"Beyond Traffic: The Smart City Challenge"

Submitted to:

U.S. Department of Transportation

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Submitted by:

City of New Haven

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Part 1:
Vision Narrative

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Part 1: Vision Narrative

I. New Haven's Proposed Vision and Approach

1. Smart City New Haven Vision

The City of New Haven's Vision for the Smart City Challenge is based on a structure whose *foundation* is comprised of the critical and valuable assets of the City:

- *Existing ITS infrastructure;*
- Current *advanced skills* of public employees and on-going training;
- *Private sector innovation* resources; and
- *Institutional capacities* for shepherding technological change.

It is upon this solid foundation that we will build *pillars* of innovation that represent:

- *Mobility;*
- *Safety;*
- *Efficiency;*
- *Sustainability;* and
- *Climate Resiliency*

These crucial pillars will stand tall as measurable indicators of the ultimate goal of the City, a goal that will use smart transportation, innovative technologies and advanced communications to elevate and *support the diverse neighborhoods of New Haven*. That ultimate goal, the 2.0 version of our unique and ambitious *Go New Haven Go* campaign, is 70 to 70.

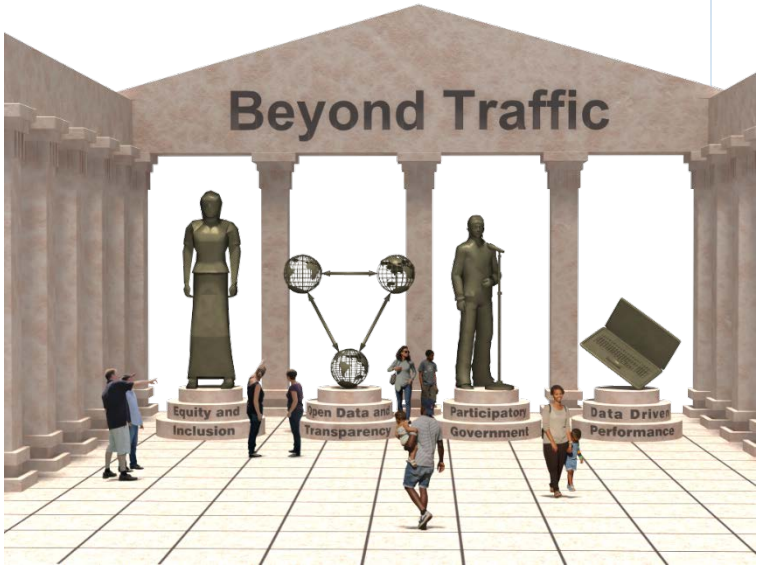
70 to 70 is a future beyond traffic that inverts the current transportation mode split, from 70% of people who use private, single-occupant automobile travel to and through the City to 70% of people who will use transit, shared vehicles, bicycling and walking on a daily basis.

The core values of *Smart City New Haven – Equity, Open Data, Participatory Government* and *Data-Driven Performance*, will guide the City to ensure that the outcomes of the measurable pillars of innovation that support our goals:

1) Consider and address the needs of the people of each neighborhood of New Haven;

2) Are created in partnership private interests (including our renowned colleges and universities) to speed up deployment of advanced, systems, reduce risks and facilitate the transferability of the systems that we innovate to other U.S. cities.

3) Are undertaken is a transparent, collaborative and inclusive process; and



4) Are measured, assessed, calibrated and re-tooled using data-driven performance measures aligned with quantitative and qualitative indicators to ensure that we understand and gauge all impacts (positive and negative, direct and indirect) of our holistic and integrated solutions.

Implicit in our core values is the belief that envisioning, deploying, operating and refining next generation intelligent transportation systems (ITS), urban automation, connected vehicles and other innovative urban mobility strategies to improve mobility, safety, reduce congestion, save energy and improve communications, is <u>not</u> the end but the means….*the equitable means by which the City of New Haven and its private partners capture the many, interrelated benefits of Smart Transportation and integrate it with smart land use and progressive public policy to achieve improved economic vitality, social equity, government efficiency and a better quality of life for all residents.*

Exhibit 1: Go New Haven Go Constellation Diagram

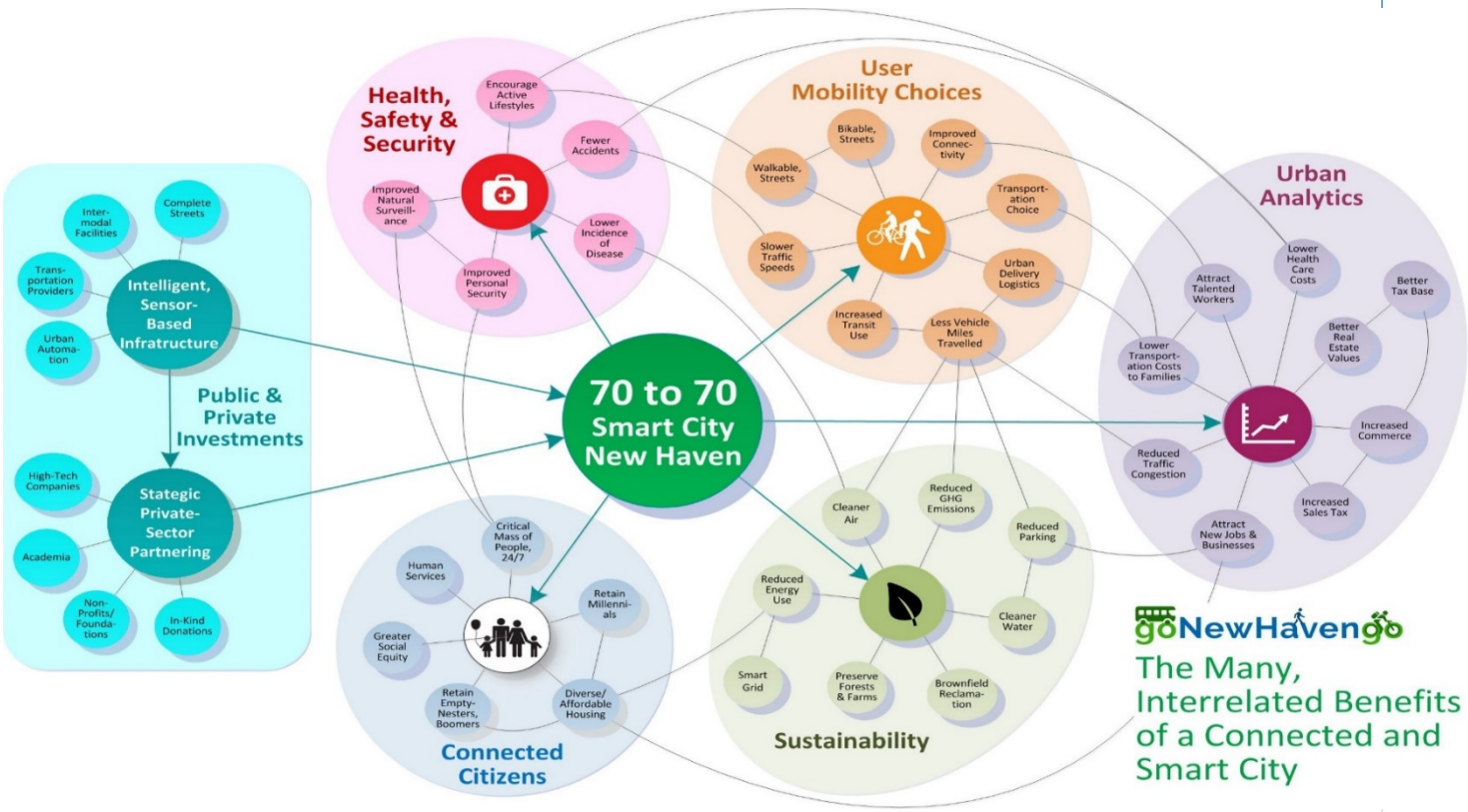


Exhibit 1, titled "*Go New Haven Go, The Many, Interrelated Benefits of a Connected and Smart City*" graphically depicts this central tenet or the economic and social imperative of our Vision.

Intelligent, sensor-based infrastructure and urban automation are exciting, emerging technologies that will set the stage for amazing, cost-saving travel. The direct benefits of the deployment of instrumentation to collect and disseminate real time data - vehicle to vehicle, vehicle to user and user to user - and the software/algorithms to enable convenient interfaces between and among vehicles, users and systems will have far-reaching applications and benefits, including:

- Traffic congestion reduction
- Real time transit vehicle locator systems
- Smart parking/ smart traffic signals
- Prolific use of shared vehicles

- More efficient, demand-responsive, fixed-route bus routing and scheduling

These direct benefits can and must ultimately result in facilitating mode shift and reducing vehicle miles travelled in the region. The City of New Haven will establish indicators or performance measures based on transportation metrics, set benchmarks for those indicators and methods to track, in real-time, progress against those indicators though the use of web-based, easy to understand dashboards (e.g., VMT, travel delay per capita…). However, as mentioned in our Vision, the City of New Haven does not believe that improved traffic flow, better management of transportation assets, and improved mobility are the ultimate goals of the Smart City program, rather, efficient and sustainable transportation and seamless intermodal mobility are the means to a grander, broader set of community goals.
This can be attained because public and private investments in smart transportation combined with a revolutionary approach to integrate transportation and land use to optimize the indirect benefits of these investments will create synergies, unsurpassed compounded benefits in five principal categories of urban structure and societal systems (as identified in the constellation diagram (Exhibit 1)) including: 1) Health, Safety and Security, 2) User Mobility; 3) Urban Analytics; 4) Sustainability; and, 5) Connected Citizens.

The following challenges and needs of the City of New Haven set the stage for our approach for implementing and operating the demonstration project, including the team's program management approach.

Challenges and Needs

- High Traffic Congestion
  - Based on recent surveys and discussions with residents, it is evident that most people choose to commute by car either due to inadequate transit service or lack of frequent transit connections among home, work, and other destinations.
  - Traffic congestion on Interstates 91 and 95 create perennial delays and many of the City's arterial streets are operating at or above capacity. For example, traffic congestion along the I-95 Corridor in the Bridgeport/Stamford and New Haven metro areas has increased by 19% over the 10 year period from 2001 to 2011 resulting in approximately 41 million hours wasted due to delay, which translates into approximately $860 million dollars wasted due to the value of time and fuel.[1]
- Underutilization of transit system
  - Employee commuting patterns result in a significant daily influx to New Haven from surrounding towns contributing to traffic congestion and parking burden. According to 2010 data (U.S. Census Bureau), 72,616 people are employed in New Haven; 55,864 of those employees (nearly 77%) lived outside of New Haven and commuted into the City. 16,752 of those employees (just over 23%) lived in the City. Another 21,771 people who lived in the City were employed outside of the City limits and reverse commute. Yet another substantial number of people commute to the City on a daily basis, not because they work in the City but because they board trains at Union Station en route to jobs or activities in other cities. In 2011, ridership on Metro North alone experienced 3,579 weekday outbound boardings (45% were at peak hour and 55% at off-peak hours). This pattern of commuting where New Haven serves as a way-station also contributes to traffic congestion and parking demand in the City.

[1] Urban Mobility Report (UMR), Texas A&M Transportation Institute, 2013.

- The concept of transit-oriented development (TOD) has not been fully developed in New Haven. The larger transportation facilities are bounded by incompatible land uses; however, the City has invested considerable resources into TOD planning in the past 10 years and has seen recent successes including the construction of 360 State Street and an anchor building (Alexion Pharmaceuticals) in the Downtown Crossing corridor.
- While there has been a significant shift in the City's transportation policy over the past decade, from promoting automobile mobility to promoting multi-modal transportation, a still significant portion of the population continues to use automobiles as their primary means of travel.

