hsph-in-the-news/curbing-distracted-driving-with-situational-awareness/> [Accessed April 30, 2023]

Hasan, Raiful & Hasan, Ragib. 2022. Pedestrian Safety Using the Internet of Things and Sensors: Issues, Challenges, and Open Problems. Future Generation Computer Systems. 134. 10.1016/j.future.2022.03.036.

Holosonics. 2023. Audio spot light. URL: [https://www.holosonics.com/?gclid=CjwKCAjwrDmhBhBBEiwA4Hx5g\\_XxVtE4CoEGL3Jo7R-W4QAhoig8q\\$zy9dpulQzOgow7rCe7qVHOPzxoCq4gQAvD\\_BwE](https://www.holosonics.com/?gclid=CjwKCAjwrDmhBhBBEiwA4Hx5g_XxVtE4CoEGL3Jo7R-W4QAhoig8q$zy9dpulQzOgow7rCe7qVHOPzxoCq4gQAvD_BwE) [Accessed April 25, 2023]

Hostetter, S., Viola, R., and Cahill, C. Borough Pedestrian Safety Action Plans Update. New York City Department of Transportation. February, 2023. URL: <https://www.nyc.gov/html/dot/downloads/pdf/ped-safety-action-plan-update-2023.pdf> [Accessed April 20, 2023]

Kawser, Mohammad & Sajjad, Syed & Fahad, Saymon & Ahmed, Sakib & Rafi, Hasib. The Perspective of Vehicle-to-Everything (V2X) Communication towards 5G. 2019. 19. 146-155. URL: [https://www.researchgate.net/publication/333193097\\_The\\_Perspective\\_of\\_Vehicle-to-Everything\\_V2X\\_Communication\\_towards\\_5G](https://www.researchgate.net/publication/333193097_The_Perspective_of_Vehicle-to-Everything_V2X_Communication_towards_5G) [Accessed April 21, 2023]

Kobara, A. 2013. The pedestrianization of New York City: An environmental history and critique of urban motorization and a look at New York City's new era of planning. Fordham University. URL: [https://research.library.fordham.edu/cgi/viewcontent.cgi?article=1011&context=environ\\_theses](https://research.library.fordham.edu/cgi/viewcontent.cgi?article=1011&context=environ_theses) [Accessed April 27, 2023]

Kolotny, L. September 9, 2021. New York law phases out most gas-powered vehicles by 2035. CNBC. URL: <https://www.cnbc.com/2021/09/09/new-york-law-phases-out-most-gas-powered-vehicles-by-2035.html> [Accessed April 27, 2023]

Kuntzman, G. April 8, 2022. New York City's pedestrian death crisis is part of an alarming and ongoing national trend. URL: <https://nycstreetsblog.org/2022/04/08/new-york-citys-pedestrian-death-crisis-is-part-of-an-alarming-and-ongoing-national-trend/> [Accessed April 25, 2023]

LaBerge, M. What are thin-film solar panels? April 02, 2023. URL: <https://www.ecowatch.com/solar/thin-film-solar-panels> [Accessed April 25, 2023]

LEDMyPlace. 2023. Led street light design technology for road lighting. URL: <https://www.ledmyplace.com/blogs/stories/led-street-light-design-technology-for-road-lighting> [Accessed April 25, 2023]

Madrigal, A.C. March 14, 2014. The state of New York City's infrastructure. The Atlantic. URL: <https://www.theatlantic.com/technology/archive/2014/03/the-state-of-new-york-citys-infrastructure/284418/> [Accessed April 27, 2023]

Marti, G., Morice, A., and Montagne, G. January 9, 2015. Drivers' decision-making when attempting to cross an intersection results from choice between affordances. Frontiers in Human Neuroscience. Vol. 8. DOI: 10.3389/fnhum.2014.01026

Masek A, Olejnik O. Aging Resistance of Biocomposites Crosslinked with Silica and Quercetin. International Journal of Molecular Sciences. 2021; 22(19):10894. <https://doi.org/10.3390/ijms221910894>

Microsoft. 2023. What is data storytelling? URL: <https://powerbi.microsoft.com/en-us/data-storytelling/> [Accessed May 18, 2023]

M. Noor-A-Rahim et al., "6G for Vehicle-to-Everything (V2X) Communications: Enabling Technologies, Challenges, and Opportunities," in Proceedings of the IEEE, vol. 110, no. 6, pp. 712-734, June 2022, doi: 10.1109/JPROC.2022.3173031.

