**U.S. Department of Transportation** Notice of Funding Opportunity #DTFH6116RA00002

# THE SMART CITY CHALLENGE

#### MAY 24, 2016 = PHASE 2 - PART 1 THE CITY AND COUNTY OF DENVER



May 24, 2016

The Honorable Anthony Foxx Secretary of Transportation

Dear Secretary Foxx:

I am pleased to present you with Denver's Phase 2 application for the U.S. Department of Transportation's Smart City Challenge. Our proposal was designed collaboratively with the Colorado Department of Transportation, Regional Transportation District, Xcel Energy and dozens of public- and private-sector contributors. This plan was built from the ground up with the underserved communities that stand to benefit significantly from the bold policies, programs and projects outlined in our application.

Our challenges are many – rapid population growth, traffic congestion, dangerous roadways, a high percentage of residents living in poverty, air pollution and significant levels of childhood asthma. But our obstacles are not insurmountable. Denver's Smart City proposal will transform our region into a global model where transportation and technology break down barriers and connect all people to mobility freedom and opportunity.

With collaboration, connectivity and opportunity as guiding principles, our Smart City program integrates three main components – Mobility on Demand Enterprise, Transportation Electrification and Intelligent Vehicles – with an ever-evolving data analytics ecosystem fueling all of it.

By making useable data readily available, we can offer consumers more and better mobility choices based directly on their needs. By hastening electrification and intelligent vehicles, we can serve as the nation's laboratory for transportation technology innovation.

Over the past 20 years, metro Denver has successfully secured and spent billions of federal dollars to construct Denver International Airport, build the 122-mile FasTracks transit network and redevelop Denver Union Station as a world-class transit hub.

Infrastructure improvements will remain vital elements of our transportation future. But they are no longer enough. We need new solutions, new partnerships and new ideas to take us further faster. Denver's Smart City proposal expands on those prior investments, includes new financial contributions from major partners such as CDOT, RTD and Xcel Energy, and will deliver measurable outcomes for decades.

This is a visionary, groundbreaking plan that will set Denver on a path to win the future, create ladders of opportunity for underserved communities and benefit the entire country.

On behalf of Denver and all of our partners, thank you for this opportunity and your consideration.

Respectfully,

Michael B. Hancock Mayor

## TABLE OF CONTENTS

EXECUTI	VE SUMMARY PAG	<del>)E</del>	1
A. TECHN	A. TECHNICAL APPROACH PAGE		6
A.1	Component 1 – Mobility on Demand Enterprise		7
A.2	Component 2 - Transportation Electrification		12
A.3	Component 3 – Intelligent Vehicles		16
A.4	Enterprise Data Management Ecosystem		22
A.5	Annotated Site Map		26
A.6	Program Management		27
A.7	Systems Engineering Approach		32
A.8	Performance Measurement		33
A.9	Data Privacy Requirements		35
A.10	Data Management and Support for Independent Evaluation		36
A.11	Safety Management and Safety Assistance		37
A.12	Communications and Outreach		39
A.13	International Collaboration		39
A.14	A.14 Participation in Relevant ITS Architecture and Standards Development Efforts		41
A.15	Interim and Final Reporting		42
A.16	Deliverables		43
A.17	Partners		43
A.18	Goals, Objectives & Alignment with Vision Elements		49
B. DATA N	MANAGEMENT APPROACH PAG	Æ	53
C. MANA	GEMENT APPROACH PAG	ЭЕ	56
C.1	Innovative, Integrated and Holistic Approach		56
C.2	Organizational Capacity to Manage All Partners		57
C.3	Existing & Future Public and/or Private Partnerships		58
C.4	Engaging Start-Ups, Small Businesses, Local Technologists and Other Partie	es	60
C.5	Leveraging Federal Resources		60
C.6	Ensuring Quality, Timeliness and Cost Control		61
C.7	Risk Management Approach		61

D. STAFF	D. STAFFING APPROACH PAGE		63
D.1	Denver's Smart City Organization Chart		63
D.2	Proposed Level of Effort		64
D.3	Description of Key Staff Members		65
D.4	Contingency Plan for Key Staff		67
E. CAPACITY AND CAPABILITY		PAGE	68
E.1	Executive Commitment		68
E.2	Workforce Capacity		68
E.3	Degree of Infrastructure Readiness		68
E.4	Data and Performance Management Capabilities		68
E.5	Program Sustainability		69

## DENJER LIST OF TABLES

Table 1 - Program Management Plan Elements	28
Table 2 - Denver Smart City Program Partners	45
Table 3 - Measurable Goals and Objectives for Mobility, Safety, Ladders of Opportunity, Efficiency, Clean Energy, Sustainability, and Climate	
Change in Denver	49
Table 4 - City Agency Participation	57
Table 5 - Denver Smart City Partner Organizations	
Table 6 - Risk Identification and Mitigation	62
Table 7 - Staff Roles and Level of Effort	64
Table 8 - Key Staff Bios	65

## DENJER LIST OF FIGURES

Figure 1 - Transportation Electrification System	12
Figure 2 - Colorado EV Market Adoption Projection	15
Figure 3 - Waze Vision Zero	17
Figure 4 - North Denver Freight Corridor	19
Figure 5 - Southeast Denver Congestion Corridors	21
Figure 6 - Enterprise Data Management (EDM) Ecosystem	23
Figure 7 - Smart City Program Lifecycle	27
Figure 8 - Denver's Smart City Schedule at a Glance	31
Figure 9 - Systems Engineering Management Plan (SEMP)	32
Figure 10 - Safety & Health Management Systems	38
Figure 11 - Approach to Updating Regional ITS Architecture	42
Figure 12 - Organizational Framework	56

## **EXECUTIVE SUMMARY**

Driven by the same pioneering spirit that carved our city from the Rocky Mountains, modernday Denver solves problems through publicprivate collaboration. Together with the Colorado Department of Transportation (CDOT), Regional Transportation District (RTD) and dozens of other partners, we will design our mobility future the same way – through cooperation and coordination – so no one gets left behind.

While the seven Smart City finalists are each distinct, we face many of the same obstacles and opportunities. Several of us are among the fastest-growing cities in the nation. We face air pollution and environmental challenges. For some, our economies are strong, but education, income and housing gaps are widening. A few have made multi-billion dollar investments in light rail. All are grappling with aging infrastructure and constrained financial resources.

Without question, technology offers the best opportunity to improve mobility, enhance our Vision Zero safety efforts, address climate change, create ladders of opportunity, and provide innovative solutions that can be scaled, replicated and exported.

#### **CHALLENGES**

Foremost among Denver's challenges are rapid population growth and traffic congestion. The city's population has increased 25 percent since 2000. We're adding more than 1,500 people a month. And compounding this phenomenal residential growth: each workday our population swells by 200,000 people – the vast majority driving single-occupant vehicles.

Expanding and widening roads is extraordinarily expensive. We recently spent \$30 million to add one lane for one mile to a major north-south arterial and we are preparing to spend – in partnership with the USDOT and CDOT – \$1.2 billion to add lanes to Interstate 70 and reconnect the urban street grid northeast of downtown. These are important improvements, but they are built on an outdated supply model that we cannot sustain financially and which do not contribute to the human fabric of our city.

Traditional infrastructure improvements also do not alleviate many of Denver's other ills. We remain out of compliance with federal ozone standards. Food deserts persist in many pockets of the city. Housing costs have skyrocketed by more than 30

#### **VISION FOR DENVER'S SMART CITY FUTURE**

A city where transportation and technology break down barriers and connect *all* people to mobility freedom and opportunity.

#### **COMPONENTS OF DENVER'S PROPOSAL**

- More and better mobility options
- Widespread transportation electrification
- Connected and automated vehicles
- Data-driven decision processing

#### LADDERS OF OPPORTUNITY

All components and projects are targeted toward the areas of greatest need: West, North and Northeast Denver, including the neighborhoods of Sun Valley, Globeville, Elyria-Swansea and Montbello.

percent in the last five years, making it harder for low-income families to remain or relocate here, and all but impossible for low-wage workers to live close to their jobs.

Perhaps most alarming – up to 40 percent of Denver's residents live in underserved neighborhoods, primarily in the western, northern and northeastern portions of the city, many of which are disconnected by physical barriers such as highways, railroads and rivers.

Nearly one of every four Denver children lives in an area of concentrated poverty. The number of homeless students in Denver has increased 41 percent since 2013-14 and has doubled across the entire metro area since 2008. About 10,000 Denver residents between the ages of 16 and 24 are not in school or working full time. Forty percent of them have children themselves and reliable transportation is one of the biggest barriers to accessing school and jobs, putting the opportunity to succeed just out of reach.

#### **DENVER'S SMART CITY VALUES**

Our proposal seeks to overcome these barriers by presenting innovative, groundbreaking and visionary solutions to the very real problems confronting our residents, neighborhoods and employers. Several guiding principles are infused in every element of our proposal:

- **Establishing mobility freedom for** *all* by making it easier, cheaper, cleaner and safer for people, goods, services and ideas to get where they need to go. This means deploying data, information and technology to deliver more and better mobility options to everyone, everywhere, anytime. It also means closing engagement and affordability gaps for unbanked, unphoned and underserved users.
- Improving connectivity by linking disparate data sets, connecting people to information and bringing mobility options to their fingertips, sidewalks and neighborhoods. This means creating pathways to opportunity by reducing barriers of the past and modern-day barriers caused by lack of access to information, data and technology. It means improving access to education, healthy food and jobs in communities with high rates of poverty, unemployment and crime.
- Leveraging USDOT, Vulcan Foundation and private partner funds and services by bringing in new resources; accelerating existing plans and projects; maximizing our region's intellectual, entrepreneurial and innovation assets; and building off prior infrastructure investments, such as the \$5 billion voter-approved FasTracks transit network and the city's 378-mile fiberoptic network. The total value of Denver's Smart City Program exceeds \$80 million and includes contributions from key partners such as CDOT (\$7 million), RTD (\$4 million) and Xcel Energy (\$3.7 million).
- Collaborating at every level. We developed our proposal with dozens of public, private, academic and community contributors.

Implementation will occur through the Startups, Municipalities, and Academic Research Technology (SMART) Council that unites Smart City applicants and finalists with local, national and international experts. This collaborative approach ensures we will deliver technologydriven solutions designed by and for our communities, solutions that are measurable, scalable, replicable and exportable to cities nationwide.

#### ENDORSED BY 20 CITIES REPRESENTING OVER 8 MILLION PEOPLE

Denver has a sincere desire to start a conversation, share data and help other cities become smarter. Denver will bring the endorsing cities identified below onto our SMART Council so we all benefit from this type of immediate scalability. We also will continue to invite additional cities to participate in the SMART Council.

Albuquerque, NM	Las Vegas, N\
Atlanta, GA	Memphis, TN
Baltimore, MD	Orlando, FL
Boston, MA	Providence, R
Baton Rouge, LA	Richmond, VA
Chula Vista, CA	Rochester, N
Columbus, GA	Seattle, WA
Des Moines, IA	Tampa, FL
Indianapolis, IN	Tucson, AZ
Jacksonville, FL	Tulsa, OK

#### DENVER SMART CITY PROGRAM 3 COMPONENTS



MOBILITY ON Demand Enterprise





#### ENTERPRISE DATA MANAGEMENT ECOSYSTEM

#### MAIN COMPONENTS OF DENVER'S Smart City Program

Just as highways, rail and other structures of the past became dividing lines of a city and barriers to opportunity, we must ensure that invisible lines in the form of access, information and data do not become new high-tech hurdles to our transportation future. Our Smart City proposal is composed of three interconnected components with a number of distinct projects that will be tested, measured, refined and institutionalized for scaling, replicating and exporting. An Enterprise Data Management (EDM) Ecosystem will empower each of the three components.

#### ENTERPRISE DATA MANAGEMENT Ecosystem

A data-driven decision processing engine will serve as the connective tissue for our entire program. It will serve as a national model for gathering disparate data sets, incorporating new data from thousands of sensors and providing a constant data feedback loop that aggregates data and continuously improves our understanding of where, when, how and why people are going places - so that ultimately we can improve their travel experience. This "living" data analytics engine will be highly scalable and replicable throughout the U.S. by leveraging a customizable web services architecture. Nationwide, people will benefit from faster deployment, declining costs and increased service capabilities by implementing a proven, replicable and extensible architecture.

#### COMPONENT 1: MOBILITY ON DEMAND ENTERPRISE

This component will reduce access barriers and use data to provide meaningful mobility connections to all users, including the underserved. Projects will include:

 Comprehensive information and payment systems. We will develop a universal payment card and smartphone app that will allow people to access information and pay for any mobility option they choose. We initially will launch the one-stop shopping card for qualified low-income residents by expanding the capabilities of the existing My Denver Card, which currently offers free entry to 100,000 school-age youth for free entry to city recreation centers, pools, libraries and museums.

- Improved access and service to underserved communities. We will install interactive kiosks in West, North and Northeast Denver neighborhoods, providing those without bank accounts, smartphones or credit cards with access to information and cash-only payment options. We will also deploy a First Mile/ Last Mile (FMLM) Subsidy Pilot Program into those neighborhoods by offering ride-sharing drivers guaranteed fares and price discounts to passengers for trips that begin or end at a transit stop or station.
- Mobility solutions designed from the ground up. We will convene a community-based Technical Working Group as a subset of the SMART Council to craft and encourage more meaningful mobility solutions for underserved neighborhoods.
- Sustainable funding model. We will initially locate 50 interactive kiosks – 35 in underserved areas and 15 in locations capable of supporting higher advertising revenues. Proceeds from all kiosks will allow us to create, change and expand subsidized mobility services for low-income areas and continue offering services beyond the life of the grant.

## **COMPONENT 2: TRANSPORTATION**

This component focuses on electrifying City, transit and other commercial vehicle fleets; incentivizing greater deployment of Electric Vehicles (EVs) for personal use; installing an advanced and strategic network of charging stations; and partnering with our investor-owned utility to further decarbonize the grid to ensure EVs are powered by ever-cleaner energy. With the National Renewable Energy Laboratory, Colorado State University's Center for the New Energy Economy and Xcel Energy – the nation's number one provider of wind energy – as Smart City partners, our proposal unites energy innovators with technology leaders.

Our Smart City proposal will leverage some of the most aggressive energy and EV policies in the nation. RTD is deploying 36 electric shuttles along Denver's 16th Street Mall – the largest fully electric bus fleet in the U.S. The State requires that 30 percent of Colorado's electricity come from renewable sources by 2020, and the Legislature just adopted a new \$5,000 point-of-sale tax credit for EV purchases. Denver intends to reduce harmful greenhouse gas emissions 80 percent by 2050 and to cut fossil fuel consumption from all sectors 50 percent by 2020. The City also requires builders to pre-wire new single-family and duplex homes for EV charging.

Projects in this component will include:

- Electric-bus service along East Colfax Avenue. We plan to leverage \$3.2 million of Smart City Challenge funds with \$4.15 million from RTD to replace traditional diesel buses with nine electric buses for exclusive service along East Colfax Avenue, one of the busiest east-west arterials in the region and home to numerous underserved communities.
- Increased deployment of EVs in Transportation Network Company (TNC) and taxi fleets. We will leverage Smart City funds to deploy 65 highmileage EVs in 2017 and 165 by 2018, electrifying 8 million miles per year. We will provide gap financing to Transdev, owner of Denver's largest taxi fleet, to deploy Tesla Model S and Nissan LEAFs, and Evercar will deploy 50 short-term EV rentals for TNC drivers in 2017, with the potential for 300 cars by 2019.
- Electrified City vehicle fleet. Denver will lead by example by purchasing 103 EVs during the grant period and making 50 percent of all light-duty City fleet purchases electric by 2020.
- Greater consumer adoption of EVs. Our plan will encourage and incentivize the purchase of 15,000 additional EVs by the end of 2019. We will use Smart City funds for a marketing and awareness campaign to support installation of workplace charging stations, electrify multi-unit housing developments, and invest in a network of fastcharging stations along major corridors.

## COMPONENT 3: INTELLIGENT

This component will usher in a new era of transformational technologies for Denver and the region, bringing greater mobility safety, efficiency and reliability to our transportation network. Projects will include:

- **Connected Traffic Management Center (TMC)** and connected fleets. We will partner with Waze through its Connected Citizens Program to reduce congestion, improve safety and inform smarter urban planning by connecting our TMC directly with travelers. To realize Connected Vehicle (CV) implementation, we will develop an architecture and build an operational environment for current and future CV applications. To jumpstart market penetration of dedicated short-range communication (DSRC), we will install DSRC in 3,000 vehicles by equipping 1,500 City vehicles and launching a DSRC Equip Program for other fleets and citizens. Connectivity will prepare us for coming advancements in automation and allow us to maximize our existing infrastructure of 1,200 traffic signals, 460 closed circuit TV cameras, and thousands of sensor and detection devices deployed citywide.
- **Travel time reliability for connected freight.** This first-in-the-nation project will deliver seamless, efficient and coordinated freight travel from highways to local roads to facilities. This is critical for Denver as we prepare for the \$1.2 billion reconstruction of Central I-70. Supported by a \$1.5 million CDOT contribution, we will establish a Freight Efficiency Corridor Program, install DSRC along key routes, and offer travel time reliability as a City service using freight signal priority to incentivize freight operators to equip their fleets with DSRC.
- Intelligent Traffic Signal Systems for CVs. Leveraging CDOT's \$7 million RoadX Managed Motorways project and bolstered by an additional \$5.5 million CDOT contribution, Denver will integrate adaptive signal control with smart freeway ramp metering to alleviate congestion and freeway spillover. We will equip two of our most congested arterials, Colorado Boulevard and Hampden Avenue, with DSRC and deploy the first installation of Econolite's new Cobalt Sky<sup>™</sup> CV intersection controller, which uses DSRC data for dynamic traffic signal control.

Rapid population growth. Increased traffic congestion. Hundreds of traffic-related deaths and serious injuries each year. Air pollution. Numerous disconnected and disadvantaged communities. Those are just some of the challenges facing Denver and cities across the country.

Denver was built by pioneers dedicated to achieving bold outcomes through collaborative, communitybased problem solving. That spirit continues to drive us forward today. Our challenges are many, but they can be overcome. Leveraging the investments offered through the Smart City Challenge, we have proposed an integrated program with bold projects that will deliver measurable outcomes and make us a model city. Underserved communities will be knit back together and afforded new opportunities to thrive. We will advance and leverage our culture of innovation, our commitment to early adoption of new technologies, our never-ending quest to transform our future into something even better. Transportation and mobility will once again create ladders of opportunity.

## **A. TECHNICAL APPROACH**

#### **INTRODUCTION**

Everyone in Denver, regardless of age, income, education or disability, will have better access to more mobility options that will connect them safely, efficiently and affordably to new opportunities. That is the premise upon which Denver's Smart City Challenge proposal is built – mobility freedom for all.

As detailed in the following pages, our proposal consists of three main components: a mobility on demand enterprise, transportation electrification and intelligent vehicles. A data-driven decision processing engine will fuel and provide the connective tissue for the three components. The plan also calls for more than a dozen pilots and projects – many of which are first-in-the-nation – that will boldly transform our future.

Much of our proposal is specifically designed to remove barriers and create ladders of opportunity for targeted neighborhoods in West, North and Northeast Denver, areas with the highest concentrations of poverty, unemployment and crime.

Denver's proposal was built through collaboration from dozens of partners. They brought a wealth of intellectual, financial and in-kind resources to leverage the funds and services offered by the USDOT, Vulcan and other partners. The total value of our package exceeds \$80 million.

In keeping with the USDOT's requirement to create a scalable, replicable and exportable model, 20 cities nationwide have endorsed Denver's Smart City Program, including Baltimore, Indianapolis and Seattle. A SMART Council, with members ranging from the local to the national to the international level, will help inform and share Denver's program.

Our application provides a clear and comprehensive roadmap to Denver's Smart City Program, explaining how each element will be funded, managed and measured. We have established innovative project management, systems engineering, performance measurement and data management approaches. Our application is composed of the following sections:

- A. Technical Approach Includes program components, site map, approach to demonstration projects, approach to partner engagement, and measurable goals and objectives.
- **B.** Data Management Approach Includes the plan for managing data, defining polices for access and sharing data, developing provisions for reuse and distribution, and archiving data.
- **C.** Management Approach Includes sophisticated, integrated and holistic strategy to manage our Smart City Program, organize and engage partners, leverage federal resources, ensure quality, timeliness, and cost control, and manage risk.
- **D. Staffing Approach** Includes organizational chart, level of effort and staffing plans.
- **E.** Capacity and Capability Includes executive commitment, readiness, capacity and capability to deliver a sustainable Smart City Program.

We have taken great pains to ensure projects can be measured, refined and institutionalized with ongoing budget, staffing and programming support. Our projects will be "living" systems capable of continuously evolving, improving and learning. We are eager to serve as a test bed, a laboratory of technology, innovation and ideas for cities everywhere.

The Smart City Challenge has provided the seed and the spark necessary to transform the nation's mobility future for everyone. This grant and the collective contributions from the USDOT and Denver partners will deliver that future faster and with far more impact than if we addressed these problems in isolation.



The Mobility on Demand Enterprise (MODE) will allow Denver to consolidate all mobility service options into one cohesive application service framework. This will offer real-time integration of disparate information sources, close the digital divide and vastly improve access and options for Denver's diverse traveling public.