- Lower Income families lacking transportation
  - More than one out of every four households and families (13,000) are "zero car" households, with no car available. In the Dixwell, Dwight, Hill, and West Rock neighborhoods, nearly half of households have no car.
  - 10 percent of workers who say they often have a car available are unemployed, whereas the unemployment rate among workers who say they do not often have access to a car is 35 percent.
  - 84% of CTWorks (a work force alliance that specializes in employment recruiting and job training) registrants identify transportation as a barrier to work, versus 60% who identify child care, 23% who identify a lack of education, and 11% who identify a lack of job experience[2].
  - According to the USDA, three census tracts in New Haven are "food deserts"– where there is a confluence of both low-income households and inadequate access to food. Many residents in these areas lack transportation to get to grocery stores and must rely on fast-food restaurants or convenience stores, which sell mostly unhealthy, processed foods.
- Lack of transit connectivity
  - About three-quarters of residents of Greater New Haven live within walking distance of a rush hour bus stop. However, because transfers are often required to travel across this area, a typical resident of Greater New Haven can use public transit to reach only 27 percent of jobs in the region within a 90 minute, one-way commute taken at rush hour.
- Overutilization of parking system facilities
  - The City of New Haven owns and operates 32 parking facilities offering daily parking. The nearly 12,000 spaces in this inventory experience very high demand averaging of 90% utilization. In particular, the parking crunch at Union Station (nearly 99% utilization rate) has led to new shuttle services to downtown New Haven and calls for new satellite parking facilities.
- Inefficient Freight Networks
  - The Port of New Haven is dependent upon the efficient operation of several modes of freight transportation: marine, highway and rail. Therefore, the success of the port in receiving, loading and distributing cargo is not only inextricably linked to the efficient flow of traffic to and from the port but also on the ability of port operators to anticipate and respond to periods of high demand. Freight specific, dynamic travel planning based on real time traffic, ship arrival, truck queueing and

[2] How Transportation Problems Keep People Out of the Workforce in Greater New Haven. A report by the Greater New Haven Job Access and Transportation Working Group; Produced by DataHaven in association with South Central Regional Council of Governments, NAACP Greater New Haven Branch and Workforce Alliance. December, 2014.

weather data could greatly improve port performance and optimize drayage, as well as improve port security.
  - The deployment of advanced sensing and communications systems will increase port capacity, provide new jobs for area residents, reduce the time and cost to get goods to markets and lead to reduced congestion, resulting in reduced air emissions and improved air quality.
  - The New Haven Port Authority looks forward to a future where coordinated, intelligent transportation systems enables improved mobility for all vehicles in greater New Haven and opportunities to greatly enhance the efficiency and reliability of the region's supply chain.

- Sustainability in New Haven
  - Sea Level Rise: The Intergovernmental Panel on Climate Change (IPCC) concludes that there has been a global mean rise in sea level between 10 and 25 cm (approximately 4 to 10 inches) over the last 100 years (Neumann et. al., 2000). Relative sea level rise in Connecticut in the same time period is between 1.5 and 3.0 mm per year. The IPCC further estimates that global sea level will rise 9 to 88 cms during the 21st century. Transportation infrastructure in New Haven at risk to adverse effects from sea-level rise includes the railroad station and track yards, the Tweed-New Haven Airport and parts of Interstate-95. Port facilities on the water's edge, docks, jetties, and other facilities, are deliberately set at an optimal elevation relative to sea level, therefore a rise in sea level leaves them at a suboptimal elevation.

- Air Quality in New Haven and Connecticut as it affects Climate Change
  - A recent report published by American Lung Association called "State of the Air 2013" provided facts and analysis on ozone and particle pollution throughout United States since 2000. While New Haven county passed the test for particle pollution with a significant decrease observed since 2006, the county was graded "F" for ozone quality in the state.
  - New Haven and other municipalities in Connecticut have been experiencing severe weather conditions more frequently due to rapid climate change, especially in the most recent years. There is an urgent need for adaptive planning for climate change at the federal, state, and local level.

Exhibit 2, below, maps out the above challenges relative to the goals of the Smart Cities New Haven Project; this effort indicates that the challenges can be matched squarely with a Smart Cities Solution.

Exhibit 2: City of New Haven Smart City Challenges

Goals	Challenges					
	High Traffic Congestion	Underutilization of transit system	Lower Income families lacking transportation	Lack of transit connectivity	Overutilization of parking system facilities	Inefficient Freight Network
Safety	X	X	X	X		
Mobility	X	X	X	X	X	X
Efficiency	X	X	X	X	X	X
Sustainability	X	X		X	X	X
Climate Resiliency	X	X				X
Urban Analytics			X	X		
Connected Citizens	X	X	X	X	X	X

The benefits associated with attaining the above goals are shown below for each goal area:

For Health, Safety and Security: Encourage active lifestyles, fewer accidents, lower incidence of disease, improved personal security, and natural surveillance.

For User Mobility Choices: Slower traffic speeds, walkable and bikeable streets, improved connectivity, transportation choice, increased transit use, and less vehicle miles travelled.

For Sustainability: Cleaner air, reduced GHG emissions, reduced parking, cleaner water, brownfield reclamation, less sprawl/preservation of forests and farms, and reduced traffic congestion.

For Climate Resiliency: The adaptation of a Smart Cities solution for New Haven will play a critical role in emphasizing the importance of preventive action when assessing the effects of climate change.

For Urban Analytics: Lower costs of transportation for families, attracting work talent, better real estate values, better tax base, increased commerce, increased sales taxes, attract new jobs and businesses, and lower health care costs.

For Connected Citizens: Retain Millennials, diverse, affordable housing, retain empty-nesters and baby boomers, greater social equity, and retain a critical mass of people in urban area.

Methodology and Process

The City of New Haven believes that, much in the way that the Human Genome project led to amazing and valuable benefits to humankind and boosted the scientific status and economic power of U.S. research and development institutions and companies, the Smart City Challenge Grant will revolutionize cities. Our Vision for *Smart City New Haven* is, in effect, a HGP-type proposal to:

1) Map and decode the "DNA" of the City to provide greater insights into how cities function;
2) Articulate the root causes of many of our current urban ills;
3) Develop methods, indicators, and metrics to benchmark, assess and quantify the many, interrelated benefits of alternative future scenarios associated with various levels of deployment of intelligent transportation systems;
4) Monitor, measure and report on the degree to which next generation ITS, urban automation, connected vehicles and other innovative urban mobility strategies succeed in attaining not only the mobility, safety, efficiency, sustainability and climate change goals directly associated with transportation systems
5) Announce to the world (using peer reviewed technical reports as well as interesting and accessible articles with engaging infographics) about how the holistic and strategic integration of smart transportation and sustainable land use can serve a much greater good.

In other words, the *Smart City New Haven* will expand our knowledge and awareness of urban systems and spur a revolution in the ways that we plan, manage and operate our cities to improve the quality of life for all citizens and to accommodate a growing demand for urban living.

2. Describe Population Characteristics

According to U.S. Census Bureau estimates for 2010 (http://quickfacts.census.gov/qfd/states/09/0952000.html), New Haven's population stands at 129,890, the city's density stands approximately at 6,948 people per square miles, and the city represents over 15.1 percent of the population of the local urbanized area (total New Haven urbanized area stands at 861,113).

New Haven does not meet one of the three the explicit population guidelines in the notice of funding opportunity. But it is important to note that of the 64 cities listed as meeting the guidelines, none were in

New England and only one, Baltimore, was in the Northeast Corridor.[3] The stated goal of the criteria was to prioritize mid-sized cities likely to experience growth over the coming decades. However, the list includes many isolated, sprawling cities with little population growth in the past 15 years and much lower population density than New Haven and its neighbors. For example, Modesto, CA, Fort Wayne, IN, Montgomery, AL, and Fayetteville, NC all meet the guidelines, while seemingly obvious examples of fast-growing mid-sized cities like Chattanooga, TN and New Haven, CT do not.

When viewed at the urban area level, greater New Haven is consistent with the cities identified by the US DOT as meeting its preferred population characteristics (Figures 1 and 2). The city of New Haven itself is much more densely populated than most of the cities on the US DOT list (Figure 4), despite having a population beneath the cutoff stated in the Notice of Funding Opportunity (Figure 3). This reflects the political legacy of New England, where municipal boundaries predate urban development and cities have expanded across multiple legally independent jurisdictions. That New Haven is home to 23% of the region's population (Figure 6), despite occupying just 6.5% of the region's land area (Figure 5) is a testament to the city's urban character and central role in the region.

In summary, New Haven's core urbanized area aligns very well with the desired population characteristics specified by the US DOT. However, the fact that this core urban area is split across multiple legal jurisdictions *will* count against New Haven's application.

Figure 1: Population of census-defined "urban area"

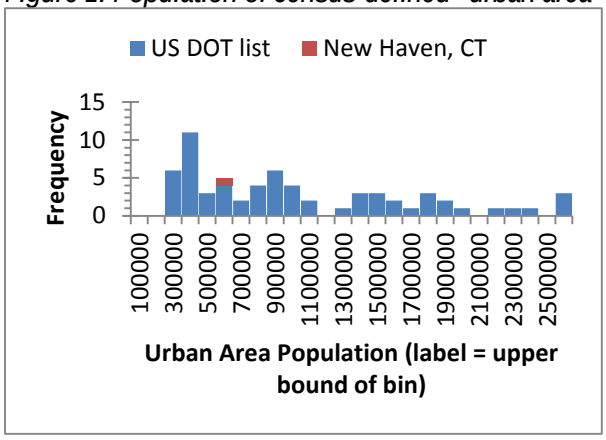
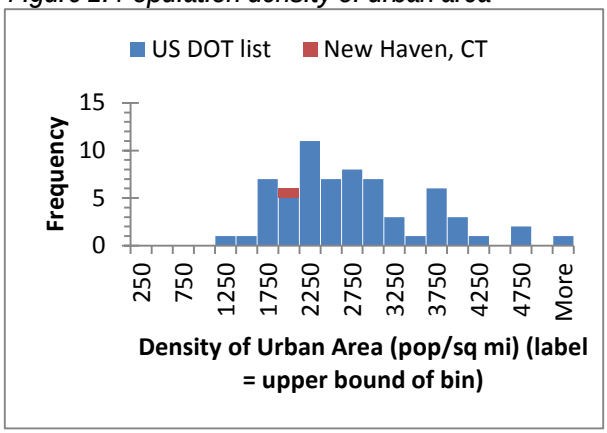


Figure 2: Population density of urban area



[3] The Boston-to-Washington Northeast Corridor constitutes 17% of US population and 20% of the nation's GDP. The megaregion's population is projected to grow by more than 18 million people between 2010 and 2050, according to research published by the Regional Plan Association: http://www.america2050.org/northeast.html

