The City of Raleigh

Beyond Traffic: The Smart City Challenge

The SmartRaleigh Plan

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VISION NARRATIVE

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Executive Summary

The City of Raleigh, NC, is pleased to submit this application for the Smart City Challenge. As the 4th fastest growing metropolitan area in the country, with an anticipated 50% population growth from 2010 to 2030, the City of Raleigh is the ideal setting to tackle the challenge of providing a blueprint for other cities to address local mobility and access issues while facing the global threat of climate change head on. Like many mid-size cities, Raleigh does not experience the sustained freeway and city street traffic congestion seen in large cities, has a modal split that is highly skewed towards SOV use, and provides travelers limited access at both ends of their trips (what we call the First/Last-mile problem) due to the nature of the spatial coverage of our transit services. For Raleigh, a "business as usual" approach when compared to the anticipated growth projections is likely unsustainable. Therefore, we must consider a paradigm shift in our transportation services. Absent this transformation, the current spare capacity in our road network will quickly evaporate, and our congestion levels – especially non-recurrent congestion due to incidents, weather or road work – will skyrocket, along with the associated detrimental effects on mobility, safety, and environmental quality. Simply stated, it is our belief that the Smart City of the future is one that grows sustainably, minimizing environmental impacts and improving mobility, access, and safety, without increasing congestion.

We propose to address this challenge with a multipronged approach that relies on four basic elements: *sensing, connectivity, automation, and electrification*. Through the use of AI-based analytics like IBM's Watson (Vision Element (VE) #4), our goal is to create an intelligent, adaptive, secure (VE #11) and sustainable transportation infrastructure (VE #3) that connects with all its users (VE #9), providing efficient and seamless mobility for their spatial activities (VE #5). Thus, our approach will be person- rather than vehicle-centric and will cover all modes, including the dominant auto mode, mainline transit service, and a new automated connector mode (EcoPRT) (VE #1 & 8).

We intend to build our intelligent and secure infrastructure starting first with currently available sensor and sensing systems deployed in the region, augmented by a city-roaming fleet of instrumented vehicles. Our approach utilizes existing Raleigh and NC State University (NC State) transit systems and testbeds. We will marshal the Smart Raleigh team's considerable expertise in the fields of urban analytics (VE #4), connected vehicle operations (VE #2), and automated transit (VE #1) to validate and demonstrate our approach. Our proposed testbeds are a 4.5-mile congested arterial (Western Boulevard) connecting downtown Raleigh on the east and Interstate 440 to the west, with key access points to NC State's Central and Centennial Campuses along Avent Ferry Road for the testing of autonomous, electric vehicles as depicted in the annotated map (p. 10).

Raleigh has assembled a strong consortium of partners committed to this effort (VE# 7), as detailed in Table 3 (p. 25) and the attached letters of commitments (beginning p. 31). The SmartRaleigh team is confident that our approach has a high likelihood of success, is readily scalable, and is naturally transferable within and beyond the city limits. We have an expansive vision of a future where analytics will drive Smart Travel, an integrated vehicle-to-city intelligent connected system actively managing and controlling the infrastructure and influencing travel patterns to optimize city traffic flow. Smart Travel will monitor and connect with a Sustainable Smart Fleet, improving both the intelligence and eco-friendliness of fleet vehicles, and address the first/last-mile problem by employing small, person-scale, automated, electric-powered vehicles.

1.0   Define your vision for your Smart City

Vision Statement: To establish a sustainable transportation system, enabled by information from a fully integrated spectrum of computing, communications, sensor, and green technologies, to increase traveler safety, reduce congestion, reduce fuel use and greenhouse gas (GHG) emissions, and increase inter- and intra-mobility choices, while supporting the economic and social goals of Raleigh.

Goal: To create an intelligent, adaptive, scalable, and sustainable transportation infrastructure that connects with all its users, providing efficient and seamless mobility for their spatial activities and achieving improved air quality in Raleigh.

Figure 1. The SmartRaleigh plan.

Focus areas: Our city of the future (SmartRaleigh) will accomplish the proposed vision and goal through the following three focus areas:

- *Smart Travel*, using sensors and integrated communication systems to address congestion problems
- *Sustainable Smart Fleet*, utilizing fleet technology to improve safety and reduce greenhouse gases
- *First-Last Mile Automation*, extending the reach of transit by utilizing small, automated vehicles

Smart Travel: Over the past few decades, there has been a dramatic increase in sensor integration into our city fabric. Traffic cameras, fixed radar, and vehicle GPS are now common fixtures in our daily lives. Not only city-owned sensors, but personal smart phones can act as sensors. Cell phone carriers amass immense amounts of cell location data everyday throughout a city. Data from these sources can be used to provide citizens with the information they need to make intelligent travel decisions in the context of the city's infrastructure and its other users. The

global knowledge and control available to travelers will enable them to dynamically calculate the optimal travel modes and routes in the city, in real time, so that everyone gets the optimal travel experience possible. For vehicles currently equipped with V2I technology, suites of sensors can communicate traffic conditions and extract vehicle locations. Data rich vehicles' transportation system sensors and user information can be collected and analyzed by means of a connected and intelligent system that reduces congestion and provides Raleigh with implementable options to improve its environment. Also, by gathering planning data from many users, SmartRaleigh can predict future congestion points and adjust recommendations accordingly.

As a demonstration, we will create a pilot connecting SmartRaleigh to available sensor and database infrastructure for a segment of the city (See annotated map on page 10). Using Avent Ferry Road and Western Boulevard as demonstration sites, roadside and vehicle-based sensors, roadside equipment, vehicle probes, cameras, message signs, and other devices will be installed to feed into an analytics database, which will in turn communicate back to users through cell phones/dashboard displays. We will also fill in gaps of Raleigh's current suite of city-wide sensors (see annotated map) by deploying a set of modular smart nodes, in-car sensors, cell phones distributed over the city to create an integrated view of traffic flow and detect accidents, dangerous weather events, and other roadway hazards. Using the above approach, we will:

- Evaluate an integrated sensor-based analytics approach that will monitor and collect real-time data sets providing live actionable feedback to affect transportation flow
- Develop framework and associate user interfaces (e.g., web, cell phone apps)
- Test and evaluate varying V2I or V2V communication approaches to support incident detection, congestion monitoring, and congestion flow maps for the general public.
- Facilitate traffic flows via smart signage, dynamic illuminated guide ways, traffic cams, social media data, and mobile devices to ease congested bottlenecks as well as saving energy.

Sustainable Smart Fleet: We recognize the importance of continued efforts to integrate renewable energy and create opportunities for smart grid technologies, as referenced in the City of Raleigh Renewable Energy Overview (CORREO), prepared in partnership with the NC Sustainable Energy Association. We have already created targets for City fleet transformation, and other targets have been identified in our Fuel and Fleet Transformation Plan, Climate Energy Action Plan, and our City of Raleigh Strategic Plan[1]. We also recognize the great benefit of tying together the growing need for efficient, sustainable transportation options with new Smart City technologies and smart grid applications to answer some of the challenges caused by rapid population growth, pollution (GHG emissions), and stressors such as extreme weather events. In fact, we have a roadmap to convert fleet vehicles to CNG and electric power. There will even be a conversion station in Raleigh that converts locally captured methane to CNG.

Raleigh would welcome the integration of USDOT's partner Mobileye's Mobileye Shield+™ technology to our bus fleet, improving pedestrian and bicycle safety. Of particular interest in this technology is the ability not only to detect potential safety situations and apply that to infrastructure improvements, but also examine the possibility of collecting bicycle, pedestrian, and vehicle counts for city planning purposes.

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[1]City of Raleigh, Fuel and Fleet Transformation Plan, 2015; City of Raleigh, A Roadmap to Raleigh's Energy Future, 2012

In specific, we propose to:
- Evaluate converting Raleigh's growing bus fleet to electric or compressed natural gas fuels
- Add MobilEye Shield+ to Raleigh's bus fleet for collision warning features
- Collect sensor data to provide pedestrian/bicycle/vehicle counts and integrate with SmartRaleigh
- Test and evaluate fast charging schemes, including charge-as-you-go infrastructure for mobile electric vehicle charging
- Assess how long-term strategies can benefit from emerging new technologies, such as autonomous vehicle components, smart visual films, advanced self-powered sensors (NC State's ASSIST Center), and augmented reality

Additionally, in conjunction with researchers from NC State and industry partners, Raleigh and NC State will demonstrate an autonomous bus serving Centennial Campus. By retrofitting self-driving technology, the bus will navigate autonomously from bus stop to bus stop, picking up passengers and dropping them off without human intervention. As part of the demonstration corridor, we will provide the opportunity to evaluate effectiveness of corridor management with an autonomous transit vehicle. Furthermore, stops at Centennial Campus will be coordinated with stops for the EcoPRT system to demonstrate the effectiveness of the last-mile solution for a full end-to-end autonomous connector, as described below.

First/Last-Mile Automation: Raleigh, NC State, and industry partners will design, implement, and test a completely new and cost-effective solution to the first and last-mile problem. NC State researchers have conceptualized a new transportation modality, EcoPRT, to fill the corridor. EcoPRTs are light-weight, electric, automated vehicles serving as a low-cost, fast, first-last mile connectors with significantly reduced environmental impact compared to any other transit modality in current wide-scale use. Conversations with a number of key stakeholders in the Research Triangle Park area have revealed significant interest for such a low-cost system at many sites. We propose to:

- Demonstrate small, autonomous vehicles using Centennial Campus as a testbed and evaluate the overall system for privacy, security, reliability, and cyber mechanisms
- Use a test bed to validate low-impact, last mile electric vehicle solutions via a mobile circulator: the "Mobile Oval". Such a test bed could be part of a Centennial Campus vision project for advanced transportation (Note that this is within Raleigh's city limits)
- Use the "Mobile Oval" as a test track for a host of technologies as part of NC State's campus "Proving Ground." Technologies to be evaluated would include inductive charging and traction motor drivers using the latest power electronics, collision avoidance cameras, sensors and software, and state-of-the-art cooling systems
- Conduct passenger studies by using the test bed to traverse between buildings. Passengers can provide input regarding experiences and suggested changes. Data from these social networking engagements will be assessed via analytic engines
- Test and evaluate additional elements of automation, including recharging, obstacle detection, safety, and reliability

All of these specific demonstrations provide the testing platform and eventual foundation for the full vision of a SmartRaleigh. The results will be brought to scale to match growth in technology, such as connected and driverless cars.

Why us, Why now? Raleigh is the 4th fastest growing city in the US and, while it does not experience the sustained traffic congestion of an Atlanta or a Washington, DC, transportation demand will quickly outstrip capacity if the status quo is maintained. It is our belief that a smart city is one that grows sustainably without increasing congestion, while minimizing environmental impact. Using emerging technology, such as autonomous and connected cars and on-demand electric fleets, can have dramatic effects on our mobility solutions. While significant adoption of driverless vehicles could be 10 to 20 years out, SmartRaleigh plans to play a proactive role in testing and demonstrating future technologies that can effectively manage (and reduce) our traffic congestion, increase traveler safety, and enhance air quality, even with the anticipated 50% population growth in our city from 2010 to 2030. Raleigh's 2014 population of 439,896 is a 59% increase from 2000 and a 9% increase from 2010.

