BEYOND TRAFFIC:
DENVER
THE SMART CITY
CHALLENGE

**FEBRUARY 4, 2016
PART 1**

**THE CITY AND
COUNTY OF DENVER**

BEYOND TRAFFIC:
DENVER
THE SMART CITY
CHALLENGE

February 4, 2016

The Honorable Anthony Foxx
Secretary of Transportation

**RE: Beyond Traffic: The Smart City Challenge, Funding Opportunity Number
DTFH6116RA00002, DFDA Number 20.200 Highway Research & Development**

Dear Mr. Secretary and Members of the Selection Committee:

The USDOT has a strong vision for America's future – one of Smart Cities that work together
holistically through an integrated approach to improve surface transportation performance. With our
available infrastructure, strong and cohesive team, and commitment to Smart Cities concepts, the
City and County of Denver is the clear choice to move your vision forward.

Our team is anchored by four foundational partners – Denver, the Regional Transportation District,
the Colorado Department of Transportation, and the State of Colorado. We are bolstered by 50+
strategic partners ranging from government to automakers, telecom to academia, and non-profits
to think tanks. This powerhouse team is prepared to provide the USDOT the most comprehensive
Smart City approach through an integrated program composed of a data management platform and
three strategic mobility components. **Our ultimate vision for this grant is to create a replicable,
adaptable, and scalable world-class Smart City Program that connects every user with flexible,
affordable, and accessible multimodal options.**

Denver's Smart City Program can be summed up in one simple phrase – **connect more with less**.
We believe that users benefit from a better-connected multimodal system that demands less of our
time and energy, requires less money, reduces our reliance on cars, and ultimately asks for less of our
space. By connecting users, systems, and infrastructure with technology and information, our Smart
City Program will generate fewer emissions, with fewer injuries and fatalities, and provide more
transportation options and a higher quality of life.

Our collaborative, adaptable Smart City Program includes a SMART Council that will embrace
the four finalist cities, allowing for a truly comprehensive program that has significant impact on
a national scale. With a meaningful local match, Denver will demonstrate its commitment to this
grant, and stands ready to lead the nation, and turn this vision into reality.

With full support of our foundational partners, as signed below, the City and County of Denver
enthusiastically submits this grant application for your review and consideration.

Respectfully,

Michael B. Hancock	John Hickenlooper	Shailen P. Bhatt	David A. Genova
Mayor	Governor	Executive Director	Interim General Manager
of Denver	of Colorado	of CDOT	and CEO of RTD

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1: DENVER'S VISION OF OUR SMART CITY

*Denver's Smart City Program can be summed up in one simple phrase – **connect more with less**. We believe that users benefit from a better-connected multimodal system that demands less of our time and energy, requires less money, reduces our reliance on cars, and ultimately asks for less of our space. By connecting users, systems, and infrastructure with technology and information, our Smart City Program will generate fewer emissions, with fewer injuries and fatalities, and provide more transportation options and a higher quality of life.*

A Smart City is composed of people who are aware and engaged, putting aside egos and agendas, and who are willing to compromise for the benefit of all. The Denver Smart City (DSC) Team is already engaged and working together to move our City forward. With a culture and mindset of continuously shrinking our footprint, reducing pollution, and optimizing precious resources – *especially time and space* – a Smart City must address ever-evolving technologies while remaining affordable and accessible.

We will move forward together, paying particular attention to the under-served.

Denver proudly boasts a long history of innovative thinking, especially when it comes to mobility and economic vitality. We have seen incredible leaps in progress when we have invested in our transportation system. In the late 1800s, a group of visionaries formed the Denver Chamber of Commerce with the express purpose of raising the funds necessary to ensure the railroad came to Colorado. This entrepreneurial mindset forever changed the landscape of Denver. More recently, metro Denver civic leaders and voters embarked on two leaps of commitment and ingenuity. The first was replacing our aging, outdated Stapleton International Airport. Denver International Airport, at a cost of $5B, is now considered Denver's gateway to the world, with an annual economic impact in excess of $26B.

The second was the voter-approved, multi-billion dollar FasTracks program in 2004, the metro-wide light rail, commuter rail, and bus rapid transit system that is reshaping our transportation landscape and changing how we choose to travel. Whether it has been our forward thinking installation of more than two million lineal feet of modern fiber optics, or upcoming investments in new technologies like connected vehicles, mobility platforms, or literally an entire smart city-development, Denver continues to make new and visionary investments in our city.

We have a vision for the full $50M grant (with the $10M Vulcan Foundation investment) that begins with an aggressive approach to the Smart City Program composed of three strategic components built on a robust data platform. Our plan incorporates a meaningful local match and includes the active involvement of our community, (see *www.denvergov.org/ smartcitychallenge*), and 50+ world class, signature partners (from energy to transportation and information technology) many of whom are exclusive to Denver on this grant pursuit. Our proactive operating structure includes a SMART Council – an advisory body including the other four finalist cities to encourage collaboration and transferability of Smart City concepts.

We stand ready to lead the nation and turn this vision into reality.

DENVER'S SMART CITY VISION
Create a replicable, scalable, world-class Smart City Program that provides ALL users flexible, affordable, and accessible multimodal options.

DENVER'S SMART CITY PROGRAM MISSION
Provide the bridge between the people, services, goods, travel choices, information, and technology, allowing for engagement, accessibility, adoptability, and adaptability while being flexible enough to continually evolve, learn, and get 'smarter'.

Denver will leverage existing investment, infrastructure, and the grant to advance new technologies and connect our users.

DENVER WILL GIVE USDOT MOMENTUM

Denver is a hotbed of innovation and opportunity, and the grant will have the most impact in this type of environment.

- Denver is the overall "Best City for Public Transportation" - *USNews.com, 2013*
- Denver is first for "Best places for business and careers" - *Forbes, 2015*
- Metro Denver ranks first among big cities in economic and job growth - *Area Development, 2015*
- Colorado has the nation's third-best economy, based on economic performance in the past year - *Business Insider, 2015*
- Denver is the #4 "Boomtown" heading for at least a decade of strong economy - *Forbes, 2016*

With the full political and programmatic support and alignment of our major partners – Colorado Department of Transportation (CDOT), Regional Transportation District (RTD), the State of Colorado, National Renewable Energy Lab (NREL), Panasonic, Xerox, Rocky Mountain Institute (RMI), and West Safety

Services – our team embodies the aspirational Spirit of the West and a winning mentality. Our partners have assisted the City in creating this Smart City Program from the very beginning. Support and alignment for this program includes Denver's Mayor Hancock, currently starting his second term, who campaigned on mobility and won reelection with 80% of the vote. It extends to Denver's City Council, whose priorities for the 2016 budget include five mobility-centric items, and to Colorado's Governor Hickenlooper, who has demonstrated his support and alignment by signing our cover letter for this grant application.

CHALLENGES & OPPORTUNITIES

Denver is a city of challenges and opportunities, and therefore perfectly situated to serve as USDOT's Smart City collaborator. We are one of the most sought after, youngest, fastest growing cities in the nation, yet our infrastructure is extremely strained. With some of the worst air pollution in the U.S., we also have the highest quality of life in the country. Similar to other mid-sized cities, our list of challenges is long:

- Changing mobility patterns, particularly for millennials and baby boomers
- Accessibility for under-served populations
- Aging and degraded infrastructure serving an ever increasing and evolving population
- Technology and cybersecurity demands

While tackling these challenges can be daunting from a transportation/mobility perspective, our solutions are summed up in our Smart City Program. Our proposal addresses all twelve of the Vision Element requirements and will achieve the three expected outcomes relative to Safety, Mobility, and Climate Change. Our program consists of an Enterprise Data Management (EDM) Platform and three individual components:

1. Mobility on Demand Enterprise (MODE)
2. Transportation Electrification
3. Intelligent Vehicles.

DENVER'S SMART CITY PROGRAM

3 COMPONENTS   *SEE SECTIONS 4 AND 5*

1: Mobility on Demand Enterprise – MODE will become Denver's bridge to mobility options by reducing the barriers to access and bringing it to our fingertips through apps and interactive kiosks, in collaboration with Xerox and Panasonic (exclusive partners). Denver's existing two million lineal feet of fiber is available and will be harnessed for this initiative.

2: Transportation Electrification – This component will enable an infant vehicle electrification market to mature and expand while addressing critical safety concerns and providing solutions in coordination with the sharing economy to enhance the rider experience. This work will leverage voter-approved decarbonization efforts through the state's renewable energy mandate.

3: Intelligent Vehicles – Denver will build a foundation in intelligent vehicles through connectivity by partnering with CDOT to expand its connected vehicle program into the urban environment. We will unleash the true potential of automated vehicles by building a connected automation environment that systematically aligns the needs of users and businesses with the transportation network for a safer, smarter, and more environmentally friendly Denver.

ENTERPRISE DATA MANAGEMENT (EDM) PLATFORM

Denver will create a holistic, functional Smart City Enterprise Data Management Platform that supports the three components and connects all of the disparate data sets for safety, mobility, transportation, freight, and weather in one place, allowing for predictive analytics and timely decision-making. The platform will be adaptable, scalable, and expandable to other cities.

IMPROVE SAFETY

USDOT's *Beyond Traffic 2045* identifies "three distinct but related streams of change and development occurring simultaneously: in-vehicle crash avoidance systems that provide warnings and/or automated control of safety functions; connected vehicle technologies – vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communications that support various crash avoidance applications; and self-driving vehicles." Denver's EDM Platform will integrate real-time data and analytics with state-of-the art information processing to facilitate intelligent vehicle performance, fostering a greater ability to operate and move effectively and with much higher levels of safety.

Denver's Smart City Program will also align with West Safety Services' Emergency Aware Services (EAS), which is an existing emergency response Smart City data platform based on industry standards, that improves safety and enhances mobility in Denver. EAS is an open, standards-based platform that securely connects disparate data sources across multiple organizations (public and private), allowing for unsurpassed collaboration between users and public safety leadership.

MARK SAVAGE, LIEUTENANT COLONEL, COLORADO STATE PATROL, AND USDOT NATIONAL FREIGHT ADVISORY COMMITTEE MEMBER

"Denver's Smart City Program will allow the Colorado State Patrol to perform predictive analytics on high-risk traffic areas, giving public safety professionals the ability to more effectively allocate resources working to reduce the number of crashes across the City."

OPTIMIZING FREIGHT MOVEMENT

As outlined in *Beyond Traffic 2045*, Denver will leverage the EDM Platform to provide the analytics to optimize the movement of goods and freight within the Denver Metro area and support the transition to connected and automated trucks and freight vehicles.

Additionally, our team will engage with the Department of Homeland Security and its *Securing the Cities* program to provide valuable and accurate support for timely decision-making to mitigate or respond to safety hazards.

ENHANCE MOBILITY

Denver boasts a robust and healthy sharing economy made up of one bike, three ride, and five car sharing companies in addition to RTD's $5B transit expansion program providing service throughout the metro area. The Denver Smart City Program presents an innovative approach to effectively link these heavily-utilized transportation options, further working to improve and expand alternative mobility choices and reducing reliance on traditional travel modes.