Figure 3: Population within city limits

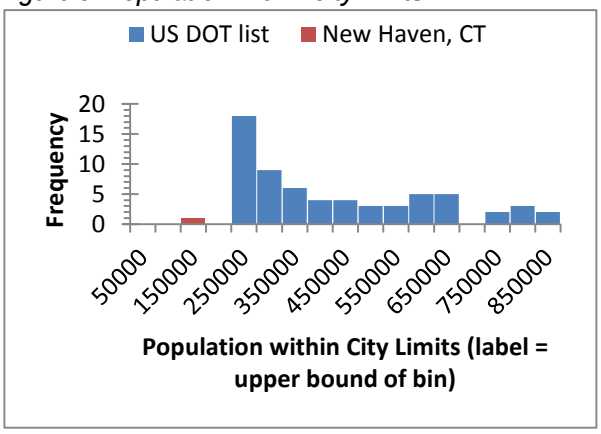


Figure 4: Population density within city limits

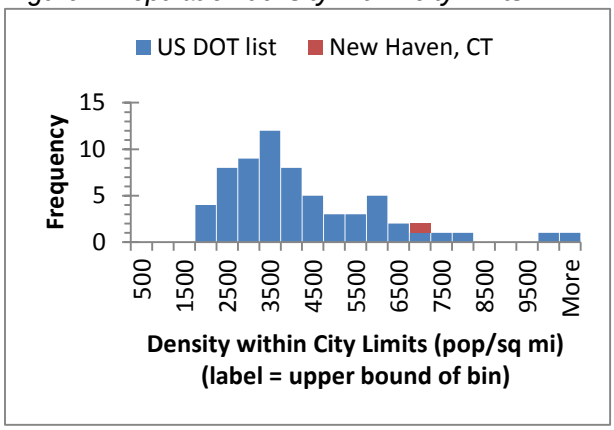


Figure 5: Percent of urban area within city limits

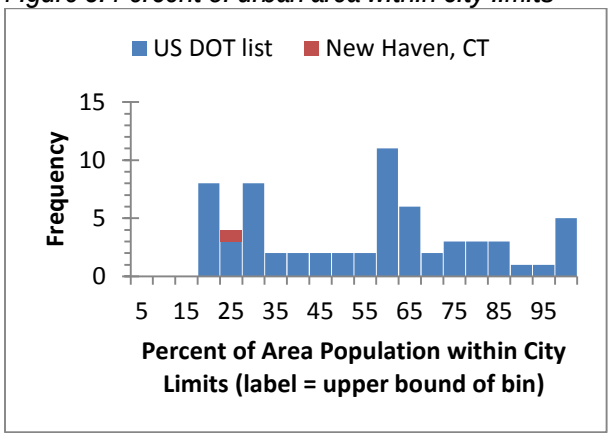
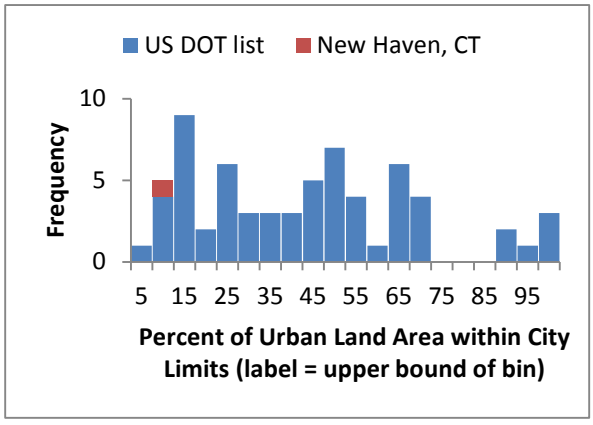


Figure 6: Population in urban area within city limits



3. Describe Other Characteristics

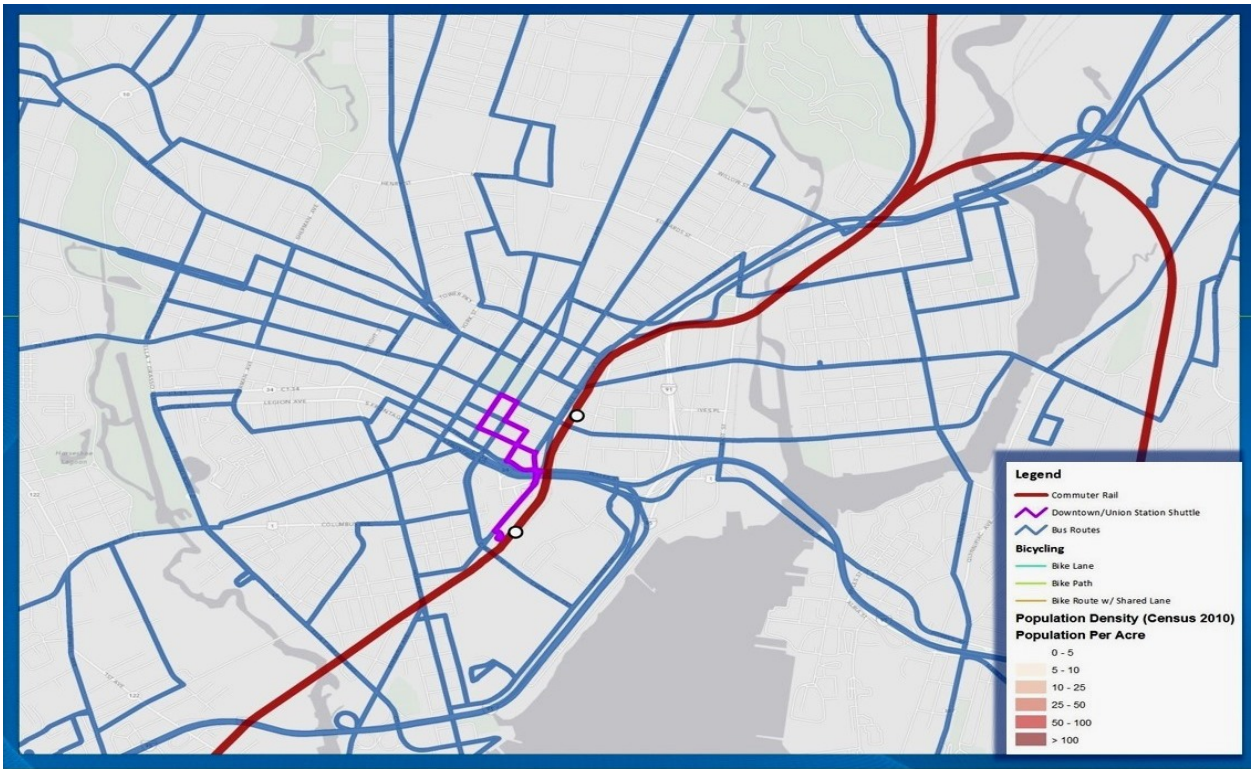
a. Existing public transportation system

Greenways and Trails: The proposed trail system provides opportunities both for recreation and for enhanced transportation/mobility. Residents are engaged in walking and cycling to work, largely by sharing the road with vehicles, but also via new bike lanes and via the Farmington Canal Greenway—one of the largest non-motorized commuting routes into the city from the north. The City recently launched the "Street Smarts" program to capture the latent demand for cycling.

Air Transportation: While many city residents utilize the major airports located in the New York, Hartford, and Boston areas, direct air transportation to New Haven is provided at Tweed New Haven Airport, a regional facility. Runway safety extensions of 1,000 feet were completed in 2009 giving Tweed an effective runway length of just under 5,200 feet. Currently, Tweed New Haven's passenger service consists of four daily American Airways flights to Philadelphia. Scheduled passenger activity has increased on this route by nearly 20 percent over the last five years, but still the facility is substantially below its operational capacity. The vision for the next decade is to attract commercial service to Florida and two to three hub cities.

An overview of the City of New Haven bus and passenger rail transit system layout is illustrated in Exhibit 3.

Exhibit 3: Bus and Passenger Rail System in New Haven



Waterborne Transportation: The Port of New Haven is the largest in the state by volume shipped. In contrast to the operations in the state's other two major ports, Bridgeport and New London, the port terminals in New Haven are entirely privately owned and operated, consisting primarily of petroleum storage, processing and distribution terminals. Other major commodities moved through the port include manufactured goods and scrap materials, primarily scrap iron and steel for export to Asia.

Freight Railroads: Freight railroad service in New Haven is provided by the Providence and Worcester Railroad (P&W) and by CSX Corporation. Service generally runs north (to Hartford) and northeast along the Northeast Corridor tracks. Freight activity between New Haven and New York City is more limited by the heavy volume of commuter rail service. The Port of New Haven is an unparalleled transportation asset. Intermodal connectivity, including freight railroad connections, is essential to growing the port in a manner that protects surrounding neighborhoods and eases demand on the Interstates.

b. Environment that is conducive to demonstrating proposed strategies

New Haven possesses unique characteristics which enable the city to successfully conceive and deploy practical, low-cost, holistic and creative systems that can serve as models for other cities that are struggling to address congestion, protect the environment, anticipate and respond to severe weather events, connect underserved communities and support economic growth. Chief among these characteristics are:
1) Sophisticated transportation infrastructure, 2) Dedicated and forward-thinking administrators and elected officials, 3) Committed and engaged citizenry, 4) A history of productive and fulfilling partnerships, 5) Diverse, compact and walkable neighborhoods, 6) Wealth of institutional resources and entrepreneurial companies, 7) Underutilized transportation infrastructure (airport, deep water port and bus transit), and 8) Highly congested highway and commuter rail corridors that provide critical links to the nation's largest market.

Furthermore, the City recently adopted a Comprehensive Plan[4] that identifies several key priorities relative to transportation, land use, programs and investments that align with the Smart City New Haven strategy or Vision (e.g., Provide real time information on transit arrivals, delays, and departures, Promote the use of electric and hybrid vehicles, Continue implementing electric charging stations and other related technologies and implementing an effective travel demand management program to conserve energy and reduce vehicle emissions, Deploy additional ITS strategies/technologies to support freight and transit mobility, smart parking strategies, and better accessibility to disadvantaged citizens, the elderly, and the driverless population)

c. Continuity of committed leadership and capacity to carry out the demonstration throughout the period of performance

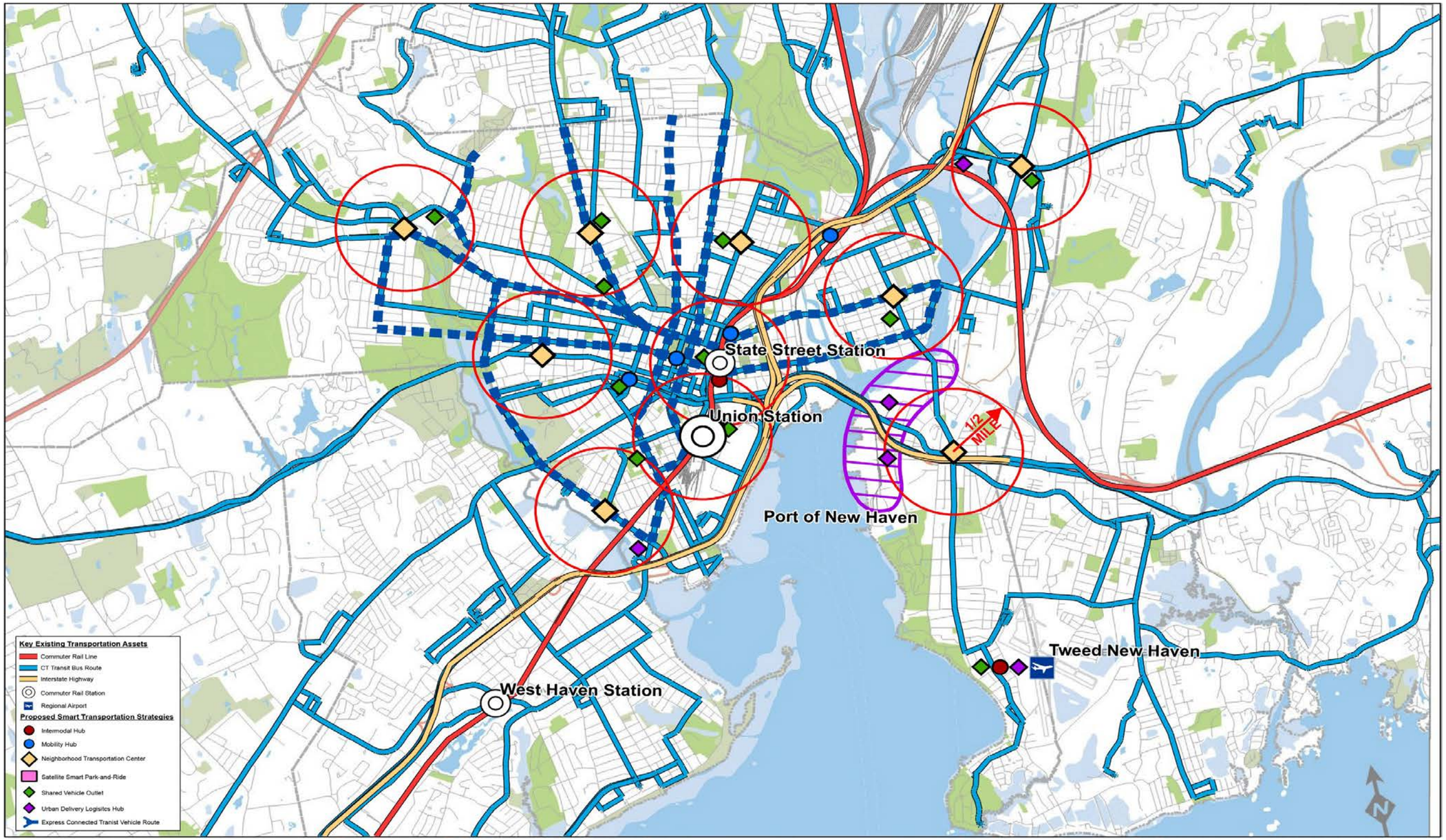
The State's and the City's top leadership is fully committed to carry out the proposed demonstration project. Doug Hausladen, the City's Director of Transportation, Traffic, and Parking will lead this effort with committed support from other City staff, state and regional public sector partners, as well as private industry leaders and relevant subject matter experts (Part II Letters of Commitment). Furthermore, this funding opportunity complements several current planning and development initiatives that the City and its regional, state and federal partners are undertaking on a number of fronts, including:

- The City Transformation Plan to expand economic opportunity, ensure that children are positioned to succeed and create safe, healthy and vibrant neighborhoods.
- The New Haven Transit Alternatives Analysis that re-envisions bus transit routes and service levels to make bus travel more convenient, efficient, and more connected with other transport modes.
- Several Transit-Oriented Development (TOD) studies (such as the Downtown Crossing) that aim to incentivize private redevelopment that provides mixed-use, mixed-income development adjacent to transit stations, reducing auto dependency because people can live in the city and walk, bike or take bus or rail transit to their jobs.
- The one-way to two-way street conversion planning and design project that will improve traffic flow, make navigating the City's streets more intuitive and enable the streets to be more multi-modal by providing bicycle lanes on right-sized streets.
- The City's Comprehensive Plan[5] recommends conducting health impact assessments when making transportation, infrastructure or land use improvements to mitigate any adverse impacts.

Finally, the City of New Haven is committed to integrating this initiative with the sharing economy; and to making open, machine-readable data accessible, discoverable and usable by the public to fuel entrepreneurship and innovation. For this application the City is partnering with key public sector players at all levels of government in Connecticut as well as key businesses (peapod, zipcar, etc.), major academic institutions (e.g., Yale University), and major technology leaders in the region (IOT Capitals) to ensure the proposed vision and associated smart city strategies and technologies meet the needs of the City as well as the needs of the urban and regional population and businesses that served and/or are serving the City.

[4] New Haven Vision 2025 A Plan for a Sustainable, Healthy, and Vibrant City, November 2015
[5] New Haven Vision 2025 A Plan for a Sustainable, Healthy, and Vibrant City, November 2015

4. Preliminary Site Map: The Preliminary Site Map depicts the major strategies of our approach including conversion of high demand bus routes to express electric bus routes, streetcars, or possibly connected or autonomous buses or shuttles, Neighborhood Transportation Centers, Mobility Hubs, Intermodal Hubs, Urban Delivery Logistics Hubs and Shared Vehicle Outlets. The Satellite Smart Park-and-Ride lots, while shown in the legend, need to be field located and vetted with the community before mapping even their general locations. Other finer grain solutions or apps identified in our approach and in the Technical Solutions/Strategies matrix, such as Smart Traffic Signals, cannot effectively be located on a map that is scaled to cover the entire city.



5. Element Matrix Aligning USDOT's "Beyond Traffic/Smart City Challenge" Vision Elements with Potential Projects for New Haven

12 Vision Elements	Challenges and Needs	Potential Technical Solution(s) or Strategy		Existing Resources / Policies
Technology Elements				
VE1: Urban Automation		TS-1	AASHTO Connected Vehicle Field Infrastructure Footprint Analysis	
VE2: Connected Vehicles	• Traffic Congestion • Motor Vehicle Safety	TS-2.1 TS-2.2 TS-2.3	US DOT Connected Vehicle Applications (V2I Safety): - Stop Sign Gap Assist (SSGA) * - Spot Weather Impact Warning (SWIW) * - Reduced Speed/Work Zone Warning (RSWZ) * - Pedestrian in Signalized Crosswalk Warning (Transit) * US DOT V2V Safety Applications: - Forward Collision Warning (FCW) * - Intersection Movement Assist (IMA) * - Left Turn Assist (LTA) * - Blind Spot/Lane Change Warning (BSW/LCW) * - Vehicle Turning Right in Front of Bus Warning* Other Applications/Strategies: - Express Connected Transit Vehicle Route	Preemption and signal prioritization
VE3: Intelligent, Sensor-Based Infrastructure	• Traffic Congestion • Traffic Incident Management • Environmental monitoring	TS-3.1	Other Applications/Strategies: - Open Source Code Software - Smart Parking *(see TS-12: Eco Smart Parking)*	• Motor vehicle, pedestrian and bicycle cameras (tracking/count) • NOAA gauges • Stormwater Sensors • Real time on-street parking sensors • Off-street garage availability and real-time wayfinding
Innovative Approaches to Urban Transportation Elements				
VE4: Urban Analytics	Internet of Things (IoT) analytical tools	TS-4.1 TS-4.2	USDOT Agency Data Applications: - Probe-based Pavement Maintenance* - Probe-enabled Traffic Monitoring* - Vehicle Classification-based Traffic Studies* Other Applications: - Rapidfire and Urban Footprint comprehensive, integrated modelling, implementation and monitoring software	
VE5: User-Focused Mobility Services and Choices	• Lack of real-time transit route/schedule info • Promote active lifestyles	TS-5.1	USDOT Mobility Applications Multi-modal Intelligent Traffic Signal Systems (MMITSS): - Intelligent Traffic Signal System (I-SIG) * - Transit Signal Priority (TSP) & Freight Signal Priority (FSP) * - Mobile Accessible Pedestrian Signal System (PED-SIG) * Intelligent Network Flow Optimization (INFLO):	• Smart screens for real-time transit • Pay by cell on-street parking • Off street parking prepay and reservation • Real time on-street parking sensors

12 Vision Elements	Challenges and Needs	Potential Technical Solution(s) or Strategy		Existing Resources / Policies
			- Cooperative Adaptive Cruise Control (CACC) * R.E.S.C.U.M.E.: - Incident Scene Pre-Arrival Staging Guidance for Emergency-Responders (RESP-STG) * - Incident Scene Work Zone Alerts for Drivers & Workers* - Emergency Communications & Evacuation (EVAC) * Integrated Dynamic Transit Operations (IDTO): - Connection Protection (T-CONNECT)* - Dynamic Transit Operations (T-DISP) * - Dynamic Ridesharing (D-RIDE) * Mobility on Demand (MOD):	• Satellite parking and employer shuttle services • Off-street garage availability and real-time wayfinding • Bike share • Complete Streets policy and Safe Routes to School engineering program
		TS-5.2 TS-5.3 TS-5.4 TS-5.5 TS-5.6 TS-5.7 TS-5.8	- Optimized Bus Network - Neighborhood Transit Centers with Smart Mobility Hubs - Smart Intermodal Hubs at Train Stations & Airport - Satellite Smart Park-and-Ride Lots Other Applications/Strategies: - Safe Corridors for Students (and for the Elderly?) - Bike-Share - On-Street Shared Vehicle Outlet	
VE6: Urban Delivery and Logistics	• Underutilized Port • Food deserts • Inefficiencies in getting local produce to City households • Need to be smarter about collecting & managing waste.	TS-6.1 TS-6.2 TS-6.3	USDOT Mobility Applications: - FRATIS (Freight-Specific Dynamic Travel Planning & Performance)* - Drayage Optimization (DR-OPT) * Other Applications/Strategies: - Urban Delivery Logistics Hub/ Fresh Food Lockers - "Big-Belly" Waste Collector, Compactor, Recycling	• Pilot for Big Belly in field • Minimum viable product for off-grid fresh food locker system ready
VE7: Strategic Business Models and Partnering Opportunities	Lack of ability to capture value of significant federal, state and city investments in transportation	TS-7.1 TS-7.2	- Value Capture Program - P3 Standardized Forms of Agreement	New statewide Tax Increment Financing statute
VE8: Smart Grid, Roadway Electrification, and Electric Vehicles	• Intolerable levels of motor-vehicle related accidents, injuries and deaths. • Traffic congestion • Excessive air emissions (non-attainment zone)	 TS-8.1 TS-8.2 TS-8.3	Other Applications: - Smart Street Lights - Adaptive Response Signal Technology - City EV Charging Stations	• Snow Emergency Blue Light Notifications • Everbridge communication system • Emergency Vehicle Preemption • Range confident City and State with over 23 eV charging stations in public facilities • Programmable LED bridge lights

12 Vision Elements	Challenges and Needs	Potential Technical Solution(s) or Strategy		Existing Resources / Policies
VE9: Connected, Involved Citizens	Citizens spend excessive no. of hours in traffic, waiting for buses or transferring between travel modes - less time for community involvement.	TS-9.1 TS-9.2 TS-9.3 TS-9.4	Other Applications: - High-Speed Internet/Fiber to the Home - Free Wi-Fi services in public spaces - e-NHV City Hall (virtual City Hall) - Extended Social Network	• Over 20,000 unique Open311 users (SeeClickFix) • WiFi on the New Haven Green • City website in process of revamp with Civica • New Haven is leading the state's CTGig FTTH project
Smart City Elements				
VE10: Architecture and Standards		TS-10.1 TS-10.2 TS-10.3	- National ITS Architecture Other Applications/Strategies: - Transportation Health Impact Assessment Tool - Open Data	• Socrata online open data portal • Downtown Crossing (TIGER) grant had HIA • OpenGov online budget reporting tool
VE11: Low-Cost, Efficient, Secure, and Resilient Information and Communications Technology	• There is current lack of integrated emergency communications network Faster emergency response times • Enable "Aging-in-Place"	TS-11.1 TS-11.2 TS-11.3	USDOT Road Weather Applications: - Motorist Advisories and Warnings (MAW) * - Enhanced MDSS* - Vehicle Data Translator (VDT) * - Weather Response Traffic Other Applications: - ICT (Information and Communications Technologies) - Technological Platform for Municipal Operations	• Reverse 911 • Variable Message Signage system on highways • VMS system pilot on local roads with MakeHaven (maker space)
VE12: Smart Land Use	New Haven's current population is less than its peak population in the mid-20th Century. The City needs to accommodate more residents contribute to and grow the economy.	TS-12.0	USDOT Environment Applications - Eco-Approach and Departure at Signalized Intersections* - Eco-Traffic Signal Timing* - Connected Eco-Driving* - Wireless Inductive/Resonance Charging* - Eco-Speed Harmonization* - Eco-Cooperative Adaptive Cruise Control* - Eco-Traveler Information Applications* - Low Emissions Zone Management* - Eco-Smart Parking* - Dynamic Eco-Routing (Light Vehicle, Transit, Freight) * - Eco-ICM Decision Support System* Other Applications/Strategies: - Rapidfire and Urban Footprint comprehensive, integrated modelling, implementation and monitoring software *(see TS-4.2)*	

The Technical Solutions (TS) or strategies identified in the third column of the preceding table that are identified with an asterisk are Connected Vehicle Applications derived from the US DOT's Intelligent Transportation Systems Joint Program Office related to V2I Safety, V2V Safety, Agency Data, the Environment, Mobility and Smart Roadside (refer to http://www.its.dot.gov/pilots/ cv_pilot_apps.htm). New Haven understands that the US DOT has expended considerable funds in the research and development of these apps or tools and believe they will prove to be very useful in achieving the goals and objectives of Smart City New Haven. In addition to these apps, the City has identified several other potential apps or strategies that would address some of the unique issues and opportunities in New Haven. They include:

TS-2.3: Express Connected Transit Vehicle Route. During the course of the comprehensive bus transit study (see TS-5.2), New Haven will identify high-demand routes and explore ways to provide express service along those routes, including the potential for bus rapid transit-type service, or electric street car service utilizing wireless inductive/resonance charging technology, as well as connected vehicle technology and even autonomous vehicle technology.