MODE will become Denver's bridge to mobility options by reducing access barriers. With a fourpronged approach that is easily replicable, MODE will:

- Be built and continuously improved through ongoing target community stakeholder engagement, ensuring that mobility solutions effectively address users' mobility needs
- Improve access to information and increase mobility options through a one-card payment method, streamlined mobile transportation apps, and by placing new interactive kiosks throughout the city, predominantly in underserved neighborhoods
- Feed a sustainable financial model, enabling us to change policy, create and expand subsidized transportation services, and continue offering innovative services beyond the three-year grant
- Generate user information that will be tracked and analyzed by our EDM Ecosystem to adjust programs and services to better meet users' needs

The power of USDOT grant dollars will afford everyone in Denver, regardless of age, income, education or disability, access to new transportation options that will connect them safely, efficiently and affordably to city wide opportunities.

MODE will vastly improve access to transportation choices that have not been widely available in underserved communities in West, North and Northeast Denver, areas we are targeting through our Smart City Program. Residents and businesses in these neighborhoods are separated from mobility options by physical or information barriers. Without home internet or smartphone access, many do not participate in today's connected economy.

These separated neighborhoods deserve connections to new opportunities. Nearly 95 percent of children living in the Montbello, Westwood, Valverde, Elyria-Swansea and Sun Valley neighborhoods qualify for free and reduced lunch programs. These are our most vulnerable populations and they have the greatest need for mobility options that are flexible, affordable and reliable.

These residents have different stories. They include high school dropouts, young unmarried parents, immigrants, homeless, formerly incarcerated or those who are experiencing physical disabilities or other special needs. In neighborhoods like Sun Valley, up to 77 percent live in poverty. Many do not own or have access to a vehicle or have a bank account, credit card or smartphone. They are largely excluded from recent innovations like car-, bike- and ride-share.

MODE will help remove these barriers and open a new world of choice that, by design, is nimble enough to respond to changing needs.

#### **MODE-1: EXPLORE THROUGH LISTENING**

Collaboration is an institutional practice in Denver. We will convene a local community-based technical working group as a subset of the SMART Council. The working group will be composed of stakeholders who live in and represent our target neighborhoods, including Mile High Connects, the Mile High United Way, and local neighborhood organizations in addition to transportation service providers (TSP) like RTD and others who offer ondemand mobility services.

The nearby City of Centennial will also serve as a key partner for the working group. Centennial will be piloting an on-demand First Mile/Last Mile (FMLM) pilot at RTD's Dry Creek light rail station. Local employers will provide their workers with rail discount passes, while public-private partnerships will fully subsidize Lyft Line rides between homerail station and rail station-job site. Centennial will share usage, ridership and other data and lessons learned from this pilot for possible expansion to Denver.

The working group also will include other TSPs, such as General Motors' new personalized ondemand mobility service, Maven. Maven is considering Denver as a launch city and has agreed to work with us to study and pilot mobility ondemand services for all communities, including underserved neighborhoods.

The working group will help identify the transportation gaps that pose barriers to jobs, education, workforce training, affordable housing, healthcare and healthy food. Listening will be a critical first step. Working group members know these communities best and will help us design a meaningful public outreach campaign. This process will show us actual origin-destination patterns and confirm the specific set of project opportunities that reduce travel burden and improve quality of life for people like Joe, a fictitious but realistic example resident.

Joe is a 38-year-old dad of two from the Westwood neighborhood. He dropped out of high school after struggling with English as a second language. His level of education, language skills and minor police record have reduced his work options but he has held the same shift job across town for four years. Joe does not have established credit and prefers cash. He has a prepaid smartphone with limited data and his vehicle is often broken down.

MODE outreach efforts will engage Joe by going to the places he and his family already frequent: local grocery stores, Denver Human Services where he receives his family's food assistance benefits, and his little girls' school. We will learn that Joe relies on RTD buses to get to work each night, but the route runs infrequently and picks up almost a half mile from his house. To catch it he has to miss dinnertime with his girls. He often rides the bus with three co-workers. They all feel like they lack options.

Outreach will ensure that Joe and the community inform the suite of mobility services that best meet

their needs, rather than today's model where the service chooses the community. This collaborative service design process will define the purpose, delivery, financing, user experience, and other key operational aspects of both existing and new mobility options. While each program will have performance evaluation criteria, public outreach will ensure that measures are based on the specific values of the community.

#### TASK:

**Task 1:** Design and implement a meaningful public outreach plan that empowers frequently unheard voices to provide feedback

#### **MEASURABLE OUTCOMES:**

- Establish technical working group as a subset of the SMART Council by Q2 2017 to formulate an outreach and education plan
- Begin to gather input, feedback and suggestions from residents in underserved neighborhoods
- Gather and analyze data from Centennial's FMLM pilot

#### **MODE-2: DELIVER MEANINGFUL CHANGE**

Denver is focused on implementing quickly but intelligently with feedback from an expansive public outreach effort.

#### 2.1 Mobility App

Capitalizing on the year-long "Go Denver" mobility-app pilot launched in February with Xerox, the City will use grant funds to expand the availability of meaningful data and information so that everyone will have customized travel options at their fingertips. New TSPs, carbon emissions estimators and transportation spending reports will be included in a new, fully integrated payment platform.

This integrated payment platform will make it easier for people to search for and purchase trips that involve multiple TSPs. "Go Denver" currently allows for search-only interactions. Payment for individual legs of a trip must be processed through the each TSP's individual app, making it cumbersome to select a trip with multiple modes.

While we anticipate payment integration with several of our existing TSP partners (including Lyft, Car2Go, ZipCar, Flitways and ParkWhiz), MODE will also enable streamlined payment integration for Denver Bike Share. It also will complement a mobile booking option for RTD, the largest TSP in the Denver area. Smart City grant funding will augment RTD funding for the development of an open Application Program Interface (API) of the payment platform, enabling any third-party app to access the new system.

In 2016, Denver will issue an RFP to procure the mobility app in anticipation of the expiration of the "Go Denver" pilot with Xerox. This RFP will allow Denver to continue testing the mobility app for the duration of the Smart City grant. Throughout the grant period, Denver will continuously re-evaluate

the app to determine whether a city-hosted, city-owned solution is the best way to get information into the hands of users.

#### 2.2 One-Card Payment System

Many existing mobile payment technologies are criticized for leaving low-income individuals

behind because they do not have mobile devices or credit. Joe has to buy his RTD bus tickets at the grocery store, which is three miles from his home. While the mobility app will help show him exactly when the bus will show up, extending his time with family, Joe cannot pay for his ticket through the app without a bankcard.

Since Joe and many unbanked residents prefer cash, we are proposing a partnership with PayNearMe so that cash-preferred customers can access the same great mobility options as credit-enabled customers.

PayNearMe offers cash processing at local retail locations where customers without mobile devices or established credit can pay for transportation services. Joe could pay at any of PayNearMe's partner retailers in Denver including a combined 468 storefronts of 7-11, Family Dollar and Ace Cash Express. Smart City funds will seed a pilot with PayNearMe to cover the transaction fees so that service charges are not passed to Joe.

The pilot will be measured by the number of PayNearMe transactions, each transaction's location, and whether individuals who utilize PayNearMe show a pattern of repeat use. If the pilot is deemed to improve access to public transit, car share, ride share and bike share, it will be extended and expanded.

While PayNearMe is one solution, the opportunity to create a one-card payment system would be transformational. Joe's daughters and their schoolage friends, already have City-issued My Denver



Cards that give them free access to Denver's 23 recreation centers and 29 pools. MODE will expand the functionality of the My Denver Card with reloadable mobility credits that can be used for a variety of TSPs, including RTD's bus and rail service. Further expansion of the one-card payment system for adults will allow for the integration of other services like food assistance. Joe will soon be able to load his card at PayNearMe and other locations to use RTD, Lyft and Bike Share and

check the balance on the mobility app. He can travel to the grocery store using a TSP and pick up food for his family all with a flash of one card.

#### 2.3 FMLM Pilot

The mobile app will also enable the City to track the pilot of a new discount program to incentivize Joe to try

new ways of accessing public transit. Through a partnership with Lyft, the grant funds will help pilot a subsidized FMLM program to link existing or new transit riders to ride share programs.

Within the three target areas of West, North and Northeast Denver, grant funds will subsidize a portion of any Lyft trip that begins or ends at transit. This program will capitalize on the model established by Centennial and measure the value of ride share solutions against the traditional Calln-Ride strategy. A driver recruitment program will also be focused on the target areas to recruit Lyft drivers and create jobs in the disadvantaged neighborhoods they serve.

Denver's FMLM subsidy program will be based on a negotiated fare with Lyft. Since rideshare drivers do not regularly circulate in the Smart City Program's three target areas, Lyft will partner with Denver by offering driver incentives, such as guaranteed fares, during the pilot. The discount program will run for the period of the grant, and will be continuously analyzed to determine the increase in ride share service utilization, increase of transit ridership, and vehicle miles traveled impacts weighed against the expenditure.

Thanks to this FMLM pilot, Joe will now be able to reach the light rail station, which offers a much more direct route and more frequent evening service to his place of work. He can use the transportation credits on his one-card payment method to pay for his entire trip. And when driverless vehicles begin to replace conventional cars in TNC fleets, Joe and his neighbors will see the cost of their trips decline.

Denver Bike Share B-Cycle, the nation's first bike-share service, currently operates 87 stations and 700 bikes, but the vast majority of stations are not located in the underserved target areas of West, North and Northeast Denver. Smart City and Denver funds will also connect Joe with 10 new bike-sharing stations that will be placed in disadvantaged neighborhoods to fill FMLM gaps.

#### 2.4 Interactive Kiosks

While 64 percent of Americans are estimated to own a smartphone, Joe is among the 7 percent with limited online access and no high-speed internet connections at home. It is imperative to bring important information on City services and transportation into these neighborhood areas and provide free, high-quality broadband internet access so that no one is left behind in this digital age.

We will initially deploy interactive kiosks throughout Denver in partnership with a privatesector provider such as Alphabet Sidewalk Labs or Colorado-based Street Media Group. Thirty-five kiosks enabled with free gigabit speed Wi-Fi will be placed in underserved communities where many low-income residents do not own vehicles and live more than a quarter-mile from a high-frequency transit service. Kiosks will be placed at schools, community centers, transit stops and libraries to provide residents with a source of transportation options, education or employment. Joe's entire household can access the internet for free.

Built on Denver's expansive fiber network, these kiosks will provide free domestic phone/video calling and offer those without a smartphone or internet a way to access and book mobility travel through Denver's mobility app. Kiosks will alert residents to various Denver, RTD or CDOT announcements. These kiosks will also function as charging stations for phones and tablets. We will explore future opportunities to offer cash processing and one-card issuance directly from

Kiosks will be ADA accessible and outfitted with Amazon's Alexa voice-data translator. Alexa will translate verbal directions from a variety of languages into digital queries and provide access to those with visual impairments.

the kiosks. Kiosks will include air quality monitors so we can better assess conditions within targeted neighborhoods.

The kiosks will also connect residents to 311 and <u>PocketGov.org</u>, two user-friendly ways to access government services. They will identify locations where social or health services are being provided in close proximity or places of cultural significance important to the communities. In addition, MODE will improve safety awareness by enabling citizens to immediately capture and report safety-related issues through MODE services similar to the RTD Transit Watch application.

Each kiosk will be outfitted with a digital screen offering both paid advertising space and a way to share information on city services or other important announcements like events, elections and other public engagement opportunities.

Through the EDM Ecosystem, Denver will monitor the use of the kiosks and commit to removing and redeploying underutilized kiosks. After the three-year test period, the overall program will be re-evaluated prior to any decision for expansion. Denver is sensitive to rapid change in global technology and will only continue down the path of further capital expenditure on expansion of the kiosks should they be deemed the most successful way to address information gaps in our target neighborhood areas.

In addition to the 35 kiosks in underserved communities, we will place 15 kiosks in areas capable of supporting higher advertising revenue. Dollars generated from these kiosks will provide a sustainable funding source to continue Smart City projects beyond the grant.

#### TASKS:

**Task 1:** Expand the functionalities of Denver's mobility app to include an integrated payment platform

**Task 2:** Establish a one-card transportation payment program

**Task 3:** Test new flexible transportation options through an FMLM subsidy pilot

**Task 4:** Provide information about resources and new opportunities at 50 interactive kiosks that will generate revenue for a sustainable mobility program

#### **MEASURABLE OUTCOMES:**

- Develop and launch the payment platform by the end of 2017, with TNCs integrated within the app
- Establish an open API for RTD's mobile ticketing within one year after launch of base mobile ticketing service
- Develop and launch the FMLM pilot with Lyft by Q3 of 2017. Establish baseline ridership trips based on first six months of program. Increase the baseline by 30 percent in year two
- Increase the number of residents with FMLM accessibility to public transit by 30 percent
- Achieve a 30 percent utilization rate for the mobility app
- Provide the option to pay for all services in the mobility app
- Reinvest 100 percent of revenue generated by the program back into mobility-related investments

#### MODE-3: EDUCATE TO CHANGE POLICY AND Improve quality of life

A critical benefit of the newly delivered mobility app and interactive kiosks will be the user data generated, which will allow decision-makers a glimpse into how best to maximize the transportation system to meet needs. Crowdsourced information from the app and kiosks, coupled with feedback received during the outreach campaign, will flow continuously to define and refine transportation services offered in Denver.

This volume of information will directly reflect the needs and travel patterns of the target communities so that the City and its partners can more quickly and directly respond to changing user patterns. Our EDM Ecosystem will be the heart of this data flow, and will be positioned as a clearinghouse house of information. In addition to pushing out relevant data to users via the app and kiosks, the EDM's robust analytics engine will receive the mass of user inputs, synthesize them, and provide customized and queryable reports that inform operational and policy-related decision-making.

Importantly, the EDM will also make it possible for the City and its data collaborators to instantly share information in an open data environment so that there is a collective understanding of behaviors and needs across modes and service providers. As a result, MODE will allow decision-makers to make intelligent and relevant adjustments to transportation services proactively and intelligently.

Partnerships with the University of Colorado Computer Science and Engineering Department and the Colorado School of Mines Department of Electrical Engineering and Computer Science will mean that information generated from the app and processed by the EDM will also feed educational research already in progress. These initiatives are working to further the understanding of route planning that optimizes overall performance of the transportation network.

#### TASKS:

**Task 1:** Regular review of computed user analytics harnessing the power of the EDM and partner academics

**Task 2:** Utilize analytic outputs to actively adjust programming and services

**Task 3:** Push information that helps improve quality of life

#### **MEASURABLE OUTCOMES:**

- Identify usable and relevant metrics and measures by Q1 of 2017. Revisit and refine every two quarters based on data produced from EDM
- Use dynamic data from the EDM Ecosystem to drive 100 percent of Smart City programming decisions
- Provide information on additional benefits to all those using PayNearMe and the transportation credit program, targeting an initial adoption rate of 15 percent

<b>,7</b>	A.2 COMPONENT 2 - TRANSPORTATION ELECTRIFICATION
TOTAL	OBJECTIVES
COST \$311M	<ul> <li>Integrate EV, charging station and utility operations data into Enterprise Data Management (EDM) Ecosystem</li> </ul>
	<ul> <li>Deploy nine electric buses on one of the busiest corridors in the City</li> </ul>
\$5.4M	Engage Xcel Energy to accelerate greenhouse gas emission reduction efforts
	<ul> <li>Purchase 103 light-duty EVS for City fleet, with half of all light-duty fleet purchases being EV by 2020</li> </ul>
\$15.7M	<ul> <li>Incentivize a doubling of consumer EV purchases by 2019</li> </ul>
VULCAN \$10.0M	

Our Transportation Electrification component is heavily focused on reducing greenhouse gas emissions and improving air quality by transitioning as many miles as possible to electric vehicles and further reducing emissions by powering those vehicles with clean energy.

Denver is poised for expansive growth in transportation electrification because:

- Colorado has a \$5,000 per vehicle tax credit the most generous in the country
- The National Renewable Energy Laboratory (NREL), an international leader in electrification, is located in nearby Golden, Colorado
- Denver assembled a world-class team of partners to electrify public and private fleets using cost-effective, scalable approaches

Smart City funds will be applied to visible, insightful and functional projects that foster transportation electrification. We will build on an existing foundation of strong policy, advocacy and regional environmental awareness to transform the market for electrified transportation solutions.

We will engage utilities, consumers, fleets, manufacturers and dealers to lower barriers to electrification, demonstrate the EV value proposition, and build out world-class charging infrastructure.

The Transportation Electrification component is an integrated program, emphasizing the following areas:

 Data Integration – EV, charging station, and utility operations data integration for smart grid implementation and user friendliness

- **Electric Buses** Testing the operational model by introducing nine electric buses serving high transit corridor and disadvantaged communities
- Grid Decarbonization Utility engagement to accelerate greenhouse gas reduction for EVs including collaboration on regulatory changes
- **Electrified Fleets** Targeting EV integration in high mileage taxi and transportation network company (TNC) operations, expanding visible City fleet EVs, and providing necessary charging facilities
- **Driving Consumer Adoption** A comprehensive approach to double EV sales, including consumer education, infrastructure growth, and unique car-share strategies to access untapped markets



**Figure 1 - Transportation Electrification System.** The Transportation Electrification component integrates multiple participants, policies and projects.

#### ELEC-1: EV INFRASTRUCTURE & DATA

Much of today's EV support equipment (EVSE) and operational data is still maturing to become useful and engaging. We will deploy EV charging infrastructure and tie these new data sources into

the EDM Ecosystem to produce a more encompassing view of EV operations, infrastructure and consumer adoption. The data can improve our understanding of charging patterns and utilization, and improve our overall system optimization, including

NREL Xcel Energy Irans

informing the location for installation of new EV charging infrastructure.

EV support equipment infrastructure is a significant investment and we will deploy several approaches to maximize utilization. We will tie a variety of data streams together to produce a more encompassing view of EV operations and infrastructure. By leveraging open standards and the EDM Ecosystem, users will have a comprehensive experience for viewing charging infrastructure availability and be encouraged to charge at times with favorable pricing and/or when there are surpluses of renewable energy.

This group project will deploy EV charging infrastructure at three large multi-unit dwelling buildings. This will specifically address challenges such as uncertainty as to who owns and benefits from the system.

The project will deploy integrated billing so that EV charging is tied to the customer's utility bill rather than point of sale transactions. The team will engage with the Roaming for EV Charging Association to ensure scalable roaming capability for EVs. Testing new roaming and billing methods will greatly reduce transaction costs, which are currently a significant component of the total public charging cost.

EVs and charging infrastructure are brand new sources of data, access points, and integration opportunities. The data can improve our understanding of charging patterns and utilization, and improve overall system optimization.

Challenges exist for multi-unit dwellings to deploy charging infrastructure because of uncertainty around ownership and how to best utilize the system for the benefit of all. We will engage partners to deploy best-in-class resources -

including 120 charging stations – to at least three residential developments. This will provide an estimated 5,000 residents with direct access to EVSE. These tools will build on the sharing economy, create queuing functions that instill collaboration among residents and lead to largerscale deployment.



Leveraging the evolving standards, the delivery of rate structures and environmental signals will help align electricity consumption with renewables generation to provide the most greenhouse gas benefit possible.

This data integration project aligns with an industry-led effort called Open Vehicle Grid Integration Platform (OVGIP) that encompasses the joint developments of six auto manufacturers and six utilities. Our technology integration will create the link between the EDM Ecosystem and Transportation Electrification allowing Denver to be a case study for the OVGIP growth plan.

#### TASKS:

Task 1: Identify initial data integration use cases

- Task 2: Partner with data providers/users
- Task 3: Coordinate EDM linkages with OVGIP
- Task 4: Enhance EV energy billing strategies

Task 5: Install 120 charging stations at 3 multiunit residential developments

#### **MEASURABLE OUTCOMES:**

- Deploy EV charging infrastructure and sharing-economy software tools at a minimum of three large, multi-unit dwelling buildings
- Complete a data analysis of charging station energy use coordinated with Xcel Energy
- Capture EV load data for at least five workplaces to inform EDM Ecosystem and Xcel Energy planning

#### ELEC-2: ELECTRIC BUS INTRODUCTIONS

The RTD transit system is an intricate overlay of 67 miles of rail, 54 rail stations, 1,100 buses and additional on-demand services. Additionally, RTD just opened a new 23-mile electric commuter rail line to Denver International Airport in April. With over 200 million passenger miles served annually by the entire electrified light rail system, RTD

has already reduced greenhouse gas emissions significantly. However, work remains to make further reductions from its other services.

For nearly 15 years, RTD has employed hybrid buses on the 16th Street Mall, serving 50,000 passengers per day. RTD has ordered 36 electric buses to replace these outdated hybrid buses.

RTD also plans to replace its entire 40-foot bus fleet with standard diesel coaches between 2017 and 2020. As part of our Smart City Program, nine new electric buses will be piloted on East Colfax Avenue. If the pilot is successful, it will provide RTD and other transit agencies with cost and logistics data that could enable a shift from diesel to electric for RTD's entire service territory. The result would be a much cleaner, quieter, healthier, and more environmentally friendly public transit system.

This corridor has significant pedestrian traffic that will directly benefit from the reduction in ground-level air pollution. These buses are expected to eliminate 9,200 metric tons of CO2 over their 12-year life cycle. These buses will be capable of providing riders with free Wi-Fi and phone charging, helping to provide connectivity to the disadvantaged communities served by this route.

The total cost of purchasing the nine electric buses will be \$7.39 million, with RTD paying \$4.15 million and the grant providing \$3.24 million.

RTD and NREL will lead a design study to define how wireless charging en route can enhance electric bus functionality and operating range. This will create a better understanding of the interactions between electrified transit, infrastructure and riders, and will influence RTD's future electrification plan. Long-term, RTD will continue to look for opportunities to deploy electric buses for the benefit of its riders, bottom line and the environment.