Driven by the challenges of rapid growth and associated traffic congestion mentioned above, Wake County is planning for a half-cent sales tax referendum in November 2016 to support a new county-wide transit plan with an investment of $2.4 billion over the next 10 years. The plan includes a significant increase in the number of buses, bus routes, and bus frequencies, along with a new commuter rail system. The plan establishes a number of high-frequency bus corridors and a commuter rail corridor. With anticipated bus capital purchases, there is a rare opportunity to make strategic decisions with upfront investment that can have considerable long-term benefits by reducing carbon impact and increasing safety. Among the opportunities include CNG conversion and electrification of buses with fast charging infrastructure through a smart grid. Further, the addition of obstacle detection technology on fleet vehicles for collision avoidance and data collection would greatly improve safety and urban planning. In fact, Raleigh has created targets for City fleet transformation and other strategies that have been identified in our Fuel and Fleet Transformation Plan, Climate Energy Action Plan, and our City of Raleigh Strategic Plan.

Raleigh is also technology-ready, having been chosen as one of Google's early cities for Google Fiber installation and already an AT&T GigaPower fiber city. Currently, there are Google and AT&T construction sites throughout Raleigh, and both companies are partnering with Raleigh to create novel uses of the connected city. Other factors that make Raleigh an ideal city for this demonstration project are:

- Raleigh is a partner in the open government community and strives to become a worldwide model for an open source city through the Open Raleigh initiative
- Raleigh's Capital Area Metropolitan Planning Organization (CAMPO) is a primary stakeholder in the development and updating of the Raleigh's strategic plan
- Raleigh (along with Indianapolis and Portland, OR) was chosen by the Rocky Mountain Institute to participate in Project Get Ready, an initiative designed to help prepare for electric vehicles
- Raleigh is an active site for Uber, Zipcar, and Lyft
- TransLoc, an NC State start-up head-quartered in the Triangle, has recently announced a partnership with Uber specific to Raleigh
- Raleigh's Regional Transportation Alliance is an active business coalition that provides a strategic, action-oriented focus and a powerful, collaborative voice to advance regional transportation solutions
- The EPA's campus in Research Triangle Park houses 15 EPA offices, including EPA's major center for air pollution research and regulation. As the largest facility ever built by the agency, the RTP campus covers nearly 1.2 million square feet

- Raleigh is highly ranked for human capital, as this area has one of the most highly educated populations in the country, with some of the highest rates of college degrees and PhDs[1].

In other words, high growth, combined with major transportation investments, uniquely situates Raleigh as an accelerated test-bed for novel solutions to managing transportation. High growth will allow Raleigh to test effectiveness of proposed "smart city" approaches more quickly by stress-testing the system. With the Wake County Transit Plan[2] in full swing, our proposal aims to look at solutions that augment and facilitate our vision with novel solutions.

Strong partnership base with emphasis on analytics - A natural partner of Raleigh is NC State University (NC State), located within the heart of the city. For instance, we will partner with NC State to assess and demonstrate autonomous systems. NC State's EcoPRT initiative focuses on small, lightweight electric cars that can run on traditional roadways at grade or on new elevated guideways, and whose price point is significantly lower than traditional roads and other PRT systems. EcoPRT will further serve as a proving ground for additional elements of automation.

NC State is also a nationally recognized hub of excellence in data science and analytics and is home to several core facilities and resources related to analytics (e.g., Institute for Advanced Analytics, Laboratory of Analytic Sciences, FREEDM and ASSIST NSF Engineering Research Centers, Center for Geospatial Analytics, Institute of Next generation IT Systems, and PowerAmerica Institute). NC State is also home to the Institute for Transportation Research and Education (ITRE). ITRE is an inter-institutional research center which conducts surface, water, and air transportation research and training.

Similarly, just adjacent to Raleigh is the Research Triangle Park (RTP) area, a global epicenter and model of technological innovation. RTP houses over 200 high-tech companies and agencies - giants such as IBM, Cisco, NetApp, EMC, GlaxoSmithKline, and the EPA. We will utilize this pool of existing resources and expertise to establish a platform for using analytics in developing innovative and smart solutions to the chronic problem of congestion in Raleigh. For instance, the Research Triangle Cleantech Cluster (RTCC) is focused on accelerating the growth of the Research Triangle Region's cleantech economy. Partner companies include ABB, Cisco, Duke Energy, SAS, Schneider Electric, RTI International, and the EPA.

Especially notable is the catalyzing impact of NC State's Centennial Campus, home to over 72 industrial, government, and academic partners. It integrates academic, industry, and government research partners to yield an award-winning model for an extremely successful collaborative education, research, and translation environment.

We believe our paradigm of *data - knowledge - action* will be critical for improving our transportation system and, in turn, ensuring our economic productivity well into the future. Therefore, the convergence of NC State and pioneer industry partners, coupled with the strong commitment of city leadership, makes Raleigh the hotbed of innovation required to be a smart city.

Impact: As described above, we propose to demonstrate the foundation pieces for the smart city of the future today. We anticipate our demonstration results will enable individuals to respond to

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[1] http://www.indyweek.com/news/archives/2015/10/30/raleigh-sixth-most-future-ready-city-says-american-privately-owned-multinational-computer-technology-company

[2] waketransit.com

real-time data made available to them and, correspondingly, our city can react in real time to facilitate an individual's travel. Whether using automobile, bicycle, or bus, our coordinated ability to dynamically affect routes, speed, and traffic signals will benefit travelers by enabling more efficient, safer, and affordable travel. Raleigh and other cities adopting our approach will also benefit through the agglomeration of real-time data to facilitate active control of traffic volume and mobility. Awareness of the surrounding congestion, roads incidents, etc., will be facilitated through sensing systems at the user and infrastructure levels and the exchange of data with connected vehicles (V2V, V2I). Shared, on-demand, autonomous vehicles can significantly reduce the burden of car ownership and increase user mobility choices, while helping better serve the underprivileged. Bus automation will offer the potential to significantly enhance air quality, reduce congestion, increase user mobility, and reduce operating costs. The proposed approaches will also impact land use planning and will be instrumental in adding strategic data in planning for a more sustainable city and allowing decisions to be made on current information and not 10-year-old studies.

Once implemented and proven, Raleigh can expand and other cities will readily be able to replicate an intelligent, automated transportation solution allowing dozens of congested, carbon-polluting cities across the US to immediately begin implementing a smart city approach.

2.0   Population characteristics of Raleigh and its alignment with USDOT's characteristics

As per Census 2010, Raleigh's population was 403,892, of which 208,749 (51.7%) were females and 195,143 (48.3%) were males. Approximately 57.5% of the population was white and 29.3% African American. Approximately 7.2% of the population in 2010 was under five years of age, 23.1% was under 18 years of age, and 8.2% was 65 years of age or older, as compared to 6.6%, 23.9%, and 12.9%, respectively, in the state of North Carolina. The education levels of Raleigh's population were also better that of the state as a whole. Approximately 90% of the population (age 25+) had a high school diploma or higher, as compared to 84.9% in NC. Raleigh's average annual unemployment rate of 7.3% in 2010 was lower than the rates for both North Carolina (10.5%) and the US (9.6%). The percentage of the population (age 25+) with a bachelor's degree or higher was 47.5%, as compared to 27.3% in the state.

In 2010, the total land area was 142.9 square miles, which resulted in a population density of 2,826.3 people per square mile. The current population density is now over 3,000 people per square mile. Raleigh is classified as an urban area, and its population count is based on the number of people living within its city limits. Raleigh is part of two other important multi-jurisdictional urban areas: the Raleigh-Cary Metropolitan Statistical Area (MSA) and the Raleigh-Durham-Chapel Hill Combined Statistical Area (CSA).

3.0   Raleigh's other characteristics and alignment with USDOT's characteristics

a. Existing public transportation system: Raleigh currently operates the GoRaleigh transit system, which has an annual operating budget of $29 million. The system carries approximately 21,000 riders daily on 32 routes across Raleigh with a fleet of 98 buses. GoRaleigh maintains partnerships with regional transit provider GoTriangle and NC State's WolfLine transit service to provide comprehensive transit options to Raleigh's citizens. Wolfline has 15,000 daily riders with 13 routes, and GoTriangle has 16 bus routes within Raleigh that serve 2,900 daily riders.

b. Environment that is conducive to demonstrating proposed strategies: Please see Section 1.0 (page 5) "Why us, Why now" for a list of factors and characteristics that uniquely position Raleigh to demonstrate novel smart city solutions.

c. Continuity of committed leadership and capacity to carry out the demonstration throughout the period of performance: The current Raleigh City Council took office in December 2015 and has already given direction to City staff regarding its desire to foster and encourage innovation. In 2015, Raleigh adopted a new strategic plan with a specific objective to establish Raleigh as the leader in transportation innovation. This objective was accompanied by two specific initiatives: 1) Identify and implement pilot projects to test transportation innovations for widespread use; and 2) Examine and plan for alternative-fuel technologies for transit services. The Smart City challenge provides Raleigh with the perfect opportunity to act on these initiatives. Additionally, the combination of the City of Raleigh with NC State provides a wealth of partnership opportunities (as described in Sections 1 and 7) to provide both the access to emerging transportation technology and the manpower to advance these new ideas.

d. Commitment to integrating with the sharing economy: Raleigh has a nascent but growing sharing economy. Our market now features ride or car-sharing companies Uber, Zipcar, and Lyft, which have provided an additional layer to our transportation system that has complemented our growing central business district. While not transportation-related, Raleigh has also been working with Airbnb for the past year to develop a system of regulation that brings these short-term rentals into line with our existing zoning and regulatory frameworks.

e. Clear commitment to making open, machine-readable data accessible, discoverable, and usable by the public to fuel entrepreneurship and innovation: Raleigh has a long history of open data, including an open data portal, an open data program, and an open government council resolution (2012). Raleigh currently pursues three primary programs under the Open Raleigh banner: an Open Data Portal, an effort to expand Internet access, and a regional broadband network initiative. The Open Data Portal lets city residents search and browse data sets and visualizations covering such areas as budget, building permits, and fire incidents. City employees can access and analyze the data as well. In the near future, Raleigh plans to expand securely the Open Data Portal, while preserving the privacy of users and data owners. Raleigh is also working with other local governments (Cary, Durham) to make the portal a shared resource. Another Open Raleigh program seeks to expand Internet access in underserved areas. Raleigh and its partners are also planning to establish the North Carolina Next Generation Network, or NCNGN, a regional project to develop high-speed broadband services. The project seeks to "create a gigabit, fiber network to foster innovation, drive job creation, and stimulate economic growth." ATT and Google currently are laying massive amounts of fiber to bring gigabit speeds to homes

throughout the city of Raleigh. Raleigh is also labeled as the "Open Source" city[1], with Red Hat located in downtown. In an effort to build on this culture of openness and transparency, Raleigh is committed to carrying on these principles across the full breadth of this project.