TS-3.1: Open Source Code Software. The City of New Haven will work with private partners to provide a functional, open, interoperable, easily expandable platform. The open-source software model or platform will enable information generated by sensors to be gathered, used and disseminated by a variety of our partners to improve collaboration between cities and among various levels of government.

TS-4.2: Rapidfire and Urban Footprint comprehensive, integrated modelling, implementation and monitoring software. Calthorpe Analytics' Rapidfire and Urban Footprint software enables communities to understand the many interrelationships between transportation and land use. The comprehensive scenario-based analysis and modeling work brings a broad range of defensible and powerful analytics to the public, leading to more informed decision making. The tools test existing conditions and alternative land use and policy futures for impacts on a range of critical indicators, including carbon emissions, travel behavior, energy and water use, fiscal impacts, public health impacts, and land conservation.

TS-5.2: Optimized Bus Network. Smart City New Haven must have a smart bus network - one that is easy to understand, intuitive, faster and better connected - so transit riders can save time and move around the city easier. The City of New Haven and its partners at CTDOT, CTtransit and Greater New Haven Transit District are studying the entire bus network of the metro area to identify ways to improve operational efficiencies. These improvements will include Smart transit systems such as: smart care, cashless fare systems, transit signal priority at traffic lights, real-time bus locator information at stops, smart management to improve speed, frequency and service provision across the city, as well as the optimization of routes and resources based on resident's current needs.

TS-5.3: Neighborhood Transit Centers with Smart Mobility Hubs. Smart mobility hubs would be located at Neighborhood Transit Centers (NTC, refer to Preliminary Map exhibit) to provide shuttle-type (even autonomous vehicles) service between the NTC and the nearest express transit service line or major station. The NTC could be co-located with other municipal services such as a police substation, a neighborhood health clinic or an adult day care center, to provide a welcoming, 24/7 presence in the neighborhood and to serve as a comfortable way station between home and an individual's ultimate destination. The NTC would have exceptional connectivity and state-of-the-art transit technology including Dynamic Transit Operations (T-DISP, an application that links available transportation service resources with travelers through dynamic transit vehicle scheduling, dispatching and routing capabilities). It could also host an e-NHV (virtual) City Hall (see TS-9.2).

TS-5.4: Smart Intermodal Hubs at Train Stations & Airport. A smart intermodal hub is similar to a smart mobility hub (see TS-5.3) that would welcome and orient commuter rail and air travelers to other modes of travel including fixed-route bus, shuttle bus, taxis, Zip Cars, conventional car rentals and bike share. It

would also provide T-DISP app that would link available transportation service resources with travelers through dynamic transit vehicle scheduling, dispatching and routing capabilities. In addition, it could be outfitted with AFV Charging and fueling stations, Connection Protection, an application that enables coordination among public transportation providers and travelers to improve the probability of successful transit transfers), and Dynamic Ridesharing (an application that uses dynamic ridesharing technology, personal mobile devices, and voice activated on-board equipment to match riders and drivers).

TS-5.5: Satellite Smart Park-and-Ride Lots. To help manage traffic congestion, increase occupancy levels in vehicles and provide a convenient place for commuters to hop on a shuttle to their final destination, New Haven is exploring new, smart park-and-ride facilities that could be constructed on the outskirts of the City. The lots would be linked to Downtown, Union Station and other key destinations with express shuttles. Smart Park technologies, such as real-time parking and transit information systems: e.g., AFV Charging and fueling stations, Connection Protection, Dynamic Transit Operations, as well as Dynamic Ridesharing could be provided at the lots to encourage its use by commuters.

TS-5.6: Safe Corridors for Students (and for the Elderly). In concert with the City's Safe Routes to School program, the City will roll-out a program to identify the safest pathways to schools and parks and provide special pavement markings to identify them. The program would also include education activities how underscore the importance of pedestrian safety and to identify volunteers that could help maintain and Safe Corridors. This encourages school children to go to and from school in an independent and safe manner. The neighborhood based program would not only improve pedestrian safety but also improve children's sense of self-reliance.

TS-5.7: Bike-Share. New Haven has long embraced bicycle travel as a safe and efficient means of transport that results in less impact on the environment and enables residents to travel about more nimbly. We have been working for years to improve bicycle systems in the City and to plan a bicycle sharing program based on the successful programs in New York City and Boston. The Bike Share program, as currently envisioned, will be easy-to-use for short, everyday journeys. We will deploy Bike Share stations at strategic locations throughout the City and will co-locate bike-share stations around transit stops to provide an ideal complement to transit. We will launch a simple Bike Share app that gives users access to real-time user information such as bicycle availability and stations.

TS-5.8: On-Street Shared Vehicle Outlet. Under this program, the City will enter into agreement(s) with private companies to operate on-street car-sharing service. Car sharing will induce some residents to give up at least one of their cars, which will reduce competition for parking, reduce travel demand and provide more affordable travel choice for residents. The program will also make cars available in neighborhoods that are further removed from Downtown and improve car use since they will be more visible to residents.

TS-6.2: Urban Delivery Logistics Hub. The objective of this logistics strategy is to customize relatively small-scale delivery hubs in the City to serve as hubs for both inbound and outbound goods, especially fresh fruit, produce, meats and dairy products from nearby farms. It recognizes an increasing demand for timely distribution and delivery of perishable products (e.g. same-day deliveries, night-time inbound services) and will be eco-friendly since consumption of locally grown or raised products will reduce the need for transcontinental, or even inter-continental shipment of quality, healthy products. The logistics hub might even located adjacent to transit stations and include locker boxes accessible to people who order on-line and can pick-up after hours, on their way home from work.

TS-6.4: "Big-Belly" Waste Collector, Compactor, Recycling. New Haven residents are very attune to the quality of the environment and very committed to protecting it. Smart City New Haven will echo that commitment by treating and managing the waste it generates, so it can create jobs, save resources and be

environmentally friendly. We envision "Big Belly" sensor-based, waste compactors and recycling stations at key locations throughout the City.

TS-7.2: P3 Standardized Forms of Agreement. Together with the State of CT, New Haven will explore public-private partnerships (P3s) to determine how they could be utilized to deploy key features of Smart City New Haven. P3s are contractual agreements formed between a public agency and a private sector entity that allow for greater private sector participation in the delivery and financing of transportation projects. The FHWA promotes the use of P3 and identifies and defines various P3 arrangements and will be a good starting point for our pursuit of mutually beneficially P3 forms of agreement.

TS-8.1: Smart Street Lights. Working with private partners, New Haven will study new smart street light prototypes with the intent to deploy them not only to reduce operational costs (new super-efficient LEDs lights can save 50-70 percent on electricity over standard bulbs and could last up to 20 years), but also to take advantage of new sensor pack technology that have video and weather sensors and can be controlled with smart city apps. New Haven can potentially take advantage of the data being generated by the sensors for public safety, transportation, intelligent digital signs and the environment.

TS-8.2: Adaptive Response Signal Technology. According to the FHWA, adaptive signal control technology adjusts the timing of traffic lights to accommodate changing traffic patterns and ease traffic congestion. The benefits of adaptive signal control technology include: distribute green light time equitably for all traffic movements; improve travel time reliability by moving vehicles through green lights; and reduce congestion by creating smoother flow. ASCT are also kinder to the environment. Using ASCT can reduce emissions of hydrocarbons and carbon monoxide due to improved traffic flow.

TS-8.3: City EV Charging Stations. New Haven, its private utility partners and area employers are discussing ways that electric vehicle charging station could be deployed to accommodate and encourage the use of electric vehicles, including electric cars, neighborhood electric vehicles and plug-in hybrids. They could be provide on-street or located at retail shopping centers and at private companies.

TS-9.1: High-Speed Internet/Fiber to the Home/ Free WiFi services in public spaces. To increase resident's access to the Internet and the use of technology in their daily lives and to make the City of New Haven a more desirable place to conduct business, the City will explore an ambitious plan to provide free WiFi Services in public spaces and high-speed internet to every corner of the City. WiFi service could also be installed on the city's buses and at the train stations.

TS-9.2: e-NHV City Hall (Virtual City Hall). A virtual City Hall located in booths that are connected to the real City Hall with high-speed internet could be provided at Neighborhood Transit Centers (see TS-5.3). The booth would have a video-conference screen, a printer and a scanner, which people could use in semi-privacy to conduct City business (e.g. obtain certificates, tax payments, complaints, etc.) both with remote assistance of City Hall staff and live assistance by a paid staff person at center.

TS 9.3: Extended Social Network. The City is committed to make the lives of the elderly more convenient and to enable the elderly to lead more active lifestyles. The City understands the importance of 'Aging-in-Place' and will explore ways to improve the quality of life and independence of people who are elderly, have disabilities and/or dependent on others, especially those who live or spend many hours alone at home. New services could include: special devices and apps that provide 24/7 communication channels to call centers or elderly care providers; immediate assistance in locating family members or designated contacts by sending; offering an appropriate response to users' requests for assistance; and, taking preventative action by maintaining frequent contact with individuals.

TS-10.2: Transportation Health Impact Assessment Tool. The City of New Haven plans to use the US DOT's and the Centers for Disease Control and Prevention's new Transportation and Health Tool (THT) to

examine the health impacts of transportation systems, reference key data sets of transportation and public health indicators, and assess how various future transportation scenarios with affect the environment, safety, active transportation, air quality, and connectivity. You can use the tool to quickly see how your state or metropolitan area compares with others in addressing key transportation and health issues. It also help residents better understand the links between transportation and health and to identify strategies to improve public health through transportation planning and policy.

TS-10.3: Open Data. The City of New Haven is committed to making public data open to anyone so that a range of individuals and entities can easily access and reuse the data. Open data has been shown to result in the creation of new companies, services, products or apps that provide significant social and economic value and improve the lives of residents.

TS-11.3: Technology Platform for City Functions. In order to meet the needs of a growing population and ensure efficient and effective government response to both everyday needs and unanticipated future events (especially emergency situations), a technological platform of services and IT solutions will be established to enable the Board of Alders to make decisions in a timely manner. This NHV Technology Platform could: 1) Integrate and correlate various city databases and convert them into information; 2) make data more accessible; 3) enable data to be analyzed and predictions to be made (e.g. simulate potential future City scenarios); and, 4) enable data and records of the services offered by New Haven to be handled both horizontally (between City Departments) and vertically (to a central City data center).

TS-11.2: Information and Communications Technologies (ICT). Improving access to information technology for all citizens is the first step to improving equity and expanding knowledge. New information and communication technologies (ICT) also can enable more inclusive government and more involved citizens. This strategy would include in-depth outreach into the neighborhoods to educate residents about the available of technology to search for jobs, use the internet, or engage in local governments - in our libraries and in future Neighborhood Transit Hubs on topics such as an introduction to mobile devices, using the internet, email, searching for jobs and open government.