Denver's Smart City Program will leverage these mobility services to enhance first mile/last mile (FMLM) connections. For example, the City stands to benefit from the experience and lessons learned from the nearby City of Centennial, which recently launched a partnership program with a ride-sharing service provider to enhance its on-demand FMLM connections to light rail services. The program provides the opportunity to simulate an Automated Vehicle (AV) business model. The program will work to harness the power of the ride sharing economy as an essential element in bridging connectivity gaps for all residents.

ADDRESS CLIMATE CHANGE

Construction and infrastructure spending isn't the only way Denver proves its innovative spirit. As climate change rose to the forefront, we became an early leader among American cities. We were among the first cities to sign onto the Climate Protection Agreement of the U.S. Conference of Mayors and were the first city to win an award for our implementation efforts under that Agreement. Denver was the first city among those eligible for the USDOT Smart City Challenge Grant to sign onto the Mayor's National Climate Action Agenda. Denver has reduced per capita greenhouse gas emissions below 1990 levels and is on course to reduce total community emissions (currently at 23.7 metric tons per person) in absolute terms by 2020. These reductions have come despite a 25 percent increase in population since 1990.

Increased ride sharing, bike access and usage, and car sharing will result in significant economic savings for Denver users. In accordance with *Smart Mobility, Reducing Congestion and Fostering faster, greener and cheaper transportation options*, by Deloitte University Press, we anticipate a societal savings of reduced CO_2 emission of $37/metric ton.

Denver will leverage the USDOT grant to further decarbonize the electric grid through the rapid and efficient transition from fossil-fuel powered vehicles to electric vehicles whose energy will come from a wide range of sources, including renewables.
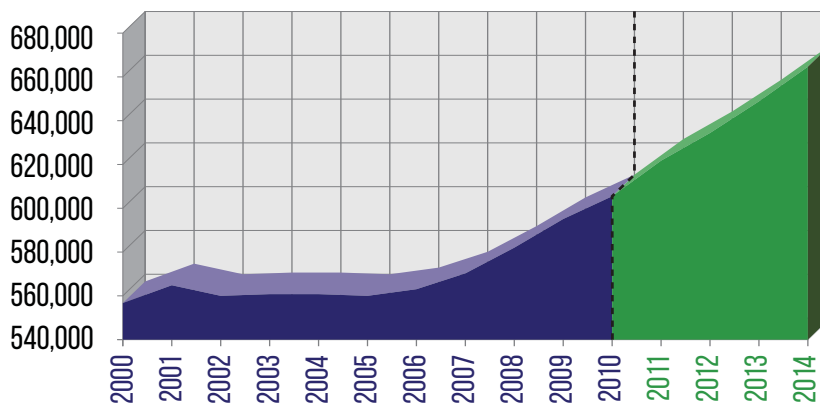
LEVERAGING OUR FIBER OPTIC NETWORK

Beginning in the 1980s, the City of Denver began creating an expansive fiber optic network. Through massive expansion over the last three decades, the network now includes more than two million lineal feet (378 miles), providing fiber optic coverage throughout the city. The network has nearly 80 percent availability, providing plenty of capacity to support the grant.

2: POPULATION ALIGNMENT

Denver is a perfect candidate for the USDOT Smart City Challenge. In the 2010 Census, Denver had 600,158 residents, sitting at the midrange of the preferred population statistics sought through this grant. Our dense urban population represents 25 percent of our total urbanized area.

POPULATION GROWTH

Denver has seen its population grow from 467,610 in 1990 to 600,158 in 2010 – an increase of more than 28 percent in 20 years. According to the state demographer's office, Denver reached 664,220 in 2014, an additional 10 percent in just four years.

DENVER EMBRACES MULTI GENERATIONS

Denver is one of the youngest cities in the country, with millennials accounting for more than 21.5 percent of the city population. Baby boomers account for 19.8 percent.

AGE
> 5
5 - 9
10 - 14
15 - 19
20 - 24
25 - 29
30 - 34
35 - 39
40 - 44
45 - 49
50 - 54
55 - 59
60 - 64
65 - 69
70 - 74
75 - 79
80 - 84
< 85

MALE   **FEMALE**

21.5%
millennials range from 25-34

19.8%
baby boomers range from 51-71 years

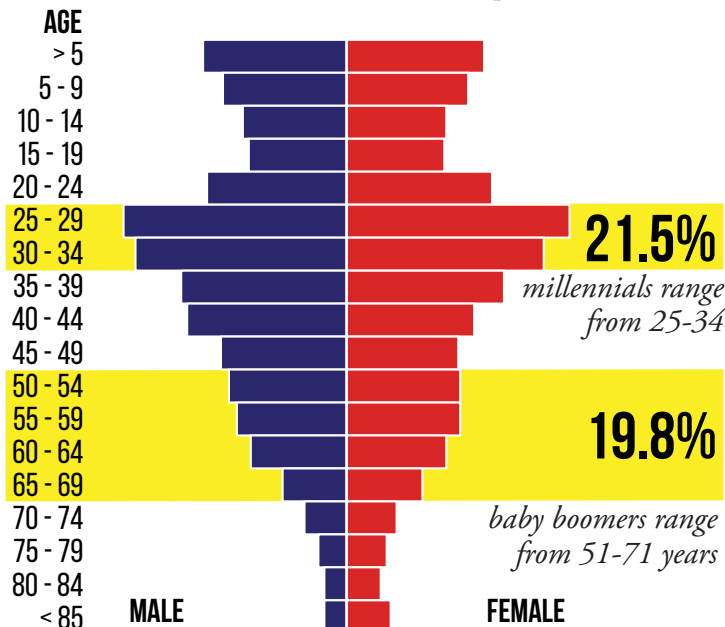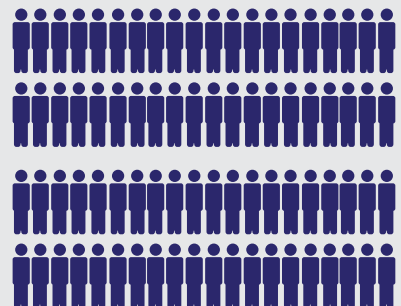**600,158** *population in 2010*

DOWNTOWN DENVER CORE

142%
increase in the number of residents since 2000

65,974
residents living in downtown Denver and the surrounding historic neighborhoods

DENSE URBAN POPULATION

DENVER REPRESENTS
25%
of the population of the local urbanized area

3: SMART CITY ALIGNMENT

EXISTING PUBLIC TRANSIT SYSTEM

RTD is metro Denver's transit agency, serving more than 2.8 million residents. With an annual budget of $460M, RTD carried more than 104 million passengers in 2014, an agency record. RTD's bus network includes more than 1,000 vehicles on 138 routes, 9,750 bus stops, and 77 Park-n-Rides. RTD operates 48 miles of light rail servicing 46 stations. An additional 10.5 miles of light rail and 50 miles of commuter rail are under construction as part of the $5B FasTracks program.

CONDUCIVE ENVIRONMENT

Over the last 20 years, Denver has been involved in projects that total over $14B. This investment exhibits the City's progressive and forward thinking mentality when it comes to instituting and approving projects that change transportation. The City has led multiple regional coalitions that helped execute the projects included in the timeline below.

CONTINUITY OF LEADERSHIP

Denver has shown a dedication to innovation and progressive investment in public projects for over 30 years, beginning in the 1980s. Then-Mayor Federico Peña led the City through massive public investment resulting in a complete revitalization of Denver's

economy. Successive mayoral administrations have continued leading the City in new public infrastructure investments, including a new airport, three professional sports stadiums, and highway and rail construction.

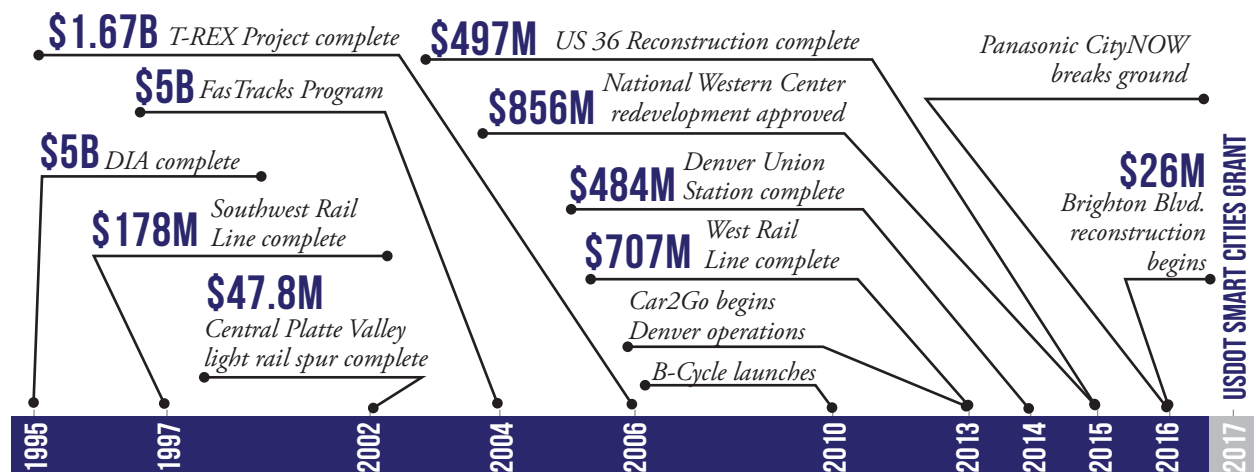## INTEGRATING WITH THE SHARING ECONOMY

The State Legislature became the first in the country to legally authorize ride sharing in 2014, and Denver's City Council soon followed suit by forming a Sharing Economy Task Force.

Denver has very positive working relationships with several ride and car sharing services, which operate throughout the city, including B-Cycle, Car2Go, eGo CarShare, Uber, and Lyft. Denver is also one of two test sites for partnership between Uber and Enterprise Rent-a-Car, thanks in large part to the City's progressive regulatory environment which encourages innovation.

BEST PRACTICES IN OPEN DATA

Bloomberg Philanthropies selected Denver to participate in its *What Works Cities* program, which provides support to revamp open data policies and build an analytics curriculum that will provide machine-readable data to the public. Denver is committed to ensuring that data is accessible, discoverable, and usable.

Both RTD and CDOT also provide open data to encourage innovation and information sharing among consumers.

Year	Project
1995	$1.67B T-REX Project complete
	$5B FasTracks Program
	$5B DIA complete
1997	$178M Southwest Rail Line complete
2002	$47.8M Central Platte Valley light rail spur complete
2004	$497M US 36 Reconstruction complete
	$856M National Western Center redevelopment approved
2006	$484M Denver Union Station complete
	$707M West Rail Line complete
	Car2Go begins Denver operations
2010	B-Cycle launches
2013	
2014	Panasonic CityNOW breaks ground
2015	$26M Brighton Blvd. reconstruction begins
2016	
2017	USDOT SMART CITIES GRANT

Twenty years of public infrastructure investment demonstrate our readiness to move forward with Smart City efforts.