4.0   Provide an Annotated Preliminary Site Map

The following annotated map identifies the specific geographic location for the proposed demonstration project and includes annotated notes. Western Boulevard and Avent Ferry Road will serve as demonstration sites to determine the feasibility, effectiveness, and applicability of Smart Travel and Sustainable Smart Fleet approaches. NC State's Centennial Campus will serve as the test-bed for the first/last-mile problem automation approaches. Our goal in Years 2 and 3 will be to extend EcoPRT to connect Centennial Campus and Central Campus at NC State. Raleigh also has a robust sensor based infrastructure, comprised of traffic monitoring cameras, microwave radar sensors, network-level probes, and micro weather stations that are augmented by an Ethernet-based single mode redundant fiber optic network that communicates and manages over 620 traffic control devices. Traffic counts, speed distributions, and volume readings are currently collected on all network links. Further instrumenting our city and adding intelligent analytics will allow Raleigh to better make both tactical and strategic transportation decisions.

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[1] http://raleighpublicrecord.org/news/city-council/2012/01/25/committee-passes-open-source-city-resolution/

EcoPRT

EcoPRT represents a new and revolutionary way to think about transportation in urban and suburban environments. EcoPRT starts with a foundation that includes all of the advantages of a normal PRT (Personal Rapid Transit) system and then adds two important additional factors.

1 Light weight: Key aspects of the EcoPRT are to shrink and lighten both vehicles and guideway as much as possible, both to save space and to eliminate unneeded costs.

2 Dual mode: EcoPRT vehicles can operate on existing roads and paths as well as on dedicated elevated guideways.

Data Analytics

High crash location data helps to prioritize safety as one of the key outcome for our sensor based infrastructure

Sensor Based Infrastructure

Traffic monitoring cameras, microwave radar sensors, network-level probes, and micro weather stations are some of the hardware that will help inform our smart city.

Congested Corridor
Western Blvd

Western Blvd is a candidate for BRT service through the regional Wake County Transit Plan. Instrumentation will enable efficiency, safety, and accessibility gains across all modes of transportation in this corridor
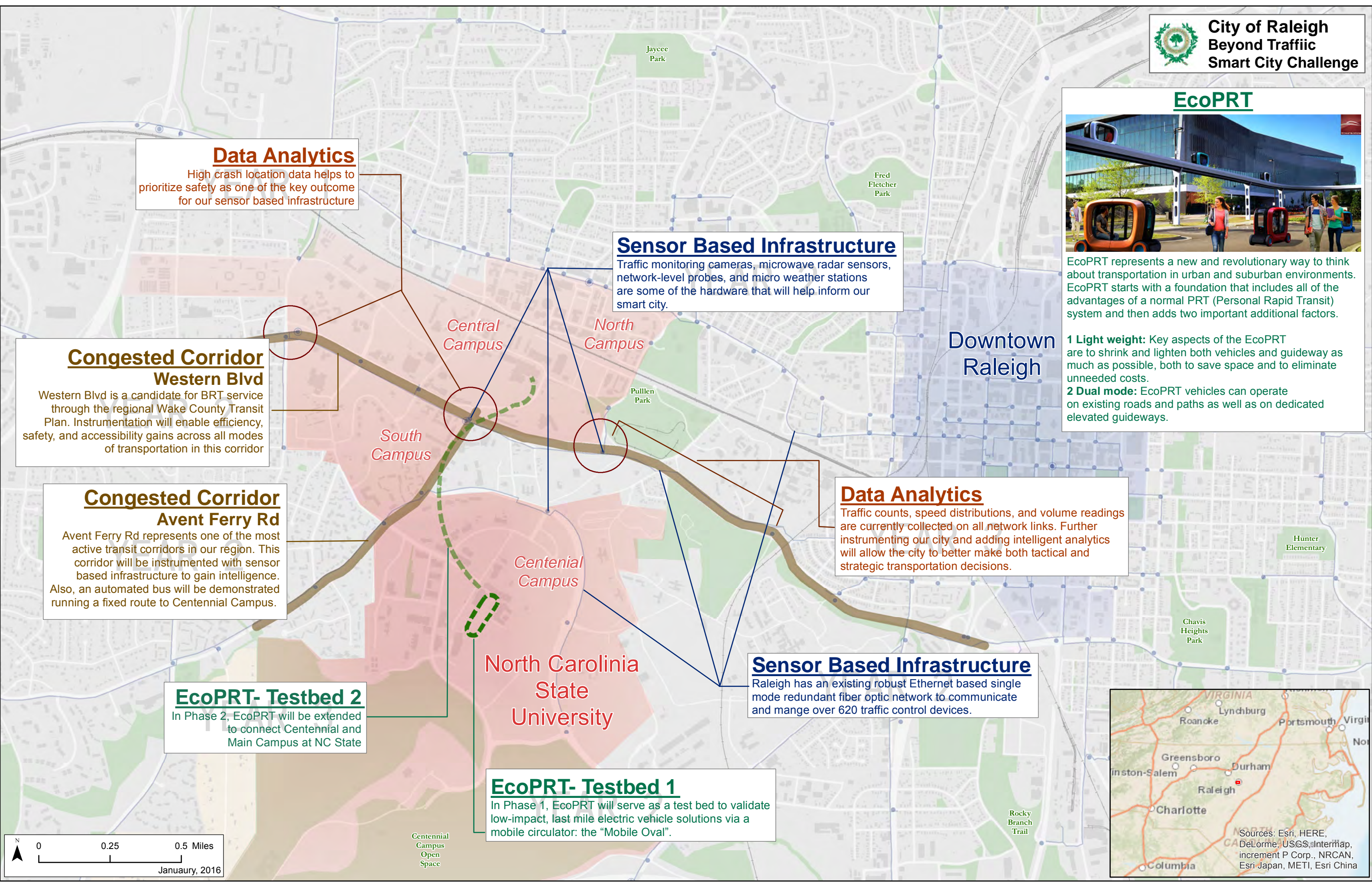
Congested Corridor
Avent Ferry Rd

Avent Ferry Rd represents one of the most active transit corridors in our region. This corridor will be instrumented with sensor based infrastructure to gain intelligence. Also, an automated bus will be demonstrated running a fixed route to Centennial Campus.

Data Analytics

Traffic counts, speed distributions, and volume readings are currently collected on all network links. Further instrumenting our city and adding intelligent analytics will allow the city to better make both tactical and strategic transportation decisions.

Sensor Based Infrastructure

Raleigh has an existing robust Ethernet based single mode redundant fiber optic network to communicate and mange over 620 traffic control devices.

EcoPRT- Testbed 2

In Phase 2, EcoPRT will be extended to connect Centennial and Main Campus at NC State

EcoPRT- Testbed 1

In Phase 1, EcoPRT will serve as a test bed to validate low-impact, last mile electric vehicle solutions via a mobile circulator: the "Mobile Oval".

Downtown Raleigh

Central Campus

North Campus

Pullen Park

South Campus

Centenial Campus

North Carolinia State University

Centennial Campus Open Space

Jaycee Park

Fred Fletcher Park

Hunter Elementary

Chavis Heights Park

Rocky Branch Trail

0   0.25   0.5 Miles

Janaury, 2016
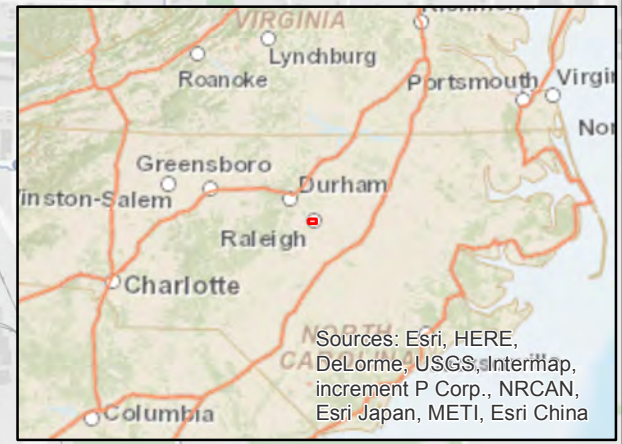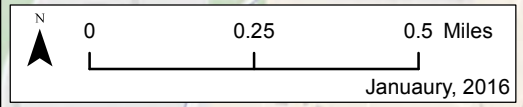
5.0 Describe how your holistic, integrated approach aligns to the 12 Vision Elements

Within the context of the vision described in Section 1, our 12 vision elements briefly describe the technologies and approaches we will demonstrate for future implementation.

VE #1: Urban Automation. Raleigh proposes to:

- Demonstrate an automated transit bus operating on a fixed route in the city. The test area will initially be on Centennial Campus, then later expanded to include Avent Ferry Road. Even when automated, SOVs may not significantly reduce congestion. With the advent of automated buses, however, there is an opportunity to dramatically improve corridor capacity while reducing costs. The question is not whether the technology is ready - already almost every major vehicle manufacturer is integrating autonomous technologies into their vehicles - it is: how can we develop a blueprint for cities to follow to accelerate adoption of automated buses? In fact, autonomous driving on fixed (predictable) routes represents a simpler problem than the generalized autonomous driving scenario. Further, the proposed route is along one of the instrumented corridors providing opportunities to evaluate performance based on interaction with the SmartRaleigh system. The process from evaluation to setup to demonstration will enable us to develop guidance and a framework for adopting automated buses for other cities to follow. For the test platform, a transit vehicle will be retrofitted with autonomous driving technology. Key aspects of study include: 1) vehicle and autonomous technology selection; 2) route preparation; 3) back-end operations management; 4) passenger interaction; 5) contingency events (anomalous events requiring human intervention); and 5) efficacy.

- Put into service small, automated vehicles that can run at grade, or on inexpensive and easily installed elevated guideway as part of the Economical Personal Rapid Transit system (EcoPRT)[1].

Figure 2. Artist's rendering of EcoPRT courtesy of Technicon Design.

EcoPRT is an automated people mover developed at NC State in partnership with Technicon Design, an automotive design and engineering company. EcoPRT differs from traditional PRT systems along two key principles: dual mode and light weight. First, EcoPRT, a rubber-tired vehicle, is designed to run as a dual mode vehicle. EcoPRT vehicles operate like traditional driverless vehicles on existing roads and also travel on dedicated elevated guideways like traditional PRT systems. Already, we are seeing a trend in this direction. Recently, the Heathrow Ultra PRT solution will be retrofitted to run on existing roads in London[2]. Compared to traditional PRT systems, EcoPRT vehicles are also extremely light weight. This is echoed in Dr. Anderson's[3] review of PRT

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[1] http://www.ecoprt.com

[2] Jane Wakefield, "London's first driverless cars based on Heathrow 'pods'" BBC News, Jan. 26, 2016

[3] Anderson, J. E. (2005) "The Future of High Capacity PRT," white paper, PRT International, LLC Minneapolis, MN, November 2005. (accessed Jan 2016 jpods.com/JPods/004Studies/FutureofHCPRT-Jan606.doc)

systems. In comparing Morgantown, PRT2000, and Taxi2000, Anderson notes a direct correlation to system cost and the vehicle weight. A table of can be seen below.