6. Risks and Mitigation

Even in instances where significant elements of a proposed system have reached a level of maturity, there remains a risk that difficulty will be encountered during the completion of development and integration of the Smart Cities Vision. These difficulties can emerge as a result of unseen technical challenges; however, more often they come about due to operational or institutional issues—namely, the acceptance of terms and conditions by the intended users. The New Haven, CT Smart Cities team has given careful consideration to these potential issues, and is confident that careful attention to stakeholder needs and concerns will allow us to avert such problems. We have examined the risks to success in depth, and offer Exhibit 4 as a summary of risks, along with measures we will undertake to mitigate them.

Exhibit 4: Key Technical, Policy, and Institutional Risks and Mitigation

Risk	Rating	Risk Description	Mitigation
Application Functionality	Medium	*Application unable to execute commands properly*	Application of sound systems engineering principles and qualified development staff
Subsystem Connectivity	Medium	*Subsystem elements unable communicate required information*	Use of standards for point-to-point and network-wide information exchange
Stakeholder Commitment	Medium	*Lack of interest on part of stakeholders to use system*	Careful and comprehensive stakeholder engagement strategy focused on value
User Issues	High	*Users unable/unwilling to use applications once deployed*	Comprehensive stakeholder engagement strategy focused on needs & interface

Risk	Rating	Risk Description	Mitigation
Process Issues	Medium	*Conflict between system use methods and business processes*	Careful and comprehensive stakeholder engagement strategy focused on needs
System Complexity	Medium	*Inability to align functionality among subsystem elements*	Focus on functional simplicity and strict control of feature sets
Budget	Low	*Possibility of overrun of planned budget*	Application of sound systems engineering principles and strict control of feature sets
Schedule	Medium	*Possibility of overrun of planned schedule*	Application of sound project management principles and strict control of feature sets
Public Relations	Medium	*Negative perception among public regarding project content*	Open communications and application of proven public relations methodology
User Turnover	Low	*Depletion of user set and/or new participants*	Simple, direct training and user-friendly interface design

From the onset the City of New Haven will work with its key teaming partners CDM Smith and Parson, to apply the principles put forth in the Technology Adoption Model (TAM). In particular, the New Haven, CT Smart Cities deployment will focus on the two specific factors that drive adoption and use:

- Perceived Usefulness – how users recognize how a system would improve their livability.
- Perceived Ease of Use – the perception users have if using a specific system, which would result in less effort.

Throughout the design, development, and implementation, the New Haven Smart Cities Team will continuously monitor its own efforts to identify risks and develop a risk mitigation plan to support a quality deliverable to the stakeholders.

7. Team and Roles

The Smart City New Haven team will establish a process that will clearly identify all stakeholders, ensure effective and ongoing communication with them, and monitor interactions to ensure that project objectives are understood and appreciated. The methodology that will facilitate the stakeholder identification includes analyzing and documenting relevant information regarding the stakeholder's interests, involvement, interdependencies, influence, and potential impact on project success. Parsons will implement a salience model to rank and prioritize stakeholders based on their involvement with the smart cities initiative. A Venn diagram with seven zones spread across three intersecting circles will provide clarity to the prioritization of the stakeholders. Those stakeholders who fall into the intersecting areas of the circles will be considered high priority. Those stakeholders who fall outside of the circles in the diagram are considered lower prioritized stakeholders however will still be included in the Stakeholder Register. A Smart Cities Stakeholder Register will be created listing the project's stakeholders identifying the stakeholders, their roles, their level of interest and power (data taken from the salience model), and their support for the project. The following is Exhibit 5 is a potential list of stakeholder register:

Exhibit 5: New Haven, CT Smart Cities Stakeholder Register

Stakeholder Name	Company, University, Public Agency, etc.	Role in achieving the New Haven Smart Cities Vision	Support Vision Element[6]
CDM Smith	Company	Project/Program Management, Data Collection, Performance Measurement, Transportation Operations	All elements
O'Donnell Company (marketing/advertising)	Company	Marketing/advertising	7
Newman Architects	Company	Architecture / Design	12
Svigals Architects	Company	Architecture / Design / Art	12
Passport	Company	Urban Automation/Analytics/Intelligent Sensor Infrastructure/User Focused Mobility provider	1, 3, 4, 5
Greywall Software	Company	Emergency management software provider	11
Elm City Cycling	Advocacy Non-profit	Providing input on bike/ped strategies/needs	9
City Seed	Non-profit	Supporting the development of food distribution logistics strategies	12, 6
EDC/REX	Economic Development Non-profit	Economic development/Smart Land Use/Outreach/Engagement	12
Parkeon	Company	Parking meter technology that encourages smart land use & provides multiple payment options	1
Veniam	Company	Technology/Communication/Data Provider	1, 2, 3, 4, 5, 6, 8, 9, 10, 12
Inex Advisors/IoTLabs	Company	Assessment/Evaluation/Identification of technologies to support the smart vision	1, 3, 4, 5, 6, 7, 9, 10, 12
See Click Fix	Company	Communications platform for citizens to report non-emergency issues, and governments to track, manage, and reply	4, 9, 10, 11
IBM	Company	ITS Solutions, innovative urban transportation planning, data mining	1, 4, 6, 11
Aerospace	Company	Planning, acquisition, testing and development of advanced technology systems.	1, 2, 3, 4, 5, 7, 8, 11
Peloton	Company	Freight signal priority with automated speed control, automated traffic jam assist, automated truck queuing, parking and docking, improved intermodal coordination via cloud-based networks, expanded data collection and analysis enabled by real-time V2X communications--to make the City a model for automated urban freight transportation.	1, 2, 6
TSPS	Company	Vehicle to Infrastructure (V to I) real time information to locate available parking and more efficiency plan truck trips including hours of service	2, 3, 4
CT Center for Advanced Technology (CCAT)	Advocacy Non-profit	Outreach and advocacy around smart technologies (identification of technologies, mentoring/educating citizens, public agencies, interest groups on new and state of the art technologies)	4, 10
Town Green Board	Non-profit	Advocacy, and community outreach and engagement support for the Smart City Vision	9

[6] 1: Urban Automation; 2: Connected Vehicles; 3: Intelligent, Sensor-Based Infrastructure; 4: Urban Analytics; 5: User-Focused Mobility Services and Choices; 6: Urban Delivery and Logistics; 7: Strategic Business Models and Partnering Opportunities; 8: Smart Grid, Roadway Electrification, and Electric Vehicles; 9: Connected, Involved Citizens; 10: Architecture and Standards; 11: Low Cost, Efficient, Secure, and Resilient Information and Communications Technology; 12: Smart Land Use.

Stakeholder Name	Company, University, Public Agency, etc.	Role in achieving the New Haven Smart Cities Vision	Support Vision Element[6]
NHPA	Public Agency	Provides 8,000 public parking spaces at 6 garages and various surface parking lots in downtown New Haven and in surrounding neighborhoods. Committing to be an integral part of the smart parking deployment element of the vision	5
Parsons	Company	Design, develop, deploy, and operate complex intelligent transportation systems.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
Peapod	Company	Internet grocer, operating in New Haven, allowing customers to place orders up to seven days a week for delivery as soon as next-day. Committing to work with the City to Support Vision/Technology deployment as it relates to Freight/Goods movement.	6
Park Mobile	Company	Mobile payment solutions for parking services	3, 5
CARE	Education	Working on this project to assist the team in identifying solutions and measurable objectives around the health, safety, and security goal/challenge particularly as it relates to access to transit and food to disadvantaged citizens.	4, 9
MakeHaven	Non-profit	MakeHaven will develop, support the development of, and provide resources for the development of free and open source software and hardware for this application. MakeHaven can play a critical role in the development of solutions that benefit the City of New Haven community through newly-available open data.	3, 4, 5, 9, 10
Urban Design League	Non-profit	The League seeks to strengthen the civic culture that is the foundation for good government, good planning, and good development, particularly as the City moves to implement its Smart City Vision	12
Zipcar	Company	Zipcar commits to further discussions on how it can partner with the City of New Haven to support the city in its efforts.	5
Yale	University	Yale University's Center for Engineering Innovation and Design will support the City of New Haven's Smart City projects with access to their labs and other resources	3, 4, 5, 9, 10
The Governor's office	Government Agency	Governor Malloy of CT supports the City of New Haven's application, and may be able to shepherd through legislative changes if they become necessary to enable new technological solutions	7
SCRCOG	Public Agency	Provides regional planning services for the area including the City of New Haven	7, 12
Workforce Alliance	Non-profit	Provides workforce development services including training in New Haven consistent with the Smart City Vision	12
HNTB	Company	ITS Standards, Urban automation, connected vehicles, Architecture and Standards	1, 2, 10
CTDOT	Public Agency	CTDOT will be involved in performance measures, and with facilitation of design and implementation of any new systems on state roads and highways.	2, 5, 10
Frontier	Company	Telephone and internet data provider in support of the deployment of technologies as part of this vision	9, 11
Senators Murphy & Blumenthal, Representative DeLauro	Government Agency	Support the City of New Haven's application, and may be able to shepherd through legislative changes if these become necessary to enable new technological solutions.	7

Once the stakeholder register is in place, a detailed communication plan will be created to provide the project team and stakeholders with an effective communications plan by describing who should be communicated with, who should do the communicating, what should be communicated, why it should be communicated (purpose), when it should be communicated (frequency, time frame), and how it should be communicated (language, format, method, technology). The team will conduct an analysis of the communication requirement of all of the parties involved to identify the type of information to be delivered, the format of the information, and specifying the flow of information, including:

- Communication expectations
- Process for communication about project progress
- Status meetings and their attendance
- Stakeholder communication requirements
- Frequency of communication
- Process for escalation of issues that cannot be resolved
- Process for communicating about project changes

8. Transportation Infrastructure

Key transportation infrastructure and system features in the City of New Haven include:

Arterial miles and Freeway miles: There are 255 miles of roadway in the city, ranging from Interstate highways to local residential streets. Of these roadways, 88 percent or 224 miles are locally-maintained public roads and 12 percent or 30.6 miles are state-maintained roads and freeways.

Transit services: Passenger Rail:

- Amtrak: New Haven is situated along two Amtrak lines: the Boston–Washington "Northeast Corridor" and the New Haven–Vermont, inland route. New Haven is also a stop and service point for Amtrak's high-speed Acela Express service. New Haven remains the 11th busiest Amtrak station in the country with a total ridership of 740,902. This represents 42.8 percent of all Amtrak riders in the state. Ridership in New Haven increased by 195 percent from 1999 to 2011.
- Shore Line East: Shore Line East (SLE) rail service is operated by Amtrak, under contract from the State of CT between New London and New Haven. In 2002, ConnDOT built a new commuter rail station on State Street to facilitate direct access to Downtown. Recent upgrades to the line, including station renovations, have caused an increase in ridership by 107 percent from 2000 to 2010.
- Metro-North Railroad: New Haven is the northerly terminus of Metro-North Railroad's New Haven Line. The Metropolitan Transportation Authority (MTA) operates the line under a service contract and subsidy from the State of CT. In 2011, annual ridership on the New Haven Line totaled 38.2 million, a 21.4 percent increase from 2000. With 3,737 daily inbound weekday and 3,579 weekday outbound boardings, New Haven was one of the busiest stations along the New Haven Line in 2011. Of these boardings, nearly 45 percent were at peak hour and 55 percent were at off-peak hours.
- Hartford Line: The planned Line will operate at speeds up to 110 mph and at 30 minutes headways during peak travel time, cutting travel time between Springfield and New Haven to as little as 73 minutes and representing an opportunity to broaden mobility and preserve capacity along Interstate 91.