#### TASKS:

**Task 1:** Collect baseline data to quantify electric bus deployment benefits

Task 2: Deploy electric buses

Task 3: Assess technology performance

Task 4: Assess wireless charging design

#### **MEASURABLE OUTCOMES:**

- Place nine electric buses in service
- Compile one year of electric bus operational data compared to baseline
- Eliminate 9,200 metric tons CO2 by utilizing electric buses

#### **ELEC-3: GRID DECARBONIZATION**

Denver has set out a bold vision for greenhouse gas emission reductions. The City has pledged to reduce greenhouse gas emissions from all sectors 80 percent by 2050 from a 2005 baseline and to cut fossil fuel consumption 50 percent by the end of 2020, from a 2012 baseline. Denver intends to be the first city to produce a detailed strategic plan to achieve the "80 x 50" goal.

Denver's investor-owned utility, Xcel Energy, has one of the strongest environmental records in the country. Xcel Energy is the nation's #1 provider of wind energy. It is on track to meet one of the nation's most aggressive "Renewable Portfolio Standards" of 30 percent renewables by 2020. Denver will work with Xcel Energy to push for regulatory changes to further reduce greenhouse gas emissions.

#### TASKS:

**Task 1:** Create detailed strategy to achieve 80 percent greenhouse gas reduction by 2050

**Task 2:** Collaborate with Xcel Energy to continue grid decarbonization efforts

**Task 3:** Partner with Xcel Energy to expand outreach and marketing for the carbon offset program Windsource

#### **MEASURABLE OUTCOMES:**

- Reduce greenhouse gas emissions below 1990 levels by 2020
- Reduce CO2 emissions from power generation 113,000 metric tons by 2019

#### **ELEC-4: ELECTRIFIED FLEETS**

Fleets are a large segment of the overall vehicle population and are typically under centralized control. These two factors make them an important part of any electrification strategy. Denver will leverage Smart City funding to lower fundamental barriers to EV deployment in public and private fleets.

One of the biggest challenges for electrifying taxi fleets is the capital expense. We will link fleet owners with interested investors to help electrify fleets. Denver also has partnered with Transdev, owner of Denver's largest taxi fleet, to deploy 10 Nissan LEAFs and 5 Tesla Model S vehicles in 2017 with the potential to scale to 65 vehicles by the end of the grant period.

To facilitate electrification of TNC fleets, Denver has partnered with Evercar, which currently is offering EVs to TNC drivers in Los Angeles for \$5 per hour. Our goal is to deploy 50 EVs for TNC drivers in Denver in 2017, laying the groundwork for large-scale expansion.

Finally, Denver will lead by example and accelerate the electrification of its own fleet. The City will purchase 103 light-duty EVs, and install the necessary charging infrastructure. The City has also committed to EVs for half of all light-duty vehicle purchases by 2020.

#### TASKS:

Task 1: Create EV taxi financing plan

**Task 2:** Support Transdev deployment of EV taxis

Task 3: Deploy EVs for TNCs

Task 4: Purchase 103 EVs for City fleet

#### **MEASURABLE OUTCOMES:**

- Electrify 3 million vehicle miles/year by 2018
- Ensure 50 percent of City light-duty fleet purchases are electric by 2020

#### **ELEC-5: DRIVING CONSUMER ADOPTION**

A major element of Denver's electrification strategy is to create a market and policy environment where purchasing an EV is affordable, convenient and popular. Colorado already offers a \$5,000 EV tax credit, the most generous in the country. Denver's goal is for 15,000 additional consumers to purchase an EV by the end of 2019 who would not have otherwise done so. This will double the number of EVs compared to the natural growth rate and has the potential to reduce carbon emissions by 70,000 metric tons of CO2 over the grant period.



**Figure 2 - Colorado EV Market Adoption Projection.** Smart City Program seeks to double consumer purchases of electric vehicles.

Denver will utilize multiple approaches to accelerate transportation electrification:

- Marketing and outreach
- Workplace charging
- Electrifying multi-unit housing
- Experiential education
- DC fast charger network
- Hydrogen opportunity analysis

By educating residents about the financial incentives available to them, we will accelerate consumer purchases of EVs. This is why one of our main strategies for increasing public adoption is a targeted, specific marketing and outreach campaign that leverages television, radio, social media, print and other media avenues.

Additionally, experiential driving events, timelimited EV discounts, and direct communication through the City and Xcel Energy will maximize the communication and education that are essential to breaking adoption barriers.

Another major component to growing the EV market is providing reliable infrastructure in the most effective locations. Denver will focus on three types of charging to provide range security to consumers: a strategically located network of fast chargers along major corridors; charging at large workplaces; and charging at multi-unit housing complexes.

Finally, planning for the next generation of zeroemission vehicles, like hydrogen fuel cells, is essential to meeting the consumer market demand and accomplishing City goals. This project will include an infrastructure planning analysis done by NREL to strategically remove barriers to fuel cell vehicles and identify future fueling locations.

#### TASKS:

Task 1: Create and launch marketing and outreach campaign

**Task 2:** Identify opportunities to install EV charging stations at workplaces, multi-unit housing complexes and along major corridors

Task 3: Host experiential education events

**Task 4:** Complete hydrogen infrastructure planning analysis

#### **MEASURABLE OUTCOMES:**

- Install 32 charging stations
- Double the number of EVs otherwise sold, to 30,000, by 2019
- Reduce CO2 emissions by 70,000 metric tons



Automated Vehicle (AV) technology continues to advance at a rapid pace. Transformational benefits are on the near horizon and will bring greater safety, efficiency and access to transportation for residents, commuters and tourists – especially the young, elderly, disabled and underserved. Early advancements in automation are driving the availability of "robotaxis" and driverless shuttles in the market.

Denver will utilize our SMART Council to leverage best practices and lessons learned from partners around the country who are actively testing AV technology, including the University of Michigan Mobility Transformation Center, Virginia Tech Transportation Institute and University of California at Riverside.

Denver will test and solve the financial, technical and social barriers for automated ride sharing to ensure AV fleets can quickly replace conventional vehicles when the technology is ready for commercial deployment. Through MODE, we will deliver transportation services that address the needs and challenges of underserved communities and will provide the framework for a seamless transition to AV operations. These services will be packaged as adoptable best practices so cities nationwide can quickly integrate AV technology.

We are working closely with transportation partners such as Lyft and manufacturers such as General Motors, Ford, VW and Audi. Our Smart City Program will advance automation by funding projects that prepare our residents, our infrastructure and Colorado's regulatory environment for this technological revolution.

We recognize connectivity as a critical first step in ensuring a safe and coordinated environment for AVs. Connected Vehicle (CV) technology enables a transportation network to operate as an integrated Thanks to the \$15 billion FasTracks rail network and transit oriented development stops, Denver is primed for early adoption of driverless technology. At Peña Station Next, partners Panasonic and Easymile will pilot an FMLM service using autonomous electric shuttles – a concept that can be expanded to the region's other 50 transit stations.

system with Vehicle-to-Vehicle (V2V), Vehicle to Infrastructure (V2I) communication, and Vehicleto-Device (V2X) communication. Many aspects of CV technology are ready for adoption today and offer significant opportunities to improve safety, mobility and environmental impact. Denver is committed to realizing CV implementation through the following three key initiatives as we prepare for advancements in automation:

- IV-1: Connected Traffic Management Center and Connected Fleets
- IV-2: Travel Time Reliability for Connected Freight
- IV-3: Intelligent Traffic Signal Systems for Connected Vehicles

We are building a future in connected automation to systematically align the needs of users and businesses with the transportation network for a safer, smarter and more environmentally friendly Denver.

#### IV-1: CONNECTED TRAFFIC MANAGEMENT CENTER AND CONNECTED FLEETS

The Denver Traffic Management Center (TMC) operates and maintains more than 1,200 traffic signals, 460 closed circuit TV cameras and thousands of sensor and detection devices in its mission to optimize traffic flow through the city. TMC operators monitor roadway conditions, special events and incidents seven days per week. The Denver TMC also shares data with CDOT's TMC. With a vast amount of data and ITS capability, Denver TMC operators often have valuable insight into the impacts of traffic, roadway construction and incidents – but they have limited ability to share that information back to the traveling public. It is critical that we leverage Smart City partnerships to enable connectivity between Denver TMC operators and the traveling public by implementing CV technology.

Our Smart City Program will develop a CV architecture and build an operational environment at the Denver TMC to reduce congestion and improve safety by connecting directly with travelers. We will immediately empower the CV environment by delivering DSRC applications for freight efficiency and by creating a live test bed on our most congested corridors – preparing Denver to be the first city that actively uses DSRC data for traffic signal control.

We will equip the City fleet of 1,500 municipal vehicles with DSRC to jumpstart market penetration and lead by example. We will launch a DSRC Equip Program to equip an additional 1,500 vehicles for citizens and partner fleets.

#### 1.1 Waze Connected Citizens Program for Safety and Mobility

Denver is home to an estimated 150,000 active Waze users who report nearly 240,000 alerts while driving 25 million miles per month. They provide valuable insight into roadway conditions and incidents.

By establishing a twoway data exchange between Waze and the Denver TMC at zero cost to our program, we will:

- Gain greater insight into roadway conditions with real-time incident and traffic jam information
- Reduce traffic congestion with improved traveler information to



Figure 3 - Waze Vision Zero. Using the Waze advertising "take-over" product to deliver messages to drivers at a complete stop, Denver can remind users to drive safely as they approach dangerous intersections or high bike/ ped collision areas.

reroute users around road closures, construction and incidents in real-time

- Implement a Vision Zero messaging campaign to improve safety at our most dangerous intersections
- Improve incident response times
- Make data-driven infrastructure decisions for smarter urban planning

#### **1.2 Denver TMC CV Operational Environment** Enabled by the EDM Ecosystem

As Denver adopts CV technology, we will establish the organizing principles and fundamental building blocks of a CV operational environment for the TMC. To utilize the expansive new data enabled by CV technology, it will be essential that the TMC be capable of collecting, parsing, storing, mining and analyzing CV data.

Using the Connected Vehicle Reference Implementation Architecture as a guide, we will partner with CDOT and the Denver Regional Council of Governments (DRCOG) to update the ITS Architecture for the Denver Regional Area and to ensure regional and national transferability of the architecture.

The CV architecture will support all physical components of a CV operational environment including existing ITS infrastructure, DSRC roadside equipment, vehicle-based DSRC devices, and other CV traveler equipment including portable DSRC, smartphones, tablets and satellite-based systems. We will utilize the computing, storage, privacy, security and data access capabilities of our EDM Ecosystem to power the necessary centerbased data management systems and connections to support services, including the USDOT Security Credential Management System, for our CV environment. We will design, build and test the Denver TMC CV operational environment as a foundation for a future with increasing CV data and to support our Smart City CV applications immediately. As an implementation policy, we will develop Geographic Intersection Description messages and broadcast signal phase and timing messages for all roadside unit (RSU) deployments.

#### 1.3 Connected Fleets

City fleet vehicles blanket the city through daily operations. Equipped vehicles are essential to the design, testing and operation of the Denver TMC CV operational environment. We will equip our fleet of light- and heavy-duty vehicles with DSRC to lead by example and immediately generate Basic Safety Messages as vehicles move throughout the city. NXP will equip approximately 300 vehicles while other partners will cover the cost of equipping an

additional 1,200 fleet vehicles.

To further drive market penetration in Denver, we will also design and launch a DSRC Equip Program for partner fleets and residents. We will incentivize

academic, public and private fleets partners to equip their vehicles with DSRC. We will initiate an equipping service to connect fleets with DSRC manufacturers and drive down the cost of devices through group purchase. Sponsored by our technology partners, we will also invite and fund 1,500 citizens to equip their vehicles using this service in order to engage and educate the community and further drive market penetration.

#### TASKS:

**Task 1:** Develop project plan, including identifying inputs and deliverables

**Task 2:** Collaborate with Waze Connected Citizens Program to enhance traveler information

Task 3: Design, build and test the Denver TMC CV environment

Task 4: Equip the City fleet with DSRC

**Task 5:** Design and launch DSRC Equip Program for other fleets and individual consumers

#### **MEASURABLE OUTCOMES:**

- Reduce injuries at identified Vision Zero intersections by 30 percent
- Reduce crashes at identified Vision Zero intersections by 30 percent
- Analyze the 240,000 monthly Waze user reports for traffic flow and incident patterns
- Reduce incident response times for citizenreported crashes by 30 percent
- Increase DSRC vehicle market penetration to 10 percent by 2020

#### IV-2: TRAVEL TIME RELIABILITY FOR CONNECTED FREIGHT

Colorado is home to three federally designated high priority corridors – Heartland Expressway, Ports-to-Plains and Camino Real – that pass directly through metro Denver. Freight movement is closely connected to the health of our economy and the transportation system in our state. The Colorado Freight System includes highways, rail



lines, airports and other intermodal facilities. It delivers goods, creates jobs and provides economic opportunities to people statewide. The transportation and warehousing sector in Colorado contributes billions of dollars to

Colorado's economy.

Given that a great majority of the region's population and traffic growth is expected to occur within the I-25 and I-70 corridors, and that significant highway expansion is not likely, congestion will continue to be a challenge for freight movement.

The Denver neighborhoods and local roads near major freight facilities and distribution centers are significantly impacted by freight traffic, noise and pollution. As plans proceed for the federally funded \$1.2 billion reconstruction of Central I-70, underserved communities such as Globeville, Elyria-Swansea and Montbello stand to face even greater impacts than they already experience.

CV technology presents a wealth of capabilities to address these challenges. Denver will implement a Freight Efficiency Corridor Program and provide travel time reliability northeast of downtown in partnership with CDOT, NXP, Peloton Technology and Econolite.

#### 2.1 Freight Efficiency Corridor Program

Denver will convene a broad stakeholder group to serve as the Freight Efficiency Corridor Program's Project Leadership Team (PLT). The PLT will consist of representatives from key equity partners to represent underserved communities. Other team members will include representatives from CDOT's Freight Advisory Committee, Colorado Motor Carrier Association, Metro Denver Chamber of Commerce, Metro Denver Economic Development Corp., Peloton Technology, UPS, FedEx, Safeway and Walmart. The program will provide:

- Designated parking and staging areas for freight movement into the Denver area
- Regularly updated and comprehensively defined routes for all freight traffic, not just oversize or hazardous movements
- Enhanced data collection capabilities to understand, assess and respond to freight movement through Denver communities

#### 2.2 Travel Time Reliability as a Service Using Freight Signal Priority

Denver will be the first in the nation to deliver travel time reliability as a service to the freight industry using traffic signal priority. This has three major benefits:

- It incentivizes fleets to equip with DSRC at their expense.
- It gives Denver the opportunity to drive business rules for freight travel through the City in order to reduce peak period traffic and lessen the impact on underserved communities, providing proactive instead of reactive guidance to the freight industry.
- It coincides perfectly with upcoming I-70 reconstruction. That project will require extensive freight industry engagement. We will

use technology to provide a service and help the industry navigate the construction impact instead of merely offering information about the impact.

To deliver this service, we will:

- Equip designated arterials and freeways with 100 DSRC RSUs in partnership with NXP
- Design, test, deploy and evaluate a DSRC-based freight signal priority application in partnership with Econolite
- Launch travel time reliability as a City service to freight fleet operators as an incentive to equip their fleets with DSRC technology facilitated by Peloton Technology
- Demonstrate a first-in-the-nation arterial freight platooning operation with signal priority using Peloton and Econolite technology to exhibit future possibilities

Providing a travel time reliability service to the freight industry will not only reduce the high cost and environmental impact of freight congestion but it will significantly improve the quality of life in the neighborhoods and underserved communities that surround many of Denver's high throughput freight facilities and distribution centers.



**Figure 4 - North Denver Freight Corridor.** Stretching from I-25 to Peña Boulevard, North Denver is dense with freight movement and facilities and is primed for improving freight efficiency.

#### TASKS:

**Task 1:** Develop project plan, including identifying inputs and deliverables

**Task 2:** Engage stakeholders and develop a Freight Efficiency Corridor Program

Task 3: Design and launch Freight Efficiency Corridor Program

**Task 4:** Design, develop, test and deploy freight signal priority on arterials

**Task 5:** Coordinate outreach and communication to freight industry via Peloton Technology

**Task 6:** Launch Denver travel time reliability service for connected freight

**Task 7:** Evaluate Denver travel time reliability service for connected freight

**Task 8:** Design, develop, test and demonstrate arterial freight platooning operation using freight signal priority

#### **MEASURABLE OUTCOMES:**

- Reduce travel time on designated arterial routes (by 20 percent) using freight signal priority
- Reduce reports of interruptive freight movement in neighborhood communities by 30 percent
- Reduce freight traffic on major freeways and arterials in the Freight Efficiency Corridor by 20 percent during peak periods
- Reduce spot measurement of emissions at heavy freight movement intersections by 50 percent for platooning demonstration
- Increase throughput at intersections by a factor of two to three times for platooning demonstration

#### **IV-3: INTELLIGENT TRAFFIC SIGNAL SYSTEMS** FOR CONNECTED VEHICLES

We will leverage CDOT's \$20 million fast-paced technology program, RoadX, to improve mobility at our major arterial and freeway congestion points. As part of the RoadX Program, we will increase the benefits of the \$7 million I-25 Managed Motorways project by integrating arterial traffic operations to improve traffic flow and reduce congestion. Bolstered by a \$5.5 million contribution from CDOT, we will implement adaptive signal control on Colorado Boulevard and Hampden Avenue to support CDOT's smart ramp metering implementation on I-25, expanding the traffic management area and delivering additional queue and storage capacity. We will then use the project area to create a live test bed that prepares Denver to be the first city that actively uses DSRC data for traffic signal control.

#### 3.1 Adaptive Signal Control Integrated with Smart Ramp Metering

The biggest congestion factor for all arterial highways is intersection capacity. Traffic signals control vehicle movements at the intersection of two roadways and must, by design, reduce the capacity of both roadways by reducing the number of vehicles that can travel through an intersection during a particular period. Thus, optimizing and synchronizing traffic lights and ramp metering is not only critical to ensuring the flow of traffic on highways but also essential to optimizing traffic operations between arterials and highways. The key project steps to achieving integrated arterial/ highway operations at I-25 on Colorado Boulevard and Hampden Avenue include:

- 1. Reform site visit and field survey
- 2. Install detection and DSRC RSUs
  - a. Evaluate system data
  - b. Define and evaluate control strategies and business rules targeting the following use cases
    - i. Dynamically adjust cycle lengths, splits, and offsets to minimize wasted green time and delay
    - ii. Actively manage queues
    - iii. Gate and feather traffic
    - iv. Address closely spaced intersections
    - v. Maintain pedestrian phases
- 3. Develop signal timing plans
- 4. Implement, fine-tune and continuously evaluate new control strategies

#### 3.2 A Live CV Test Bed for DSRC-based Traffic Signal Control

CV technology provides an opportunity to redefine the inputs of traffic control completely, enabling an entirely new methodology for signal control. Denver will partner with Econolite to launch its new CV intersection controller, Cobalt Sky<sup>™</sup>. This will provide the traffic controller with DSRC-based geometric awareness of the intersection and vehicle trajectory data as an input for vehicle demand. This is the first ever traffic controller fully designed with the intent to apply the robust inputs offered by DSRC. This broadened awareness will open a platform for an entirely new set of traffic control strategies, optimization models and features. Through an in-kind contribution, Denver will be the first deployment site for Econolite's new CV intersection controller Cobalt Sky™ Cobalt Sky<sup>™</sup> enables tracking vehicles through their approach to an intersection, including any standing vehicle delay and reacceleration past the intersection. This

tracking enables intersection measurement and control via new metrics that transcend the traditional measures of stops and delays. These new attributes can be directly measured from real-time vehicle trajectories, and the signalization control strategy can be optimized in real-time to adjust to the imminent future state of these vehicle trajectories.

Denver will implement the new traffic controller as software-in-the-loop on its new Live Test Bed on Colorado Boulevard and Hampden Avenue. We will use this opportunity to continuously evaluate the market penetration necessary to support DSRCbased traffic signal control, driving towards our vision of replacing adaptive signal control and smart ramp metering along the corridor with DSRC-based traffic signal and ramp metering control.

#### TASKS:

**Task 1:** Develop project plan, including identifying inputs and deliverables

**Task 2:** Design, test, and deploy adaptive signal control on Colorado Boulevard and Hampden Avenue

**Task 3:** Integrate I-25 smart ramp metering operations and arterial adaptive signal control operations

**Task 4:** Install DSRC infrastructure for the connected live test bed on I-25, Colorado Boulevard and Hampden Avenue

**Task 5:** Develop and evaluate the connected live test bed for DSRC-based traffic signal control

#### **MEASURABLE OUTCOMES:**

- Reduce travel time on Colorado Boulevard by 15 percent during peak periods
- Reduce travel time on Hampden Avenue by 15 percent during peak periods
- Define the level of market penetration necessary to transition to DSRC-based traffic signal control



**Figure 5 - Southeast Denver Congestion Corridors.** I-25 has the highest volume of all state highways with more than 250,000 vehicles per day at three different segments around Downtown Denver, including Colorado Boulevard and Hampden Avenue, which will be transformed into a Live CV Test Bed.



The Enterprise Data Management Ecosystem (EDM) is based on an industry leading architecture model that uniquely combines big data and analytics, Internet of Things (IoT) and cloudbased services. The EDM will provide a large data repository to collect and process data from many sources to support our entire Smart City Program.

To advance connectivity, the EDM will comply with Denver's Open Data Policy and deliver open standards-based web services for data producers and consumers. The EDM cloud implementation will enable Denver to provide Data as a Service (DaaS) and Analytics as a Service (AaaS), delivered through dashboard analytics tools, which will be developed to evaluate our Smart City projects.