4: PRELIMINARY SITE MAP
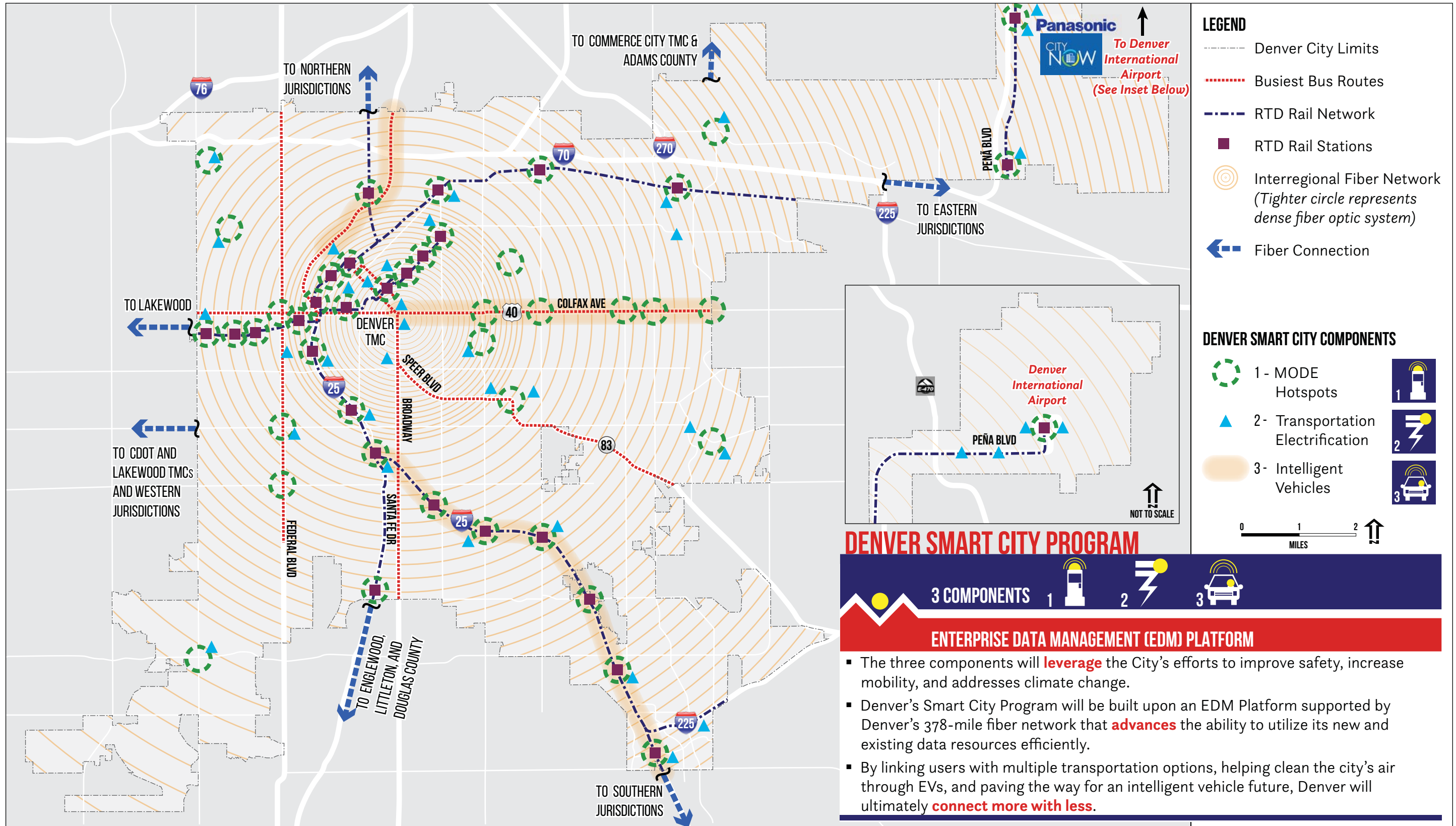
LEGEND

- — · — Denver City Limits
- ········ Busiest Bus Routes
- — · — RTD Rail Network
- ■ RTD Rail Stations
- ◎ Interregional Fiber Network *(Tighter circle represents dense fiber optic system)*
- ◀-- Fiber Connection

DENVER SMART CITY COMPONENTS

- 1 - MODE Hotspots
- 2 - Transportation Electrification
- 3 - Intelligent Vehicles

0   1   2 MILES

DENVER SMART CITY PROGRAM

3 COMPONENTS 1 2 3

ENTERPRISE DATA MANAGEMENT (EDM) PLATFORM

- The three components will **leverage** the City's efforts to improve safety, increase mobility, and addresses climate change.
- Denver's Smart City Program will be built upon an EDM Platform supported by Denver's 378-mile fiber network that **advances** the ability to utilize its new and existing data resources efficiently.
- By linking users with multiple transportation options, helping clean the city's air through EVs, and paving the way for an intelligent vehicle future, Denver will ultimately **connect more with less**.

5: APPROACH ALIGNMENT

Our approach is to connect users with technology, as well as educate and engage the public to accelerate the adoption of programs that align with USDOT's 12 Vision Elements. The end result will be a program that improves safety, enhances mobility, and addresses climate change, and that can be replicated by other cities.

SMART CITY PROGRAM OVERVIEW

Denver will create a replicable Smart City Program that weaves together three main components, built upon a robust EDM platform. The platform will help facilitate traveler choice and knowledge, and enable informed decision-making at the City level. The common theme in all components of our program is that we will **leverage** existing infrastructure and business practices, **advance** new technologies and business models, and **connect** users. The three main components are:

1. **Mobility on Demand Enterprise (MODE) –** Provide enhanced mobility choices and technologies to users.

2. **Transportation Electrification –** Improve electrification access for users while creating smart grid integration opportunities and drive rapid electrification through innovative business models, financing, and improved infrastructure.

3. **Intelligent Vehicles –** Build a foundation for intelligent vehicles through connectivity by partnering with CDOT to expand its connected vehicle (CV) program into the urban environment. We will unleash the true potential of automated vehicles (AV) by building a connected automation environment that systematically aligns the needs of users and businesses with the transportation network for a safer, smarter, more environmentally friendly Denver.

The future is not an either/or decision about how to travel, such as transit versus personal vehicle, but instead one that facilitates engaged, informed decision-making and improved options for all users. Improved options include those that leave little or no footprint. For traffic to reach "beyond 2045," it is critical to focus on how enhanced mobility will also lessen the impact of all transportation modes on our communities.

DENVER SMART CITY PROGRAM
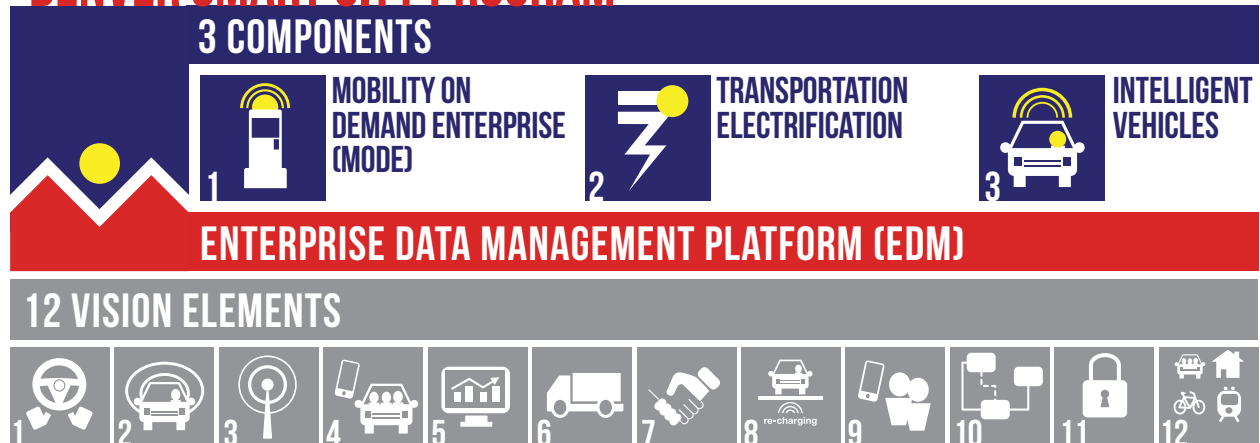
These icons represent USDOT's twelve Vision Elements. Our program features three core components built on the foundation of an EDM platform. The table on the next page provides an overview of how each Vision Element is specifically addressed. Further discussion of EDM and the three components follow.

Table 1 - How Denver's Smart City Program Achieves the Vision Elements

Urban Automation
- Leverages City of Centennial's FMLM pilot and validates AV's role in Mobility on Demand while analyzing a new business model
- Addresses barriers to widespread AV adoption by testing performance in the snow and other harsh weather conditions
- Works with technology partners to automate particular features of transit and City fleet vehicles

Connected Vehicles
- Tracks AV simulation vehicles in real-time and integrates data into the user application and provides information about traffic flows
- Collects data via the EDM platform to be aggregated and analyzed to improve safety and increase mobility
- Integrates CVs into the current Intelligent Transportation Systems (ITS) infrastructure, including the Traffic Management Center (TMC), to deliver cellular, satellite, and dedicated short range communication (DSRC) based applications

Intelligent, Sensor-Based Infrastructure
- MODE component collects, analyzes, and disseminates real-time, on-demand, sensor-based data to improve overall effectiveness of transportation network
- Receives sensor information via V2V and V2I communication

Urban Analytics
- EDM platform collects, compiles, organizes, and analyzes data from multiple sources throughout the City, informing future operations of the transportation network

User-Focused Mobility Services and Choices
- Optimizes RTD routes in dense urban areas to improve travel times and reliability, attracts riders for short trips, reduces overall vehicle miles traveled, and provides better and more frequent service to underserved areas
- Empowers all users to make transportation choices based on their personal preferences by linking the sharing economy and transit

Urban Delivery and Logistics
- Improves the movement of freight by partnering with suppliers to target viable CV applications along key corridors that will share real-time road information

Strategic Business Models and Partnering Opportunities
- Partners with 50+ public and private entities, including research institutions and Non-Governmental Organizations (NGOs)
- Connects Mountain Plains Consortium, Colorado School of Mines, and NREL to lead research efforts into vehicle electrification infrastructure opportunities
- Partners with firms such as Panasonic and Xerox to develop Mobility on Demand applications to improve mobility
- Leverages ongoing work from initiatives including Funding Advancements for Surface Transportation and Economic Recovery (FASTER), FasTracks, and CDOT RoadX

Smart Grid, Roadway Electrification, and Electric Vehicles
- Focuses on electrifying buses, taxi fleets, and sharing economy
- Leverages Panasonic's CityNOW transit-oriented development near Denver International Airport
- Grows the electrification infrastructure footprint by increasing the accessibility of charging stations
- Increases municipal fleet vehicle electrification by 2025

Connected, Involved Citizens
- EDM platform includes a framework for users to engage in crowdsourcing data
- Xerox app utilizes real-time transit data to enable commuter secure transportation

Architecture and Standards
- Builds an EDM platform that is adaptable, scalable, and expandable
- Leverages available architecture standards and work completed by USDOT for CV concepts and coordinate with national standards stakeholders on lessons learned

Low-Cost, Efficient, Secure, and Resilient Information and Communications Technology
- EDM includes a functional storage platform, comprehensive data model, and robust infrastructure capable of information sharing across systems and enhancing data connections governed by stakeholder requirements and well-documented policies that utilize existing standards and architectures

Smart Land Use
- Allows for update and refining of land use plans to support and enhance mobility

ENTERPRISE DATA MANAGEMENT PLATFORM

A challenge for many cities is the ability to efficiently define, integrate, and retrieve data for both internal applications and external communication. Our EDM platform will help Denver overcome these challenges.