Public Bus System: The system is operated by CTTRANSIT. The New Haven Division is the second largest bus transportation system in the state. The service area covers 476 square miles, including New Haven and all or part of 19 surrounding towns. The 23 service routes cover 462 directional miles. On an average weekday, CTTRANSIT carries approximately 30,000 passengers.

Connecticut Transit Shuttle System: The CTTRANSIT Downtown to Union Station free shuttle service, launched in September 2009, provides service to passengers traveling from Union Station to Downtown. Ridership on this service is growing fast with a nearly 430 percent increase in riders observed from 2009

thus indicating the demand for this type of 'first mile-last mile' service. Besides this, private shuttle services are offered by Yale University and Yale–New Haven Hospital (YNHH) for their students and employees.

Shared-use mobility services: Various share-used mobility services are currently operating in New Haven including: biksesharing, carsharing, taxis, ridesourcing (Uber, Lyft), employer shuttles, and pedalcabs.

Information and communication technology (ICT): New Haven relies on a range of tools and equipment to support a variety of transportation data including: High resolution portable video data collection devices. Data collected include intersection counts, volume counts, road volume counts, vehicle gap data, and junction and pathway count; Standard video detection that collect traffic that collects 24 hours traffic counts and occupancy; 24 hour closed circuit video equipment/incident management cameras; Fiber cables, wireless system and telephone lines connecting 245 intersections to the City's TMC monitoring intersection operations, signal malfunctions, incidents, and delays; Tide, stormwater, and weather sensors; and Radar sensors to collect speed data

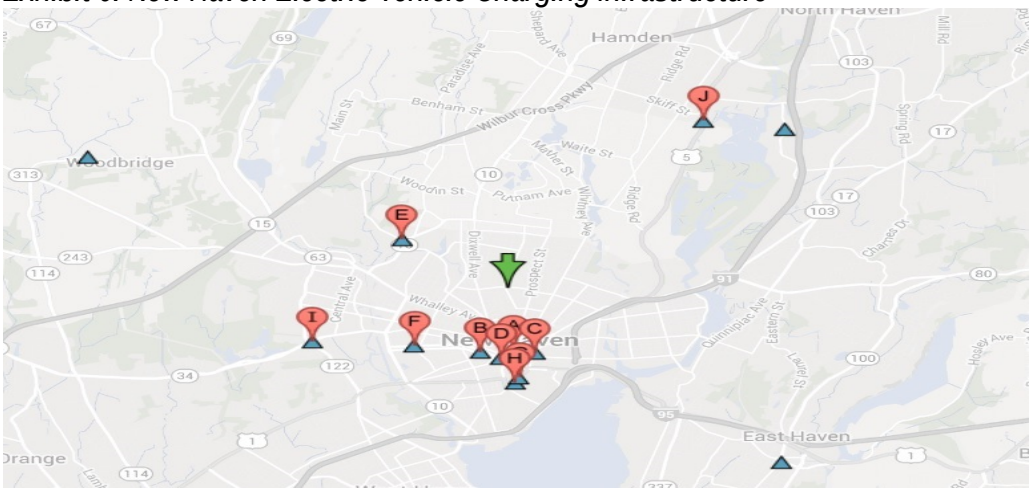
Intelligent Transportation Systems (ITS) including transportation management centers

- The City of New Haven has 307 signalized intersections which 288 City owned and the remaining 19 are State owned (Closed loops system). These intersections are inter- connected via fiber optic cables (over 20 miles), leased telephone lines and wireless to Traffic Management Center (TMC).
- The City TMC manages over 245 computerized real time traffic signals on the City busiest arterials, collectors and local street corridors. Real time traffic information such as traffic counts, occupancy and speeds and surveillance (24 hours recording)/incident management cameras is gathered from many video detection (over 200 cameras), closed circuit video equipment/incident management camera (over 180 cameras) installed at intersection and mid-blocks and fire emergency preemption.
- The City has over 2,990 parking meter which over 2000 of them are smart meters that accept coins, credit cards and pay by cell and the remaining are schedule to be replaced within the next three years.
- The City is in process of introducing exclusive bike lane, bike box and bike signals in Edgewood corridor within the next few months.
- The City is introducing an adaptive traffic signal control system with Transit signal priority by upgrading the City exiting Advanced Traffic Management System (ATMS) to improve efficiencies for the motorist.

Smart Grid Infrastructure including electric vehicle charging infrastructure

Exhibit 6 illustrates New Haven's main smart grid infrastructure: The electric vehicle charging infrastructure.

Exhibit 6: New Haven Electric Vehicle Charging Infrastructure



9. Define Data Collections

Current Data Collected: The City of New Haven currently collects a wide array of data that will be instrumental in measuring system performance before vision deployment and in measuring the impact of proposed technology solutions, post deployment. These include:

- Traffic congestion: Vehicle miles traveled and average daily traffic counts for all arterials and freeways
- Intersection counts, roundabout counts
- Transit Ridership: Passenger Rail, Bus and Shuttle Services, at Train Station Counts
- Port Authority, City of New Haven freight volumes by commodity
- New Haven Regional Airport hub and passenger counts
- Parking Facilities condition, revenues, and usage
- Bicycle and Pedestrian counts, origin/destination
- Employment, unemployment, workforce, wage data, employee/employer commuting patterns
- Crowd-sourced weather data; Sewage and Stormwater data; Water and Air Quality data
- Accident data by mode and location: fatalities/injuries/physical damage and response time.

Data Needs: The high-level data and communications needs for the New Haven Smart Cities vision will be identified from interactions with the stakeholders. For each required application, we expect to determine the data needs by performing the following activities:

- Identify data sources.
- Characterize the data (objects and attributes).
- Decide how available the data needs to be to the applications, which will affect how data is replicated and how changing policies are configured.
- Determine data ownership.
- Determine data access strategy.

If data are imported from other sources, develop a strategy for both bulk imports and incremental updates. As a part of this strategy, try to master data in a single place and limit the number of applications that can change the data. Also, limit the number of people who write to any given piece of data. A smaller group ensures data integrity and reduces overhead.

Determining the data needs will involve defining how to efficiently and effectively we can match voice and data communication needs with the applications by identifying current and future user requirements, developing an inventory of present and future systems and networks, determining all the interdependencies and evaluating the technological options.

The data needed by each application would then be reported in the following matrix shown in Exhibit 7.

Exhibit 7: Data Measures Matrix

		Data/Measures		
Application name	Is data needed on day 1 or in the future?	Data identified in use case	Essential data needed	Future enhancement

Resulting from the needs assessment, the related data elements are defined as shown in Exhibit 8.

Exhibit 8: Data Elements Matrix

Data element name	Preferred description	Source	Directly measured or derived	Required accuracy if known	Required frequency if known (both temporal and spatial values)	Comments

Our field performance data collection approach will measure both the current city operational performance (no Smart Cities Application deployment) and the new Smart Cities operational performance (with Smart Cities Vision deployed) using a combination of existing data sources (sensors, weather stations, operational and infrastructure management), embedded data collection in Smart Cities applications. Using Teaming Partner Parsons' PAR-PRO™ tool, we will capture requirements for message sets and attributes, including sources, data elements, frequency, precision, sample rate, units, ancillary data elements, and correlation with participant action logs. This ensures traceability of data elements through message sets, data flows, and, ultimately, into the technology solutions.

The Parsons data-sharing framework approach will be integrated with an Open Data Exchange and augment it with complementary performance measure dashboards. Open data-sharing and stakeholder/participant-specific dashboards will be implemented. The dashboards available through an online portal will provide public access to selected information and private access for PII and/or BII.

Our team will rely network of connected vehicles, highway sensors, and weather stations which join forces to offer wireless Internet access to citizens, businesses, and city employees and share vital data to improve the mobility, safety, efficiency quality of life, and social value of city services. To build such a network, we equip every municipal service vehicle with an affordable multi-network on-board unit called NetRider OBU. Vehicles are ideal WiFi hotspots, because they have a battery, they are densely spread over the city at street level, and they can communicate with 10x the range of normal WiFi at the 5.9GHz frequency bands. Passengers, employees, and businesses can use the onboard WiFi inside a bus or service car as they would at home or in the office. By connecting the OBUs to the OBD2 interface of the vehicle we can acquire large quantities of data from the sensors inside the vehicle. Additional sensors can be connected to the OBU via Bluetooth or WiFi. The vehicles can access the Internet via the DSRC Access Points (APs) installed around the city and use LTE as backup in DSRC white spots. Since the vehicles form a wireless mesh, they can serve as relays to each other using multi-hop communications. This reduces the need for costly infrastructure. Large amounts of actionable data can thus be gathered, transmitted in a cost-effective delay–tolerant fashion, and stored in the cloud to support the city operations. Data processing applications infer the ground truth and inform the actions of municipal agents on the field. Our approach will produce a series of series of relevant data including: Micro-weather data, Pollution data, Pedestrian/bicycle counts, storm water level alerts/statues, traffic status around the city and in/out of the city, crowd density data, anonymized mobility patters, parking availability/location status, accident statues and related clearly time statuses.

With teaming partner Veniam's solutions, any sensor located close to the road can upload the collected data to the vehicles going around the city, which in turn takes care of forwarding the data across the wireless mesh to the cloud. Veniam is agnostic to the sensor make and model, provided that it uses Wi-Fi and a REST API to upload data to vehicles, thereby ensuring its compatibility.

Data is stored in Veniam's databases and displayed in its Network Operations Center (NOC), a web portal used to configure and maintain the whole network, access service metrics and analytics. Optionally, the data can be made available to third-parties through secure RESTful APIs.

The transportation data collected will be used to improve the management and operations of the different city players and authorities, while improving the urban living conditions and optimizing urban productivity, efficiency, environmental impact and safety and security of the city as a whole. Examples of improving the management and operations at the city level include:

1) Utilizing the appropriate number of shuttle/transit buses to meet the actual demand for passenger mobility
2) Better understand key origins and destinations within the city. This too will help guide investments in transit operations, highway infrastructure, and parking facilities.

The gathered transportation data can be used to optimize other types of operations of the same or different city players. Some examples are: (1) with the notification of the location of several number of buses in real-time, the drivers of private transportation fleets can be quickly advised to re-think the right places to perform services; (2) with the knowledge of the mean number of vehicles and citizens moving around several city areas at a particular time of the day, city network providers can better plan, configure or dynamically adapt their infrastructure and services; (3) the quick access of information about an accident can lead to a more effective actions by policemen or other city officials, thus decreasing the patrolling actions in areas without knowing accidents; (4) the knowledge of the location of every city vehicle can also be used by distinct applications and/or services deployed to guide people to use the most appropriate transportation, or to tell drivers about the availability of empty roads, thus reducing unnecessary traffic, traffic jams, and thus pollution.

The City of New Haven intends to provide much of the data as open source. In addition, we will seek to establish partnerships with all the players in the smart city ecosystem. The partnership agreements will set the rules and policies for information sharing among the partners, which will then be implemented in cloud platform.

Safety Plan

The safety of participants and others who will interact with the smart cities technology and infrastructure will be ensured through a safety process integrated with the smart city solution. The safety management plan (SMP) will describe the requirements on the involved organizations and a methodology to optimize safety- related decisions under resource constraints.

The safety management plan will define the safety-related performance measures relevant to the project and their required and target levels, as well as a description of the underlying assumptions relating the measure to system safety. These measures will include but are not limited to the following:

- Reliability and maintainability metrics, such as mean time between failure, mean time to repair, or parameters for distributions that model the failure characteristics of components (e.g., Weibull)
- Probability of loss of life or loss of significant assets

Development of all system will follows the ISO 26262 standard for road vehicle functional safety throughout the concept development, design-build-test, and operations and maintenance phases of the program. This standard goes beyond treating safety as a component reliability problem, to actively identifying scenarios in which the system's components are all operational but the system is in an unsafe condition.