The EDM will be the central repository for all Smart City data. Data will be accessible from the centralized system for reporting, analysis and information sharing. This holistic approach will allow for multidimensional analysis on complex transportation challenges, leading to better outcomes. By hosting the data in the centralized platform, the EDM will foster information sharing and innovation through collaboration with government agencies, cities, research institutions, universities, private companies and the public. The USDOT's Independent Evaluator also will have dedicated EDM access.

The EDM is, at its core, a data lake capable of ingesting data in any format. By allowing data providers to deliver content in flexible formats, delivery is simplified for owners. This streamlined approach to data acquisition encourages strong adoption of the platform, ultimately ensuring that more data are available for deep analytics, such as operational optimization, trend analysis, predictive analytics and machine learning. To accommodate the velocity of data acquisition, interfaces are optimized for a multiplicity of data flows that support batch and real-time data streaming. Adaptability to new or changing datasets is accomplished through configuration-driven workflows while traceability, data fidelity and transformational lineages are preserved – offering further insights into dataset evolution.

Data mastering and cleansing functions are augmented by versatile data cataloging and indexing services, which ensure that data consumers, whether human or machine, can efficiently and effectively mine the data. Consumers are able to interact with the analytical models and data, and to publish refined content back into the data lake for further dissemination. Creating a pervasive cybersecurity framework will ensure that data producers and consumers interact with the volume of data assets in accordance with established policy.

The EDM will be used to conduct data-driven analytical research to identify and confirm the City's challenges and needs in the targeted project areas. Denver's key performance indicators (KPIs) will be coded into the EDM to track successful outcomes. The goals, objectives and performance measures will be monitored on a continuous basis to assess quantified targets against actual targets and mitigation plans when necessary. The EDM Web Services portal will allow the City to collaborate and share data with key stakeholders.

As previously discussed, the primary function of the EDM is to integrate data from a wide variety of sources and perform big data

It is important the EDM not only solves Denver's Smart City needs of today, but that it is flexible and adaptable to meet the needs of tomorrow for all Smart Cities.



**Figure 6 - Enterprise Data Management (EDM) Ecosystem.** The diagram highlights each of the Amazon Web Services components necessary to fully support the EDM Ecosystem. The individual component boxes describe the core functions necessary to deliver the EDM Ecosystem including: data storage, catalog, analytics, search, entitlements, security and management.

analytics to develop new meaning from the data. Keeping with the City's vision, and aligning with USDOT ITS Joint Program Office Strategic Plan, the EDM will be architected with scalability, flexibility and extensibility in mind.

To accomplish this, the EDM will be built using a three-pronged strategy:

- Industry Standards Architecture Advances in technology are changing how technical, business and security needs are being addressed. There is an ever-increasing adoption of open, standards-based architectures, cloud computing, and virtualization that provide an excellent framework for development. The overarching architecture of the EDM will leverage these open, standards-based technologies, following industry best practices.
- 2. **Open Platform Interfaces** The ingress and egress of data is largely based on requirements

and functionality of the public/private data producers and data consumers. By utilizing industry standard web services and open API's, a flexible data dictionary can be maintained to enable the integration and dissemination of massive amounts of disparate data, supporting current and future Smart City use cases.

3. **Comprehensive Security Framework** – Critical to any Smart City ecosystem is the concept of security. Whether there is an outside malicious attack or an honest mistake made by an authorized user, Smart City systems must be able to remain resilient and protect the privacy and segregation of the data and its users. To accomplish this, the EDM will be architected with the industry standard National Institute of Standards and Technology (NIST) Cybersecurity Framework and Cloud Security Alliance (CSA) controls implemented by the City. This will enable the EDM and its administrators to identify, protect, detect, respond and recover from internal and external threats.

The EDM will be built utilizing a comprehensive suite of Amazon Web Service's (AWS) flexible and cost effective solutions. Previously, disparate data warehouse solutions each required dedicated hardware (redundant and scaled for peak usage and storage), dedicated, reliable power, physical security, identity management, and other infrastructure and software solutions combined to create a useable data platform.

AWS eliminates the cost and operational

overhead of multiple solution components by virtualizing many aspects of DaaS and AaaS functionality into the cloud. AWS is:

• **Easy to Use:** Software as a Service (SaaS) and API components are pre-canned and

well-documented, allowing for rapid EDM development. Simple web applications can be deployed for stakeholders with minimal IT involvement.

- **Flexible:** Deployment variables such as operating systems, database platforms, and other services can be easily selected and deployed.
- **Cost Effective:** Pay-as-you-go usage models for data transfer, storage and computing power will help Denver control costs.
- Reliable: A reliable, global computing infrastructure ensures the highest availability.
- **Secure:** Multiple levels of security and Identity Access Management (IAM) are native to the service.
- Scalable and Extensible: The "elastic" nature of AWS services will allow rapid deployments of additional EDM solutions from the smallest city requiring minimal storage and load balancing, to the largest city requiring a robust, complex EDM Ecosystem.

By implementing the EDM, Denver will be able to leverage the full complement of information assets to optimize multi-modal transportation services for a rapidly growing urban population. The sections below describe how the Denver's three main Smart City components will be empowered by the EDM Ecosystem.

#### **MOBILITY ON DEMAND ENTERPRISE (MODE)**

MODE will offer data-driven services to provide citizens with optimal transportation choices based



on price, travel time and climate impact. EDM will connect users, data and transportation choices. It will provide users with better access to safe, efficient and affordable mobility options.

When MODE launches its universal transportation payment system, predicated on information sharing, EDM will manage data assets from various transportation service providers (TSPs), such as route information and route costs that must be collected, aggregated, analyzed and disseminated. EDM will provide the means for TSPs such as Lyft, Car2Go and ZipCar to share their data. When

the data are combined with other data, such as RTD routes and Denver Bike Share station locations, an integrated, multi-modal payment capability will be created.

EDM also will support the interactive kiosks to be deployed as part of MODE. EDM

will receive detailed logs of all aspects of users' interactions with the kiosks – either through the kiosks' interactive media or through Amazon's Alexa technology. The data will be instrumental in providing analytics on kiosk usage.

Finally, EDM will collect and aggregate environmental sensor data generated by the kiosks themselves. This data can feed the mobile application directly, or be made available to researchers and data scientists to better understand transportation impacts on the environment and public health.

#### TRANSPORTATION ELECTRIFICATION

EDM will be the centralized repository for aggregated data on Electric Vehicle Supply Equipment (EVSE) usage, queuing and billing.

Supplemental City data housed within EDM – such as demographic data, traffic patterns and typical TSP vehicle type use – will be leveraged to help determine quality locations for EVSE installation.

The EDM will support our Transportation Electrification projects through integration of EV data with the utility grid to provide real-time information for users. The Electric Power Research Institute (EPRI) Open Vehicle Grid Integration Program (OVGIP) provides an opportunity to enhance visibility, control and interoperability between Xcel Energy and the City's EV data environment. And several project data sets will be captured in the EDM for further analysis and reporting on grid decarbonization, fleet electrification and consumer adoption performance measures.

#### **INTELLIGENT VEHICLES**

EDM will integrate V2V/V2I/V2X systems with the Intelligent Vehicle component of Denver's Smart City Program. For example, data from the CV operational environment will combine with common interfaces to deliver interoperability across sub-systems including DSRC, Waze crowd sourcing, Denver's TMC data warehouse, and realtime traffic management and detection.

Transportation agencies collect, manage, and process extensive amounts of data from ITS systems to support traffic operations, revenue generation, traffic incident management and traveler information, but are constrained in their ability to share data. EDM will advance the connectivity of drivers with each other and relevant government agencies by analyzing data that supports contextual and spatial data elements. Decision making will move from a reactive mode to one of intelligent, real-time decision making.

The EDM will act as a secure data clearinghouse for CV data storage, management, security and access management for the various users such as vehicles, infrastructure, administrators or data scientists. The Denver TMC CV operational environment will expand on the existing network of 1,200 traffic signals, 460 closed circuit TV cameras, and thousands of sensor and detection devices. These large amounts of data will be collected, stored, processed and analyzed to enable real-time and future decision making.

One of the primary, enabling technologies within numerous CV use cases is DSRC. With DSRC technology, vehicles evolve from individual transportation objects to connected, mobile sensors. However, the infrastructure needs to be in place to enable the communication between various entities in real-time. DSRC on-board units will broadcast Basic Safety Messages 10 times per second. The speed at which these communications will be taking place is near real-time and provides reliable communication in emergency situations when seconds matter. For these critical events that require real-time communication and dissemination, the EDM will be the aggregation point that passes data to consumers.

The TMC will also use third party data providers such as Waze for complementary capabilities to deliver location-specific messages about high-crash intersections or high pedestrian/bike traffic areas. The EDM will integrate these various data sets from static sensor data as well as streaming data from Waze, allowing communication and notifications that promote safer driving in high-crash areas.

The EDM will be critical in supporting the TMC's CV operational environment and planning efforts for future deployments. Data supported by the EDM will provide valuable insight into the impacts of traffic, roadway construction, and incidents and in the future deliver real-time event notification, roadway construction updates, and parking availability information to Denver.

Cities are facing an ever-changing landscape in the way their data is managed and utilized in order to improve services and drive innovation. The emergence of Open Government and Open Data policies, combined with advancements in Smart City and CV technologies, has changed the role and responsibilities of government.

Data are no longer generated and stored "just in case;" all citizens expect transparency for the operation of their city as well as services that allow for safe and efficient mobility options. EDM, therefore, is the technological linchpin of Denver's Smart City proposal.

#### TASKS:

**Task 1:** Develop project plan, including inputs and deliverables

**Task 2:** Deliver API interfaces to enable data to be consumed in the EDM Ecosystem

Task 3: Design and deliver data environment in the Cloud

Task 4: Deliver web services for data producers and consumers

**Task 5:** Fully integrate Denver's Smart City projects into the EDM Ecosystem

**Task 6:** Implement administrative and sustainability program management components for EDM Ecosystem

#### **MEASURABLE OUTCOMES:**

- Reduce data load processing times based on automated streaming interfaces with existing systems
- Increase efficiency in multi-organization data analysis based on pre-loaded data sets and analytic model sharing
- Increase efficiency in monitoring systems from automated business rules and analytics.
- Reduce data sharing processing times based on the establishment of open standards-based interfaces

#### **A.5 ANNOTATED SITE MAP**



#### THE CITY AND COUNTY OF DENVER



#### A.6 PROGRAM MANAGEMENT

Our overall program management approach, is based on a lean management structure capable of making timely decisions when they are needed most. We will operate as a Smart City that understands the functional systems, organizational constructs, and implementation strategies that ensure we function in alignment with our values and are achieving desired outcomes.

The Smart City Program controls and contract administration procedures cover baseline budget control, pending and approved change control, schedule control, monthly progress reports, and all necessary federal funding reports. Our program management approach is tailored to support the continuous advancement of the entire Smart City Program while also supporting engagement of targeted underserved communities.



**Figure 7 - Smart City Program Lifecycle.** Denver's Systems Management & Performance Measurement Lifecycle fully engages academic, private, philanthropic and start-up communities in a way that truly advances Denver's Smart City environment even after the grant ends. The contract program manager will be responsible for ensuring the monitoring and reporting of the following elements of Denver's Smart City Program as described under the "Program Management" section of the NOFO:

#### Program Management Plan (PMP)

Our proposed program relies on a robust and proven PMP that describes the organization, management control systems, and processes that guide the full range of activities required to implement this groundbreaking program. Our team is well-versed at successfully managing key PMP processes that will drive this program from initiation, planning and execution to monitoring controlling and closing. Denver will adhere to the Project Management Body of Knowledge (PMBOK), 5th ed., as outlined in the NOFO.

The PMP will be updated and submitted for USDOT review on a monthly basis, and will contain scope, schedule, communication, cost, quality, configuration management and risk management plans. If acceptable to USDOT, Denver will add a deliverable titled "Systems Management and Performance Measurement Lifecycle Program" to the PMP, which is described at a high level below.

Our contract program manager will be fully responsible for ensuring compliance with the PMP throughout the duration of the contract. Denver's PMP will:

- Summarize the Smart City Program, including the scope, schedule and capital budget (Part 2)
- Describe organizational, partner and reporting relationships
- Establish goals and objectives that form the basis of the Smart City Program
- Provide information about the organization, control systems, processes, roles, responsibilities and lines of authority within the Smart City Program
- Cite definitive and authoritative references, including specific policies and procedures
- Designate inter-relationships between the Smart City practices and the agency-wide policies and procedures
- Establish consistent management practices
- Form mechanisms for managing technical and financial risks
- Demonstrate that Denver's program is structured in accordance with City and federal requirements

The following table describes the specific elements of Denver's Smart City Program management plan and execution strategies:

Program Elements (What)	Program Execution (How)
Scope Management	: Plan
Work Breakdown Structure (WBS) for Scope Identification	<ul> <li>A minimum three-level WBS will be the framework to organize all work elements. The WBS will form the basis for all scheduling, cost, estimating, and document control.</li> <li>Coding cost and schedule information will align with the appropriate MODE, Electrification, Intelligent Vehicle, and EDM Ecosystem WBS elements, and at all appropriate costing levels.</li> <li>The WBS will be arranged in hierarchical levels of scope definition, from most general deliverables (i.e., Data Management System) to most specific work task (performed by a single resource or team), and will describe: the name of the work activity, expected start and end dates, name of the individual with the primary responsibility for accomplishing the work, dependencies with other work activities in the project schedule, and all deliverables, procurements, and milestones resulting from the work activity.</li> <li>The WBS will identify the first two levels of component deliverables (types, location, and lifecycle phase) for scope definition, budget allocation, design development, and responsibility assignment. These elements are defined by the comprehensive Master Schedule.</li> <li>The WBS for each major deliverable will be further defined below level three of the WBS hierarchy. These more discrete deliverables drive the planning, procurement, and cost/schedule control.</li> </ul>
Key Delivery and Interface Milestones	<ul> <li>After mutually exclusive and exhaustive WBS is established, the component project tasks are arranged in the delivery sequence driven by the critical path in the Master Program Schedule. The interdependent items between stakeholders are given a finite delivery Milestone Date and identified as a Key Delivery or Interface Milestone.</li> </ul>
Responsibility and Accountability Controls	<ul> <li>The Organization Breakdown Structure will combine defines the program's functional, technical, and managerial responsibilities.</li> <li>WBS and Cost Breakdown Structure will combine to form a control account to identify who is responsible for scope, schedule, and budget.</li> <li>The Resource Breakdown Structure (RBS) will be a hierarchical catalogue of assignable resources with accountability for the delivery of the WBS scope.</li> </ul>
Schedule Managem	ent Plan
Master and Baseline Schedules	<ul> <li>The master schedule of projects segregates program baseline schedules from working schedules and controls access by contractors and consultants to their respective projects within the master schedule.</li> <li>Consultants/contractors will submit baseline schedules for approval by the program manager.</li> <li>Baseline schedules are used to measure work progress and to provide important variance data to identify problems and determine corrective actions.</li> </ul>
Current Updates	<ul> <li>Schedules are updated on a monthly basis to assess progress versus the baseline plan.</li> <li>The current schedule for the first monthly update will be based on the approved baseline schedule.</li> <li>Subsequent updates are based on the previous month's approved update.</li> </ul>
Earned Value Reporting	<ul> <li>The program's planned progress, actual costs, and percentage of work-completed to date is monitored and reported through the life of the project. Earned value indicates how much of the budget and time should have been spent, with regards to the amount of work actually done to date.</li> <li>Actual costs and percent complete will be tracked and compared to the plan to determine if the project is ahead or behind schedule, and whether the actual dollars spent are in line with percent complete earned.</li> </ul>

#### Table 1 - Program Management Plan Elements

Program Elements (What)	Program Execution (How)
Monthly Progress Reporting to Stakeholders	<ul> <li>We will deliver monthly reports that summarize cost and schedule information with an overall update of the project.</li> <li>The report includes an updated master schedule and will be presented monthly to the USDOT's Agreement Officer Representative (AOR).</li> <li>Consultants/contractors will provide required schedule reports and performance measurement reports to support these reports.</li> </ul>
Communications M	anagement Plan
Key Deliverables	<ul> <li>The Communications Plan will be a living playbook that will outline the full Smart City engagement with the other stakeholders within Denver's organizational construct.</li> <li>We will ensure that the team has effective internal communications and governance methods, as well as communications with the AOR.</li> </ul>
Cost Management I	Plan
Baseline Budget	<ul> <li>A baseline budget will be the authorized time-phased budget plan used to measure cost and schedule performance for the project. The baseline budget will be maintained under formal change control through an annual program evaluation process in collaboration with the AOR.</li> </ul>
Budget at Completion (BAC)	<ul> <li>The BAC is the sum of all budget values for work to be performed on the program and will be used to measure the monthly earned value of the projects. The BAC is closely monitored to ensure that the project will be completed within the allocated and approved budget.</li> </ul>
Cost Controls	<ul> <li>We will download actual cost and commitments on a periodic basis into the cost control system to determine the actual cost of work performed, and the project controller will determine the estimate at completion report variances.</li> <li>We will monitor the financial/cost performance of the project and take responsibility for addressing cost-related issues as they arise. Our cost control staff will be able to explain the root cause for variances and recommend whether corrective, remedial or reconciliation actions need to be taken.</li> </ul>
Control Accounts	<ul> <li>WBS elements of work will be defined and form the 'accountability' basis for project planning, scheduling, budgeting, work authorization, cost accumulation, performance measurement, analysis and progress reporting.</li> </ul>
Cost Breakdown Structure (CBS)	<ul> <li>The cost breakdown structure will identify unit cost components, and the top levels of the CBS hierarchy directly associates with the WBS; indicating where and for what major assets, costs are being allocated. The CBS at the lower levels indicates resource or permanent material costs.</li> </ul>
Invoice Verification	<ul> <li>All invoices, including consultant and contractor, will be verified accurate regarding measured units and agreed costs, against WBS items and can be authorized for payment. All invoices will be processed in accordance with program standard invoicing requirements established by contract terms and conditions. Invoices will be accompanied by required reports as stipulated by contract terms and conditions, and verified by project controls staff for accuracy.</li> </ul>
Estimate at Completion (EAC)	<ul> <li>Estimate at Completion forecasts the cost at completion for the original and amended scope and will be calculated using earned value formulas, spreadsheet functions, manual estimate input/pricing analysis or an appropriate combination thereof.</li> </ul>
Contingency and Management Reserve	<ul> <li>Contingency and management reserve funding is a fiscal planning tool for managing the risk of cost escalations and covering potential cost estimate shortfalls. Inclusion of a contingency amount in the cost estimate will minimize the impact of cost increases inherent in an overly optimistic estimate and provide for an earlier discussion of how potential circumstances can be addressed.</li> </ul>

Program Elements (What)	Program Execution (How)				
Quality Management Plan					
Quality Management System	<ul> <li>Our program quality management system meets or exceeds federal guidelines and conforms to the international quality standard ISO goo1:2008. The system allows supplemental procedures, as needed, to ensure adequate oversight of planning consultants, design consultants, construction contractors and materials suppliers (collectively referred to as the "Contractors"). All Contractors will submit a Quality Management Plan for approval by program management based on requirements of their respective contracts.</li> </ul>				
Document Control	<ul> <li>Quality records will be collected, stored and preserved in a manner that precludes damage, loss or deterioration. The Contractors' storage requirements will be in accordance with the contract and project specifications. The Contractors will be responsible for safeguarding quality records during the project duration. At the conclusion of the contract, quality records will be turned over for archival storage.</li> </ul>				
Quality Assurance and Quality Control	<ul> <li>Our Quality Assurance and Quality Control plan consists of clear, correct, complete and concise project work properly checked, reviewed and authorized for use, and will be essential to achieving project performance requirements. Denver has multiple policies in place to assist our staff in delivering a quality product.</li> </ul>				
<b>Configuration Mana</b>	igement Plan				
Change Control	<ul> <li>The Program's overall configuration management procedures provide methods of control to maintain and ensure all projects remain consistent with appropriate design standards and criteria.</li> </ul>				
Program Commitments (Program Configuration Controls)	<ul> <li>Program commitments between investors especially with respect to delivery, coordination, or funding of the program, are recorded and controlled at the appropriate WBS level, with Milestone Dates and assignments/commitments of responsibilities and accountabilities, usually in the form of a legally executed Contract or Agreement.</li> </ul>				
Risk Management P	lan				
Risk Register	<ul> <li>The Program risk register is a catalogue for identified risks, which includes the WBS reference, Request of Materials (ROM) cost estimate, potential schedule impact/ duration, ownership responsibility and the priority/probability status. Each project under the Program maintains a detailed working risk register to update the Program risk register monthly.</li> </ul>				
Risk Assessment and Tracking	<ul> <li>Routine and adhoc risk assessments will be conducted at the program and project levels, to review, amend and append the risk register. Each project team will be responsible for assessing the adequacy of their remaining contingency funds against the active or unmitigated risks on their register.</li> </ul>				
Risk Matrix/ Reporting	<ul> <li>The risk register includes risks assessed and mitigated during the life of the program, however, a separate report of active/potential risks with high priority and probability, will be routinely reviewed. A Risk Matrix will be used as a summary overview report, which graphically categorizes and highlights the risks from most severe/likely (cost/ schedule consequence) to least severe/likely.</li> </ul>				

#### **Schedule**

Our detailed schedule and associated milestone deliverables can be found in **Part 2** of this proposal. Below are high-level summaries:



MODE-2: Deliver Meaningful Change MODE-3: Educate to Change Policy and Improve Quality of Life

ELEC-5: Driving Consumer Adoption

**Connected Freight** IV-3: Intelligent Traffic Signals Systems for Connected Vehicles

Figure 8 - Denver's Smart City Schedule at a Glance

#### A.7 SYSTEMS ENGINEERING APPROACH

Our approach to systems engineering is founded in three core values: safety, security and sustainability. We will deliver Smart City systems that address Denver's real needs and challenges while prioritizing the safety of all users and operators for new technologies. We will implement privacy and security by design in the delivery of all systems while maintaining open access and interoperability for collaboration locally, regionally and nationally.