PURPOSE

With data as the core of a Smart City, a key first step in our approach is to create an EDM platform upon which our three program components will be built. The EDM platform will allow Denver to use data it already has for its existing operations while serving as the foundation for the expansion of future services. The platform will also be expandable to accommodate other data systems, ensuring scalability for ready adoption by other cities around the country.

Denver currently collects, manages, and shares data quite effectively. However, our challenge is that many of our systems are constrained by the "silo effect," which means that any data sharing and analytics across systems must happen manually. This is time-intensive and impedes our ability to use data resources efficiently. The EDM platform will help to remove organizational barriers and conflicts by implementing a structured data delivery strategy – from data producer to data consumer.

KEY TASKS

STEP 1: FRAMEWORK

We will build a framework that addresses the hallmarks of EDM – data quality, master data management, metadata management, data warehousing, and data integration. We will utilize an open data protocol in existing data formats or standards coordinated regionally to maximize the usability of the platform design and resulting data, encouraging partnerships and innovation. We will also focus on privacy and security in the development of the EDM platform, recognizing that data sharing without proper policies and procedures can compromise sensitive information.

STEP 2: DATA SHARING

Data sharing standards and agreements will set expectations and clearly define roles and responsibilities. The City has evaluated existing data sharing efforts within Colorado and has identified three partners that have set the stage for additional information sharing.

1. **OpenColorado** is a volunteer-run, nonprofit organization that currently hosts 1,503 data sets from 12 entities across Colorado.
2. **The Colorado Information Sharing Consortium (CISC)** is making statewide data sharing and analytics possible.
3. **Denver Regional Council of Governments (DRCOG)** is the custodian of federal funds for ITS and maintains the Denver Regional ITS Strategic Plan.

We will explore existing internal and external data sharing agreements and identify potential data connections. The goal is to identify barriers that keep connections from happening and understand the barriers that are preventing data sharing. We will evaluate the willingness of our partners to share datasets through enhanced data sharing agreements and the development of policies and procedures.

STEP 3: ANALYTICS ENGINE

The analytics engine will serve as the data processor to either deliver user needs-driven applications to the City or provide well-defined interfaces and data schema to empower data consumers. We will also leverage the analytics engine to establish critical system monitoring and report data-driven performance measures. This reporting functionality will cut across the available data stores and provide key performance indicators to decision makers.
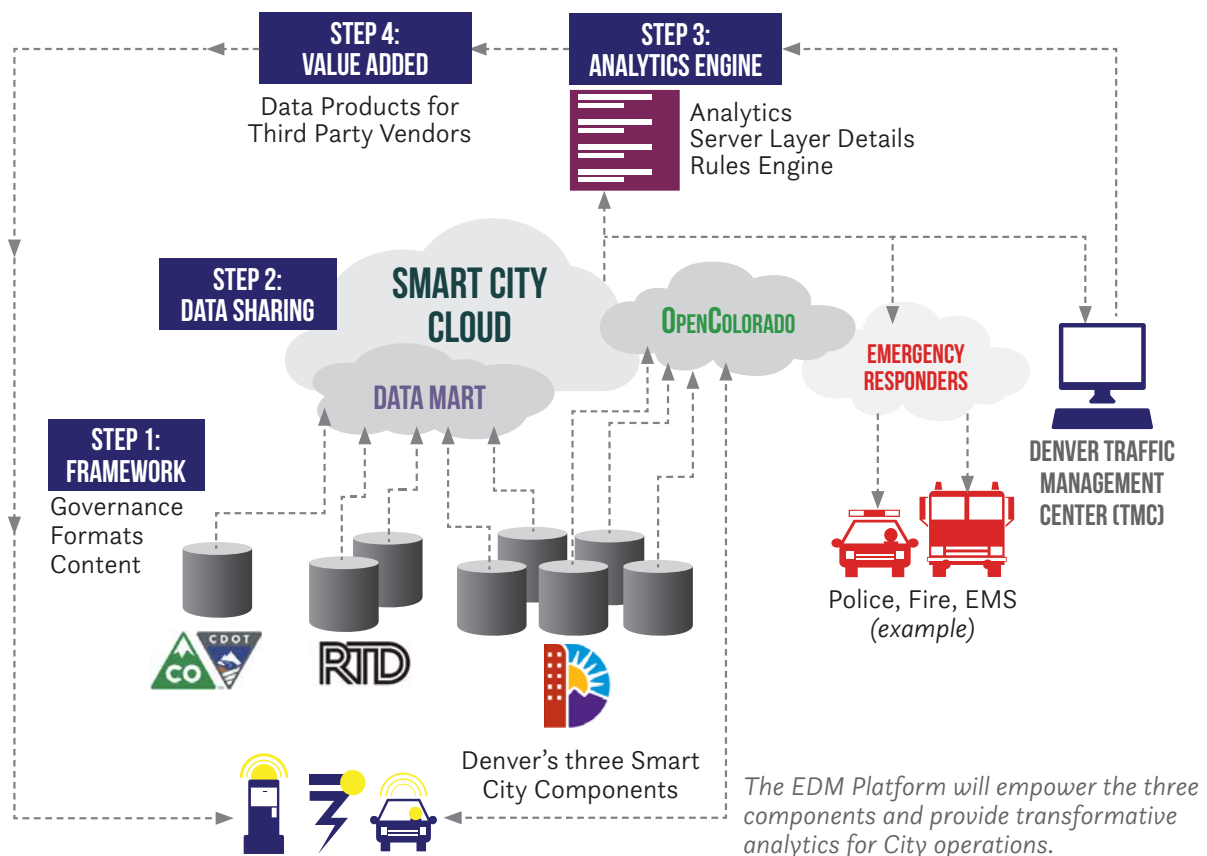
STEP 4: VALUE-ADDED DATA PRODUCTS

Building off our analytics engine, third party developers will be able to integrate our open data with their various programs and applications to deliver improved real-time solutions.

BENEFITS

The EDM platform will integrate, disseminate, and manage data for all existing and future Denver Smart City applications, processes, and entities. It will deliver clear and cohesive information to internal users, external stakeholders, and the public. The City currently has numerous data stores that support various functions. Similarly, other agencies outside the City (RTD, CDOT, etc.) have their own data stores which support their operations while also influencing City operations, and vice versa. Many of these data stores are currently sharing data through existing open data sharing efforts, but organizational barriers still exist. An EDM platform will help us overcome these barriers, allowing us to:

- **Leverage** existing infrastructure and business practices:
  - » Optimize Denver's 378-mile fiber optic network (80 percent available) as the backbone for network communications.
  - » Expand existing open data sharing efforts by identifying high-value datasets and working with data owners related to security, privacy, and performance.
  - » Facilitate conversations among data owners, data managers, and data consumers to understand the business case for collaboration, data sharing, and prioritization.
- **Advance** from managing data to generating information and value through data analysis, data integration, and data interfaces that provide data in formats that benefit the community.
- **Connect** data sources within and outside the city by delivering a framework that enables expanded data sharing through a data governance structure that will break down barriers.

The EDM Platform will empower the three components and provide transformative analytics for City operations.

COMPONENT 1: MOBILITY ON DEMAND ENTERPRISE (MODE)

This component will enable users to benefit from seamless multimodal travel across Denver. Combining choice and technology together will serve to advance multiple modes of "on demand" services, and make significant progress toward the goals of Beyond Traffic 2045.

1   2   3   4   5   6   7   8 re-charging   9   10   11   12

PURPOSE

This component is focused on changing behavior around travel mode use, creating new options for mobility services that didn't exist previously, and building both virtual and physical platforms that connect supply and demand. A host of supporting technologies will empower users to determine their "best" service and allow them to engage and pay for that service. It will also monitor the travel situation so that if "best" changes, the traveler has the ability to modify their trip. Many related initiatives are currently underway, and MODE will link these initiatives under one enterprise mobility service.

KEY TASKS

Mobility Options at Your Fingertips
Denver, with our partner Xerox, will launch a mobile application called Go Denver in early 2016 that will allow users to select, reserve, and estimate cost for multiple modes of transportation and parking options in the Denver metropolitan area. Suggestions are provided to the user based on their preferences for the fastest, most cost effective, or healthiest transportation options. Panasonic also will be providing mobility services in Denver through its cloud data platform. In addition, Denver plans to use grant funding to create the MODE Cloud to share data inputs in a common, open environment.

The MODE Cloud
With increased data volume and velocity key concerns, the MODE Cloud will be scalable, replicable, and extensible geographically and applicable to other dimensions of the EDM platform. We also plan to integrate MODE with existing built infrastructure and fiber optic networks to provide travelers easily accessible multimodal transportation options. MODE will enable Denver to leverage the $14B in major infrastructure projects made over the last 20 years.
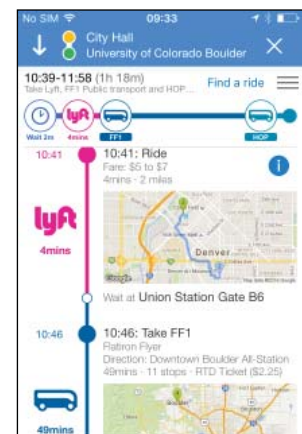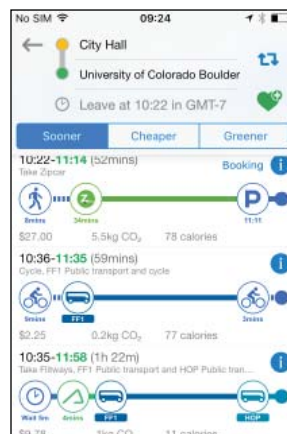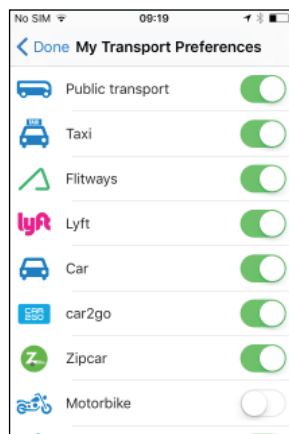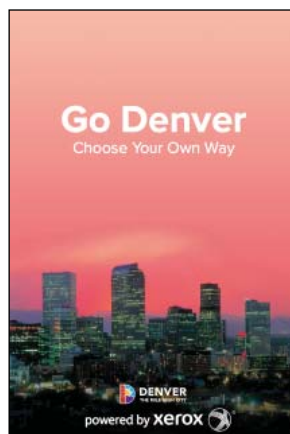
Xerox Go Denver mobile app provides mobility options at users' fingertips.

Improving Mobility with Information Services

MODE will design and implement next-generation mobility hubs where all modes are easily accessible. The focus is to maximize use of the existing transit system with an initial focus on the Colfax Avenue, US 36, and I-25 corridors. Using grant funding, we plan to expand on that concept by installing ruggedized interactive MODE kiosks strategically located throughout Denver and connected to our existing fiber system. This will engage a greater percentage of our population that either does not have a smartphone (16 percent) or is intimidated by technology. These MODE kiosks will provide important information about the area and "push" information to wireless devices to satisfy users' transportation needs.