Table 1. Weights and install costs of PRT vehicles

	Year First Run	Gross Vehicle Mass (Kg)	System Install Cost ($/mile)
Morgantown PRT	1972	5,350	$40M
PRT 2000	1995	3,000	$40M
Ultra PRT	2009	1,300	$15M to $20M
EcoPRT	2017*	450	$3M to $5M

(* projected first run)

Recent estimates from Kimley-Horn and Associates, a civil engineering design firm, put fixed guideway costs for EcoPRT at approximately $1 million per mile.

To date, NC State researchers have built a full-size prototype vehicle and a small test track. The Smart City Challenge would enable a fully realizable, end-product demonstration of the system that carries students across campus. Further, the small, light-weight, low-cost nature of the vehicle is a requirement that imposes unique design constraints on the subsystems of the vehicle. The demonstration project will allow us to test additional features of automation including on-the-go electrical charging, low-cost collision avoidance, ADA accessibility, overhead guideway design considerations, compliance with existing PRT/APM design standards, and emergency egress considerations.

At vehicle costs of $10,000 and overhead guideway cost of $1M per mile, a business case can be made for funding through private investment. After a successful first phase at NC State, additional phases can connect and expand the existing system driven by private funding on a market pull approach as opposed to a public push solution. Because of the per-mile pricing model and the low capital costs, the EcoPRT model can be easily replicated in other cities across the US.

VE #2: Connected Vehicles. Raleigh and the RTP region have significant experience with probe and connected vehicle data for the purpose of monitoring the mobility, safety, and environmental performance of the transportation system. Since April 2014, our partners at NC State, assisted by an international partner, have deployed multiple vehicle probes equipped with on-board diagnostics (OBD) devices called i2D (for Intelligence to Drive). i2D is an integrated Car Telematics solution to collect, transfer, and process data, primarily designed to support services and policies associated with road mobility, road safety, and energy efficiency by monitoring and quantifying driving behavior. The system consists of an On-Board Unit (OBU) powered from the vehicle OBD Port, a GPS receiver, a triaxial accelerometer, a barometric altimeter, a 4GB internal memory, a GPRS module, and a Bluetooth module for short range communication. M2M Communications with automatic national and international roaming delivers data to a central server for processing and storage and creates a web-based user interface. Once connected, OBU immediately starts recording data and storing it in internal memory. As soon as a data connection is available, the data is sent through the GPRS connection. Although close to real-time (less than 2 seconds delay) communications are possible, in practice data is sent every 23 seconds in order to reduce communication costs. A second communication channel is available for real-time communications enabling VIV (Vehicle-Infrastructure-Vehicle) or V2V (Vehicle to Vehicle) applications. Current connected vehicle applications have focused on basic safety messaging and

on queue warning in a freeway environment. A trip is the basic unit that is reported. Algorithms calculate mobility, safety, fuel use, and emissions and are presented on a secure website to the user in a graphical, easy to understand format.

The system has thus far logged over 30 million data entries of travel, based on the limited fleet of i2D instrumented vehicles roaming in the Raleigh region. Our approach is to use the proposed demonstration to expand the instrumented fleet to 1,000-2,000 i2D-equipped connected vehicle units which will provide broad, high-resolution coverage of the Raleigh city roadway network, with special focus on the priority congested corridor on Western Boulevard, which connects I-40 from the West and downtown Raleigh and adjoining neighborhoods to the East, and its complex intersection with the Avent Ferry arterial road on the NC State campus. We will exploit the collection of high-resolution dynamic data to develop predictive analytics for travel time and other mobility metrics, crash and near incident events, and trip-based energy use and emissions. Further analytical work will assess the utility of real-time connected vehicle information by contrasting the performance of travelers with and without connected vehicle information capability. A key distinguisher of our proposal is the focus on city arterials, as opposed to freeways only. The connected vehicle data constitutes just one piece of the entire big data puzzle, which will need to incorporate other vehicle types in the proposed Raleigh demonstration (e.g., Transit buses, EcoPRT, taxis, Uber, UAVs), as well as infrastructure-based sensing. The latter includes deployed RTMS units, Blue Tooth devices, video surveillance, and third party mobility data (HERE, INRIX, TomTom) accessible to the Raleigh team. Pieces of this integrated database system, including i2D data, are currently being collected and are described elsewhere in the document.

VE #3: Intelligent, Sensor-Based Infrastructure. Proliferation of sensors, actuators, and "smart" objects in urban settings is accelerating. They range from video, photo, gas, and magnetic sensors, to geolocation, sound, and cell and wifi detectors. Information provided is used in a variety of applications that allow monitoring and control of day-to-day operations and active real-time situation awareness. This may include traffic volume, traffic congestion, visibility, air pollution, road conditions, and emergency situations. In fact, a smart phone just affixed to a city vehicle can be a very rich source of information. For example, vibration measurement coupled with accurate location information may be able to tell us the condition of the road surface the vehicle is traveling on (and whether the surface may be in need of repair). When augmented, such platforms could tell us about noise pollution, wireless spectrum pollution, air pollution, vehicle counts, and so on. These mobile sensor platforms can provide information complementary to what fixed sensors offer. In addition, the quality and granularity of the sensor-collected information and the associated analytics is in many situations sufficient to allow proactive control of some factors. For example, situation-aware control of city signaling can translate into proactive congestion control, re-direction of traffic in the case of accidents or maintenance work, and dispatch of emergency vehicles and crews, as well as facilitation of their transit through city.

Framework. Sensor infrastructure and associated analytics platforms need to be engineered correctly and be reliable, secure, credible, and trusted. In the case of video cameras and other identity collection devices (e.g., smart cell phone counters), citizens need to be assured that their privacy and security will not be endangered. Users need to know that the information collected is trustworthy, safe, and secure. Only then will both the city and its citizens be comfortable with the deployment and use of these devices. Essential to this sensor infrastructure are networks that

carry the data collected from the sensors analysis applications. Such networks can range from simple twisted-pair phone lines to fiber-optic links (such as the ones recently installed in the City of Raleigh) to wireless channels that can range from a city-wide canopy to ad hoc WiFi transmissions.

Our entire framework is designed to be future-ready, but useful now. We design our approaches to fit into an overall city infrastructure so that it serves the specific advances we will make during this demonstration project. While we do not assume the existence of specific emerging technology during the lifetime of the project, such as very significant adoption of autonomous cars or automated supply drones, our approach balances the present and the future. It is scalable, and special attention is paid to its sustainability. We are also very aware of urban planning and management, particularly transportation management, dimensions of time, space, and transportation modes, since our initial demonstration applications will focus on transportation applications.

At the heart of the whole operation is information and data feeding SmartRaleigh analytics and management algorithms, dashboards and decisions (i.e., an information system that will have an unprecedented level of intelligence and self-learning). For example, one of the components of this system will be an IBM Watson[1] solution that we will train in Smart City analytics. For many SmartRaleigh applications, the source will be what could be called "BigData" – terabytes of data that will need to be aggregated, fused with other sources, and managed.

In order to achieve this, we propose to extend the existing City of Raleigh sensor, actuator, and smart-node pool, and situation analysis and management analytics environment, with real-time (reactive and proactive), short-term, and long-term analytics solutions. Data would be collected from a variety of sources – city-owned static and mobile sensors, vehicles in the city, regional information systems, and national resources such as Google Maps. Weather and climate data would come from national and local sources (including satellite derived data), and information will be collected from specialized platforms and services that collectively may cover much of the city roads on a daily basis, such as trash collection, city transportation, Uber and taxi services, county school buses, and potential use of Unmanned Aerial Vehicles (UAVs).

It will be important that the data and interfaces to the data and framework platforms are usability aware. We plan to leverage NC State's extensive engineering knowledge and experience in the Cloud Computing and Data Science and Analytics domain, along with the expertise our industrial partners have – IBM, Cisco, SAS Institute, NetApp, LexusNexis, etc. – to stand-up the SmartRaleigh framework as a flexible distributed sensor and cloud computing solution that will host a variety of applications and tools. NC State has been operating a production-level private cloud (called VCL) for over a decade. More recently, VCL interoperates with commercial cloud offerings (e.g., Amazon and IBM). NC State is also in the process of developing an NC-wide university data science and analytics cloud environment and data-bus (called iRODS). The SmartRaleigh test platform of production quality will be developed in this context. We also expect to bring IBM's Watson solution into the analytics framework (see description in VE# 4 - Urban Analytics).

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[1] www.ibm.com/outthink; http://www.ibm.com/smarterplanet/us/en/ibmwatson/;
http://www.ibm.com/cognitive/outthink/

While non-Raleigh data sources will abound, Raleigh-based data collection is much more city specific and, as already mentioned, will consist of sensors (static and mobile), actuators, and smart-nodes. To complement and enhance the sensors and actuators, we will use a set of smart nodes distributed over the city. Some of these will be fixed, mounted on either existing civil structures, such as traffic signs, or new dedicated ones. Others will be mounted on fleet vehicles. These nodes will embody local computer, networking, and storage capabilities. They will provide localizing capability for mobile sensors and actuators - when a mobile node comes within reach of a smart city node, its location will be captured even if the mobile node is not equipped with GPS.

Smart city nodes can also serve as network connection points for sensors, obviating the need to make every mobile node a cell client. The compute capability of these nodes forms an edge cloud for the computing cloud that will form the back-end of the smart city intelligence and analytics. Specific computing tasks of local importance can be distributed to these nodes dynamically.

Framework architecture will also be enhanced with novel components. For example, the newly emerged discipline of Software-Define Networking and Software-Defined Systems will allow seamless integration of computing and networking at many different levels (so called deep programmability). These nodes can go anywhere on-demand to provide targeted connectivity, localization, and computing power. NC State has considerable expertise in this space.

Future-Ready: In the future, we expect that smart city innovations will come not just from a city, but also from private enterprise and members of the public, at various granularities. Our infrastructure will contain application programmable interfaces, or APIs, to all its capabilities (such as data contribution and data retrieval), thus private enterprises (say an Uber-like service) may use the information system easily to build their own proprietary and value-added analytics. Individual researchers and citizen-scientists may contribute specific ideas. Such ideas will be first run in a simulation using the historical data we will amass, to check for safety and stability. If safe, they will be integrated into our smart city on an ongoing basis. Over time, we expect that more and more cars will become automatic, and our system of APIs will then seamlessly integrate them into the smart city. Other parts of our architecture will also provide additional benefit later. We can envision that our drones will be used to deliver first aid to accident locations in advance of an ambulance. Law enforcement may use the drones to dispatch cameras to locations where crimes are suspected to be in progress. In summary, our project will not just create a smart-city system, but provide a public access smart-city platform, for a city that, as it grows, grows steadily smarter.