The systems engineering (SysEng) process is critical to the successful implementation of Smart City, CV, ITS and technology concepts. Figure 9 showcases how each Denver Smart City project will be



**Figure 9 - Systems Engineering Management Plan (SEMP).** The Denver SEMP will govern how each Smart City technology project follows the systems engineering lifecycle through all stages from concept design to operations and maintenance.

governed by our Systems Engineering Management Plan (SEMP) to complete essential project milestones and documentation based on Institute of Electrical and Electronics Engineers (IEEE) standards as applicable. Stakeholder engagement is fundamental to our approach to ensure the needs of our users are consistently identified, tracked and met during each project. We will execute each project in three complementary phases:

- Phase I Plan & Develop Concept(s)
- Phase II Design/Build/Test
- Phase III Operate & Maintain

Aligning our phased approach with the SysEng lifecycle and critical milestones will reduce budget and schedule risks and result in better documentation that is reusable across projects. For software and development-intensive projects, we will employ agile development methodologies to deliver, test and re-test incremental functionality early and often throughout a project, resulting in more adaptable, resilient systems.

All concept development and design phase documentation will remain living during the project, promoting fast-paced delivery of capabilities and managed, documented changes to the final product. All planning and development systems engineering documentation produced under the Smart City projects will be available for public consumption and formatted for Section 508 compliance. Additional systems engineering documents that will be developed but will likely not be for public consumption due to system security considerations include the System Test Plan, Interface Control Documents (ICDs), Testing Documentation, and Operations and Maintenance Manuals.

#### **A.8 PERFORMANCE MEASUREMENT**

Performance measurement is strongly embedded in the City's culture and provides significant value to Denver. For the last four years, Peak Performance, Peak Academy and Peak Analytics have established a performance framework throughout the entire City enterprise to actively manage, innovate and improve delivery of services. The simple framework requires agencies to:

- Establish a strategic plan
- Develop performance measures
- Create a cadence of accountability
- Participate in training and receive coaching on improving service delivery

Each agency meets regularly with the Mayor, Budget Director, Chief Performance Officer and others to review key performance indicators and discuss innovations and challenges within the agency. Peak Academy works with every agency's front line staff on problem solving, process improvement and innovation. Since the inception of Peak, this nationally recognized program has trained more than 5,000 employees and executed on \$15 million worth of hard and soft savings to the City and additional value created for citizens. In the second half of 2016, Peak will be conducting multiagency report-outs on coordinated efforts to achieve the City's 2020 Sustainability Goals.

Following Peak standard practices in problem definition, Denver will begin a Performance Measurement Plan for the Smart City Program by creating a logic model for each project. Using stakeholder input, these models will outline the project scope and enumerate all relevant inputs, outputs, key short- or long-term outcomes and metrics that will be used to quantify performance. The plan will also detail major assumptions, including identification of external factors that could impact results, and will create an actionable plan to achieve outcomes.

To establish metric baselines, we will gather statistics on the major variables identified in the Performance Measurement Plan and shown from subject matter experts/literature reviews to drive change in these outcomes. This data will be drawn from currently accessible City-owned data, public data from other governmental and external organizations, private datasets available from stakeholder partners, purchased private datasets, and primary data collection efforts when no dataset or proxy currently exists.

For some program areas, specific baselines and target goals are already established. For example, Denver utilizes a "Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories," a peer reviewed greenhouse gas inventory methodology for community-wide emissions. For transportation sector emissions, Denver estimates the fuel (gasoline and on-road and off-road diesel) consumed within boundary from state fuel sales data. Denver also accounts for the Scope III emissions from the production of those fuels. Emissions factors are taken from Environmental Protection Agency's (EPA) Emission Factors for Greenhouse Gas Inventories, Updated 2014.

In addition to fuel sales data, Denver regularly analyzes National Emissions Inventory data and DRCOG vehicle miles traveled studies. Combining these three types of analyses allows Denver to adjust projections of National Emissions Inventory and vehicle miles traveled growth to match more recent fuel sales. We anticipate projecting impact according to the number of EVs displacing fossil fuel vehicles and comparing that to a business as usual trajectory with flat EV growth. We are also able to project our utility grid emission factor based on reported Electric Resource Plans and can account for existing decarbonization already planned as of our baseline year.

To create a baseline for air quality, Denver already has a number of data sources, including an emissions inventory, ambient emissions stations and emissions modeling. The most recent air pollutant emissions inventory for Denver was completed in 2011 by the Air Pollution Control Division of the Colorado Department of Public Health and Environment. This inventory is aggregated by county and is updated on a fiveyear cycle. In addition, the Air Pollution Control Division issues yearly Air Quality Data Reports. The division is also responsible for four ambient air-monitoring stations in Denver that meet strict EPA standards for pollutant measurement. The City will be supplementing this existing network with its own additional monitoring station that is expected to start collecting data during the fall of 2016. All of these stations will form the basis for the tracking of air quality benefits resulting from our Smart City Program.

With respect to single occupant vehicle commuting, Denver will continue to rely on annual data from the American Community Survey conducted by the U.S. Census Bureau.

Specific evaluation design to assess each program will be determined by many factors, including:

- Nature/type of research question
- Evaluation objectives and scope
- Study timeline and resource availability
- Data collection methods/sampling procedures

Prior to program inception, Denver will establish the exact collection methods/requirements, data gathering roles/responsibilities, timeframes and collection/reporting frequencies, and technical specifications around storage in Denver's EDM Ecosystem.

The EDM Ecosystem will collect or generate the data needed to calculate the actual to target performance measures, which will be automatically uploaded into the EDM Ecosystem through machine-readable interfaces or manually entered into the EDM Ecosystem by the demonstration data owner(s). The EDM Ecosystem will include an open standards-based performance management dashboard to access the performance measures based on pre-defined reports and queries or through adhoc query analysis. Both static and dynamic reports will be run from the EDM dashboard web interface to evaluate point-in-time or trending over-time analysis.

The EDM Ecosystem performance management dashboard web service also will be available to a larger ecosystem of academic, research institutions, government entities, and private companies authorized to access this information. The type of data to be produced in the course of the demonstration will include:

- Machine-readable data
- Metadata
- Structured relational data
- GIS data
- Columnar files
- Survey data
- Unstructured data files
- Emergency management data

In addition to these communication methods, quarterly public performance readouts will be broadcast on the City's public access cable TV channel to provide additional context from program leadership.

Data collection, storage and analysis costs will be established upfront and be budgeted accordingly in the City's annual budget cycle. All assumptions made about these costing models will be clearly laid out and evaluated by the Department of Finance. Budget data will be analyzed for conformance with 2 CFR 200 Subpart E Cost Principles. Indirect costs require adherence to the City's Federally Negotiated Indirect Cost Rates.

If agencies' data costs exceed initially budgeted allotments for data collection/analysis, agencies will be required to follow the City's regular budget cycle procedures to request budgetary expansions, stating all assumptions about drivers of costs, supplying outcome-based justifications for the expense, and connecting the need to both agency and citywide goals.

#### **Hypotheses and Data Collection**

a. The one card payment option will empower the un- and under-banked by making available a full spectrum of mobility options.

- » Measure data at the individual user level to understand frequency and volume of use to better target programming.
- b. By installing Smart City kiosks throughout the city, especially in underserved areas, Denver will enable all residents to access the mobility apps that will enhance data-driven decision-making.
  - » Gain better insight into neighborhood mobility needs because kiosk users will enter their zip code to access kiosk information and services.
  - » Track specific services users are accessing through the kiosks.
- c. By supplying high quality data on transportation options and timing, citizens will make more efficient and frequent use of public transit.
  - » Track usage of each mode of transportation to understand our program's impact on trends.
  - » Collect data from mobility apps on payment and planning usage (methods of transit chosen, whether payment was made through the app, start and end point of trip).
- d. Denver's electric utility has suggested a possible goal of reducing greenhouse gas emissions 45 percent to 50 percent by 2030.
  - » Use the Greenhouse Gas inventory, prepared annually since 2009, as the baseline for greenhouse gas emissions.
  - » Use data for a suite of pollutants from two Colorado Department of Public Health and Environment EPA compliant air quality monitors in Denver to measure change over a baseline year to be selected.
  - » Use data during life of the grant to support performance monitoring and evaluation.
- e. The EDM Ecosystem will be replicable and scalable to meet large, mid and small-sized cities.
  - » Conduct large and small sized load testing based on mid-sized city data.
- f. The EDM Ecosystem shall be able to process various data types or formats to meet other cities' unique requirements.
  - » Test various structured and unstructured data types without requiring a new software release.

#### A.9 DATA PRIVACY REQUIREMENTS

Denver appointed a Chief Information Security Officer in 2013 who put in place a security team that manages incident response, protection of the computing and network environment, and threat and vulnerability management and handling. This team maintains artifacts that advise the management of information security. Agencies and departments are encouraged to have their own processes or procedures that address the handling of and protection of specific City data.

Denver maintains policies, standards and procedures that address the privacy and security of personal information and has systems in place to meet the federal and state requirements for the treatment of Personally Identifiable Information (PII). Denver also follows federal requirements and standards including but not limited to: the National Institute of Standards and Technology (NIST), the Payment Card Industry Data Security Standard (PCI-DSS), the Family Educational Rights and Privacy Act (FERPA), the Health Insurance Portability and Accountability Act (HIPAA) and the Children's Online Privacy Protection Act (COPPA).

#### Denver Data Classification and Handling Policy:

This policy establishes ownership, guidelines and governance over information assets for all technology and business domains within Denver. The policy sets protocols for ensuring data and information assets are classified by value, criticality, sensitivity, and whether the information is subject to applicable third-party requirements (including but not limited to federal, state, local legislation or industry specific regulations). The classification of data sets the level of security and technical controls put in place to protect the information.

The policy requires each agency (or department) to identify their data and information assets for the purpose of classification. Agencies are instructed to identify data owners, stewards and custodians.

Data is to be classified in categories: public, reserved, confidential and regulated. The policy describes requirements for access and handling of data by classification. Access control guidelines specify the identification and authorization requirements for access to data and include additional requirements on data redistribution. Technical control protocols describe the requirements for safeguarding information and data assets, specifically storage and transmission of information.

**Denver Information Security Policy:** This policy addresses information security for Denver's information technology environments. It addresses confidentiality, access control, identification, authentication, monitoring, media protection, physical security, internet security, remote access, encryption, and virus control. This policy is currently being updated to include recommendations from NIST and the SANS Institute.

The Information Security Policy is currently being updated to meet the most current security standards and threats using guidelines from NIST SP 800-53 and other applicable regulations. The updates will expand on and update existing protocols as well as address security awareness training, incident response, physical and environmental protection, security planning, risk assessment, system and service acquisition.

**Risk Management and Controls:** Denver manages risk primarily through the Office of the Auditor, which conducts risk assessments throughout the City, and a Governance, Risk and Compliance team within the Technology Services Department. The Information Security team currently manages security and other controls and performs periodic testing to ensure compliance.

#### Proposed Data Privacy Plan for Smart City Implementation

Denver will ensure resources are adequate to develop and implement the additional policies and procedures that are needed to ensure privacy of Smart City data. Smart City information will be added to risk control to ensure privacy and security are monitored regularly.

For this program, a Data Privacy Plan will be developed, which will address technical, policy and physical controls to be implemented to address risks, mitigation and testing to ensure data privacy. Existing information security artifacts, risks and security controls will be verified and updated to confirm that the PII and Sensitive PII (SPII) requirements for the program are met or exceeded. The City will enforce and ensure the privacy processes are followed by all sub-recipients, sub-grantees, contractors and other partners who have access to or handle PII data and will ensure these entities provide policies and procedures to safeguard the privacy and security of participant data. The Data Privacy Plan will address the required privacy controls for the Smart City Challenge to validate that PII and SPII are only stored on and shared within an IT infrastructure with security controls in place for all associated risks which would result from unauthorized access, disclosure or use of information.

Denver will use the NIST Special Publication 800-122 as a guideline for creating the Privacy Plan and other artifacts addressing privacy and security of data for the Smart City Program.

#### A. 10 DATA MANAGEMENT AND SUPPORT FOR INDEPENDENT EVALUATION

Currently the City collects and maintains 209 open data assets with the exclusion of third party privacy and security requirements, including Criminal Justice Information System data, 9-1-1 data, HIPPA records, PII and Payment Card Data Security Standard data. The City plans to collect, manage and share Smart City data in the EDM Ecosystem during the life of the grant. The data will be included in the EDM Ecosystem with data from multiple sectors. The EDM Ecosystem will include open standards-based Application Program Interfaces (APIs) and access to historical data records for the purpose of real-time and archived data inputs and outputs.

Smart City data will reside in the EDM Ecosystem and comply with the City's data governance standards and open data policy. The EDM Ecosystem includes web services for public access, subject to applicable privacy, security, and other safeguards. In the case where data includes PII or other restricted data, the City will make the data available to qualified researchers in compliance with all City privacy policies.

The EDM Ecosystem will access current City data sets, including data associated with the Smart City projects, and third party data sources. By taking this approach, all related stakeholders will be able to contribute to and conduct comprehensive analysis to better understand the City's challenges and achieve the Smart City goals and objectives.

Denver's EDM architecture will establish open standard protocols and interfaces, which expose synergies and enable interconnection of systems from multiple sources to integrate with other functions or services in the City. The EDM Ecosystem will interface with transportation industry standards: National Transportation Communications for ITS Protocol and the Traffic Management Data Dictionary Standard for the Center-to-Center Communications. The EDM Ecosystem will conform to industry standards protocols such as REST API, OASIS OData and oneM2M standards for Machine-to-Machine (M2M) and Internet of Things (IoT), and security based framework recommendations from NIST and OWASP. For direct system-to-system or centerto-center integration, Denver will conform to the defined industry standard specifications.

Improvements in City functions and services will occur by combining transportation data with other data sources to improve management and operations. For example, transportation data will be combined with the Department of Safety computer aided dispatch system and Department of Public Works data to reroute traffic around construction areas and incidents identified from these data sources. In addition, the integration of these data sources will enhance situational awareness, real time decision processing, and communications across the City management systems.

Denver's EDM architecture will define the open standard API specifications to integrate data from various sources and sectors (travelers/users and their personal device information, non-traditional data sources like weather and social media, shared transportation providers like Uber, Lyft, Google Maps and Waze ) with the City's transportation data. The integration of this data will improve transportation operations in areas such as reducing congestion, traffic light prioritization, emissions reporting, real time bus routing, events planning and citywide communications.

Denver's open data policy specifies the data sharing agreements for preserving project data for future use. Denver's Open Data Catalog provides open data licensed under the Creative Common Attribution 3.0 license. The data will be collected, managed and shared in the City Open Data Catalog and City EDM Ecosystem, including data from outside organizations. Access to this data will be governed and controlled by the City's open data policy. Data ownership will continue to be responsible for the data owner designation(s) and the City's Technology Services Department will be the custodian of the data assets to protect, secure and serve the data to users.

Denver's Evaluation Support Plan will provide a single point-of-contact to coordinate activities for independent evaluation purposes. The single contact will provide full access to all information requested in line with our data management policy. We will appoint this contact to have the authority and ability to work with all City teams to ensure access to site, site staff and data throughout the duration of the program.

Denver has a separately elected independent auditor, and we will work closely with the Independent Evaluator assigned by the USDOT. Denver considers all outside evaluation as a way to drive continuous improvement through the City's Peak Performance process improvement team. The Evaluation Support Plan will collect, store and manage relevant data and metadata in the EDM Ecosystem as a central repository for the Independent Evaluator applying quantitative and qualitative evaluation methodologies. The EDM Ecosystem will collect demonstration performance measures, additional field test data, and experiments to supplement data not available from the site. The performance measurement data and targets will be available for independent evaluation through the EDM Ecosystem portal. The EDM Ecosystem will collect and generate the necessary data to evaluate the Performance Measurements and targets defined in the City Performance Measurement Plan. The City will conform to Denver's Data Classification and Handling Policy to secure and restrict access to the Independent Evaluation data assets.

The City will work with the Independent Evaluator to upload the defined database schema into the EDM Ecosystem and implement the appropriate City Data Classification and Handling policy requirements for data ownership, guidelines and governance to support the Independent Evaluation. The EDM Ecosystem will be set up to transmit only the data required to support the Independent Evaluation on a pre-defined schedule and using a medium agreed upon with the Independent Evaluator. The data collected to support the independent evaluation is "owned" by the USDOT and the EDM Ecosystem will store and separate from additional data collected in compliance with the Denver Information Security Policy. The Independent Evaluator will have full access to the Performance Measurement data through authorized access to the secure data from the Independent Evaluator landing page.

In order to implement the sharing of Smart City data most effectively, the City will establish and manage partnership, data, or information sharing agreements that will include data sharing aspects such as: data types, legal, ownership, storage, access, approval, roles, training, analysis, dissemination and timelines. Any policies and procedures that are not currently in place will be developed to address Smart City data integrity and sharing.

## A.11 SAFETY MANAGEMENT AND SAFETY ASSISTANCE

Denver considers safety a top priority. The City has a vital interest in providing and maintaining a safe environment for employees and the public. As such, Denver has several Executive Orders and Safety and Health Standards that demonstrate our commitment to safety.

Executive Order 65 establishes the Safety and Health Program to which all departments and agencies must adhere. As a local government, the provisions from the Occupational Safety and Health Administration (OSHA) generally do not apply to the City. However, we recognize OSHA standards embody an important and comprehensive framework for occupational safety that also affect the public. Per Executive Order 65, it is the responsibility of Risk Management to work with departments and agencies to create a Safety and Health Management Program specific to their needs and monitor the success of each program. Industry and professional standards are consulted for development of such City standards and safety programs.

Executive Order 94 ensures that all City employees operate in a drug and alcohol free environment. This Executive Order also requires employees be tested for substances if there is a reasonable suspicion. Finally, Executive Order 3 assures that employee who operate vehicles for official City business understand their roles in promoting Denver as a safe city.

#### **Workplace Safety**

Risk Management is authorized to develop workplace safety standards that assist in meeting the City's goal of providing a safe and healthy work environment that is free of hazards. Risk Management works closely with all departments and agencies to develop job specific workplace safety policies to remove hazards and minimize workplace injuries and illnesses. It also works with agencies to identify and manage risks related to partnerships or projects involving the business community and the public. hazards will be identified and addressed as they arise. A set of scenario-specific safety needs will be developed for future consideration.

#### **Risk Management**

Using existing risk assessment processes, Risk Management will identify levels of risk associated with the Smart City projects. Risk control strategies will be implemented to mitigate and control the known and newly identified risks. Using the Peak Performance Model, Risk Management will continually provide insight and analysis for improving safety and minimizing risks as identified during the life of the grant.

Risk Management utilizes STARS as its Risk Management Information System (RMIS) for capturing incidents and losses. This system has the functionality to provide reports for analytics and trending. Currently, STARS is used to capture all insured incident/claim data as well as all types of incidents at Denver International Airport (including airline on airline incidents) as required for their Safety Management System.

Similarly, STARS can be utilized to capture incidents that are a result of or related to the Smart City Program for trending and modeling use. For example, tracking and trending incidents of bodily injury or property damage resulting to or from City fleet vehicles with intelligent vehicle capabilities. Metrics and goals will be developed with key players as Smart City projects are developed.

The City will select an accredited Institutional Review Board to comply with the requirement defined in Section F of the NOFO.

The Safety and Health Management System is structured to reflect the continuous improvement of the City's Peak Performance Standards. Working with departments and agencies, Risk Management will identify levels of safety risk associated with our Smart City projects using existing safety standards. During the Smart City grant period, Risk Management will ensure proper safety precautions are taken to minimize risk and reduce the causes for injuries. Regular reviews of the safety procedures, will be conducted and new



**Figure 10 - Safety & Health Management Systems.** The City's Safety & Health Management System is an enterprise-wide program encompassing all aspects of City functions. It is designed to protect employees and the public from loss.

#### A.12 COMMUNICATIONS AND OUTREACH

Denver's path forward has always been informed by the voices of our public. The people who fill Denver's neighborhoods, make up its workforce and visit our growing retail and commercial offerings have a long tradition of engagement in our decisionmaking processes.

Yet, many groups are under-represented. They do not attend meetings, actively lobby or write letters to the editor. These are the people we will invite to inform our suite of Smart City mobility services. Ongoing public feedback will guide our Smart City Program from start to finish.

Our program will be designed so that communities are able to choose the mobility services that best meet their needs, rather than today's model where services choose the community.

Denver's program will build bridges – connecting residents, neighborhoods and businesses to increased mobility solutions by making advanced technology and new transportation options accessible to everyone. Our Smart City solutions will address the very real challenges of our growing community, including rising housing and transportation costs, involuntary residential displacement, and widening income and educational gaps. Our Smart City innovations will be built by listening to and engaging directly with the people who need them most.

Just as our Smart City Program will be designed by the communities it will serve, we also will create and implement a comprehensive communication, awareness and education plan. Plan components will include:

- 1. Creating a broad-based communications and community engagement workgroup to leverage and expand resources, reach and expertise. Workgroup members will include representatives from the USDOT, Denver, public- and private-sector partners, finalist cities, transportation providers and users, and community stakeholders.
  - a. Develop a robust communications and engagement plan to promote and market Smart City projects in Denver as well as nationally and internationally.
- 2. Collecting and disseminating data to better understand the effectiveness of Smart City projects.
  - a. Conduct baseline and ongoing research to establish an understanding of our diverse transportation users, barriers to adoption of

new technologies and mobility services, and the transportation options that are proving successful.