National Highway Traffic Safety Administration (NHTSA). Summary of motor vehicle crashes. September 2020. URL: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813369> [Accessed April 20, 2023]

NBC New York. 2019. Hyperloop: Is this the future of transportation in NYC? Video. URL: <https://www.youtube.com/watch?v=33hn-m1rHiuo> [Accessed April 27, 2023]

New York State. 2023. Department of Transportation. URL: <https://www.dot.ny.gov/funding> [Accessed April 25, 2023]

NYC Department of Environmental Protection. 2022. Analyzing the urban heatisland effect. URL: <https://www.nyc.gov/assets/dep/downloads/pdf/environment/education/10-analyzing-urban-heat-island-effect.pdf> [Accessed April 28, 2023]

NYC Department of Transportation. 2022. Red light camera program review. URL: <https://www.nyc.gov/html/dot/downloads/pdf/nyc-red-light-camera-program.pdf> [Accessed April 28, 2023]

NYC.GOV. 2023. OneNYC 2050 – Building a strong and fair city. Thriving neighborhoods. URL: <https://onenyc.cityofnewyork.us/wp-content/uploads/2019/05/OneNYC-2050-Thriving-Neighborhoods.pdf> [Accessed April 27, 2023]

NYC.GOV (2). 2023. OneNYC 2050 – Building a strong and fair city. A livable climate. URL: [https://onenyc.cityofnewyork.us/wp-content/uploads/2019/04/G\\_OneNYC\\_2050\\_Interior\\_r5\\_v3\\_ALivableClimate\\_190422\\_web.pdf](https://onenyc.cityofnewyork.us/wp-content/uploads/2019/04/G_OneNYC_2050_Interior_r5_v3_ALivableClimate_190422_web.pdf) [Accessed April 27, 2023]

Office of the Mayor of New York City. 2023. URL: <https://www.nyc.gov/office-of-the-mayor/> [Accessed April 26, 2023]

Pace University. Seidenberg School of Computer Science and Information systems. 2023. New York Design Factory. URL: <https://www.pace.edu/seidenberg/faculty-and-research/centers-and-labs/nyc-design-factory> [Accessed April 27, 2023]

Pace University (2). April 25, 2023. Pace University a core institution for world-leading climate center on Governors Island. URL: <https://www.pace.edu/news/pace-university-core-institution-world-leading-climate-center-governors-island> [Accessed April 27, 2023]

Ravuri, S. October 11, 2021. The evolution of New York City. Rethinking the future. URL: <https://www.re-thinkingthefuture.com/2021/11/15/a5880-the-evolution-of-new-york-city/> [Accessed April 27, 2023]

Sabiha, M. February 5, 2018. Robert Moses and the decline of the NYC subway system. URL: <https://eportfolios.macaulay.cuny.edu/alonso2018/2018/02/05/robert-moses-and-the-decline-of-the-nyc-subway-system/#:~:text=live%20in%20today,-%E2%80%9CRobert%20Moses%20and%20the%20Decline%20of%20the%20NYC%20Subway%20System,well%20as%20people%20of%20color.> [Accessed April 27, 2023]

Sajid, A., Abbas, H., & Saleem, K. February 21, 2016. Cloud-assisted IoT-based SCADA systems security: a review of the state of the art and future challenges. National Plan of Science. URL: <https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7445139> [Accessed May 18, 2023]

Shaikh, Mohd Rizwan & Shaikh, Sirajuddin & Waghmare, Santosh & Labade, Suvarna & Tekale, Anil. 2017. A Review Paper on Electricity Generation from Solar Energy. International Journal for Research in Applied Science and Engineering Technology. 887. 10.22214/ijraset.2017.9272.