During the development phase, a structured and systematic hazard analysis and risk assessment approach will be applied to identify potential hazards, assign Automotive Safety Integrity Levels (ASILs), and help identify functional safety needs/goals. While ISO 26262 defines exposure scales E0 (Incredible) to E4 (High Probability), another approach to handling the inherent subjectivity in this scale is to consider only severity[2]; however, doing so prevents an efficient application of resources to address the most likely hazards.

Aerospace has pioneered the successful use of quantitative risk assessment techniques which reduce qualitative judgments of risk through the application of logic models, and would apply these techniques to reduce subjectivity in assessing exposure rates. Aerospace has extensive experience in deductive analysis methods (fault tree analysis, reliability block diagrams) and inductive analysis methods (failure modes effects and criticality analysis, event tree analysis) for identifying systematic failures and safety hazards.

For the deployment and operations and maintenance phases of the project, a quantitative risk management process will be used to optimize a portfolio of risk control plans, track progress in their implementation, and assess any newly identified risks. Aerospace has extensive experience in planning risk management processes; training staff to facilitate the process; and performing the identification, assessment, and tracking tasks associated with the risk management process.

Security

Our team combines unique cyber security capabilities and disciplined analytical processes to produce a thorough and implementable security management operating concept (SMOC). The SMOC will provide a secure operational environment that meets user privacy needs and protects personally identifiable information (PII) and business identifiable information (BII). This task is led by The Aerospace Corporation, which has a proven track record in delivering complex security solutions in very demanding operational environments. This expertise, coupled with subject-matter experts (SMEs) from transportation operations and management, CV applications development, and stakeholder outreach, ensures a comprehensive and executable SMOC.

Our team's security experts have first-hand knowledge of public key infrastructure (PKI) and Security Credential Management System (SCMS) designs. We understand the challenges in designing and deploying an integrated security concept across multiple dimensions to meet user privacy and security needs. We will also explore the concept of a "broadcast" methodology of information exchange, which would permit all users, regardless of certificate status, to receive critical information, such as data found in the Basic Safety Message (BSM), from a trusted infrastructure element, with minimal security risk.

The management and distribution of cryptographic keys associated with a PKI approach for a system of this magnitude presents some unique challenges. A key management system similar to the Department of Homeland Security (DHS) Over the Air Rekeying (OTAR) and Over the Air Programming (OTAP) system will be investigated as a possible solution. Our team will categorize PII, PII-related, and BII information with a supporting rationale describing the need. Additionally, we will leverage the work already accomplished in Wireless Access in Vehicular Environments (WAVE), described in IEEE Standard 1609.2.

A standardized approach and process is fundamental to a successful privacy and security management program. Teaming partner Aerospace Corporation has been involved with information assurance (IA)/cyber security from the inception of IA standards (e.g., Orange Book, etc.). Aerospace is the prime federally funded research and development center (FFRDC) supporting the National Information Assurance Partnership (NIAP), having supported it and its predecessor organizations in the development of IA standards, the definition of IA product requirements (i.e., common criteria protection profile and the evaluation of both products and systems. Aerospace continues to work with NIAP and the National Institute of Standards and Technology (NIST) to develop all information security standards being used in commercial and unclassified federal markets. Aerospace is the honest broker between government and industry to help ensure the provision of competent IT security evaluation and validation services and the integration of trusted products into their systems. In recent years, Aerospace has assisted a number of Department of Defense (DoD) and civil-sector systems to identify and implement cyber-resilience requirements, allowing a system to continue to provide mission-critical services, even during a cyber-attack. In the absence of standardized data formats across all systems, Aerospace has achieved success in designing software wrappers that work with a super set

of all expected data, with all anticipated data fields assigned a specific location and normalized to the same measurement units, ensuring the quality and readability of the available data.

10. Approach for Using Existing Standards and Technologies

One of the objectives of the Smart Cities challenge is that it be used as a model for future smart city deployments. To effectively serve as a model, it is critical that the selected city base their deployment on accepted industry standards and document the lessons learned through the design, deployment and operations. The New Haven team has a proven track record in using the applicable industry standards in the execution of related projects.

The New Haven team will use the fundamentals of the systems engineering approach along with our experience in planning, design, procurement and implementation in applying ITS technology. In this task, system requirements will be presented which is inclusive of functional, interface, performance and data requirements for the applications that will be deployed. The requirements should have the following properties:

- *Be a unique set,* i.e., each requirement should be stated only once.
- *Are Normalized.*- Requirements should not overlap
- *Linked set* – Requirements relationships should be defined
- *Complete* – Should include all relevant requirements identified by the stakeholders
- *Consistent* – Consistent style and not contradict
- *Bounded* – by scope and context
- *Modifiable*
- *Configurable* – maintainable version control
- *Granular* – sufficiently detailed

In addition, each requirement should be abstract, unambiguous, concise, traceable and validatable. We often see requirements sets that fail to meet these minimum characteristics and as a result is a faulty system specification which leads to implementation challenges.

A functional approach to developing the requirements is key to the ultimate success of an ITS deployment. While there are current ITS vendors and products in the marketplace, it is crucial that a set of functional and performance requirements are developed, especially given the complexity of the applications included in this Smart Cities project. Basing the requirements on the users helps to ensure that any eventual deployment meets a broad base of needs from a wide range of stakeholders. Also, the approach allows vendors to apply their capacity and experience to respond to the requirements in creative and innovative ways when there is a procurement or deployment.

Based on our team's experience with developing, refining and overseeing the implementation of systems using functional and performance requirements, there are three areas of consideration to be used in developing the requirements. The three considerations are:

1) Ensure that the requirements address the identified needs. This includes ensuring that any integration issues and constraints are incorporated into the requirements;
2) Base the requirements, in part, on the understanding that our team has developed through similar recent projects about the capabilities of existing software or systems. This understanding avoids unnecessary customization or modification and can minimize the cost and risk associated with new development by vendors; and
3) Ensure that each requirement can be tested/demonstrated using a practical and reasonable test procedure. This ensures that the eventual testing can be completed in a reasonable amount of time and any potential issues that arise during testing can be identified sooner rather than later.

Additionally, the requirements will be developed taking into account some of the practical tradeoffs and constraints, including:

- Cost versus functionality/performance,
- Size and dimensional constraints for installation,
- Opportunities to avoid duplication between the capabilities of individual components that could be combined into an integrated system (e.g. there should be only one GPS receiver or mobile data communications link),
- Cost versus expandability for future features (e.g. interface with fare collection systems),
- Documentation requirements versus costs, and
- Expected useful life of system and underlying technologies.

Members of the New Haven team are currently working with the USDOT through the Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle Pilot (CVP) project. As a part of this project, HNTB is developing an architecture for the CVP deployment using the USDOT Connected Vehicle Reference Implementation Architecture (CVRIA) and the associated SET-IT software tool. The deployment in Tampa will utilize the most current standards for connected vehicles from SAE, IEEE and others, including the V2I deployment guidance document that is expected to be released in the coming months. As part of the THEA CVP project, HNTB is providing feedback to USDOT and appropriate standards development organizations on all aspects of the program, ranging from standards to security to the architecture and its associated tools. The New Haven Smart City team will continue to work with USDOT in this same manner to ensure that feedback is thorough and continuous.

A vital aspect of the development of the requirements is the link between the needs that are identified and the functional and performance requirements, as well as any sub-systems and/or interfaces. A "Needs to Requirements" matrix will be used to demonstrate this traceability. The ability to trace the needs to requirements and then the requirements throughout the life of the project has been found to be critical for ITS projects. Our team's experience in overseeing the implementation of various ITS and CV technologies around the US has proven the importance of this "Requirements Matrix." The Team's experience constructing requirements is supplemented by our experience observing how the requirements are deployed and tested.

11. Vision Goals and Objectives and Impact Monitoring Approach

Proposed measurable goals and objectives for the New Haven City vision and the associated approach for monitoring the impact of the demonstration on mobility, safety, efficiency, sustainability, and climate change is provided in Exhibit 9.

Exhibit 9: Challenges, Goals and Objectives, and Associated Performance Measures

Challenge	Performance Measure	Impact on the Program Goals				
		Safety	Mobility	Efficiency	Sustainability	Climate Resiliency
High Traffic Congestion	Decrease Traffic Congestion by 20%		✓	✓	✓	✓
Underutilization of transit system	Improve Transit Reliability by 15%		✓	✓	✓	✓
Lower Income families lacking transportation	Improve transportation access to jobs from 30% in five years 50%	✓	✓	✓	✓	✓
Lack of transit connectivity	Improve Transit Connectivity from 16.3 minutes median wait	✓	✓	✓	✓	✓

Challenge	Performance Measure	Impact on the Program Goals				
		Safety	Mobility	Efficiency	Sustainability	Climate Resiliency
	time for any rush hour vehicle to 10.1 minutes.					
Overutilization of parking system facilities	Improve participation in Transportation Demand Management Program from two major employers to top 25 employers in 5 years.			✓	✓	✓
Inefficient Freight Network	Reduce travel time through New Haven for freight deliveries by 15%	✓	✓	✓	✓	✓

12. Capacity to Conduct

Executive Commitment – The City of New Haven's executive commitment to a project of this magnitude is evidenced by the letters of support and commitment to the City's Smart City Challenge from 1) Governor Dannell Malloy, Connecticut DOT's James Redeker, New Haven Mayor Toni Harp, U.S. Senators Richard Blumenthal and Chris Murphy, U.S. Congresswoman Rosa DeLauro New Haven's 3rd district, as well New Haven's Economic Development Corporation (Please see Section II, Letters of Commitment).

Workforce capacity – The City's Transportation, Traffic, and Parking Office will lead this effort with staff support from the City's Economic Development Administration, Plan Department, Engineering Department, Public Works, Emergency Operations, as well as the New Haven Port and Parking Authorities. The City will also be supported by various contractors committed to the project with leading expertise in projects of similar magnitude and content including CDM Smith, HNTB, Parsons, IBM, Calthorpe Analytics, Veniam, and Park Mobile to name a few (Please see Section II, Letters of Commitment).

Infrastructure Readiness – Per *Section 8 Transportation Infrastructure,* the City of New Haven's existing infrastructure and experience at ITS/Communication Technologies deployment will help assure integration and successful deployment of the City's proposed vision and associated smart city technologies.

Data – Per *Section 9 Define Data Collections*, the City currently collects a range of data including real time traffic, bus and transit, train, parking, weather, stormwater, emergency preemption, and incident data.

Performance Management Capabilities – The City has partnered successfully with USDOT on a number of projects, including TCSP (Wayfinding Signs); TE (Farmington Canal Greenway); CMAQ (Traffic Control System Upgrades); and Tiger (Downtown Crossing). Furthermore the City has a long history of executed and successful agreements with the federal government which bind the City to imposed requirements.

13. Cost Share

The City of New Haven is providing in-kind support on the challenge vision, goals, objectives, and deployment plan. In addition, the city will utilize its full resources and will have access to committed local, regional, state, and academic partners to provide and produce relevant data to assess system performance pre and post vision deployment. The City will leverage key private partners to further invest in and contribute to this smart city challenge. The Yale University Center for Engineering, Innovation, and Design has offered the support of their laboratories to test technologies and applications. Internet of Things (IOT) Capital Partners has committed to invest in transformative transportation technologies in New Haven and is moving key resources and installing a lab facility in the city within the next twelve months. IOT is offering to support the City's smart city vision development and deployment.