Improving Mobility with FMLM Services

The City of Centennial, Denver Metro Chamber of Commerce, and RTD are partnering on a Bloomberg Philanthropy grant to explore supplement Call-n-Ride RTD (on-call transit) service with a ride-sharing service. This project will work to increase transit ridership and reduce automobile dependence by creating an FMLM connection for some of the 130,000 employees in the Denver Tech Center. Following the Centennial pilot program, we will evaluate lessons learned and possible expansion into Denver. The ultimate goal is to expand on-call ride sharing services to RTD stations where applicable and useful throughout the city.

Transit Priority Corridors

We are leading efforts to improve the transit capacity of East Colfax Avenue in Denver. A congested urban arterial, East Colfax is a state-owned asset operated by the City that enjoys 22,000 daily bus boardings. The Colfax Corridor Connection Study proposes the City's first urban bus rapid transit (BRT) corridor

capable of moving upwards of 50,000 people without increasing the roadway footprint. Users will benefit from the incorporation of MODE kiosks and mobility hubs which will share real-time, FMLM connection, trip planning, and other information. The trip will be optimized by intelligent sensor-based infrastructure that will also be sharing data with the user through MODE. This includes traffic signal controllers that transmit information to buses via V2I communication, enabling transit signal priority (TSP).

BENEFITS

Improved mobility is not something that can only be obtained from one's personal vehicle, but can also be accessed via interconnected information, transportation, and financial services. Denver will integrate MODE into the fabric of how we live and move. We will:

- **Leverage** existing infrastructure and business practices:
  - » Optimize RTD's bus fleet of more than 1,000 vehicles, 77 Park-n-Rides, 9,750 bus stops, and four new rail corridors opening in 2016 (nearly 50 miles of additional fixed guideway transit)
  - » Bolster the existing bike, car, and ride sharing economy
- **Advance** new pilots that demonstrate Mobility on Demand, electric and automated vehicle technology, and integrated corridors that pull it all together.
- **Connect** people to more choices and information. The more information at their fingertips and the more that the barriers are removed to access different transportation modes, the more the demand for such services will increase.
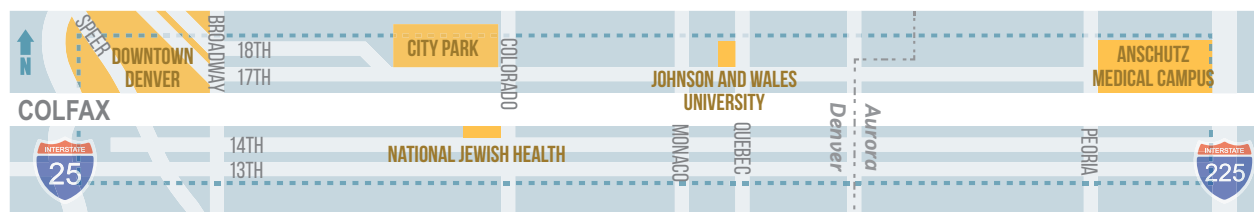
East Colfax will serve as a prototype for urban BRT and mobility options throughout the City.

COMPONENT 2 - TRANSPORTATION ELECTRIFICATION

Denver is perfectly positioned for expansive growth in transportation electrification. This component will build upon an existing foundation of strong policy, committed advocacy, and state-wide environmental awareness, to implement a multi-faceted strategy to expand vehicle electrification infrastructure and accelerate EV adoption.

PURPOSE

According to the Environmental Protection Agency, Denver is located in an ozone and carbon dioxide non-attainment area. This designation poses a serious public health concern for residents with respiratory illnesses. This component will allow Denver to harness the power of renewable energy for EV usage. Colorado voters approved a statewide renewable energy mandate in 2004, which has since been increased to 30%. The mandate requires energy utilities to either generate renewable energy themselves or purchase that energy from other sources. This component will support decarbonization efforts underway through the mandate, while working to harness the environmental benefits of EV technology. This effort will put the City at the forefront of evolving charging technologies while providing an example for other cities around the country to improve poor air quality conditions.

KEY TASKS

Expanding EV Infrastructure

Denver will work with its partners to expand EV charging stations across the city to further support an increase in market penetration for EVs. The City currently boasts 36 City-owned EV charging stations with an additional 34 available for public use. Grant funds will be used to evaluate and implement expansion of EV charging stations for public use (City-owned or otherwise) while also working with our technology and energy partners to further research rapid charging stations, allowing for charging in less time. The City will evaluate deploying fast-charging EV stations to strategic locations across Denver, including RTD Park-n-Rides. The City will work with regional partners such as the Regional Air Quality Council (RAQC) to provide incentives for companies to adopt EV charging stations at workplaces, thereby increasing the convenience of EVs.

Regulatory barriers currently hamper EV infrastructure deployment at multi-unit housing sites across the country. Denver will work to remove these barriers to further expand EV infrastructure and provide an example for other cities across the country on how to tackle obstacles that hinder EV market penetration.

Increasing EV Market Penetration

Electrification for high-mileage vehicle operations, such as taxis, offers a great opportunity to demonstrate the immediate benefits of EV adoption. EVs will stand as visible banners of health and vitality throughout the city. Long-term viability depends on both long-range and fast-charging capabilities with a target of providing both. Next-generation batteries are also poised to provide pivotal assistance in the widespread adoption of EVs. The City will work with partners to increase high-mileage fleet electrification efforts to increase EV market penetration while creating a test bed in the city for battery technology.

Denver International Airport (DIA) has also expressed an interest in the deployment of EV shuttle buses to travel between the main terminal and rental car sites. These new shuttles would replace gas-powered shuttles in operation today and work to further City-led efforts to decarbonize the grid while working to improve air quality across the city. DIA will also work

with project partners to evaluate the best ways to expand EV charging station operations at the airport. DIA currently has 20 publicly available and popular charging stations and will evaluate expansion efforts in the future, including the adoption of quick-charging technology.

Colorado's $6,000 alternative fuel vehicle tax refund is one of the highest incentives in the nation for purchasing an EV and supports increasing EV market penetration. The City will work with legislative partners to ensure that the existing tax refund is maintained while also evaluating opportunities for complementary incentives such as access to high-occupancy vehicle (HOV) lanes.

Wireless Charging Technology Adoption
RTD has purchased 36 new electric buses for operation along the 16th Street Mall in downtown Denver. The shuttles will be delivered in late 2016/early 2017. RTD has expressed an interest in evaluating wireless charging technology. NREL and other energy and technology partners will build on existing research efforts to evaluate wireless power transfer systems for use along the 16th Street Mall as well as expand research into technology utilization for other light- and heavy-duty applications. The City and RTD will work together to evaluate deployment and adoption of wireless charging technology at strategic locations across the city, including public parking lots and garages. There are more than 10,000 City-owned parking spaces throughout Denver, providing an opportunity to further test wireless charging at public parking facilities.

Smartgrid and Microgrid Expansion Efforts
Panasonic's CityNOW project near DIA will harness the power of smartgrid and microgrid

technology to help deliver a true smart city development. Panasonic is partnering with Xcel Energy and DIA to build a microgrid that will demonstrate the use of solar photovoltaic and lithium ion storage batteries working together. The microgrid will represent the most comprehensive project of this type in the state and the first with actual customer participation in a real-world environment. The City will work with Panasonic to share lessons learned on their deployment efforts while evaluating expansion efforts at strategic locations across the city. We will focus on leveraging smartgrid and microgrid technology to make Denver a national leader in energy efficiency efforts while harnessing the research already underway by a wide range of program partners.

BENEFITS

Vehicle electrification benefits are ripe in multiple market segments, including transit. The City will raise the bar in all sectors through key, focused expansion efforts. We will:

- **Leverage** existing investment in vehicle technology and research opportunities to further implementation in real-world environments while also harnessing Colorado's renewable energy mandate to further incentivize adoption.

- **Advance** market penetration of EVs by increasing the availability, accessibility, and convenience of charging technology.

- **Connect** vehicle manufacturers and drivers to the clean future of EVs.

Wireless is one of several charging options Denver is exploring. Image courtesy of Josh Bauer, NREL.

COMPONENT 3 - INTELLIGENT VEHICLES

Denver, in cooperation with CDOT and industry technology leaders, will leverage ongoing work in CVs to establish the technical, physical, legislative, and social infrastructure necessary for AVs.

PURPOSE

Advancements in telecommunications and sensor technology are transforming travel into a new age of CVs and AVs that can deliver powerful data on the movement of people, goods, and services to City operators and the traveling public. CV technology enables a transportation network to truly operate as an integrated system with V2V, V2I, and vehicle-to-device (V2X) applications. Vehicle automation offers an endless range of benefits such as improving safety with fewer crashes, reducing the costs of travel time and congestion, increasing fuel efficiency, and providing better access to transportation for the young, elderly, and disabled.

According to analysis by RMI, a Denver Smart City partner, the cost of time lost to traffic each year in Denver is nearly $4.5B, impacting both the movement of people and freight through the city. To unleash the true potential of CV and AV, we envision establishing a connected automation environment that systematically aligns the needs of users and businesses with the transportation network for a safer, smarter, more environmentally friendly Denver.

TASKS

Building a Foundation in CV

Denver is partnered with CDOT on a $20M fast-paced enterprise program called RoadX. Under this effort, CDOT has invested $10M on a CV deployment project along the I-70 Mountain Corridor, west of Denver, representing one of the nation's first real-world implementations of CV technology. The City will work closely with CDOT to expand its CV deployment into the urban environment and stands to benefit significantly from CDOT's investments and lessons learned in CV design and implementation. To integrate CV with our current ITS infrastructure, we have engaged our regional partners to update the Regional ITS Architecture to deliver cellular, satellite, and dedicated short range communication (DSRC)-based applications. With two million lineal feet of fiber and an advanced Traffic Management Center (TMC), we are already equipped to support a large scale DSRC infrastructure of roadside units (RSUs) and the backhaul necessary to support connected vehicle applications that improve safety, mobility, and reliability and reduce environmental impact. The City is committed to equipping our own vehicle fleet (e.g., parking enforcement, snow plows, and waste management) with DSRC onboard units (OBUs) to lead by example as we engage private, university, and commercial vehicle fleets and users that can benefit from CV technology.

To improve the movement of people, the City will prioritize safety by focusing on urban safety applications such as Red Light Violation Warning, Reduced Speed/Work Zone Warning, and Spot Weather Impact Warning to provide motorist advisories and warnings throughout the city. As Denver continues to experience record breaking population growth, it is also essential to prioritize mobility on our most congested arterials and city streets, which are the lifeline to regional highways for commuters and freight movement. The City will start by leveraging CDOT's $7M Managed Motorways investment to improve interstate traffic flow with advanced sensors and enhanced ramp metering on I-25, one of the most congested corridors connecting

downtown Denver to its north and south suburbs. The improvements and lessons learned from Managed Motorways will pave the way for deploying advanced CV applications on our City's critical throughways, targeting USDOT developed dynamic mobility application bundles such as INFLO and EnableATIS to deliver speed harmonization and enhanced traveler information. Denver is the northern end of the Ports to Plains corridor: local shipments for businesses in the area depend on the reliability of the local roadway system in Denver. We have partnered with our major suppliers such as FedEx to target viable freight CV applications along key corridors to deliver V2I applications that share real-time road information about congestion, traffic, accidents, or weather conditions and allow truckers to re-route their CV for efficient, reliable delivery.