VE #4: Urban Analytics. Urban analytics is a broad concept. It covers everything from using data to design a city and its components, to proactively managing its functions and environments, protecting its citizens and improving their well-being, and growing its businesses and economic impact. For example, rapid prototyping may help decide how to deal with congestion and pollution scenarios and where to deploy resources. Real-time models and controls can be used to dynamically control signaling and manage traffic situations and emergencies. In the context of this proposal, we will focus on the data and services relevant to our demonstration projects – Western Boulevard decongestion, the last-mile access Centennial test-bed, and eco impact and friendliness.

Open data is at the core of our SmartRaleigh vision. Our sensor infrastructure allows continuous collection of highly relevant data, our APIs allow contribution of more data by citizen scientists,

and our analytics applications utilize the data to improve citizens' transportation experience in our city. Several analytics applications are enabled by our data infrastructure, which allows integration of up-to-the-minute system information and historic data. Initially, analytics will be driven by established model and current wisdom. Over time, as historical data accumulates, the system will become smarter, as it learns what works better and what does not. The overall goals of the project, as we have pointed out before, are to improve transportation access, reliability, and convenience for citizens.

To make the most effective and efficient use of buses and EcoPRT shuttles, their schedules and routing must be adapted to those who will use them, which our analytics will do. Beyond access itself, the phenomenon of congestion impacts the reliability and convenience of all travelers, whether they use public transport or private, mass transit or single-person cars. A growing mid-size city like Raleigh suffers from intermittent and unpredictable peak congestion. Experience in urban development repeatedly shows that, with growth, this develops into consistent congestion that spreads over time and space. In keeping with our goal of evolving into a smarter city that pioneers a model for sustainable growth, we will use analytics to ameliorate congestion. We propose to approach the analytic problem – what to analyze, to what extent, and how to use the results (in real time, or asynchronously) in two distinct ways.

On one hand, we will use classical analytics engines and approaches. A good deal of theory has been developed showing that it is possible to ameliorate congestion using analytics[1], and many tools are already available. Some may be more general packages such as GIS software, SAS, SPSS and R which we would use to display and develop new algorithms and solutions. This environment would be complemented with mobile apps that would bring into our echo system not only static, city, and NC DOT-provided sensors, but also dynamically collected information emanating from participants in cars, pedestrian smartphones, and possibly special UAV flights. We expect that the amount of raw information will be huge. Full use of that information, particularly when scaling, will require an additional component – cognition. "Cognitive services allow apps to learn, reason, and consider context. The more data that one feeds to an app, the smarter it gets.[2]" IBM, one of our partners in this project, will provide access to the IBM Watson platforms and tools. NC State has considerable experience with artificial intelligence "big data" analytics in a number of domains, and we intend to apply that knowledge and skills to develop Watson-assisted SmartRaleigh components. We plan to train Watson in reactive and proactive congestion management and eco assessment. Of course, the plan is to operate both the "classical" data-driven congestion control mechanisms and the cognition-based solution. The goal is to not

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[1] Examples include:

K. Barry, The Traffic Lights of Tomorrow will Actively Manage Congestion, CityLab, Sept 11, 2014, http://www.citylab.com/commute/2014/09/the-traffic-lights-of-tomorrow-will-actively-manage-congestion/379950/

http://www.cts.virginia.edu/wp-content/uploads/2014/05/Task4._SystemDesign_3_Revised_v.2.pdf Multi-Modal Intelligent Traffic Signal System (MMITSS)

http://dusp.mit.edu/transportation/project/data-analytics-urban-transportation

Sundar, R., Hebbar, S., Golla, V., Implementing Intelligent Traffic Control System for Congestion Control, Ambulance Clearance, and Stolen Vehicle Detection, Sensors Journal, IEEE 15(2):1109-1113, 2014.

P. Hemmerle, M. Koller, H. Rehborn, B.S. Kerner, M. Schreckenberg, Fuel consumption in empirical synchronised flow in urban traffic, IET Intelligent Transport Systems, p8, July 2015

[2] http://www.ibm.com/cloud-computing/bluemix/solutions/watson/

only understand and control a typical set of city road and other data sets, but also to develop an intelligent, Watson-based advisor that can enhance decision-making processes by tracking that information and offering insights we otherwise may not have. While we do not expect to have Watson control traffic in real-time, the learning aspect of our analytics approach will be most beneficial. Simply by estimating congestion in the immediate future along various corridors and providing this information to individuals who are approaching them, or are predicted to approach them from their driving habits, a good deal of benefit can potentially be obtained.

This strategy is also in line with our focus on people rather than traffic. Further, network models of roadways can be utilized to provide drivers with alternate route suggestions. Google Maps already performs most of these functions, but in a city-operated smart system, data is much more comprehensive and such information can be used to manipulate smart speed limits and traffic lights in areas leading up to congested corridors. We must be somewhat cautious about applying such analytics methods, because it has been shown that in some cases such traffic manipulation (whether by people acting individually or by a coordinated system) can lead to worse rather than better situations. This is where the learning aspect of our analytics approach will be most beneficial, and our pilot demonstration projects will provide valuable learning. We will learn what strategies contribute to what impact on the targeted congestion and people's commute experience; for example, whether (or what fraction) of individuals modify their routes upon receiving congestion information and whether they use suggested routes. This will be an ongoing process; as motorist behavior changes due to advancing technology or acceptance of alternate modalities, our smart system will continuously learn the new behaviors. Such changes may be significant - for example, with the introduction of automatic cars, commuters may well become more tolerant of a moderate increase in transit time. Thus over time, the system will seamlessly start improving not just reliability, but convenience and ease of access. There are many other urban analytics uses that will be enabled by the same system of accumulated historical data, detailed models, and smart algorithms. Examples include "what-if" simulations for large projected changes, such as highway construction, new residence construction, or rezoning.

Notably, validation of our overall concept will also be a job of analytics, helping us answer questions like: "Did air quality improve? Can it be attributed to EcoPRT?" or "Did availability (access) and reliability (predictability of transit times) improve for underprivileged citizens?" Another crucial part of such an "introspective" use of the analytics system will be to ensure that it fails safely - the analytics system can detect its own malfunctions by noting "impossible" events (defined a priori, e.g., a car cannot be traveling along a roadway in excess of 100 miles per hour), and reducing trust in corresponding data, or conclusions derived thereof.

For example, data analytics will be used to:
- Predict the impact on roads, highways and public transit networks caused by congestion, planned road-works, or transit maintenance projects, and recommend the optimum change in transit schedules and communication strategy to deal with the impact
- Detect and predict the likely occurrence of everyday unplanned service incidents such as a traffic accident or vehicle breakdown, and recommend optimum responses
- Pinpoint everyday events, such as late-arriving buses, bus breakdowns, or signal outages that have the highest economic impact/cost to a transit agency and recommend ways to eliminate the events or mitigate the economic impact
- Examine the impact of a major commercial or residential development to take into account the relationships between transit usage and other relevant factors such as demographics,

geospatial data (e.g., number of licensed restaurants and other establishments), and commerce/residential activities

- Model and predict the effect of planned expansion of transportation networks with clear understanding of the patterns of usage and the impact of land use and development decisions
- Examine major events such as the NC State Fair to determine specifically where and when services should be adjusted or supplemented to better accommodate visitors and avoid congestion due to additional cars on the road

VE #5: User-Focused Mobility Services and Choices. Individually owned automobiles can be very expensive to citizens (cost of car, maintenance, insurance, parking, etc., estimated at an average cost of $8,600 per car per year), businesses (cost of parking and access) and the city (cost and land consumption of roadways, parking, pollution, runoff, etc.). Yet, at least in relatively low density population areas, they are currently the only option. To many, automobiles provide a sense of independence, timely on-demand transportation, and security. Therefore, assuming that the ultimate goal of a smart city is to provide alternatives to personal automobile ownership, we need to provide mobility options that compare favorably to these qualities of timeliness, security and independence. Our proposal addresses these needs in two ways, with: 1) SmartTravel and 2) EcoPRT.

1) SmartTravel: SmartRaleigh provides the mobility-enabling analytics for the city. SmartTravel provides citizens with the information they need to make intelligent travel decisions in the context of the city's infrastructure and its users. Imagine this scenario. A citizen tells SmartTravel that she wants to travel from Downtown Raleigh to NC State University. Like Google maps on steroids, SmartTravel understands every travel option available to her, along with the cost, time and environmental impact of each. SmartTravel knows that she could ride a bike, take a bus, hail a cab, request an Uber, or take her personal automobile. SmartTravel presents all of these options to her, along with its recommendation: given current traffic conditions, available time, and costs of the different modes, taking the bus is the best option. SmartTravel is discreet and very mindful of the person's privacy, security and safety. Her trip data will be kept confidential, but will help in overall analysis of the city traffic profile. Now, SmartRaleigh takes her travel intention and confidentially combines it with the intentions of tens of thousands of other citizens. What if thousands of people are, for some reason, all intending to travel to the university right now? Then SmartRaleigh may dynamically route more transit buses or feed that knowledge into car sharing companies like Uber or recommend a ride sharing arrangement.

The global knowledge and control available to SmartRaleigh make it possible to solve global optimization problems, for example, dynamically calculate the optimal travel modes and routes for everyone in the city, in real time. Therefore, everyone gets the optimal travel experience possible. Participation from many users improves overall prediction of the system.

2) EcoPRT: With the introduction of EcoPRT, an alternative to the traditional mobility choices is presented. Small, autonomous, on-demand, electric vehicles provide convenient, confidential and personal point-to-point transit for the last mile.

As one example, imagine a typical commuter in downtown Raleigh or RTP today. During rush hour, buses, cars, and taxis share the same road and therefore are all affected by congestion. The most significant transit need in any growing city is an inexpensive way to add transit capacity. Raleigh will therefore demonstrate a new low-cost transit modality called EcoPRT. EcoPRT will allow the city to easily and inexpensively add new transit capacity in the form of lightweight,

narrow, and, where necessary, elevated EcoPRT guideways. The connection between NC State University's Central and Centennial Campuses offers a simple example of the problem and solution. Currently, this corridor is highly congested during peak periods because not only are commuters driving through the university, but also students and staff themselves are shuttling across the 34,000 student university. There is no room to add additional lanes in the tight urban area, nor is it cost effective. Adding an EcoPRT guideway would be a simple solution that could easily and inexpensively create significant new capacity in the corridor. Now that the new capacity exists, how can people utilize it? The SmartRaleigh information service will show Raleigh commuters all of the available transit modalities, the respective travel times of each, and the environmental impact. The hope is that as the EcoPRT system and other travel options expand, more and more trips will switch away from cars, until citizens can see a natural path to eliminating car ownership.

Traditionally, suburban neighborhoods have had little uptake on public transit because transit stops were too far away to effectively serve the population. As a further pain point, the disabled, the young, the elderly, and the underprivileged may not have access to a private automobile. As an alternative, EcoPRT's small, on-demand, electric, autonomous vehicles could provide an inexpensive circulator solution within a neighborhood with a connection point at a transit stop. Individuals could simply call up a vehicle to their house through the cell phone. The vehicles could pick up one or more people and bring them to the transit stop. As a public transit enabler, EcoPRT could bring transit to the doorstep of those who do not have reliable access to the private automobile and at the same time increase adoption of sustainable transit.