- b. Track key messaging and engagement approaches to gauge effectiveness of the messages, engagement tactics and the projects themselves.
- 3. Creating distinct engagement and education strategies and supporting materials for each Smart City project.
  - a. Develop website, social media presence, marketing brochures, fact sheets, press kits, videos and infographics, including multilingual material.
- 4. Gathering feedback and collecting results from each Smart City project on an ongoing basis.
  - a. Develop an iterative process of community and media engagement, message development and communications outreach for each project.
- 5. Sharing information about each project.
  - a. Set regular meetings with the Smart City implementation team and communications and community workgroup to share insights and collaborate on messaging and engagement strategies.
  - b. Establish web-based engagement tools to drive a two-way conversation between our Smart City team and users, researchers and other interested parties.

#### A.13 INTERNATIONAL COLLABORATION

Denver is well-positioned and eager to collaborate with international partner cities related to the planning, structuring and operation of a Smart City mobility program. We intend to involve global partners in our SMART Council to help inform our projects and share best practices with those beyond our borders.

We are proposing a three-tiered approach to guide international collaboration:

- 1. Participate in one- to three- three-day intensive visits annually throughout the life of the grant with representatives from other cities who are working in this area. Visits and meetings will allow for the sharing of experiences, case studies and expertise.
- 2. Develop a website to serve as a marketplace of resources and technical documents for any city interested in learning about, discussing and advancing smart city initiatives.

3. Host an annual global Smart City Summit, open to cities and individuals from around the world, to serve as a forum for an exchange of ideas about this topic.

We have identified four cities as initial global partners whose smart city work can help inform Denver's program: Manchester, England; Dubai, United Arab Emirates; and Fujisawa and Tsunashima, Japan. Each of them brings worldrecognized smart city experience to the table.

Manchester's CityVerve Project aims to test better services using IoT technology, including talkative bus stops, networks of sensors across the city, and data analytics. The project introduces sensors to equipment such as streetlamps, vehicles, and home heating equipment to deliver more personal, efficient and flexible products and services.

North Dakota State University and the University of Modern Sciences in Dubai have begun a collaboration focusing on Intelligent Transportation Solutions to develop an urban transportation system for Dubai with zero delays, zero crashes, zero property damage and zero environmental pollution.

Fujisawa and Tsunashima, both developed by Panasonic, are testing grounds for transformative solutions in energy and utilities, transportation and mobility, city services and security, the built environment, and community well-being. The 17-acre Fujisawa and 32-acre Tsunashima projects represent Panasonic's first two iterations of its smart city deployments.

The 384-acre Peña Station Next project near Denver International Airport will be the third.

Over the course of the grant, we will continue to broaden this international subset of our SMART Council. We will set up in-person, interactive, multi-day collaboration sessions (one to two annually) where project team members, staff and representatives will meet with counterparts from other cities to share ideas, case studies and lessons learned. Each delegation will cover its own travel costs. Sessions will be recorded and transcribed, with the goal of building a working "field guide" after each collaboration that will be available through our Smart City website.

Beyond these international case study cities, Denver will collaborate with and host visits from other

cities around the country and the world who want to see our Smart City Program in action and benefit from the hands-on experience of investigating how our Smart City team is deploying our innovative technology platform. Each participating city will be responsible for its individual travel budget costs.

Collaboration will be both digital and in-person. Digital participation will be open to any city interested in learning more about smart city planning, design and implementation. The focus for this group will be a web resource compiled and maintained by Denver and our partners. This will be set up to accept technical contributions from any participating city and serve as a virtual resource and forum for cities to discuss and advance smart city projects.

This web-based resource will be supported by an annual multi-day conference to be held in Denver, bringing together city representatives, technical experts, professionals, manufacturers, academics and others.

Denver and our case study collaborators will also establish quarterly video conferences to discuss specific issues associated with these topics. We also will commission a series of white papers from researchers, academics and Smart City partners to examine key issues, challenges and opportunities. These grant-funded papers will be collected, reviewed and compiled into a library of information. We will house them on our Smart City website and make them accessible to any city worldwide.

Panasonic's third smart city development – the 384acre Peña Station Next – will bring the same kind of innovations and technology solutions now at work in Fujisawa and Tsunashima, Japan, including microgrid energy storage and smart LED streetlights. With 2,800 homes at buildout, Peña Station Next along the newly opened rail line linking Downtown Denver to Denver International Airport will serve as the headquarters for Panasonic Enterprise Solutions Company. The company is planning to launch a First Mile/Last Mile pilot with Easymile to deploy autonomous electric shuttles that would ferry passengers between the rail stop and Panasonic's campus. If successful, the pilot could be expanded to many of the region's 50 other transit stations.

#### A.14 PARTICIPATION IN RELEVANT ITS ARCHITECTURE AND STANDARDS DEVELOPMENT EFFORTS

Smart city and connected vehicle (CV) technologies provide an exciting opportunity to revitalize the transportation network with transformative data analytics and powerful applications, and are another form of Intelligent Transportation Systems (ITS) that should adhere to the national and regional vision for ITS architecture, standards and certification processes.

In 2007, Denver participated in the Denver Regional Council of Government (DRCOG) and CDOT effort to develop a Regional ITS Architecture for the Denver area. This architecture now provides a framework for ensuring institutional agreement and technical integration for the implementation of ITS projects. It was developed based on the National ITS Architecture in conformance with federal guidance.

Denver is home to the largest local Traffic Management Center (TMC) in the metro area. It shares information via physical fiber optic connection with the statewide, 24-hour Colorado TMC and another local TMC in Lakewood, making Denver a key adopter of the architecture for the successful implementation and management of ITS assets in the region.

We will continue our partnership with DRCOG and CDOT to track the status of existing standards as we move forward with the deployment of Smart City, CV and ITS applications. We understand we are targeting innovative and transformational concepts not currently defined or proposed in the existing ITS Architecture and will have the opportunity to inform new developments in architecture and standards regionally, nationally and internationally.

The Smart City initiative provides an exciting opportunity for Denver to partner with CDOT in expanding the architecture and establishing the framework for Smart City and CV concepts to be implemented across the metro area, positioning the entire region as an agent of change and a benchmark for the nation.

We will jumpstart an update to the architecture by leveraging CDOT's RoadX project and the available architecture and standards work completed by the USDOT for CV concepts. The USDOT's CV Reference Implementation Architecture (CVRIA) provides the physical, functional, Denver is uniquely positioned as the only Smart City finalist partnered with a state DOT that is proactively investing in real-world CV deployment independent of federal funding.

communications and enterprise architecture viewpoints as guidance for implementing CV applications. More importantly, the CVRIA was built to ensure CV deployments fit into the greater National ITS Architecture, enabling a standardsbased implementation that will ensure the new system can be seamlessly integrated into existing transportation management and ITS systems for the region and as a model for additional smart cities to follow.

For CV technologies, Denver will coordinate with USDOT-appointed certification bodies in the selection and procurement of all DSRC devices and utilize the newly developed Crash Avoidance Metrics Partnership (CAMP) security certificate management system processes and procedures for the deployment and management of security certificates for DSRC devices.

For all Smart City or CV architecture and standards activities, Denver will engage and coordinate with national and international standards development organizations named in the NOFO to ensure future deployments benefit from the experiences and lessons learned from the Denver implementation.

Denver will assign an architecture and standards lead (ASL) at the program level who is charged with coordination of all Denver Smart City, regional, national and international architecture and standards development activities. The ASL is responsible for attending the USDOT-approved national and international architecture and standards meetings and is tasked with remote participation in conference calls/webinars and drafting of technical input where necessary.

After in-person participation in standards development organization working group/ committee meetings, the ASL will provide a report to the USDOT describing meeting outcomes, any impacts to the Smart City Program, and inputs made by the Smart City projects.

Figure 11 showcases how Denver will approach and coordinate the use of and updates to architectures and standards throughout the Smart City deployment.



**Figure 11 - Approach to Updating Regional ITS Architecture.** Denver will integrate its Smart City Program into the existing regional ITS Architecture process; utilize USDOT, Society of Automotive Engineers, and other relevant standards; and engage the appropriate standards development stakeholders for new Smart City concepts.

#### A.15 INTERIM AND FINAL REPORTING

Our Smart City team is committed to providing USDOT and other program partners with relevant and timely information throughout the life of the program. These interim and final reporting efforts will ensure that the work Denver completes is both replicable and scalable to cities across the country and around the world. All interim and final reports will be publicly issued and available.

Interim reporting efforts will provide a thorough description of the progress of the program annually, and will:

- Compare accomplishments vs. goals established for the program, described in both qualitative and quantitative terms (if program goals are not met as intended, the reason for this will be explored, including what steps have been taken to right the situation).
- Identify opportunities that are not within the conventional definition of business as usual, but represent Smart City concepts that will have profound impact on the future, such as smart lighting and smart water. These are opportunities that could languish without an avenue for exploration.
- Detail the role of consultants, as outlined and described in the approved program plan.

- Describe the role innovative partnerships and funding mechanisms play in helping execute the program.
- Define how the Smart City Program is impacting Denver's transportation system from a performance perspective.
- Assess how Smart City data is being used by the academic community.
- Provide detailed financial reports.

We will develop a final report that summarizes the processes and findings of the Smart City Program. Documentation of this information will begin as we complete each step or task in the research. Topics will include:

- Summary of the key activities occurring throughout each task
- Comparison of deployment and operational costs with benefits and cost savings realized through the program
- Overview of the system engineering processes undertaken during the development of the prototype application
- Assessment of the shortcomings in application performance identified during testing
- Opportunities for improving bus service reliability

- Accounting of areas for reducing costs or enhancing integration of components
- General conclusions and lessons learned
- Recommended next steps for advancing the application to pilot or production-ready versions
- Issues and initiatives that go beyond the Smart City boundaries and have impacts on other cities – large and small

We will deliver an annotated outline at the 2-1/2 year mark of the program. We expect feedback from USDOT within four weeks of this delivery, at which point we will proceed to develop the full draft final report.

To allow sufficient time to make any necessary revisions, we expect to receive comments on the draft final report from the USDOT within four weeks of delivery. At that time, we will make the necessary revisions and submit an electronic version of the final report within two months of the program's three-year term.

It is the Denver Smart City team's intent that our partnership with USDOT does not end at the threeyear mark, but continues into the future to help shape the Smart City movement going forward.

#### A.16 DELIVERABLES

The Denver Smart City team is committed to delivering all of the required deliverables (reports, websites, videos and webinars), as detailed in Section 6 of the NOFO. City staff and our lead Smart City consultant will complete the required documents in a timely, efficient and satisfactory manner. Our Smart City consultant has experience developing innovative project delivery and execution methods across multiple projects and in coordination with various governmental entities. All plans, reports, documentation and other deliverables, including the following, will be Section 508 compliant:

- Systems Engineering Management Plan (SEMP)
- Concept of Operations (ConOps)
- Program Site Map and Installation Schedule
- Systems Requirements Specification (SyRS)
- System Design Document (SDD)
- System Architecture and Standards Plan
- Performance Measurement Plan
- Data Privacy Plan
- Data Management Plan
- Independent Evaluation Support Plan
- Safety Management Plan

- Communications and Outreach Plan
- Promotional video
- Smart City Program website
- Smart City Program Final Report
- Other systems engineering documents

#### A.17 PARTNERS

Denver recognizes that cities need to move beyond fragmented or incremental thinking in today's fastpaced global economy, especially when it comes to instituting new technologies. Cities must build and continuously renew networks of collaborators and partners.

#### **SMART Council**

With this in mind, Denver will create the Startups, Municipalities and Academic Research for Technology (SMART) Council to lead and inform our Smart City Program and provide us with a vehicle for sharing, replicating and exporting results. The SMART Council will unite the City with start-ups, tech innovators, municipalities across the nation and the world, academic researchers, and transportation service providers.

The Council will be organized into four sub groups that will meet quarterly and report to the Smart City Executive Team:

#### 1. Local SMART Council Work Group

At the local level, Denver will establish a community-based SMART Council Work Group. Mobility users, neighborhood residents, stakeholder organizations and nonprofit providers such as Mile High United Way and Mile High Connects will provide key input into our program. We also will engage foundations, neighboring municipalities, and organizations such as the Regional Transportation District, Denver Regional Council of Governments and the Metro Mayors Caucus. This local SMART Council Work Group will meet at least quarterly.

#### 2. National/International Cities SMART Council

The reach of the SMART Council will go far beyond our local borders. We will invite the six other Smart City Challenge finalist cities to join the national and international arm of the SMART Council, as well as other national and global cities. This concept has already received support from 20 cities, including Atlanta, Indianapolis, Baltimore and Seattle.

Denver will partner with Transportation for America (T4A) and utilize its already established network of partner cities and organizations to ensure that we share our successes and challenges with a dedicated group of communities. This group will serve as an assembly of ideas, where concepts will be shared during an annual global summit, regular face-to-face meetings, online webinars and on our Smart City website.

This will be the forum for the brightest minds from around the country and the globe to help us refine our projects and prepare them for scaling and exporting.

#### 3. Start-Up/Entrepreneurial Community – SMART Council Spark

Denver has cultivated powerful partnerships with the Colorado Technology Association, local tech incubators Galvanize and Innovation Pavilion, and national organizations such as 1776. These and other engines of innovation and new ideas will serve on the SMART Council's Spark Committee to infuse new energy into our thinking and project applications.

1776, based in Washington DC, is recognized as a national leader in start-up incubation efforts. Working with thousands of cities and transportation agencies, 1776 will act as a curator for Denver, helping us bring together transportation and smart city start-ups from across the country and around the world.

Innovation Pavilion (IP) is an entrepreneurial incubator located in nearby Centennial IP will help us ensure the best local start-ups are coordinating with the project team.

Galvanize has two locations in Denver and represents the alignment of industry and academia, providing training to software engineers, data scientists, and entrepreneurs within a physical space that houses industry partners. Galvanize makes education and growth accessible to all, especially underrepresented groups in the tech industry and provides an inclusive physical space for innovation and entrepreneurship.

The Executive and Project Management Teams will collaborate with start-up partners, working handin-hand on effectively incorporating start-up energy throughout the project and beyond. Denver will coordinate with the start-up team for the life of the project, bringing influential partners to the startup community while enabling innovative thinking to permeate the project and hopefully into the respective cities of our SMART Council partners.

#### 4. Research and Education – Academic SMART Council

Academic SMART Council, co-led by Colorado State University and the University of Colorado Denver (UCD), will bring an important research component to our Smart City Program. Other coalition members will include Colorado School of Mines, North Dakota State University, Mountain Plains Consortium University Transportation Center, Virginia Tech Transportation Institute and University of California Riverside. The National Renewable Energy Laboratory and Electric Power Research Institute will also contribute to this subset of the SMART Council.

This research arm of the SMART Council will bring together multidisciplinary teams of researchers, educators, policymakers and stakeholders to conduct collaborative research that addresses the fundamental challenges of implementing smart city technologies and informs decisions that lead to energy, economic, environmental, social and cultural sustainability. Understanding these challenges and the underlying impacts of smart city technologies is a vital component of replicable strategies.

The Academic SMART Council will also focus on education and workforce development to help develop the next generation of smart city professionals, particularly women and underrepresented minorities in STEM fields. The committee will oversee a K-12 educational outreach program through partnerships with UCD, Colorado Mathematics, Engineering and Science Achievement (MESA) and the Denver Schools of Science and Technology (DSST).

MESA, a non-profit organization formally affiliated and housed within the UCD College of Engineering, encourages and prepares women and underrepresented minorities for a STEM college education. DSST, a network of public, openenrollment schools, focuses on STEM education and eliminating inequity in urban public education. DSST serves a student body of 4,100 students (75 percent students of color) with a plan to exceed 10,000 students by 2025. The Academic SMART Council will partner with both MESA and DSST to provide hands-on educational activities to underrepresented STEM students for a range of smart city careers.

Table 2 represents the full range of Denver's Smart City partners.

#### Table 2 - Denver Smart City Program Partners

Organization	Smart City Program Role	EDM Ecosystem	MODE	Transportation Electrification	Intelligent Vehicles
1776	1776 will serve as a curator for Denver throughout its extensive start-up community, introducing the City to relevant start- ups. 1776 and Denver will explore further collaboration efforts throughout the life of the grant.	x	x	x	x
Amazon Web Services (AWS)	AWS is providing \$750,000 of secure cloud data services for Denver's EDM Ecosystem and \$250,000 in technical assistance, which will provide solution architecture and best practice guidance. This will help Denver leverage AWS for Smart City solutions and ensure that Amazon Professional Services are effectively engaged.	x	x		
AT&T	AT&T is providing up to \$300,000 worth of in-kind products, services and support: \$150,000 for cellular data connectivity to support sensors and technology, and an additional \$150,000 worth of products and services related to IoT security, consulting assessments, big data solutions, and a proof of concept pilot for LTE cell broadcast technology for V2X communications.	x			x
Autodesk	Denver will use Autodesk Infraworks technology throughout the first year of project implementation to effectively, yet simply, portray project components and deployments to the public.	x	X	x	x
City of Manchester, England	Manchester will participate in the international SMART Council and share lessons learned and best practices related to CityVerve, the UK's IoT city demonstrator.	x	X	x	x
Colorado Department of Transportation (CDOT)	CDOT will invest \$5.5 million to expand its smart, adaptive ramp metering project to Hampden Avenue and partner with Denver for collaborative control over the management of the traffic signals of the roads and arterials entering onto I-25. CDOT is also committing \$1.5 million to support implementation and acceleration of the Freight Efficiency Corridor Program to help prepare for the \$1.2 billion Central I-70 project by outfitting fleet services with DSRC to facilitate travel time reliability via freight signal priority.				x
Colorado Technology Association (CTA)	CTA will provide support from its 45-member Board of Directors to convene the vital public-private partnerships that will be necessary to realize the City's vision.	x	x		x
Denver Regional Council of Governments (DRCOG)	DRCOG will participate in the local and regional SMART Council.	x	x	x	x
Econolite	Denver will partner with Econolite to launch its new CV intersection controller, Cobalt-Sky <sup>™</sup> . This is the first-ever traffic controller fully designed to apply the robust inputs offered by DSRC. Denver will implement the new traffic controller as software-in-the-loop on its new live test bed on Colorado Boulevard.				x

Organization	Smart City Program Role	EDM Ecosystem	MODE	Transportation Electrification	Intelligent Vehicles
Evercar	Evercar will bring at least 50 electric vehicles, valued at \$1 million, to serve as short-term EV rentals for TNC drivers. It will also provide cost share, in conjunction with the Regional Air Quality Council, to pay for charging infrastructure.			x	
HERE	HERE will provide Denver with a robust package of data and platform services for CVs. HERE can provide these solutions for the three-year project duration. HERE will discount the data, platform, and services cost by \$1 million as an in-kind donation. The HERE package includes premium map content, real-time and archived traffic probe data, location platform, and technical and implementation support.				x
Metro Area County Commissioners (MACC)	MACC will participate in the local and regional SMART Council.	x	x	x	x
Metro Mayor's Caucus (MMC)	MMC will participate in the local and regional SMART Council.	x	x	x	x
MetroTech	MetroTech will provide up to \$300,000 of in-kind value to support the deployment of its IntelliSection ITS solution, which provides traffic analysis software leveraging lane-level sensor feeds from existing roadside cameras to deliver accurate, real- time lane counts and lane speeds.	x			x
Mobileye	RTD and Denver Public Works will participate in small deployments of the Mobileye Shield+ technology on fleet vehicles. Subsequent deployments will be determined by the success of this first phase.			x	x
National Renewable Energy Laboratory (NREL)	NREL will assist in the Transportation Electrification component and lead efforts to advance renewables and energy efficiency with a key focus on photovoltaics and battery technologies.			x	
NXP	Denver will work with NXP to equip the 1,500-vehicle Public Works fleet with DSRC technology to generate Basic Safety Messages as they blanket the city for daily operations. NXP's in-kind contribution will equip 300 vehicles and deliver 100 roadside units to support our Intelligent Vehicle deployment projects.		x		x
Panasonic	Panasonic will work with Denver to leverage lessons learned and best practices through its Peña Station Next project. Panasonic will also coordinate collaboration between the City and its Fujisawa and Tsunashima developments in Japan.	x		x	X
Peloton	Peloton Technology will support Denver with \$165,000 to launch travel time reliability as a City service to freight fleet operators as an incentive to equip their fleets with DSRC technology.				x

Organization	Smart City Program Role	EDM Ecosystem	MODE	Transportation Electrification	Intelligent Vehicles
Qualcomm	Qualcomm will provide up to \$100,000 of in-kind DSRC chipsets, engineering design support and services to extend the range of V2V and V2X capabilities.				x
Regional Transportation District (RTD)	RTD will contribute \$4.15 million towards the purchase of nine electric buses to operate along East Colfax Avenue. RTD's investment represents a 56% contribution to the total cost of these vehicles. RTD will also lead a design study to define how inductive charging en-route can enhance functionality and operating range. Lessons learned from this deployment will inform RTD's long-term electrification plans. RTD will also partner with the City to enable mobile ticketing.		x	x	
Rocky Mountain Institute (RMI)	RMI will provide resources to scale the solutions Denver develops as part of the Smart City Challenge.	x	Х	x	x
Sidewalk Labs	Sidewalk Labs will distribute 50 standalone kiosks as part the Denver Smart City Program. These kiosks – the majority of which are destined for underserved neighborhoods in West, North and Northeast Denver – will offer free Wi-Fi and transit information for users who might not have a smartphone or robust data plan. Sidewalk Labs will also deploy Flow, a new data analytics platform, in Denver. Flow will serve as a platform that ingests a wealth of data from a variety of sources – sensors, cameras, third-party apps – and uses analytics to let cities map assets against demands. Flow data will be fed into the EDM Ecosystem.	x	x		
TransCore	Transcore will contribute \$100,000 for the deployment of its Adaptive Control Decisions Support System software on Colorado Boulevard. The contribution will cover the cost of licensing and installation for the TransSuite Traffic Management System module and integration with the Cobalt Sky <sup>™</sup> traffic signal controller.				x
Transdev	Transdev will work with Denver to electrify a portion of its taxi fleet while tackling barriers to fleet electrification efforts. Transdev will deploy up to 50 short- and long-range EVs. This will be made up of a mix of Nissan LEAFs and Tesla Model S. Transdev will also work with RMI to develop an operational model for electric taxis.			x	
Transportation for American (T4A)	T4A and Denver will partner on national coordination efforts through the SMART Council in an effort to share best practices and lessons learned with other municipalities.	x	x	x	x
Uber	Uber will work with Denver and the State of Colorado on a variety of green vehicle initiatives including investigating ways to educate drivers about existing subsidies and tax credits. Uber is also examining potentially subsidizing a portion of FMLM rides and introducing an integrated payment system in identified disadvantaged neighborhoods.		x		