Launching AV Corridors for Mobility on Demand

AV technology could significantly reduce the costs of congestion by helping commuters recapture productive time with AV-enabled transportation models such as mobility on demand. Income inequality, cost of living, and equity access to all that Denver has to offer are growing concerns as the economy continues to expand and the cost of living increases. AV mobility on demand can also provide improved access to jobs for those who live in low-income and underserved transit areas.

Denver stands to benefit from Centennial's on-demand FMLM pilot. The program provides the opportunity to simulate the business model of enhancing ride sharing with an AV service. Studies have shown the driver is the single largest cost in the mobility on demand equation, and the potential exists for electric AV mobility on demand to cost less than half that of individually owned vehicles. Electric AV mobility on demand can improve reliable access to transportation for low-income, disabled, and elderly people, who spend a significant portion of their income on transportation. Partnering with RTD, the City will identify critical travel routes and corridors where an AV mobility on demand service could enhance FMLM services and transportation access for disadvantaged users.

Transit and City Fleet Vehicle Automation

We will work with technology partners to automate particular features of our transit and fleet vehicles. Automation features will be explored to help introduce improvements in safety and efficiency. Safety features such as the Mobileye Shield+ will help alert RTD bus operators of pedestrians and bicyclists in their blind spots while creating a safer environment for everyone. Lane keeping or platooning applications will improve the efficiency of City fleet vehicle operations such as snow plowing.

BENEFITS

Establishing a Future in Connected Automation

With our EDM platform, we will have laid the groundwork necessary to immediately benefit from the data-rich environment created by the deployment of CV and AV technologies. Our efforts to establish a foundation in connectivity will further advance the role and opportunity for AVs and secure the future of a transportation network driven by connected automation. Our efforts will:

- **Leverage** upcoming projects to build on the lessons learned about new technology, including CV deployment, advanced traffic management, and AV business models.
- **Advance** the movement of people and freight through the city by building a foundation in connectivity and experience with automation.
- **Connect** drivers to a transportation network with a future in connected automation.

CV technology enables drivers to maintain constant communication between other vehicles and infrastructure.

6: RISK IDENTIFICATION AND MITIGATION

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 (PMP) 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 2 - Risk Identification and Mitigation			
Risk Category	**Risk**	**Mitigation Strategy**	**Impact**
Technical	**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
	Prioritizing Smart City solutions	Build a cross-discipline stakeholder group representative of the users of the system	Medium
	Addressing system security and data privacy	Prioritize security and privacy using national and regional standards to guide the design of the EDM platform and ensure all data in and data out of the Smart City system is properly managed	High
	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
Institutional	**Cost overruns/ scope creep**	Develop and implement a meaningful and actionable PMP 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
	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
	Inability to reach agreement among project partners	Reinforce agreements with project partners prior to beginning of Program, and require adherence to the PMP 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

7: GOVERNANCE AND PARTNERSHIP

Denver has a long history when it comes to developing and maintaining partnerships on major projects. In 2004, voters approved RTD's $5B FasTracks program, which is delivering more than 120 miles of new fixed-guideway transit across the Denver metro area. Denver's then-mayor, now Governor John Hickenlooper, led an effort to assure support from all 64 municipalities within the RTD taxing district. This unified front helped FasTracks pass by an 18 percent margin.

The City isn't the only entity on our team with a history of collaboration and partnership. In 2001, CDOT and RTD partnered to reconstruct I-25 between downtown Denver and the Denver Tech Center, and to construct 19 miles of light rail. The Transportation Expansion Project (T-REX) was executed under one design-build contract with CDOT and RTD working together to seamlessly deliver this $1.7B project 22 months ahead of schedule and more than $50M under budget. It is viewed as one of the best examples of intergovernmental cooperation ever undertaken.

CITY ROLE IN GOVERNANCE

The deputy chief of staff for Mayor Hancock and the director of transportation for the City will lead a Denver Smart City Team and an Executive Oversight Committee. The City will lead coordination among all partners (listed in the appendix) with support from agency staff and consultants. Task forces, each including a City representative, will be formed for the Denver Smart City Program and each component.

CITY ROLE IN PARTNERSHIPS

The City will lead the DSC Team and manage all partners involved in implementation. In addition to our four foundational partners, the team includes strategically selected members of government, academia, automakers, energy, policy, technology, safety, telecom, transportation and professional organizations. As the EDM Platform expands over time, additional strategic partnerships will be secured. Our history of regional collaboration and partnership provides a legacy of strong and well-established networks to facilitate Denver's Smart City Program, platform, and components.

DSC TEAM PARTNERS

The DSC Team includes four foundational partners who ensure interagency coordination, technical innovation and user representation essential to all Smart City investments. These partners are:

- Denver
- CDOT
- RTD
- The State of Colorado

Each of the foundational partners brings a wealth of resources to support platform development through research, personnel, and project execution assistance. In addition, based on our "future readiness," Denver has been fortunate to be selected by a number of organizations for strategic investments that will complement and broaden our Smart City Program:

Bloomberg Grant - *What Works Cities* – an initiative to provide technical support, access to expertise, and peer-to-peer learning to cities and their mayors, with the goal of better utilizing data and evidence to engage the public, improve services, evaluate progress, and fund "what works."

Uber/Enterprise Rent-A-Car Pilot - a program to rent cars to potential Uber drivers to facilitate those without acceptable vehicles to work with Uber.

Additional strategic partners, including universities, non-profits, think-tanks and corporations, will provide direct technical expertise, research assistance, infrastructure installation capabilities, project execution, and other benefits directly related to the grant itself. In particular, the DSC Team includes

the Mountain Plains Consortium University Transportation Center, led by North Dakota State University, and the Electric Power Research Institute.
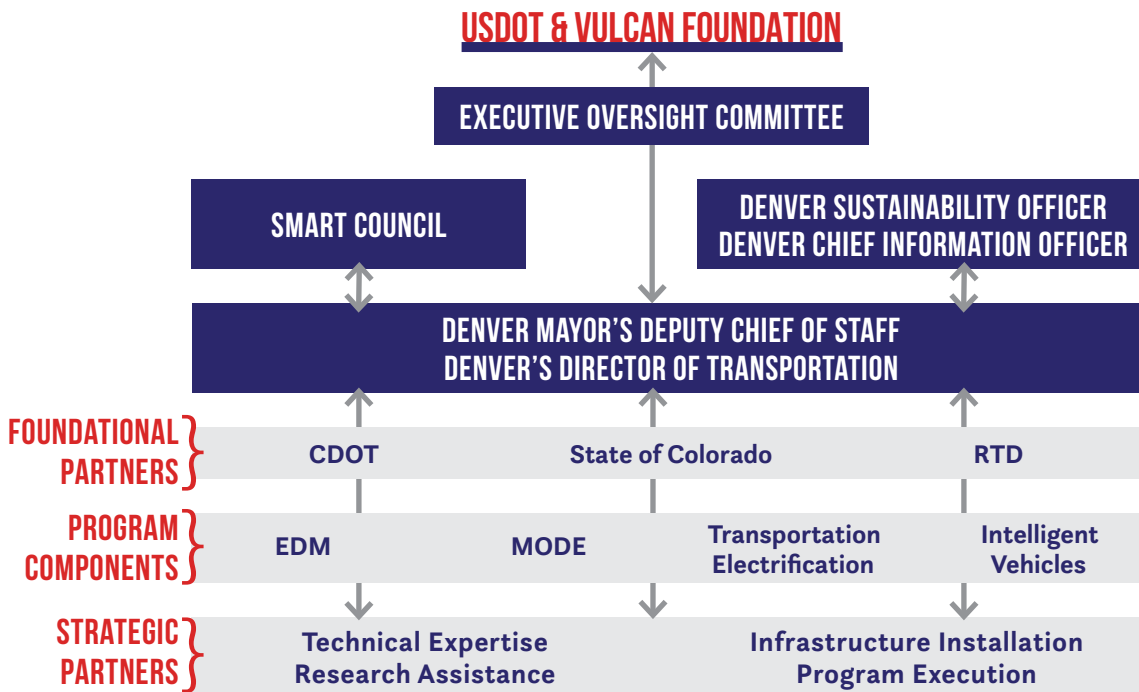
CITY ROLE IN DEVELOPMENT

Denver's sustainability and chief information officers will participate and assist in development of problem statements, solution workshops, creation of scaling models, and protection of proprietary information and confidentiality of project participants.

CITY ROLE IN SMART CITY PROGRAM

Denver will play a pivotal role in execution of the Smart City Program. Responsibilities will include providing access to and the use of City assets and data, determining and providing access to pilot-supported locations, managing conflicts among City entities and project partners, securing strategic partnerships, coordinating interagency participation and communication within the City and the DSC Team, supporting project implementation, and reviewing outcomes.

The City will lead the creation of a "Lessons Learned" Report following completion of the Smart City Program. This report will help other municipalities learn from Denver's experience.

SMART COUNCIL INTERACTION WITH OTHER CHALLENGE FINALISTS

Denver is dedicated to creating a replicable and scalable Smart City Program that can be adopted by other jurisdictions looking to create efficiencies, solve long-standing problems, and improve the lives of their users through technology. If the Smart City Challenge Grant is awarded to Denver, the finalist cities will be invited to join a Supportive Municipalities Advocating for Revolutionary Technology (SMART) Council. This Council will be a place where Denver and the other finalist cities can share ideas and help spread Smart City technology around the nation and the world. We recognize partnering is essential and the Council will bring the best and brightest minds to the table and ensure that the Smart City Program reaps optimal benefits for Denver and other municipal participants.

Our flexible organization and communication framework allows Denver to work seamlessly with foundational and strategic partners, the SMART Council and key Denver Smart City program members.

8: TRANSPORTATION INFRASTRUCTURE

Denver is ready and poised to implement a Smart City Program, including the EDM platform and its three components. As a fast growing city, Denver will maintain its status as the best city to in the west to live in and a magnet for millennials. The following represents existing roadway, ITS, signal systems, transit, rail, and smart grid infrastructure for Denver, RTD, and CDOT.