VE #6: Urban Delivery and Logistics. While this is not a key component of SmartRaleigh, NC State has considerable expertise in logistics analysis. Dr. George List (Civil Engineering) has authored works such as the "The Statewide Logistics Plan," which aims to "address the State's long term economic, mobility, and infrastructure"[1]. Additional work from ITRE examines logistics villages as a means for economic development[2].

The cost of delivery within a city can be affected by congestion and the inability to park in front of buildings. Some cities like Boston have contemplated separate traffic lanes for trucks and automobiles to minimize interference. As previously mentioned, the proposed SmartRaleigh solution facilitates coordinated movement of vehicles on the road network without the need for separated lanes. With the ability for logistics companies like UPS and Fedex to interface into SmartRaleigh, their delivery vehicles could also benefit by optimizing their route to minimize cost and time.

Intra-city courier services fill a need for on-demand product delivery within a city. Costs can be relatively high, which provides opportunities for companies like Uber to enter the market with their shared driver model. One step further, driverless vehicle systems such as EcoPRT could be leveraged to move not just people but also shipments, creating the foundation for a low-cost

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[1] George List, PhD, PE, "Statewide Logistics Plan for North Carolina," North Carolina Office of State Budget and Management, 2008.

[2] Robert Foyle, P.E., "An Investigation of Economic Development in North Carolina through Logistics Villages," ITRE, Final Report, Dec. 2011.

automated delivery system. Research in NC State's Industrial Engineering Department is investigating home delivery logistics using driverless delivery vehicles[1].

VE #7: Strategic Business Models and Partnering Opportunities. Raleigh's vision necessitates the careful orchestration of many leading-edge sub-systems into a cohesive, innovative, and holistic system. This will require a coalition of numerous multi-disciplined and innovative entities, with strong visionary leadership. With this in mind, Raleigh is partnering with NC State to co-lead the Smart City effort via a cooperative agreement and governance structure to leverage the extensive resources of each. NC State, the flagship university of the 17-campus UNC System, with 34,000 students, and the 4th largest Engineering College in the US, is uniquely positioned with its award winning Centennial "Partnership" Campus with extensive industrial and federal relationships into the mix. It is also one of three Research One universities (Duke, NC State, and UNC) that comprise the Research Triangle.

Additionally, Raleigh will strategically engage partners to integrate critical technology and solution elements into the proposed holistic approach. Most of the partners reside in this region's high tech corridor and RTP and are in close proximity to facilitate efficient engagement. Another part of the strategy will be to "pair" these external partners with Raleigh operational units (e.g., EMS, Transit, Traffic, IT) and NC State (e.g., Centers, Institutes, Labs, IT). In this respect, the network of partners will be aligned with the work-scope elements to achieve the functional objectives. Note that many of these partners have demonstrated a willingness to participate via support letters. This collaborative structure will bring together a strong coalition of triple helix partners from industry, other government units, and academia. An executive advisory board representing the City, University, and principal partners will also be included as part of the governance model.

The point-of-contact for Raleigh is Eric Lamb, Manager of Transportation Planning, reporting to Planning Director Ken Bowers. For NC State, the point-of-contact is Dennis Kekas, Associate Vice Chancellor of Partnerships and Economic Development, reporting to Alan Rebar, the Vice Chancellor for Research, Innovation, and Economic Development.

VE #8: Smart Grid, Roadway Electrification, and Electric Vehicles. The demonstration approach to achieve smart grid roadway electrification, including electric vehicles, will be comprised of two main thrusts. One will focus on rapid dynamic vehicle charging and other strategies for both large electric vehicles like buses/trucks, and the other on small electric last-mile pod cars. Both will involve instrumented test beds located on NC State's Centennial Campus "proving ground" to leverage a smart DC micro grid planned to be located on Main Campus Drive of the Centennial Campus in the near future, connecting the NC State-led NSF FREEDM (smart grid) Systems Center to ABB's Smart Grid Demonstration Center. This cooperative effort includes FREEDM, the University Smart Grid Council, RTP Clean Tech Cluster and campus tenants such as ABB. The DOE/NC State PowerAmerica National Manufacturing Innovation Institute is also involved in commercializing extraordinarily efficient wide-band-gap power-electronics to efficiently drive electric motors and connect renewable sources (wind, solar) to the grid. The NC State-led NSF ASSIST center is focused on self-powered sensors for many smart applications (medical uses, vehicles, etc.). These leading-edge resources will facilitate assessment of solution elements for smart city deployment.

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[1] Michael Kay, "Design and Control of Home Delivery Logistics Networks," Industrial Engineering Colloquium at Penn. State, 2015.

The test beds will be two-fold and evolutionary, with an objective of tech transfer to spur early mass adoption. A last mile "Oval Mobile" EcoPRT circulator will be implemented on the Centennial Campus Engineering Oval. This one-mile test bed will exploit in-motion inductive charging, V2V and V2I communications, user (students) interactions, energy efficiency, safety, autonomous controls, etc. Telemetry data will be sent via the existing outdoor Centmesh programmable test bed in the Centennial Campus. The second test bed will be implemented along Main Campus Drive with High Voltage rapid charging stations at strategic locations to assess functionality, reliability, cost structures, and other parameters. The objective would be to evaluate emerging WBG technologies that will be much smaller, more efficient and cost effective. These are being developed by FREEDM and PowerAmerica faculty/partners. A major partner for this test bed will be ABB, located on Centennial Campus with over 500 employees.

VE #9: Connected, Involved Citizens. The benefits of SmartRaleigh solutions must be clear to the citizens of Raleigh; therefore it is crucial to obtain input and feedback from Raleigh citizens regarding user preferences, reliability, ease of use, and affordability of the proposed SmartRaleigh solutions. In addition to hosting on-site public input meetings each quarter, Raleigh will embrace citizen engagement by providing an online app for citizens to learn more about the project and provide a mechanism to allow the citizens and Raleigh to have an open conversation with city officials and planners. This tool will allow Raleigh to get feedback in an informal way as well provide a mechanism (such as smart phones) to capture digital dialog around the proposed demonstration project in general. It is important to note that Raleigh currently publishes 100+ datasets from crime locations to lane closures[1]. Citizen feedback data will be published on this website.

VE #10: Architecture and Standards. Development of transportation elements of the Raleigh Smart vision will be guided by the regional ITS architecture defined in the 2010 update to the Triangle Region Intelligent Transportation System Strategic Deployment Plan. The Capital Area Metropolitan Planning Organization (CAMPO) was a primary stakeholder in the development and updating of the strategic plan. The strategic plan and architecture development effort included the identification of published ITS standards applicable to the current and planned ITS user services. Therefore, key architecture features and ITS standards have been identified for vision elements such as transit signal priority and ramp metering. This update occurred just prior to the rapid upswing in interest and activity in connected and autonomous vehicles. The USDOT ITS Joint Programs office and NHTSA are actively sponsoring and overseeing programs to develop the necessary architecture and standards for connected and autonomous vehicles. As described in more detail in Section 10 below, the SmartRaleigh team will play an important role in advancing these architecture and standard development activities.

VE #11: Low-Cost, Efficient, Secure, and Resilient Information and Communications Technology. The backbone of SmartRaleigh is a distributed infrastructure of computing and storage capacity, connected by a high-speed network. Fortunately, much of this infrastructure already exists in the region, and will be enhanced as needed.

Networking. The state of North Carolina, especially the Triangle area (comprising the cities of Raleigh, Durham and Chapel Hill), was one of those to first adopt a regional optical network, enabling an information superhighway. The North Carolina Research and Educational Network

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[1] (http://data.raleighnc.gov/)

(NCREN), with a resilient ring-based architecture, has evolved to continue providing advanced networking services. It now provides various Internet2 services as well as connectivity to very high-speed National Lambda Rail. In the last two years, MCNC (regional networking hub) has started operations to provide a Software Defined Network service, with NC State as one of the partners. In addition, Google chose Raleigh for one of its earliest Google Fiber deployments, which is currently being installed in Raleigh.

Computing. Cloud computing has come to maturity, and basic variants are now considered commodity. NC State developed its own cloud technology, the Virtual Computing Lab (VCL), over 10 years ago. VCL is now an open source code Apache Foundation product and continues to evolve. At this time, it serves a population of 40,000 students and faculty and allows flexible, scheduled reservation, both of virtual and as bare metal machines, with integrated floating license management and authentication mechanisms. A number of NC Community Colleges are also being served. VCL has the advantage that it can be customized as our needs develop through the planned smart city demonstration project. VCL also allows leveraging of commodity cloud computing offerings such as Amazon's EC2, IBM SoftLayer, and SAS OnDemand for Academics. We are also in the process of developing an NC-wide university data science and analytics cloud environment and data-bus (iRODS). The SmartRaleigh platform of production quality will be developed in this context.

Figure 3. Envisioned SmartRaleigh data management, networking, and analytics framework

Analytics. To achieve a high level of analytics capability along with the appropriate security level, we will leverage the knowledge and experience NC State has in the Cloud Computing and Data Science and Analytics domains, along with the expertise of our industrial partners – including IBM, Cisco, SAS Institute, NetApp, and LexusNexis. The SmartRaleigh framework will host a variety of applications and tools. We also expect to bring IBM's Watson solution into the analytics framework.

Data. The envisioned SmartRaleigh data and analytics framework (Figure 3) will allow four types of data interaction modes:

- Very confidential data that may be only accessible and shared in an isolated environment (e.g., those that may pertain to city and national security).
- Confidential "unmovable" data (perhaps very large-scale) that would be available only to authorized and authenticated individuals and devices. Data sets of this type may be in the terabyte range and may not be easily moved around. There also may be data that for some reason we may not wish to move around even when we can. So, a mechanism will need to exist where computations and desired analytics will be performed close to the data. Authorized users may range from researchers, to traffic engineers, to government organizations (e.g., NC DoT, NC Highway Patrol).
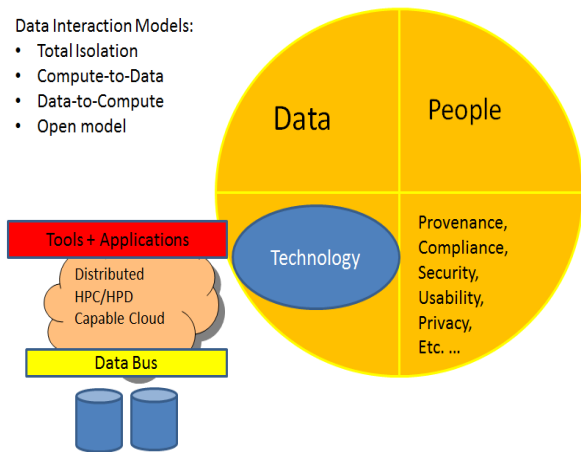
- Confidential "movable" data (often low-volume data from variety of sources; e.g., processed road vibration data and locations that may indicate where pot-holes and road imperfections are) that can be moved if so desired. This data would also be accessed only by authorized and authenticated users, but could be moved to the place of computation (e.g., desktop, another cloud).
- Open data that are made available to the broader public as well as the general SmartRaleigh community (e.g., Google Map information). Different levels of expertise and training will be needed for the users of the data. It is important to note that in order to be reliable, trustworthy, secure, and safe, the SmartRaleigh framework will collect provenance information about the data sources, transactions on the data, users, and so on.