Organization	Smart City Program Role	EDM Ecosystem	MODE	Transportation Electrification	Intelligent Vehicles
US Department of Energy (DOE)	DOE will provide in-kind support in the form of expertise and resources, including DOE's extensive experience in transportation electrification and alternative fuel vehicle fleet deployment.			x	
Volkswagen	The Volkswagen Group will support Denver with personnel and material support that drives realization of project goals. This contribution will focus on connectivity, automation and automotive electrification.			x	x
Vulcan Foundation	The Vulcan Foundation will provide support to target grid decarbonization, electrified fleets, and drive consumer adoption of EVs. These three focus items were selected to achieve the greatest greenhouse gas emissions reduction possible by accelerating natural market trends.			x	
Waze	The Waze Connected Citizens Program will reduce congestion, improve safety, and inform smarter urban planning by connecting with travelers.				x
Xcel Energy	Xcel Energy will make more than \$200 million in capital investments over the next several years to support an advanced, intelligent, and secure grid that will directly benefit customers in Denver. Xcel Energy has expressed interest in exploring electric vehicle pilot programs, research, data and investment opportunities; community outreach, education, and utilization of renewable energy offerings; and additional in-kind support.			x	

#### A. 18 GOALS, OBJECTIVES & ALIGNMENT WITH VISION ELEMENTS

Goal setting, continuous improvement and performance measurement are fundamental to Denver's entire business practice. For example, we set goals for sustainability and measure against them in every possible category, including air quality, climate, housing, mobility and workforce. Four years ago we also launched Peak Performance, a citywide improvement program designed to transform Denver into a data-driven government. For the Smart City Program, we have identified five overarching goals built on bold and innovative objectives. The table below presents each goal and its relevant impact area and component. For each goal, we present our detailed objectives, targeted measurable outcomes and alignment with the 12 USDOT Vision Elements:

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

#### Table 3 - Measurable Goals and Objectives for Mobility, Safety, Ladders of Opportunity, Efficiency, Clean Energy, Sustainability, and Climate Change in Denver

Objectives	Measurable Outcomes	Vision Element Alignment				
Goal #1: Establish Mobility Freedom for All Impact Area(s) – Mobility and Ladders of Opportunity Related Components – MODE						
<ol> <li>Create a universal information and payment platform</li> </ol>	<ul> <li>Develop and launch universal payment platform by Dec. 31, 2017, with TSPs integrated within the mobility app</li> <li>Provide information about additional benefits to all those using PayNearMe and the transportation credit program, targeting an initial adoption rate of 15 percent</li> </ul>	VE-3, VE-4, VE-5, VE-7, VE-9, VE-10 VE-11				
2. Develop a one-card payment solution	<ul> <li>Provide the option to pay for all services in the mobility app</li> </ul>	VE-4, VE-5, VE-7, VE-11				
3. Improve access to mobility information through a smartphone app and interactive kiosks	<ul> <li>Achieve a 30 percent utilization rate for the mobility app</li> </ul>	VE-3, VE-4, VE-5, VE-7, VE-9, VE-10, VE-11, VE-12				
4. Generate revenue to create and expand subsidized mobility services beyond the grant	<ul> <li>Develop and launch FMLM pilot with Lyft by Q3 2017, establishing baseline ridership trips based on first six months of program</li> <li>Increase baseline ridership by 30 percent in year two</li> <li>Increase the number of residents with FMLM accessibility to public transit by 30 percent</li> <li>Reinvest 100 percent of revenue generated by the program back into mobility-related investments</li> </ul>	VE-3, VE-4, VE-5, VE-7				

Objectives	Measurable Outcomes	Vision Element Alignment
5. Generate user information processed by our EDM Ecosystem to better understand community mobility needs	<ul> <li>Gather and analyze data from Centennial's FMLM pilot</li> <li>Establish a technical working group as subset of SMART Council by Q2 2017 to formulate outreach and education plan</li> <li>Identify usable and relevant metrics and measures by Q1 2017 and revisit and refine them every two quarters based on EDM Ecosystem data</li> <li>Use dynamic data from the EDM Ecosystem to drive 100 percent of Smart City mobility programming decisions</li> </ul>	VE-3, VE-4, VE-5, VE-7, VE-9, VE-10, VE-11
<b>Goal #2: Improve Connectivity</b> Impact Area(s) – Ladders of Opportunity Related Components – IV, EDM	, Mobility, and Safety	
<ol> <li>Build a connected vehicle operational environment at the Denver Traffic Management Center</li> </ol>	<ul> <li>Reduce injuries at identified Vision Zero intersections by 30 percent</li> <li>Reduce crashes at identified Vision Zero intersections by 30 percent</li> <li>Analyze 240,000 monthly Waze user reports for traffic flow and incident patterns</li> <li>Reduce incident response times for citizen- reported crashes by 30 percent</li> </ul>	VE-2, VE-3, VE-4, VE-7, VE-10, VE-11
2. Equip 3,000 vehicles with dedicated short range communication (DSRC) to jumpstart market penetration	<ul> <li>Increase DSRC vehicle market penetration to 10 percent by 2020</li> </ul>	VE-2, VE-3, VE-9, VE-10
3. Offer travel time reliability service to freight industry using DSRC-based traffic signal priority	<ul> <li>Reduce travel time on designated arterial routes by 20 percent using freight signal priority</li> <li>Reduce reports for interruptive freight movement in neighborhood communities by 30 percent</li> <li>Reduce freight traffic on major freeways and arterials in proposed Freight Efficiency Corridor by 20 percent during peak periods</li> <li>Reduce spot measurement of emissions at heavy freight movement intersections by 50 percent for platooning demonstration</li> <li>Increase throughput at intersections by a factor of two or three times for platooning demonstration</li> </ul>	VE-2, VE-3, VE-4, VE-6, VE-7, VE-10, VE-11
4. Leverage CDOT funding and technology projects to improve traffic flow and reduce congestion at key arterial and freeway connection points	<ul> <li>Reduce travel time on Colorado Boulevard by 15 percent during peak periods</li> <li>Reduce travel time on Hampden Avenue by 15 percent during peak periods</li> </ul>	VE-2, VE-3, VE-4, VE-7, VE-10, VE-11

Objectives	Measurable Outcomes	Vision Element Alignment
5. Create the first municipal test bed to use DSRC data for traffic signal control	<ul> <li>Define the level of market penetration necessary to transition to DSRC-based traffic signal control</li> </ul>	VE-2, VE-3, VE-5, VE-7, VE-9, VE-10, VE-11
<ul> <li>6. Create a data-driven decision making ecosystem that orchestrates across systems that is accessible to all users and infinitely replicable to the city, state, national and international levels. The EDM Ecosystem will:</li> <li>» Deliver open-standards based environment</li> <li>» Enable research and analytics capabilities for data consumers</li> <li>» Support all Smart City projects and deliverables</li> <li>» Allow third parties to integrate data to deliver improved applications and services</li> <li>» Leverage EDM to establish critical system monitoring and report data driven performance measures</li> </ul>	<ul> <li>Reduce data load processing times based on automated streaming interfaces with existing systems</li> <li>Increase efficiency in multi-organization data analysis based on pre-loaded data sets and analytic model sharing</li> <li>Increase efficiency in monitoring systems from automated business rules and analytics</li> <li>Reduce data sharing processing times based on the establishment of open standards-based interfaces</li> </ul>	VE-2, VE-3, VE-4, VE-5, VE-6, VE-7, VE-8, VE-9, VE-10, VE-11, VE-12
<b>Goal #3: Electrify Denver Travel and Dec</b> Impact Area(s) – Clean Energy, Sustainal Related Components – ELEC	carbonize the Grid Dility, and Climate Change	
1. Integrate EV, charging station and energy use data into the EDM Ecosystem	<ul> <li>Deploy 120 charging stations and sharing- economy software tools at a minimum of three large, multi-unit dwelling buildings</li> <li>Demonstrate one data integration use case in collaboration with Open Vehicle Grid Integration Platform and Xcel Energy</li> <li>Capture EV load data for at least five workplaces to inform EDM Ecosystem and Xcel Energy planning</li> </ul>	VE-6, VE-4, VE-7, VE-8, VE-10, VE-11
2. Deploy nine electric buses on one of the busiest corridors in the city	<ul> <li>Place nine electric buses in service</li> <li>Compile one year of electric bus operational data compared to baseline</li> <li>Eliminate 9,200 metric tons of CO2 by utilizing electric buses</li> </ul>	VE-7, VE-8
<ol> <li>Engage Xcel Energy to accelerate greenhouse gas reduction efforts</li> </ol>	<ul> <li>Reduce overall greenhouse gas emissions 45 percent to 50 percent by 2030</li> </ul>	VE-4, VE-7, VE-8
4. Purchase 103 EVs for City fleet, with half of all light-duty fleet purchases being EV by 2020	<ul> <li>Electrify 3 million vehicle miles/year by 2018</li> <li>Ensure 50 percent of City light-duty fleet purchases are electric by 2020</li> </ul>	VE-7, VE-8

Objectives	Measurable Outcomes	Vision Element Alignment
5. Incentivize a doubling of consumer EV purchases by 2019	<ul> <li>Install 32 charging stations on high-traffic corridors</li> <li>Double the number of EVs otherwise sold, to 30,000, by 2019</li> <li>Reduce CO2 emissions by 70,000 metric tons</li> </ul>	VE-3, VE-4, VE-5, VE-7, VE-8, VE-9

The following goals and objectives are broad reaching and unrelated to specific Vision Elements.

Objectives
<b>Goal #4: Leverage Partners</b> Impact Area(s) – Efficiency Related Components – MODE, ELEC, IV, and EDM
<ol> <li>Create a sustainable financial model that supports flexible, accessible and affordable transportation solutions to reinvest hundreds of thousands of dollars back into the mobility system (MODE).</li> </ol>
2. Partner with Xcel Energy to double the rate of electric vehicle adoption in Colorado through marketing and deployment of the first 150kW fast charging network, a comprehensive marketing campaign, and strategically located infrastructure. These efforts will influence an additional 15,000 electric vehicle purchases through 2019 (ELEC).
3. Partner with Transdev, owner of Denver's largest taxi fleet, to deploy 10 Nissan LEAFs and 5 Tesla Model S in 2017 with the potential to scale to 65 EVs by the end of the grant period. Beyond the grant period, there is potential for an additional 360 vehicles in Denver (ELEC).
4. Leverage CDOT's \$20 million RoadX Program and its \$7 million Smart City contribution to bolster our projects focused on freight efficiency and integrated freeway and arterial operations (IV).
<ol> <li>Deploy the first implementation of Econolite's new Connected Vehicle intersection controller, Cobalt Sky<sup>™</sup> (IV).</li> </ol>
6. Link the sharing economy with transit, ensuring that all users have the mobility services they are looking for (EDM).
7. Create public-private partnerships around data sharing, and integrate crowd-sourced data into both the open data catalog and privately created apps (EDM).
Goal #5: Collaborate at Every Level Impact Area(s) – Efficiency Related Components – MODE, ELEC, IV, and EDM
<ol> <li>Unite Smart City applicants and finalists with local, national and international experts through our SMART Council.</li> </ol>
2. Deliver technology-driven solutions designed by and for our communities that are measurable, scalable, replicable and exportable to cities nationwide.
3. Collaborate with and provide open access to USDOT's independent evaluation team to monitor our progress towards our goals, objectives and measurable outcomes.
4. Publish our Smart City tracking dashboard to visualize progress towards our goals and objectives.

## **B. DATA MANAGEMENT APPROACH**

Denver will implement a Data Management Plan describing how data will be collected, integrated and disseminated throughout the lifecycle of the Smart City Program. The plan will include a description of the data the City currently collects and plans to collect, the standards to be used, policies for data access, policies for data re-use, re-distribution and derivative products, and plans for archiving and preservation of data.

Denver's Smart City Enterprise Data Management (EDM) Ecosystem will establish open standard protocols and interfaces, which expose synergies and enable interconnection of systems from multiple sources to integrate with other functions or services. The EDM will connect to transportation industry standards: National Transportation Communications for ITS Protocol and the Traffic Management Data Dictionary Standard for the Center-to-Center Communications. The EDM will conform to industry standards protocols such as REST API, OASIS Data and oneM2M standards for Machine-to-Machine (M2M) and Internet of Things (IOT) and security based framework recommendations from NIST and OWASP. For direct system-to-system or center-to-center integration, the City will conform to the defined industry standard specifications.

Denver currently collects and maintains 209 open data assets. The EDM will access that data as it also collects, manages and shares new data generated from the planned Smart City projects. Data from third-party sources also will be included. The EDM will include open standards-based APIs and will have access to historical data records for the purpose of real-time and archived data inputs and outputs. This will allow all stakeholders to contribute to and conduct comprehensive analysis to better understand challenges and achieve Smart City goals and objectives.

Smart City data will reside in the EDM and comply with City data governance standards and open data policy. The EDM will include web services for public access, subject to applicable privacy, security and other safeguards. In the case where data includes PII or other restricted data, the City will make the data available to qualified researchers in compliance with all City privacy policies.

Improvements in City functions and services will occur by combining transportation data with other data sources to improve management and operations. For example, transportation data will be combined with the Denver Safety Department's computer aided dispatch system and Department of Public Works data to reroute traffic around construction areas and incidents identified from these data sources. In addition, the integration of these data sources will enhance situational awareness, real time decision processing, and communications across City management systems.

Denver's EDM architecture will define the open standard API specifications to integrate data from various sources and sectors (travelers/users and their personal device information, non-traditional data sources like weather and social media, shared transportation providers like Uber, Lyft, Google maps, and Waze) with the City's transportation data. The integration of this data will improve transportation operations in areas such as reducing congestion, traffic light prioritization, emissions reporting, real time bus routing, events planning and citywide communications.

The EDM will gather additional data assets from partner organizations such as CDOT and RTD, and new data assets being generated by the Smart City mobile applications, third-party providers and citizens. The EDM will provide a flexible, open construct for data on-boarding, while still maintaining privacy and data segregation where necessary. In a Smart City construct, data exists in many formats, and the ability to connect to data sources and integrate data as broadly as possible is paramount. A key tenant of the EDM data on-boarding process is a flexible data delivery methodology, to allow for the quick importation of data from the entire continuum of Smart City layers and data producers.

The City's open data policy specifies the data sharing agreements for preserving project data for future use. Denver's Open Data Catalog provides open data licensed under the Creative Common Attribution 3.0 license. The data will be collected, managed and shared in the City's Open Data Catalog with City EDM data from outside organizations. Access to this data will be governed and controlled by Denver's open data policy. The City's Technology Services Department will be the custodian of the data assets to protect, secure and serve the data to users.

The City's EDM will include the ability to capture Smart City project sensor and device data through the IoT enablement software modules. Multiple protocols will be supported to interface with sensors and devices from different hardware and software platforms included in the Smart City components and projects. Sensor and device data will be aggregated with the other data sets to create a comprehensive view of the projects to foster innovation and collaboration. Data exchanged with the Independent Evaluator, USDOT, and Research Data Exchange (RDE) will be handled securely (stripped of PII data) and in compliance with the City's Information Security Policies that will be developed before any data exchange commences. The EDM will provide standard interfaces to share appropriately prepared system control, performance and evaluation data collected under the Smart City Program with the USDOT and entities such as RDE. Denver will work with the USDOT to determine the data to be shared and made freely available to the public on the RDE and in compliance with the City's Open Data Policy. The Denver team recognizes the opportunity to improve the completeness, efficiency and cost effectiveness, working with the USDOT to create automated interfaces to transmit the real-time data between entities in a timely and secure manner. The City EDM will retain all data produced during the Smart City Program.

Data produced during the program will consist of test data, machine-readable data, transaction data, intelligent infrastructure data, qualitative data, and unstructured data. Open Data policy goals exist to ensure public data assets are proactively made available through the City's open data portal, while appropriately safeguarding protected and sensitive information. The City is committed to publishing high quality, updated data on the open data portal free of charge and in open formats, with no restrictions on use or re-use, accessible to the broadest range of users to use for varying purposes. By aligning open data efforts with the City's priorities, the City can drive innovative uses of publishable data by agencies, the public and other partners, effectively driving full disclosure of public information. All agency and department heads or their designees shall support these goals to publish data assets on the open data portal under the authority of an Open Data Steering Committee.

Data assets are currently located at <u>http://www.</u> <u>denvergov.org/opendata</u>. Notable exclusions include Criminal Justice Information System (CJIS) data, 9-1-1 data, HIPPA records, and Personally Identifiable Information.

The data Denver now collects include financial and tax, geospatial, human resource, design and construction, planning and community development, permitting, election, aviation, transportation, public health, legal, economic development, library and arts, telecommunications In order to ensure the USDOT's investment in Denver's Smart City Program lives on, Denver will fully integrate the Smart City asset data into the Asset Investment Management System (AIMS), which is fully functional asset management software built on the Deighton dTIMS platform.

and public safety data. The majority of these data assets are currently maintained in structured databases. In addition, data assets exist in unstructured formats such as flat files, images, facsimile, video and proprietary formats.

The traditional approach of manually curated data warehouses, where data are selected from a larger dataset to satisfy some repeatable and understood business need, is not a satisfactory construct in the Smart City environment. Instead, the EDM will utilize an open "data lake" architecture which lends itself to storing many variations of both structured and unstructured data in a mostly untransformed state. By accepting as much raw data as possible from as many data sources as possible, data scientists can merge and view data in a way that allows unexpected correlations and conclusions to be reached.

When deploying an EDM, the over-arching principles of enterprise data governance are critical to long-term success.

Data governance encompasses the people, processes and information technology required to create a consistent and proper handling of an organization's data across the business enterprise. A proper data governance framework ensures that data are properly managed by defining and maintaining:

- Data stewardship
- Data standards
- Standards
- Definitions and taxonomies
- Retention
- Data architecture
- Integration
- Migration
- Metadata management
- Data quality management
- Data security

Recognizing that Denver has initiated a data management architecture, EDM will fully integrate with the existing framework.

The City is composed of many departments that collect and utilize data to manage their operations. The engineers and operators in these departments best understand the complexities of the data that are critical to ensuring safe and efficient city operations. By aligning the EDM governance concept around the government's existing organizational structure and expertise, a framework will be created that helps ensure the success of the overall EDM.

Consistent with pending and current City policy, the EDM framework will align with Denver data management policies in that:

- Current data assets will be classified and cataloged appropriately, and emerging opportunities to enhance current data formats may drive operational efficiencies
- Future data assets might adopt newer standards/ formats

Denver follows a retention policy that describes retention and destruction timelines by data type,

such as unemployment records and construction projects. In addition, the City maintains destruction requirements by data classification (public, reserved, confidential and regulated.) We will adhere to rules mandated by the USDOT Contracting Officer.

Policies and provisions for the re-use, redistribution, and the production of derivatives are governed under City policy.

In order to implement the sharing of Smart City data most effectively, the City will establish and manage partnership, data or information sharing agreements that will include data sharing aspects such as: data types, legal, ownership, storage, access, approval, roles, training, analysis, dissemination and timelines. Any policies and procedures that are not currently in place will be developed to address Smart City data integrity and sharing.

## **C. MANAGEMENT APPROACH**

To ensure the highest possible rate of return on the USDOT's Smart City investment, we have designed impactful performance measures, processes, systems and skills. We will deliver accurate and quality work products that leverage the most up-todate technologies available.

#### **Detailed Management Approach:**

Denver's Smart City Program will be co-chaired by Crissy Fanganello, the City's Director of Transportation and Mobility, and Evan Dreyer, Mayor Michael Hancock's Deputy Chief of Staff. They will head up an Executive Leadership Committee and serve as primary points of contact for the USDOT. The Leadership Committee will include several other key City officials, and also will include representatives from two of our primary Smart City collaborators: CDOT and RTD.

The Executive Leadership Committee will provide strategic guidance and support to our component leads and project teams throughout the duration of the grant. The committee will also be responsible for engaging with our SMART Council and other strategic partners.

Each of the main components of Denver's Smart City Program – Mobility on Demand Enterprise (MODE), Transportation Electrification, Intelligent Vehicles and Enterprise Data Management (EDM) Ecosystem – will be supervised by a component lead. The component teams will mobilize sequentially, and work concurrently, to perform their duties. Technical input from our partners will be critical to the successful implementation of our proposed management approach. These partners will provide reach-back capabilities for technical and quality issues the component leads may encounter, and will serve as Denver's quality control resources when needed.

## C.1 INNOVATIVE, INTEGRATED AND HOLISTIC APPROACH

Denver's Smart City Program unites multiple partners to improve mobility and connectivity through a comprehensive approach that leverages existing assets and investments with new contributions and new ideas.