CITY ROADWAY INFRASTRUCTURE

FREEWAY
41 *miles*

ARTERIAL
320 *miles*

TRANSIT INFRASTRUCTURE

BUS
138 *fixed routes*

45,246,715 *annual fixed route miles*

RAIL LRT & CRT
48 *miles as of 2015*
50 *additional miles to open in 2016*

RTD FasTracks
$ 5 BILLION
voter-approved transit expansion

SHARED USE MOBILITY SERVICES

BIKE SHARE
87 *stations*
74,000+ *members*
OVER 700 BIKES

CAR SHARE
5 *operators*
550+ *permitted vehicles*
18,000 *members*

SMART GRID INFRASTRUCTURE

ELECTRIC VEHICLE CHARGING STATIONS
34 *city-owned*
36 *others available to public*

CITY INTELLIGENT TRANSPORTATION SYSTEMS INFRASTRUCTURE

FIBER OPTIC CABLE
2,000,000 *lineal feet (378 miles), 80% of which is available*

DENVER TMC
48-SCREEN WALL
functions include operating signal system, special events, CCTV cameras, HAR, VMS, and operated 7 days a week (6 am - 7 pm)

COLORADO TMC
STATEWIDE OPERATIONS
operated 24/7, 306 CCTV, 236 VMS

TRAFFIC SIGNALS
1,276 *total* *(1,128 on system)*
52 *equipped with transit signal priority*

CCTV CAMERAS
460 *250 digital 210 analog*

DENVER INFORMATION TECHNOLOGY INFRASTRUCTURE

TransSuite Central Signal System
real time signal control, monitoring, alarms, and logs

SolarWinds
monitors integrity of the fiber network

9: COLLECTION OF DATA

In December 2015, Denver was selected to participate in Bloomberg Philanthropies' What Works Cities, *one of the largest-ever philanthropic efforts to enhance the use of data and evidence in the public sector. As part of the announcement, Denver Mayor Hancock emphasized Denver's commitment to "transforming city government to make data-based decisions," thereby solidifying efforts for data collection and open data sharing started years previously, including involvement in OpenColorado.org.*

OpenColorado's mission is to 1) enable open access to government information and 2) host, organize, and partner with others to educate governments and users on how to create more transparent, participatory, and collaborative communities. Denver shares 193 datasets through its Open Data Catalog program created in partnership with OpenColorado, such as:

- Intelligent traffic system devices
- Parking meters
- Budgets, including detailed information about estimated revenues and expenditures
- Bike rack locations
- Sidewalk conditions
- Traffic signals

In addition to Denver's data collection and sharing efforts, RTD and CDOT also have extensive data collection, data warehousing, analytics, and reporting capabilities, such as:

- Automatic vehicle location
- Automatic passenger counting
- General transit feed specification data (real time data is coming Q1 2016)
- Geographic Information Systems

In 2008, the City embarked on an exciting initiative to understand and address our current and future transportation needs by developing a Strategic Transportation Plan (STP). The STP considers future growth and transportation system demands, and balances these demands with community-identified needs. Within the STP, we identified the seven key challenges for Denver as they relate to the transportation system and reliance on motor vehicles: Urban Sprawl, Traffic Congestion, Number and Length of Automobile Trips, Consumption of Land

for Parking and Roadways, Safety Concerns, Community and Environmental Health Impacts, and Health Issues (including respiratory illnesses, obesity, and mental health).

With these challenges in mind, we established a vision for a safer, more efficient, and more environmentally friendly transportation system in Denver by identifying five primary areas as guidance to the City in the consideration and prioritization of future transportation improvements.

Table 3 on the following page clearly demonstrates that partnerships and collaboration with local and regional stakeholders are central to the data integration opportunities enabled by our Smart City vision. Denver has a long track record of innovative, cross-discipline partnerships that are the driving force behind our continued top rankings in economic and job growth. RTD, CDOT, and DRCOG are key partners for the advancement of Denver's connected city data capabilities. The Smart City Program will reaffirm the open lines of communication that have existed for years between these key agencies. For example, DRCOG's Denver ITS Strategic Plan identified opportunities for CDOT and Denver to coordinate their separate ITS maintenance and construction systems in order to minimize the impact on road and lane closures. It is not always intuitive how a certain roadway is maintained by multiple transportation agencies, and it can be frustrating to users when construction and maintenance information is inconsistent or incomplete. The three agencies work closely to identify the important data sources, harmonize data formats, and establish a connection to share information, resulting in the delivery of more seamless information to users. Smart City concepts will

clearly define data needs and provide added inspiration for breaking down any institutional barriers and for continued collaboration.

We will work closely with our partners to clearly establish the expectations, roles, and responsibilities through data sharing agreements.

Policies and operating procedures resulting from bringing the Smart City vision to life will be documented, maintained, and regularly evaluated to prioritize the security and integrity of the data shared by all partners.

Table 3 - Smart City Data Integration Opportunities		
Denver Smart City Vision Area	**Data Integration Opportunities**	**Data Sources**
A MULTIMODAL Transportation System ■ Safe pedestrian connections ■ Comprehensive bicycle system ■ Dependable transit options ■ Efficient and well-maintained infrastructure	Denver and our partners aim to transform the City into a world leader in demand responsive transit. We already have a wealth of existing data, data collection initiatives, and data sharing efforts will be accelerated through the Smart City Challenge by connecting data from available modes and sharing mode options and real-time data back to users.	■ Denver ped and bike maps ■ Denver B-Cycle ■ RTD AVL & APC Denver ■ Denver Public Works ■ Xerox app GoDenver
A SAFE, EFFICIENT & RELIABLE Transportation System ■ Connected multimodal system ■ Safe transportation network ■ Manage congestion ■ Accessible to all	Denver's TMC gathers local road conditions from sensors and video and uses it for local traffic management. We also share information with the statewide, 24-hour Colorado TMC. Denver will work closely with CDOT to further integrate traffic information, safety analysis of incidents, multimodal information, and deliver this information to users in a safe, useful format.	■ RTD GTFS ■ Denver Safety Analysis ■ Denver TMC data ■ Denver pocketgov data (mobile app) ■ CDOT TMC data
A CONNECTED Transportation System ■ Link land use and transportation ■ Enhance modal connections ■ Offer transportation choices	We envision a connected transportation system that integrates data from all of the services that we offer to our users: transportation, public safety, emergency services, public services, health and human services, environment, and financial. We recognize transportation as the lifeline of our City and want to connect these resources in order to provide the most efficient, useful transportation options possible.	■ Denver Public Works ■ RTD data ■ CDOT TMC data ■ Denver TMC data ■ Denver public safety data ■ Denver emergency services data
A GREEN & SUSTAINABLE Transportation System ■ Limit roadway footprint ■ Align with *Greenprint Denver* ■ Promote alternative public transit modes ■ Improve air and water quality ■ Provide alternatives to fossil fuel	Denver has convened a cross-discipline steering committee including our Department of Environmental Health, Office of Sustainability, Public Works, and Traffic & Parking to identify private and public partners to share data and deliver analytics that directly measure and influence the environmental impact of the City's transportation system.	■ Denver TMC data ■ Denver GIS data ■ Denver air quality data ■ Denver energy use data
A Transportation System that supports a HEALTHY, LIVABLE COMMUNITY ■ Mixed-use streets support great neighborhoods ■ Provide transportation choices that improve community health and well-being ■ Integrate land use and transportation choices	We have established relationships with local businesses, medical centers, and AARP to make more informed planning and transportation decisions for healthy, livable communities. The City has prioritized community well-being and will identify data sharing opportunities with our partners to achieve this vision.	■ Denver GIS data ■ Denver real estate data ■ Denver TMC data ■ Denver public safety data ■ Denver public health data

10: APPROACH TO EXISTING STANDARDS

In 2008, Denver embarked on an exciting initiative to understand and address its current and future transportation needs by developing a Strategic Transportation Plan (STP). The STP considers future growth and transportation system demands, and balances these demands with community-identified needs. The result: a comprehensive approach to investing city resources wisely on the right projects – and the right solutions.

Intelligent Transportation Systems (ITS) consist of the application of all types of technology, sensors, communications, and data management for effectively and efficiently managing the transportation system. From Denver's perspective, Smart City and CV technologies provide an exciting opportunity to revitalize the transportation network with transformative data analytics and powerful applications, and are another form of ITS that should adhere to the national and regional vision for ITS architecture, standards, and certification processes.

Denver named its 2008 STP *Moving People* in coordination with important planning efforts in the region. In 2007, Denver participated in the DRCOG and CDOT effort to develop a Regional ITS Architecture for the Denver Regional 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 regulations. Denver is home to the largest local Transportation Management Center (TMC) in the metro area. It shares information via physical fiber optic connection with the statewide, 24-hour Colorado TMC – making Denver a key adopter of the Architecture for the successful implementation and management of ITS assets in the region.

As a regional stakeholder, Denver has engaged DRCOG and CDOT to adopt the Regional ITS Architecture and track the status of existing standards as it moves forward with the deployment of Smart City, connected vehicle, and ITS applications. The ITS Architecture for the Denver regional area consists of two items:

- **Turbo Architecture Database version 4.0:** The Turbo Architecture database is the key element describing the ITS architecture.

- **ITS Architecture Document:** The document entitled *ITS Architecture for the Denver Regional Area* (November 2007) reflects the information contained in Turbo Architecture Database version 4.0 in a more user-friendly format.

Denver will work closely with DRCOG and CDOT to evaluate the feasibility and suitability of adopting available standards as they relate to the regional architecture. This is the initial step in an on-going process to identify and adopt National ITS Standards and CDOT Regional ITS Standards. The Architecture document describes the processes and procedures for maintaining the Architecture for the Denver regional area, which will require updates as ITS projects are implemented and regional needs and priorities change.

In this same vein, we understand that we are targeting innovative and transformational concepts that are not currently defined or proposed in the existing Architecture. The Smart City initiative provides an exciting opportunity for our City to serve as a leader in working closely with DRCOG and CDOT to expand the Architecture and establish the framework for Smart City and connected vehicle concepts to be implemented across the Denver regional area, positioning the entire region as an agent of change and benchmark for the nation. A Denver-led update to the Architecture will be jumpstarted by leveraging the available architecture and standards work completed by the USDOT for connected vehicle concepts. The USDOT's Connected Vehicle Reference Implementation Architecture (CVRIA) provides the physical, functional, communications, and enterprise architecture viewpoints as guidance for implementing connected vehicle applications. More importantly, the CVRIA was built to

ensure connected vehicle deployments fit into the greater National ITS Architecture, enabling a standards-based implementation that will ensure the new system can be seamlessly integrated into existing transportation management and ITS systems for the region.