The framework will also be concerned with compliance issues (e.g., privacy and protection of personally identifiable information) and security (e.g., some or all of the data may need to be collected and moved over encrypted channels, and in some cases encryption at rest will be a must).

VE #12: Smart Land Use. For many years, Raleigh has utilized a comprehensive plan to guide the growth and development of the community. Updated in 2009, the 2030 Raleigh Comprehensive Plan establishes a vision for the City that demonstrates a strong synthesis between land use and transportation. Shortly after that update was completed, Raleigh embarked on developing a Unified Development Ordinance (UDO) that provides the tools for new development to build at a more urban scale. While Raleigh was established as a compact, walkable state capital city in 1792, the majority of its development pattern has been characterized as very low density suburban-scale, most of which occurred post-World War II. With a footprint of 143 square miles, much of Raleigh's development landscape has been dominated by single family homes on quarter-acre lots. The recent trend has been to develop at a more compact urban scale, with renewed interest in developing within our central business district and in our burgeoning Midtown area. Raleigh's UDO is facilitating this development scale and providing for complementary infill development opportunities to help to create more walkable, bikeable, and transit-friendly environments. To accomplish this, the Raleigh UDO has several hallmarks which include prescriptive setbacks/set-to boundaries, new multimodal street cross-sections that promote Complete Streets, and new street grid requirements that scale to development intensity. The end result will be a city that grows responsibly with a complementary transportation system. Raleigh recently partnered with Wake County to complete a new countywide transit plan. In addition to planning for regional rail service, it proposes a substantial expansion of our traditional bus services and introduces Bus Rapid Transit options. In order to be successful, transit operations require sufficient density along major corridors, which Raleigh's UDO facilitates. Gathering multi-modal traffic information for city planning purposes is essential. In addition, individual rezoning/small area plans to more accurately project transportation patterns for various buildout scenarios will be assessed.

6.0 Identify and rate key technical, policy, and institutional risks and discuss plans for mitigating them

Table 2. Project risks and mitigation strategies

Issue	Risk	Plans to mitigate
Involvement	The right people are not included, invited, or available to participate	Outline project team roles Identify key partners and stakeholders
Governance and Support	Executive governance and sponsorship is not properly implemented to support the entirety of the project	Define structure, document role, and develop
Scope creep	One of the more ubiquitous risk in project management, especially applicable to projects involving emerging technology	Provide good project lockdown requirement mechanisms Implement simple but rigorous change management process
Unrealistic schedule	Low or unrealistic work estimates as well as scheduling for non-optimal conditions can lead to project falling behind original schedule	Create realistic schedule, use three-point effort estimates, have teams responsible for work estimate, use actuals from similar past projects
Staff turnover	Continuity of key staff involvement	Develop staffing contingency plans, develop cross training and communication plans
Specification breakdown	Incorrect coordination and communication of technical specifications	With large technology/construction projects, coordination and agreement around specification is very important
Technology and uncertainty	Challenges with functionality /capabilities of emerging technology	Every technology demonstration project has some level of risk just because of the nature of emerging technology

7.0 Outline team partners, key stakeholders, and demonstration governance processes

Partners*:* A natural partner of Raleigh is NC State, located within the heart of the city. NC State is a nationally recognized hub of excellence in data science and analytics and is home to several core facilities and resources related to analytics (e.g., Institute or Advanced Analytics, Laboratory for Analytical Sciences, FREEDM and ASSIST Engineering Research Centers, Center for Geospatial Analytics, Next Generation IT Systems Institute, and PowerAmerica Manufacturing Innovation Institute). Especially notable is the catalyzing impact of NC State's Centennial Campus, home to over 72 industrial, government, and academic partners. Centennial Campus integrates academic, industry, and government research partners to yield an award-winning model for an extremely successful collaborative education, research, and translation environment. NC State's Institution for Transportation Research and Education (ITRE) is also a partner in two University Transportation Centers, a member of the National Center for Strategic Transportation Policies, Investments, and Decisions housed at the University of Maryland, and a partner in STRIDE (Southeastern Transportation Research, Innovation and Development and Education) housed at the University of Florida. These consortia include seven and eight other universities, respectively, and have enabled joint research projects in areas that are germane to the demonstration project in Raleigh. ITRE has also cultivated international partnerships with universities and transportation research entities in Portugal, Sweden, Germany, Korea, and Australia. ITRE is currently partnering with Live Drive, a sustainable mobility enterprise housed in Lisbon, Portugal, which originally conceived the i2D system described in Section 5.b.

Research Triangle Park: located northwest of Raleigh is the Research Triangle Park (RTP) area, a global epicenter and model of technological innovation. RTP houses over 200 high-tech companies and agencies. Therefore, the convergence of NC State and pioneer industry partners, coupled with the strong commitment of city leadership, makes Raleigh the hotbed of innovation required to be a smart city.

Governance: The Raleigh City Council will serve as the Governing Body for the proposed demonstration project. We believe that there is no one route to becoming a smart city. Different approaches should be adopted to address different circumstances. However, three general principles will guide the SmartRaleigh agenda: 1) integration with social and economic development policies and public service delivery plans; 2) pragmatic focus on approaches that are practical, achievable, and financially viable, and 3) participation of community representatives, local businesses, and citizens to ensure projects are relevant to the city's opportunities and challenges. To achieve these aims, the City Council will use information and communication technologies (ICTs) and data to improve citizen participation, implement public policies, and provide public services. A Project Director, jointly identified by the City and NC State, will ensure active participation of citizens and partners to create a sense of ownership and commitment, local-level coordination to ensure integration of SmartRaleigh solutions across the portfolio of city and county initiatives, and participation of city and county departments and partners in implementation of the proposed project.

Existing and future public and/or private partnerships: The following table outlines public and private partners the City of Raleigh would look to engage as needs arise during the demonstration project.

Table 3. Internal and External Partners. External Partners shown in bold have submitted letters of commitment included in this proposal.

Vision Elements	Institutional Partners	External Partners
VE 1: Urban Automation	MAE, ECE, CS, ITRE, EcoPRT, NCDOT, WolfLine	**Red Hat**, **IBM**, **Cisco**, **NCSEA**
VE 2: Connected Vehicles	NCDOT, ITRE, EcoPRT	**Technicon**, **Transloc**, **GoTriangle**, Live Drive
VE 3: Intelligent, Sensor-based Infrastructure	ASSIST, ITRE, NGAT, ECE	**Cisco**, **TransLoc**, **IBM**, **NetApp**, **NCSEA**, Sensus, Wavetronics
VE 4: Urban Analytics	IAA, DSI, ITRE, NCDOT	**IBM**, **SAS**, **LAS**, **NetApp**, **Red Hat**, **Cisco**
VE 5: User-Focused Mobility, service choices	COD, Social Network Analysis at Carolina (part of UNC-CH)	**TransLoc**, **Technicon Design**, **IBM**, **Cisco**, **NetApp**, **Red Hat**
VE 6: Urban Delivery and Logistics	CHASS, COD, COM, NCDOT	**IBM**, **Red Hat**, **TJCoG**
VE 7: Strategic Business Models & Partnering Opportunities	CHASS, COD, COM, NCDOT	**IBM**, **Red Hat**, **TJCoG, RTA**
VE 8: Smart Grid, Roadway Electrification, Electric Vehicles	PA, FREEDM, ECE, NCSU Clean Energy Technology Center	**ABB**, **IBM**, **Technicon**, **RTCC**, **NCSEA**
VE 9: Connected, Involved Citizens	CHASS, COD, COM, NCDOT	**IBM**, **Red Hat**, **TJCoG, NCSEA**
VE 10: Architecture & Standards	ITng, NCDOT, ITRE	**RTCC**
VE 11: Information & Communications Technology	ITng, CS, SoSL, OIT Security	**IBM**, **Red Hat**, **NetApp**, **Cisco**
VE 12: Smart Land Use	COD, UNC-CH	Urban Land Institute

Definitions of Institutional units: *ASSIST*: Advanced Self-powered Systems of Integrated Sensors

& Technology Engineering Research Center (ERC) (NSF Sponsored); *CHASS*: College of Humanities & Social Sciences (human factors, etc.); *COD*: College of Design (Industrial Design & City planning); *COM*: College of Management; *CS*: Computer Science; *DSI*: Data Sciences Initiative; *ECE*: Electrical and Computer Engineering; *FREEDM*: Future Renewable Electric Energy Delivery & Management ERC (NSF Sponsored); *IAA*: Institute for Advanced Analytics; *ITRE*: Institute for Transportation Research and Education; *ITng*: Next Generation IT Systems Institute; *MAE*: Mechanical and Aerospace Engineering; *NCSEA:* NC Sustainable Energy Association; *PA*: PowerAmerica (DOE NMI for Power Electronics); *SoSL*: Science of Security Lablet (NSA Sponsored)

Other Definitions: *LAS*: Lab for Analytical Sciences (NSA Sponsored); *NCDOT*: NC Department of Transportation; *RTA*: Regional Transportation Alliance; *RTCC*: Research Triangle Cleantech Cluster; *TJCoG*: Triangle J Council of Governments.

8.0 Raleigh's existing transportation infrastructure and system features

a. Arterial miles, freeway miles, transit services, and shared-use mobility services: The street network within Raleigh's planning jurisdiction features 54 miles of freeways and over 200 miles of major arterial streets. On this street system, the City's GoRaleigh service operates 98 buses on 32 routes across the City. Two of these routes currently operate with 15-minute headways and cover 14 miles. Under the proposed Wake County Transit Plan, 15-minute services would be dramatically expanded across Raleigh to provide 83 miles of high-frequency routes. In addition to fixed route services, Raleigh also offers a premium paratransit service to people with disabilities. The Accessible Raleigh Transit (ART) program provides subsidized door-to-door transportation service from participating taxi companies to Raleigh's citizens.

Information and communication technology (ICT): Raleigh has recently completed construction of an Ethernet based single mode redundant fiber optic network to communicate and mange over 620 Traffic Control devices. This scalable communication network was designed for resiliency and continuity and now is the primary operational communication network for Raleigh's signal system and traffic CCTVs.

Intelligent Transportation Systems (ITS) including transportation management centers and field equipment: Along with the fiber network mentioned above, Raleigh is in the process of converting its analog-based cameras (which require encoders and decoders) to a digital-based camera system. This camera system will take advantage of our fiber infrastructure as well as power over Ethernet technology to enable plug and play capabilities. The completion of this fiber infrastructure has allowed Raleigh to take on a signal coordination and optimization project. This is approximately 75% complete and has already resulted in: 17.6% reduction in travel times, 2.7 million less pounds of CO_2, and cost savings of ~$41 million in fuel savings and lost time.