One of our primary partners is West Safety Services, our EDM Ecosystem lead. Our Smart City proposal will build off of West Safety's existing emergency responder platform, which is installed in thousands of municipalities around the nation. This means that once the EDM Ecosystem is complete in Denver, it can be scaled around the country at a fraction of the cost it would take to develop a custom-made system for every city. With Amazon Web Services on our team, we have already worked out the complete architecture to turn this solution into reality.

Our proposal also will leverage the recently launched "Go Denver" mobility app we are piloting with Xerox. Our MODE component will expand this app by creating a universal information and payment platform that will include all transportation service providers. Users will be able to access the platform through their smartphones, smart card or interactive kiosk. MODE will be a powerful new tool for Denver, made possible only by the EDM Ecosystem.

#### US DEPARTMENT OF TRANSPORTATION



**Figure 12 - Organizational Framework.** Denver's framework provides a solid structure and deep bench of expertise and experience to support the Smart City program.

Panasonic, Denver's exclusive partner, is a leader in green and sustainable technologies, and is a producer of batteries for Tesla and Toyota vehicles. Panasonic is in the process of building the Peña Station Next smart city, a 384-acre transit oriented development that will employ numerous smart city technologies, including intelligent devices, real-time data and responsive infrastructure. Panasonic's Enterprise Solutions Company, with 330 jobs, will anchor the Peña Station Next project near Denver International Airport. For this grant, Denver will collaborate with Panasonic on the development of an Intelligent Vehicle pilot project.

Bloomberg Philanthropies' \$420,000 investment in "What Works Cities" is an initiative to provide technical support, access to expertise and peerto-peer learning for cities and their mayors. The goal is to better use data and evidence to engage the public, improve services, evaluate progress, and fund "what works." Denver will use the datadriven results from this effort to inform the EDM Ecosystem for this grant.

Uber/Enterprise Rent-A-Car Pilot is a program that rents cars to Uber drivers who may not own an acceptable vehicle of their own. Denver is the only pilot site for this program in the entire country, and the initial results have been positive. Serving as a test bed of innovation, Denver will leverage data sets and solutions from this pilot program into the EDM Ecosystem.

#### C.2 ORGANIZATIONAL CAPACITY TO Manage all partners

With a strong-mayor form of government, Denver has the organizational capacity to manage all partners that will be participating in our Smart City Program. We have developed a management structure that will be led by top City officials, including the City's Director of Transportation and Mobility and the Mayor's Deputy Chief of Staff. In all, 30 City employees will be participating in the Smart City Program, with 10 in key roles. The management structure will include an Executive Leadership Committee, component leads and project leaders. A SMART Council and Smart City consultants also will provide program and partner oversight. Denver also has worked with our primary Smart City partners – including CDOT, RTD and Xcel Energy – and will build on past successes to ensure effective and efficient deployment of Smart City projects.

Here are the specific Denver agencies that will be responsible for managing Smart City partners:

		Pro	ogram	Elements				
Agency	Role/Responsibility	EDM	MODE	Transportation Electrification	Intelligent Vehicles			
Office of the Mayor	Responsible for overall program leadership and oversight, ongoing communications with team partners, SMART Council and Executive Leadership Committee engagement, and Smart City component performance.	x	x	x	x			
Public Works (DPW)	DPW will leverage its TMC, fiber network, fleet resources, parking and mobility services to support the development of all components of this grant. In addition, DPW will be responsible for integrating Smart City concepts into its capital projects.	x	x	x	x			
Environmental Health	Denver's Environmental Health Department will be responsible for integrating Smart City solutions that will benefit air and water quality, focusing on the reduction of carbon-based transportation, incorporating renewables into the grid, and greenhouse gas reduction.	x		x				
Food Systems Development, Office of Economic Development	Denver's Food Systems Development Director will help our team ensure that Denver creates smart solutions that reduce food deserts across the city.	x	x					

#### Table 4 - City Agency Participation

		Pro	ogram	gram Elements				
Agency	Role/Responsibility	EDM	MODE	Transportation Electrification	Intelligent Vehicles			
Office of Human Rights and Community Partnerships	Denver's Human Rights and Community Partnerships Office will serve as the lead agency for underserved communities, local residents and equity stakeholders. These will be some of the most important partner relationships to manage during the grant period.	x	x					
Technology Services Department	Denver's TS Department will provide IT services throughout the development of the EDM Ecosystem and will engage in the integration of the fiber network for MODE.	x	x		x			
Denver International Airport (DEN)	DEN will provide a critical link to numerous Smart City projects and partners, including RTD and Panasonic. RTD recently opened a new commuter rail line linking downtown and the airport, and Panasonic is working collaboratively with DEN and RTD to develop a headquarter campus and automated vehicle pilot program along the rail line.	x	x	x	x			
Office of Sustainability	Similar to the Department of Environmental Health, Denver's Office of Sustainability will be responsible for maintaining the performance of all environmental-related projects in the Smart City Program.	x	x	x	x			

#### **C.3 EXISTING & FUTURE PUBLIC AND/OR PRIVATE PARTNERSHIPS**

Our team includes a proven set of strategic public, private and non-profit partners with a history of collaboration.

		Pro	ogram	Eleme	nts
Partners	Role/Responsibility	EDM	MODE	Transportation Electrification	Intelligent Vehicles
Colorado Department of Transportation (CDOT)	CDOT will bring insights from its \$20 million RoadX and Connected Vehicle deployment programs to inform our Intelligent Vehicles component. CDOT also is contributing an additional \$7 million directly to the Smart City Program for Connected Vehicle projects.	x		x	x
Colorado Energy Office	Denver will partner with the Colorado Energy Office to support the development and execution of the Transportation Electrification component.			x	
Colorado School of Mines	Colorado School of Mines will participate in the academic SMART Council and provide technical knowledge, insight and research capabilities related to big data management, statistical analysis, optimization methodology, engineering design, automation and sensor networks.	x			x

Table 5 - Denver Smart City Partner Organizations

		Pro	ogram Elements					
Partners	Role/Responsibility	EDM	MODE	Transportation Electrification	Intelligent Vehicles			
Colorado State University (CSU)	CSU will co-lead the Academic SMART Council with CU Denver. CSU's College of Engineering will explore academic research opportunities related to smart, connected and electrified transportation projects. Coordination will be performed through CSU's Center for the New Energy Economy.			x	x			
Jacobs Engineering	In the role of Program Management Oversight (PMO) and Denver's lead Smart City consultant, Jacobs will draw upon its program management capabilities and leverage its work with CDOT on connected vehicle deployment. Jacobs will be responsible for helping Denver ensure the effective execution of the Smart City Program.	x	x	x	x			
Mile High Connects	Denver will engage with Mile High Connects to ensure that Ladders of Opportunity principles are impactful to the communities they serve.	x	x					
Mile High United Way	Denver will partner with Mile High United Way to remove access barriers and bridge opportunity gaps throughout the city.	x	x					
North Dakota State University (NDSU)	NDSU will coordinate with other research partners and leverage its research, education and outreach teams at the Upper Great Plains Transportation Institute to explore research opportunities in advanced traffic analysis; agriculture; energy; industrial freight; small, urban and rural transit; transportation safety systems; and surface mobility applications and real-time simulation environments.	x			x			
NREL	NREL will support the Transportation Electrification component and advance the deployment of renewables and energy efficiency with a focus on photovoltaics and battery technologies.	x		x	x			
Panasonic	Panasonic will share lessons learned and best practices from its Peña Station Next project and facilitate collaboration with its Fujisawa and Tsunashima Smart City projects in Japan.			x	x			
RMI	RMI will support Denver on the development and execution of the Transportation Electrification component and other elements of Denver's Smart City Program.		x	x				
RTD	RTD will be involved in the MODE mobility payment system. RTD will also contribute to the procurement and operation of electric buses along East Colfax and the integration of automation features of transit buses.	x	x	x	x			
University of California, Riverside (UCR)	UCR will collaborate in the Academic SMART Council and leverage its UCR Center for Environmental Research and Technology to directly address overall goals to provide, demonstrate and evaluate a holistic, integrated approach to improved surface transportation performance.							

		Pro	ogram	Elements				
Partners	Role/Responsibility	EDM	MODE	Transportation Electrification	Intelligent Vehicles			
University of Colorado Denver (CU Denver)	CU Denver will operate as a facilitator, bringing together researchers, experts and data scientists, to support the major components of Denver's Smart City Program. CU Denver also will bring expertise, technical knowledge, insight and research capabilities on multi-modal integration and big data networks to this grant.	x	x	x	x			
University of Michigan Mobility Transformation Center (MTC)	MTC will serve as a test bed for "reference deployment" where connected vehicle devices can be pre-tested and certified in a real V2X environment. MTC will also participate in the SMART Council to leverage best practices and lessons learned.				x			
University of Modern Sciences (UMS)	UMS will collaborate in the International and Academic SMART Councils as well as align and coordinate its smart city research and workforce development efforts with Denver to form a collaborative partnership that will sustain learning and progress in both Dubai and Denver.	x	x	x	x			
Virginia Polytechnic Institute and State University (VTTI)	VTTI will collaborate in the Academic SMART Council and share expertise on connected vehicles, autonomous driving, real- time information, and connected devices to ensure sustainable operations, increased mass transit use, enhanced community engagement, improved energy efficiency, heightened public safety, and increased accessibility to healthcare and a wider range of mobility solutions for residents.	x			x			
West Safety Services (WSS)	WSS will lead the development and implementation of the EDM Ecosystem and ensure proper integration with and analytics from the other components of Denver's Smart City Program.	x	x	x	x			
Xcel Energy	Xcel Energy's plans to decarbonate the grid will play a significant role in many Smart City projects.			x				
Xerox	Denver will work with Xerox to develop a universal mobility app, using Xerox's "Go Denver" app as a baseline.		x					

#### C.4 ENGAGING START-UPS, SMALL BUSINESSES, LOCAL TECHNOLOGISTS AND OTHER PARTIES

As identified in Section A.7, we are creating a SMART Council subcommittee with the express purpose of engaging start-ups, small businesses and local technologists as trusted partners in the development of program elements.

#### **C.5 LEVERAGING FEDERAL RESOURCES**

The City and its partners have a long-standing track record of successfully securing and leveraging state and federal transportation money as described below. Denver will also work with numerous contributing partners to leverage funding, and those partners are fully outlined in Section A.17.

**Grants Awarded** – Denver Public Works has received nearly \$90 million in grant funding over the last three years, including funds from the federal government, Denver Regional Council of Governments, Colorado Department of Transportation and the Regional Transportation District.

**Funding Advancements for Surface Transportation and Economic Recovery Program (FASTER)** – The Colorado State Legislature passed the FASTER Act in 2009. It generates about \$200 million annually through a range of vehicle registration fees and new or increased fines. It enables the State to improve roadway safety, repair deteriorating bridges, and support and expand transit.

FASTER funds have improved the mobility and safety of Colorado's transportation system through hundreds of projects across the state. FASTER does not sunset; the uncertainties in federal transportation funding and the continued decline in the purchasing power of the gas tax will make this funding source ever more important in coming years.

**FasTracks** – In 2004, metro Denver voters approved RTD's FasTracks program, at a cost of \$5 billion, to construct 122 miles of new fixed guideway rail and 18 miles of bus rapid transit, and to redevelop historic Denver Union Station into a multimodal hub. The FasTracks program has been awarded more than \$1.5 billion in federal grants and loans. The FasTracks sales tax will not sunset and will transition to help pay for operations and maintenance of the expanded transit network.

The FasTracks program saw three commuter rail corridors and a new commuter rail maintenance facility constructed through one Design-Build-Finance-Operate-Maintain contract. The three corridors will open for service in 2016.

#### **Colorado Department of Transportation RoadX**

– CDOT created its Transportation Systems Management and Operations Division in 2013 to align core functional business areas and to "systemically improve travel time reliability and safety on Colorado highways through technology, innovative programs and strategies, targeted traffic management activities, and safety improvements to maximize the return on investment of transportation funds."

The RoadX Program typifies the Transportation Systems Management and Operations Division's mission: using technology to improve the safety, mobility and efficiency of the transportation system. The RoadX vision is to make transportation in Colorado crash-free, injury-free, delay-free and technologically advanced. CDOT is committing \$20 million in funding in 2016 to obtain congestion relief and safety improvements through the deployment of technology.

#### C.6 ENSURING QUALITY, TIMELINESS AND COST CONTROL

The foundation of any project management approach must address the three most important performance metrics of quality, schedule and budget. We have a disciplined management team that is proven in its ability to align these performance metrics, and will adhere to the Program Management Plan in Section A.6 that goes into these three areas in greater detail. By having weekly reviews with our team, generating monthly status reports, and communicating status with USDOT on a monthly basis, we will work to ensure that Denver stays on top of quality, schedule and cost in a way that ensures we remain on track.

#### C.7 RISK MANAGEMENT APPROACH

Full realization of a Smart City Program requires a strong foundation that is rooted in data analytics, secure systems and a robust infrastructure. Equally important is the need to continuously identify the associated risks and mitigation strategies required to maintain this bold new open data type of platform. As a part of our Smart City Program Management Plan, we will have a Risk Management Plan, which will become the source for risk-based decision-making. While there are many risks associated with deploying a Smart City Program, the table below identifies our top ten identified key risk categories with an associated mitigation strategy.

#### Table 6 - Risk Identification and Mitigation

<b>Risk Category</b>	Risk	Mitigation Strategy	Impact
	Addressing system security and data privacy	Prioritize security and privacy using national and regional standards to guide the design of the Enterprise Data Management platform and ensure all data in and data out of the Smart City system is properly managed.	High
	Managing the complexity of a Smart City system	Establish an experienced team of systems engineers prepared to handle the multilayered task of integrating multiple system inputs for a large, complex deployment.	Medium
Technical	Prioritizing Smart City solutions	Build a cross-discipline stakeholder group representative of the users of the system.	Medium
	Addressing data quality and integrity issues	Avoid the "trash-in, trash-out" problem by establishing data quality standards and checking data quality before, during, and after implementation.	Medium
	Matching the pace and availability of emerging technology	Institute a user-needs approach to implementing technology. Allow the needs and availability of technology to drive the solutions rather than select and implement a technology without a defined goal.	Low
Policy	USDOT drops commitment to Smart City implementation	Leverage other federal funds and seek additional local resources to implement as many of the Smart City Program elements as possible.	Low
	Cost overruns/scope creep	Develop and implement a meaningful and actionable Program Management Plan to help control costs and ensure minimal scope creep while continuing to allow for changes to the Program that maintain alignment with the grant's goals.	Medium
Institutional	Lack of (or reductions in) stakeholder support	Reinforce stakeholder support prior to project kick-off and maintain positive working relationships and open communication with all stakeholders.	Medium
institutional	Inability to reach agreement among project partners	Reinforce agreements with project partners prior to beginning of Program, and require adherence to the Program Management Plan throughout the life of the project.	Low
	Lacking financial sustainability to continue program	Ensure partners' long term commitment to Program components and institutionalize those elements moving forward.	Low

## D. STAFFING APPROACH

For this program, Denver carefully selected nearly 30 dedicated city employees (including 10 in key positions) who will participate in and lead the effort. These individuals represent the agencies that will have the most impact on the program, including the Departments of Public Works, Technology Services and Environmental Health, the Offices of the Mayor, Sustainability and Human Rights and Community Partnerships, and Denver International Airport. Our staff will be augmented by Jacobs Engineering, which will serve in a Program Management Oversight role and perform program and project management services. West Safety Services will lead the EDM Ecosystem development. Other partners, such as NREL, the Rocky Mountain Institute, CDOT and Regional Transportation District also are providing staff support.

#### **D.1 DENVER'S SMART CITY ORGANIZATION CHART**



## E. 1 EXECUTIVE COMMITMENT

Denver, led by Mayor Michael B. Hancock and the City Council, is fully committed to the goals of the USDOT's Smart City Challenge. All City departments have been directed to collaborate and provide assistance and resources as needed.

#### **E.2 WORKFORCE CAPACITY**

To ensure successful implementation and completion of the Smart City Program, the City has dedicated nearly 30 personnel and organized a cohesive, collaborative Smart City team. The team includes leadership from the Mayor's Office, Division of Transportation and Mobility, Department of Public Works, Technology Services, and Office of Human Rights and Community Partnerships. In addition, key partner agencies, such as CDOT and RTD, bring significant workforce resources to our Smart City Program.

The City and our partners also will contribute to program development and implementation by providing research, technical expertise, and infrastructure installation capabilities. Additional workforce resources will be provided through other partnerships as well, including those with the Center for the New Energy Economy at Colorado State University and the Mountain-Plains Consortium.

City staff will be augmented by Jacobs Engineering, which will provide program management and perform additional services as needed. West Safety Services will lead the EDM Ecosystem development, and NREL and Rocky Mountain Institute will lead the electrification component alongside the City.

## E.3 DEGREE OF INFRASTRUCTURE READINESS

The City's existing infrastructure offers a robust foundation for our Smart City Program components and projects. This includes 2,100 centerline miles of city streets, five major interstate highways, 128 miles of bike lanes, hundreds of miles of rail, and the sixth-busiest airport in the United States. We are currently building out FasTracks, a voterapproved 122-mile rail and 18-mile bus rapidtransit network that will include 90 stations when complete. The newest rail line opened in April, providing a vital link between Downtown Denver and Denver International Airport. Additional infrastructure improvements will soon include the addition of managed travel lanes to Central Interstate 70 just north and east of Downtown.

Other infrastructure assets include a reliable and expandable 378-mile fiber optic network and a vibrant sharing economy of bike-, ride-, and carsharing companies. Several taxi companies provide citywide coverage, and in addition to rail service, the Regional Transportation District offers an extensive network of 138 bus routes, 77 park-n-ride stops and 9,750 bus stops.

Over the last 20 years, Denver has participated in major infrastructure reconstruction and expansion projects totaling more than \$14 billion, including the development of the airport, redevelopment of Denver Union Station as a world-class transit hub, and the FasTracks transit network. These investments embody the City's bold, progressive, and forward-thinking approach toward implementing transformational change.

#### E.4 DATA AND PERFORMANCE MANAGEMENT CAPABILITIES

Denver and its partners currently possess a wealth of data and have recently launched several data collection and sharing initiatives that would be significantly accelerated with Smart City Challenge funding. Denver is home to the largest local Transportation Management Center (TMC) in the metro area. The City's TMC gathers local road conditions from sensors and video and uses it for local traffic management. We share information with the statewide, 24-hour Colorado TMC via physical fiber optic connection. As a regional stakeholder, Denver has engaged CDOT and the Denver Regional Council of Governments to adopt a Regional ITS Architecture and track the status of existing standards.

All City data is stored on a private network which travels through firewalls for public distribution via <u>www.denvergov.org</u>, CDOT's <u>www.cotrip.org</u> website and radio (1260 AM). The Smart City grant will help the City expand distribution and dissemination. It also will improve the integration of traffic information, safety analysis of incidents and multimodal information, ultimately providing information to users in safe, meaningful formats.

The City manages and shares more than 200 datasets through its Open Data Catalog program, including:

Intelligent traffic system devices

- Parking meters
- Budgets, including detailed information about estimated revenues and expenditures
- Bike rack locations
- Sidewalk inventory
- Traffic signals

RTD and CDOT also have extensive data collection, warehousing, analytics and reporting capabilities, such as:

- Automatic vehicle location
- Automatic passenger counting
- General transit feed specification data
- Geographic Information Systems

We will work closely with our partners to establish formal agreements governing data sharing. Policies and operating procedures will be documented, maintained and regularly evaluated, with high priority given to the security and integrity of shared data.

Our team will monitor the progress of each Smart City component and project by collecting clean, accurate, machine-readable data, which will be made publicly available in the City's open data catalog as well as on a tracking dashboard. Through regular meetings, agency and organization leaders will review these data and document outcomes and progress.

Independent auditing and evaluation firms will be tasked with validating performance data and providing recommendations for program improvements

#### **E.5 PROGRAM SUSTAINABILITY**

Denver is fully committed to furthering our Smart City efforts outside of the USDOT Smart City grant opportunity. We are already working with existing private partners such as Panasonic, Xerox, and the Rocky Mountain Institute to identify, test, and refine a variety of Smart City efforts and applications. Additionally, we have strong ties with our public sector partners at RTD and CDOT as well as our regional neighbors and organizations such as the Denver Regional Council of Governments, Metro Chamber of Commerce, and the Metro Mayors Caucus. Our work on Smart City efforts has already led to the development of a Smart City Executive Steering Committee (SCESC) housed in the Office of the Mayor with sub-committees on:

- Safety and Security
- Utilities
- Housing and Small Offices
- Transportation and Mobility
- City Services
- Community and Wellbeing

The USDOT Smart City work, along with all of our ongoing Smart City efforts, is being prioritized to ensure we meet the current and future expectations of our customers in the community. This prioritization is evident in our ongoing budgeting processes for a variety of resources including staffing, materials, and evaluation. Our commitment will stand strong as we continue to set goals and drive towards a variety of outcomes, many of which will only be achieved outside of the three-year USDOT grant period.

Denver is and intends to continue to be transparent in our priorities and funding for innovative, entrepreneurial, and technological approaches to achieve affordable, safe, reliable transportation outcomes and mobility freedom for all members of our community. We believe our commitment to transparency with our community necessitates accountability with our staff and elected/ community leaders.

We reinforce our day-to-day commitment by continuing to build upon the foundation of strong policy and committed advocacy at the local, regional, state, national, and international level. This will increase awareness and build capacity that will achieve a multi-faceted Smart City strategy to expand vehicle electrification infrastructure, address climate change, and provide ladders of opportunity for underserved communities.