Where architecture and standards gaps exist for Smart City or connected vehicle concepts, Denver will engage and coordinate with national standards stakeholders such as Institute of Electrical and Electronics Engineers (IEEE),

Society of Automotive Engineers (SAE), National Transportation Communications for ITS Protocol (NTCIP), and/or American National Standards Institute (ANSI) to be sure future deployments benefit from the experiences and lessons learned of the Denver implementation. The image below showcases how Denver will approach and coordinate the use of and updates to architectures and standards throughout the Smart City deployment.
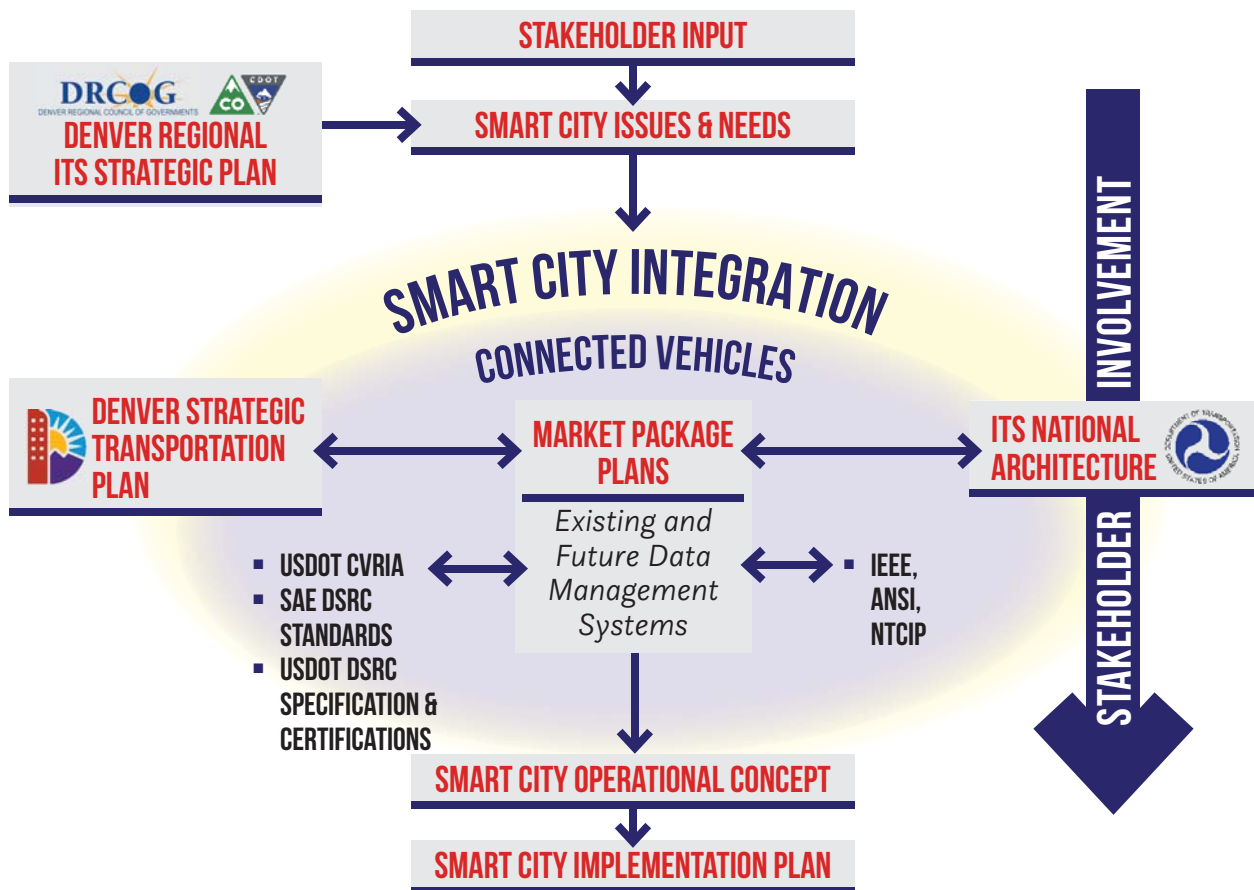
Denver will integrate its Smart City Program into the existing regional ITS Architecture process, utilize existing USDOT and SAE standards, and engage the appropriate stakeholders for new Smart City concepts.

11: MEASURABLE GOALS AND OBJECTIVES

Our measurable goals and objectives for this ambitious program are far-reaching, impactful, and scalable to other cities across the U.S. Denver's Smart City Program will allow us to meet the USDOT goals of mobility, safety, efficiency, sustainability, and climate change.

SMART CITY GOALS

Ensure that Denver's transportation system accommodates the mobility needs of all users. Denver's Smart City EDM platform and all three components outlined in Section 5 reinforce our commitment to the mobility needs of all users. We are creating this Smart City Program in such a way that it can be adopted in other cities across the U.S.

Make all Denver Smart City data public and machine-readable. We believe in providing data that is public and machine-readable, enabling the public to easily consume the data and aid in civic innovation. Denver's Smart City EDM platform will achieve this goal.

Improve Denver Smart City data analytics capabilities for major mobility systems. Denver's EDM Platform integrates the data with user-generated information to comprehensively and continually assess Denver's transportation environment and specific urban mobility challenges.

Create a regulatory/policy environment that enables the successful introduction of Automated Vehicles to Denver streets. A key area of focus for Denver is to ensure that the barriers for AVs are being removed appropriately so that we can bring them to Denver.

Improve infrastructure and mobility service options. Denver's MODE platform will promote efficient, dependable transportation for people and property throughout the city. MODE can also be mobilized to other cities across the U.S.

Support the expansion of Electric Vehicles. As described in Section 5, Component 2, Denver supports the expansion of EVs, and is committed to expanding the required infrastructure for this to become a reality.

SMART CITY OBJECTIVES

USDOT's grant will help Denver advance Smart City data by:
- Increasing transportation-related open data sets
- Producing real-time transportation open data sets available to the public by 2018, aligning with the USDOT's grant timing
- Creating public-private-partnerships around data sharing, and integrating crowd-sourced data into both the open data catalog and privately created apps
- Reducing data integrity issues and increasing public utilization of transportation-related data

Mobility Objectives *(Section 5, Component 1)*:
- Achieve a combined 15 percent walk/bike commute mode share by 2020
- Pursue Platinum Status as a Pedestrian Friendly City (Walk Friendly Communities)
- Achieve Gold status as a bicycle friendly community (League of American Bicyclists)
- Ensure every household is within a quarter mile of a high ease-of-use bicycle facility, such as a protected bike lane
- Implement 15 additional miles of bicycle lanes and/or sharrows per year
- Reduce single occupancy vehicle commutes to less than 60% mode-share by 2020

SMART CITY OBJECTIVES

Automated Vehicle Objectives (Section 5, Component 3):
- Create legislative and policy environment that invites AV operations in the state
- Enhance existing infrastructure to support AV operations
- Work with automaker and technology partners to place an AV fleet in the City by 2020
- Increase education and public awareness of AVs

Electrification Objectives (Section 5, Component 2):
- 10x increase in EV miles traveled (taxi electrification, consumer adoption, city fleet, RTD) by 2020
- 10x increase in capacity of charge infrastructure and 5x increase in # of stations by 2020
- 20 percent of municipal fleet vehicles operated by the City will be electric by 2025
- Increase virtual and physical visibility of charge infrastructure and availability by 2020

Safety Objectives (All Components):
- Launch comprehensive Vision Zero program in 2016 to significantly reduce and ultimately eliminate vehicle related crashes, injuries, and fatalities.

Sustainability Objectives (All Components):
Denver has an existing set of sustainability goals that the City is working to achieve by 2020; several of these tie directly into our Smart City Program and are aligned with USDOT's 12 Vision Elements:

- **Air Quality:** Attain all National Ambient Air Quality Standards
- **Climate:** Reduce greenhouse gas emissions 80 percent below 2005 levels by 2050
- **Energy:** Hold energy use below 2012 levels, while cutting fossil fuel use 50 percent
- **Land Use:** Move Denver's Walk Friendly rating from Gold to Platinum
- **Mobility:** Reduce trips in single-occupant vehicles to less than 60 percent of commuting trips

MONITORING OF PROGRESS

Our team will monitor progress toward each initiative and their combined impact on mobility, safety, efficiency, sustainability, and climate change by collecting clean, accurate, machine-readable data on the objective metrics listed above. Data will be made publicly available in the City's open data catalog as well as on a tracking dashboard, which will visualize progress toward the defined targets. Through regular meetings, agency and organization leaders will review these data and progress towards goals.

We have relationships with multiple outside auditing and evaluation firms who can validate performance data, evaluate goals, processes, and outcomes, and provide recommendations for program improvements. City departments and leaders are used to working with outside evaluators and will provide these consultants with access to sites, staff, and data systems.

12: EVIDENCE OF CAPACITY

Multiple agencies across a wide range of specialties have successfully leveraged federal resources throughout the City, ranging from highway and transit construction to renewable energy and multimodal transit. Residents and public officials in Denver have long supported significant civic investments that make Denver the world-class city it is today. From outstanding parks and recreation system to our myriad cultural facilities, each generation continues to contribute to this investment.

CITY OF DENVER

Currently, Denver invests over $150M annually on capital improvements, including critical maintenance and rehabilitation projects, high priority capital investments, and leveraging state and federal dollars.

In November 2007, the residents of Denver passed eight ballot measures to develop new or improve existing infrastructure and facilities. These measures addressed major street and transportation improvements, health and human services, safety, and cultural facilities, libraries, and parks. The program included over 380 projects, with a budget of $575M that was leveraged to over $700M by public and private

THE CITY

OVER 300 BUILDINGS
including Denver libraries, recreation centers, maintenance facilities, and other state-of-the-art facilities

584 BRIDGES

OVER 1,900
centerline miles of paved streets

OVER 2,000 MILES
of storm drainage and sanitary sewer lines

240 URBAN PARKS
totaling more than **4,000 ACRES**

OVER 14,000 ACRES
of mountain parks

contributions. $200M was dedicated to major transportation projects.

CDOT

CDOT has a long record of successfully securing and completing federal grants and is in good standing with the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA). CDOT has received Transportation Investment Generating Economic Recovery (TIGER) funds for a variety of projects including the US 36 Managed Lanes Project – for which CDOT was able to leverage a $10M TIGER grant into a $497M project.

CDOT worked with Congress on language in the FAST Act to make V2I communication equipment an eligible expenditure, and worked to provide grants to develop model deployment sites for large scale installation and operation of advanced transportation technologies.

RTD

With a staff of more than 2,600 and an annual budget exceeding $460M, RTD transported a record 104 million riders in 2014. RTD is a direct recipient of 5307 Formula Funds, and more than $400M in federal grants ranging from New Starts, TIGER, Bus & Bus Facilities, and Transit Infrastructure Finance and Innovation Act (TIFIA) funding programs.

DIA

DIA averages receipt of approximately $20 million annually in FAA Airport Improvement Program (AIP) grants to fund runway and taxiway rehabilitation, airfield lighting, aircraft rescue and firefighting vehicles, and expenditures to enhance the overall safety of the airfield.

13: LEVERAGING FEDERAL RESOURCES

Grants Awarded - Denver Public Works has received nearly $90M in grant funding over the last three years, nearly half of which came from the federal government. The other half was split among DRCOG, CDOT, RTD, and other sources.

FASTER PROGRAM

The Colorado State Legislature passed the Funding Advancements for Surface Transportation and Economic Recovery (FASTER) Act in 2009. FASTER generates about $200M 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 FASTER funding ever more important in coming years.

FASTRACKS

In 2004, metro Denver voters approved RTD's FasTracks program, at a cost of $5B, 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 $1.5B 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 (DBFOM) contract. The three corridors will open for revenue service in 2016.

CDOT ROADX

CDOT created its Transportation Systems Management and Operations (TSM&O) 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 TSM&O'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 $20M in funding in 2016 to obtain congestion relief and safety improvements through the deployment of technology to kick-start RoadX. CDOT is currently adjusting its policies so funding categories further align with the integration of technology in transportation and mobility.

PANASONIC

Panasonic is partnering with Denver and a number of local private entities to enhance community engagement, energy efficiency, water conservation, public safety, healthcare, and other public services. Panasonic's application of smart technologies to the city's infrastructure, including in and around DIA, is expected to provide people effortless access to information about services, including utilities and mass transit. In addition, this responsive infrastructure will transform smart urban infrastructure like street lighting and energy systems to dynamically sense and respond to the presence of people and deliver services as needed.

XEROX

Denver is one of two pilot cities for Xerox's mobility marketplace app, Go Denver, which enables all mobility participants to share information and find matches between mobility supply and demand.