Smart Grid Infrastructure including electric vehicle charging infrastructure: Raleigh has installed roughly 30 EV charging stations since 2009 to help drive the local EV market and encourage the local economy to invest in EV vehicles and charging stations (citizens and public and private organizations). There are currently approximately 250 EV charging stations connecting Raleigh to all of the Triangle and major highway systems in the region.

9.0 Data Raleigh currently collects

Members of the SmartRaleigh team at NC State have already begun collecting historical data from state-wide data providers that can be integrated with transportation data in the North

Carolina Transportation Data Warehouse (NCTDW). Each dataset includes data from 2009 to present and covers all or part of the proposed pilot study region. Archived METARS reports, weather reports based on atmospheric monitoring stations, are available at hourly or more frequent intervals depending on changes in weather conditions. Incident and crash data are available when reported to city or state operators with information on location, type of incident, as well as number of lanes impacted. Side-fire microwave radar sensors are placed on all freeways in and around Raleigh and provide speed, volume, and occupancy data for each travel lane at one minute intervals. Probe-based data available in Raleigh include i2D trajectory and vehicle data from instrumented vehicles, as well as link-based data on speeds and travel times from HERE and INRIX for each major roadway in Raleigh including the entirety of the pilot corridor. Additionally, members of the Raleigh Smart Cities team have extensive experience deploying Bluetooth sensors for temporary traffic studies to analyze origin-destination choices and travel times. Each of these datasets is georeferenced, and relationships between datasets have been established to allow for data fusion techniques to be utilized for a unified analysis of traffic operations, safety, and environmental impacts.

Raleigh has a long history of open data including an open data portal, an open data program, and an open government council resolution (2012). In an effort to build on this culture of openness and transparency, we envision carrying on many of these principles across the full breadth of this project.

Open Data: We will proactively release data, while appropriately safeguarding sensitive information, collected via the vast sensor network required for this project. This data will be published in a variety of formats including modern technology to enable real-time data consumption (websockets, streaming services, etc.). In addition to this data, suitable processed data (see analytics section) will be published through this platform as well. This aggregated processed data will be published in a standard and with appropriate licensing so that it can be seamlessly integrated with existing/future best of breed consumer routing and trip planning applications (Google maps, GTFS, etc.). This data will be published alongside existing and future city data such as current bus locations, bus stop locations, next bus predictions, road race locations, road closure information, Capital Projects, Parking meter status, and Parking deck current capacities. Raleigh has a vibrant and active community of civic hackers and civic entrepreneurs. These communities can leverage this real-time data as a platform for innovation for both civic and consumer-grade products and services

Crowdsourcing: As more and more of Raleigh is instrumented, both through assets as well as civic scientists, we will encourage citizens to share this data via citizen to citizen (social media), citizen to city (311, citizen sensors, and citizen scientists), and develop city to citizen (push notifications) models. Additionally, the city will pilot publishing a standard and endpoint for new non-city-based sensors to report a variety of variables (status, condition, speed, temp, etc.), as outlined below.

Table 4. Data collected by the City of Raleigh

Measure	Definition	Data Source
% change in public transportation ridership	Self-explanatory	Raleigh Transit
% Change in annual delay per commuter	Change in amount of time commuters spent getting from home to work and back again.	Inrix/Texas Transportation Institute

Measure	Definition	Data Source
% of commuters using a travel mode to work other than a personal vehicle	Self-explanatory	Census/American Community Survey
Change in miles of bicycle paths/greenways and bike lanes	Tracks miles of greenways and bike lanes built by the City	Raleigh Parks & Recreation/Transportation Planning
Change in miles of Sidewalk	Tracks miles of sidewalks built by the City or by new development	Raleigh Public Works Dept.
Change in miles of streets	Tracks miles of streets built by the City or by new development	Raleigh Public Works Dept.
Pavement condition surveys	Annual review of pavement condition on every city-maintained street	Raleigh Public Works Dept.
% Change in incidents by mode of transportation.	Change in the number of incidents by mode of transportation. Include greenway, sidewalk, transit, road, bike, and pedestrian.	Raleigh Police Dept./Public Works Dept.
% of the population within 1 mile of a greenway	Self-explanatory	Raleigh Parks & Recreation
% of population living within 1/4 mile of public transportation	Self-explanatory	Raleigh Transit
% Change in the number of alternative vehicles in the City's fleet	Self-explanatory	VFS

10.0   Describe your approach for using existing standards, architectures, and certification processes for ITS and connected vehicle based technologies

Raleigh's approach will be founded on the Triangle Region's ITS Regional Architecture. The regional architecture is defined in the March 2010 architecture document and was based on version 6.1 of the National ITS Architecture. The architecture elements were entered into version 4.1 of the Turbo Architecture software tool. The regional architecture development also included identification of standards applicable to the defined user services, service packages (known as market packages at the time), and planned ITS projects. As a first step toward ensuring architecture and standards compliance, the team will translate the 2010 regional architecture to the National ITS Architecture 7.1 and Turbo Architecture 7.1. The second step will be to identify the National ITS Architecture 7.1 elements applicable to the ITS components in the Smart City vision that were not addressed in the 2010 regional architecture. These architecture elements and relevant standards will be added to the regional architecture and Turbo Architecture database. Current applicable standards and standards guidance will be followed for all ITS and connected vehicle technology applications. For example, the National Transportation Communications for ITS Protocol (NTCIP) family of standards will be central to the Smart City vision. As a ground-breaking effort, there will of course be features of the Smart City vision that are not covered by existing architecture elements or standards. For example, although the National ITS Architecture has been aligned with the national connected vehicle program since version 7.0, standards development is lagging in this area. Also, even though there is an Automated Vehicle Operations service package under the Advanced Vehicle Safety Systems user service bundle, neither this service package nor any under the Public Transportation Management user service bundle adequately address the architecture requirements for the EcoPRT vision. Therefore, architecture and standards development will be a key activity of the SmartRaleigh effort.

Plans for documenting experiences and cooperating with architecture and standards developers to improve quality of these products based on lessons learned in deployment: Creating new standards requires a comprehensive and inclusive approach. There are many examples of standards bodies that have well-defined processes for developing, submitting, and approving standards within the transportation ecosystem. The project will use the appropriate existing open standards in order to achieve maximum extensibility and application to other locations and environments. Where existing standards are lacking, we will collaborate with the existing standards bodies to develop the needed solutions. The SmartRaleigh team has firsthand experience leading this type of standards development effort. Specifically, members of the team were part of the leadership team for development of the Digital Interchange for Geotechnical and Geoenvironmental Specialists (DIGGS, diggs.org) Schema, a new international standard first released in 2008. The DIGGS Schema is an XML-based, GML-compliant transportation data transfer standard developed as a collaborative effort under Transportation Pooled Fund Project TPF-5(111). The process followed known standards development practices by involving DOTs, Federal transportation groups, universities and industry. The resulting standard was then transferred to the American Society of Civil Engineers (ASCE). ASCE is the home to a number of national standards including the ASCE-7 wind standard and has well-defined mechanisms to maintain and improve standards. As an example of envisioned activities, the Smart City team will work closely with the Connected Vehicle Reference Implementation Architecture (CVRIA) project recently established by USDOT's ITS Joint Programs office. The mission of this project is to develop the architecture high-lighted in the project's name along with an accompanying standards development plan. The Connected Vehicle Reference Implementation Architecture and the standards that follow will be fully aligned with the National ITS Architecture. The Smart City team will become an important player in this effort. All activities and collaborations in the area of architecture and standards development will be carefully documented.

11.0   Provide measurable goals and objectives for your vision

Raleigh will leverage existing and emerging data sources in order to first establish the baseline conditions of the pilot study corridors. Ongoing data collection will monitor changes in mobility, reliability, safety, sustainability, and environmental impacts of the transportation system. Specifically, the following measures can be monitored:

- Multimodal Delay: Delay for vehicles, bicycles and pedestrians on the study corridors
- Travel Time Reliability: Travel time data will be utilized for monitoring the frequency and severity of congestion
- Transit Ridership and On-Time Performance: These measures are already used to monitor transit use and performance
- Mode and Fleet Shift to Sustainable Transportation: Transportation modes used on the corridor as well as the composition of the vehicle fleet will be monitored to identify trends towards more sustainable transportation
- Crash Rate: In addition to collecting crash data, shifts to safer transportation modes will be monitored
- Greenhouse Gas Emissions: Using vehicle dynamics data collected from connected vehicles, changes in emissions can be estimated through emissions modeling

Based on the baseline conditions identified and the technologies to be implemented in the study corridor, goals for each of these performance measures will be identified.

12.0 Provide evidence that establishes your capacity to take on a project of this magnitude

The partnership between Raleigh and NC State brings a powerful duo that can execute highly innovative solutions to smart cities' challenges. First and foremost, the two have a longstanding positive relationship, working closely together for the overall betterment of the broader community. One historic example is the creation of the master plan in 1987 that led to the creation of NC State's Centennial Campus within the City of Raleigh. This entity has withstood the test of time over the past 32 years and is the gold standard for triple helix partnering on a large scale. Without the master plan (updated every 5 years) that led to this development, it would not be the successful model of public-private partnerships that it is today. Also, each entity has worked on specific major changes on its own, as evidenced by the downtown revitalization that has been hugely successful. More specifically, from the University standpoint, NC State is the lead in several major partnership projects with the Federal Government.

NC State is also home to the National Security Agency's Lab for Analytic Science (LAS) that includes a certified Secure Compartmentalized Information Facility (SCIF) representing an investment of over $63 million. In addition, in 2014, NC State was selected by DOE to lead the 2nd National Manufacturing Innovation Institute, PowerAmerica. This $146 million (with 50% cost share) endeavor is focused on commercialization of emerging wide band gap power electronics for a sustainable and clean economy. NC State's College of Engineering is the lead institution for two NSF Engineering Research Centers (no institution can lead more than two). One is the Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center, focusing on smart grids. The second is the Advanced Self-Powered Systems of Integrated Solutions (ASSIST) Center. The investment by NSF into both of these is in excess of $75 million. Additionally, ITRE and NC State are part of a multi-university consortium that was one of the five selected by USDOE's ARPA-E program to conduct a $4.5M study on energy optimization using individualized incentives for travelers on an urban, multimodal transportation network. All of the above entities involve a very large and broad network of coalition partnerships to execute on their respective units. NC State is one of a few institutions of higher learning capable of winning and executing on such huge projects.

13.0 Describe any opportunities to leverage Federal resources

The proposed project has the potential to leverage several federal resources:
- FREEDM Systems Center, researching smart-grid technology
- ASSIST Center, developing wearable, self-powered health monitors
- $146 million PowerAmerica Institute, developing an advanced power electronics manufacturing sector for USDOE
- $63 million Laboratory for Analytic Sciences, studying data analytics for the National Security Agency