Syed, A.S.; Sierra-Sosa, D.; Kumar, A.; Elmaghraby, A. IoT in Smart Cities: A Survey of Technologies, Practices and Challenges. Smart Cities 2021, 4, 429–475. <https://doi.org/10.3390/smartcities4020024>

Stora Enso. 2023. Biocomposites – Replacing plastics with renewable materials. URL: <https://www.storaenso.com/en/products/biocomposites> [Accessed April 28, 2023]

The City of New York (1). 2023. Vision Zero: Safe driving. URL: <https://www.nyc.gov/html/dot/html/motorist/vision-zero-safe-driving.shtml#:~:text=No%20level%20of%20fatality%20on,serious%20injuries%20from%20traffic%20incidents> [Accessed April 20, 2023]

The City of New York (2). April 23, 2022. Mayor Adams announces historic investment of more than \$900 million in traffic safety to turn the tide on traffic violence crisis. URL: <https://www.nyc.gov/office-of-the-mayor/news/243-22/mayor-adams-historic-investment-more-900-million-traffic-safety-turn-the-#/> [Accessed April 20, 2023]

The City of New York (3). September 17, 2021. Notice of adoption of rules. URL: <https://www.nyc.gov/html/dot/downloads/pdf/noa-various-amendments-traffic-rules.pdf> [Accessed April 20, 2023]

The City of New York (4). January 19, 2022. Mayor Adams, Commissioner Rodriguez, Commissioner Sewell announce major new actions & investments to improve pedestrian safety at intersections. URL: <https://www.nyc.gov/office-of-the-mayor/news/037-22/mayor-adams-commissioner-rodriguez-commissioner-sewell-major-new-actions-investments#/0> [Accessed April 20, 2023]

The City of New York (5). April, 2023. PlaNYC – Getting sustainability done -report. URL: <https://s-media.nyc.gov/agencies/mocej/PlaNYC-2023-Full-Report.pdf> [Accessed April 25, 2023]

The City of New York (6). 2022. Mayor's Office of Climate & Environmental Justice. PlaNYC – Getting sustainability done. URL: <https://climate.cityofnewyork.us/initiatives/planyc-getting-sustainability-done/> [Accessed May 17, 2023]

The City of New York (6). 2023. Vision Zero – What is it? URL: <https://www.nyc.gov/content/visionzero/pages/what-it-is> [Accessed April 27, 2023]

Transportation Alternatives. Last year was the deadliest under Vision Zero. Here's how Mayor Adams can save lives in 2022. January 26, 2022. URL: <https://www.transalt.org/writing/last-year-was-the-deadliest-under-vision-zero-heres-how-mayor-adams-can-save-lives-in-2022> [Accessed April 20, 2023]

Unit LED. 2021. Energy saving LED screen. URL: <https://www.unit-led.com/energy-saving-led-screen> [Accessed April 28, 2023]

Vision Zero View. Map of traffic crashes. March 31, 2023. URL: <https://vzv.nyc/> [Accessed April 20, 2023]

Vigneshwaran Shanmugam, Rhoda Afriyie Mensah, Michael Försth, Gabriel Sas, Ágoston Restás, Cyrus Addy, Qiang Xu, Lin Jiang, Rasoul Esmaeely Neisiany, Shuvra Singha, Gejo George, Tomlal Jose E, Filippo Berto, Mikael S Hedenqvist, Oisik Das, Seeram Ramakrishna. 2021. Circular economy in biocomposite development: State-of-the-art, challenges and emerging trends. Composites Part C: Open Access. Volume 5, 100138, ISSN 2666-6820, DOI: <https://doi.org/10.1016/j.jcomc.2021.100138> [Accessed April 21, 2023]

World Health Organization (WHO). Road traffic injuries. June 20, 2022. URL: <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries> [Accessed April 20, 2023]

Zegeer, C. & Max Bushell. 2012. Pedestrian crash trends and potential countermeasures from around the world, Accident Analysis & Prevention, Volume 44, Issue 1, Pages 3-11, ISSN 0001-4575, <https://doi.org/10.1016/j.aap.2010.12.007> [Accessed April 29, 2023]

Zipper, D. April 27, 2023. Anatomy of an American transit disaster. Bloomberg. URL: <https://www.bloomberg.com/news/features/2023-04-27/chronicling-of-the-collapse-of-public-transit-in-the-us?srnd=citylab> [Accessed April 27, 2023]

Zwawi M. A Review on Natural Fiber Bio-Composites, Surface Modifications and Applications. Molecules. 2021. 26, no 2: 404. DOI: <https://doi.org/10.3390/molecules26020404> [Accessed April 21, 2023]

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