



# INDIANAPOLIS SMART CORRIDORS

## Inclusive, Connected, Resilient

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*DTFH6116RA00002 Beyond Traffic: The Smart City Challenge*



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# DOT Smart Cities Challenge

## 1.0 Vision Overview

Indianapolis' (Indy's) vision for Smart Cities is to support a connected, healthy, resilient, inclusive, and competitive city. Technology provides a platform where we can realize this vision. By balancing innovation with stewardship, Indy's vision will achieve the best individual mobility for residents both economically and in terms of transportation. Connecting our systems of transportation, communications, emergency services, and data will enable the city to maximize resources, make smarter investments, and attract talent.

Indy has long been at the forefront of transportation innovation. We built the first union railroad station in the nation. The Indy 500, which celebrates 100th running this year, was started as a testing ground for automotive innovation, with technologies like front wheel drive, seat belts, and alternative fuel research coming out of the race. Its founder, Carl Fisher, conceived of the Lincoln Highway, one of the earliest transcontinental highways built in the nation. Highways have always been important, with Indy having been the intersection of the National Road and the Dixie Highway, and today being connected by more interstate highways than any other city in the nation. More recently, Indy set the bar for urban trails with our Indianapolis Cultural Trail, an 8-mile bicycle and pedestrian network downtown lined with public art, streetscaping, and linking our cultural districts, destinations, and regional trails. We also set the bar for modern airports, building the only new airport since 9/11 to continued acclaim. The city is putting the finishing touches on its RebuildIndy program, a \$500 million infrastructure investment initiative that repaved streets, added bike lanes and greenway trails, and rebuilt bridges. Through a public-private partnership, North America's largest all-electric car share program, Bluelndy, is open and expanding. And soon Indy will build America's first electric bus-rapid transit (e-BRT). Time and time again, Indy has been at the forefront of transportation innovation and the management of significant public infrastructure investments, and with the help of Smart Cities, we'll deliver again.

Technology has revolutionized the way we travel and manage city infrastructure. From the advent of vehicle-detecting traffic signals to real-time crowd-sourced GPS systems innovations have enhanced user experience and improved system efficiency. Private sector innovation will bring automated vehicles to our streets in a matter of years. We must bring this same level of innovation to the public sector—into the way our infrastructure is built, programmed, and connected, into the way our systems work together to promote mobility and system efficiency, into the way our users access and pay for the network, and into the way we make investments for the long term that are data-driven yet flexible. Indianapolis will take advantage of these opportunities through a Smart Corridor model built around personalized mobility using new technologies to expand consumer options, build safer and engaged communities, and spark new solutions while maximizing system capacity.

This strategy includes:

- Automation of bus rapid transit (BRT) & car share routes
- Dynamic pricing & Transportation Savings Accounts
- Personalized mobility app/interface
- Intelligent infrastructure & Intelligent Traffic Systems (ITS)
- Real-time data & dynamic modeling to manage travel demand

The Smart Corridor model will use pilot corridors, including the planned electric-bus rapid transit network, downtown arterial grid, and major commuting arterial streets as sites for

integrated transportation technologies. The base of this system requires the installation and support of Information and Communications Technologies (ICT) and dynamic analytics using a cloud-based platform available in real-time. This model will provide a feedback loop, where real-time traffic information motivates transportation choice, maximizes the capacity of our existing infrastructure, and helps government and community leaders plan for and evaluate transportation investments.

The Smart Corridor objectives are to reduce congestion, improve air quality and safety, and enhance mobility through:

1. System optimization: Using connected signs, signals and raised pavement LED/light markers (similar to INROADS) and monitors, operators will be able to remotely program infrastructure to accommodate congestion, manage emergencies, and redirect overflow traffic to priority corridors.
2. Improved safety and on-time performance: Installing the infrastructure for users to predict and avoid crashes, support connected and autonomous vehicles and eBRT lines will provide a more predictable, smooth, and safe user experience.
3. Improve resident safety and mobility: A user interface will integrate real-time data on all modes and payment platforms, provide live routing based on congestion, allow live reporting, enhance trip chaining, and encourage mode shift through economic incentives.
4. Dynamic pricing: Building a base audience and capital reserve through major employers, Indy will provide transportation savings accounts to app users accessible through the Internet to implement congestion pricing incentivizing transit, biking, and walking based on real-time traffic flow information made possible through cloud computing.

### **1.1 Element 1: Commercial Integration of Autonomous and Connected Vehicle Technology**

Indianapolis is unique as the only city in the United States that stands ready to automate transportation systems in a clean and sustainable approach. Indianapolis offers and is developing an electric transportation system including Bluelndy, an all-electric car-share service, and the eBRT “Red-Line.” Combined, these systems are the result of more than \$100 million invested in their initial phases. Electrifying the city’s vehicle fleet alone has saved over 42,000 gallons of gas and will contribute to Indy’s goal of becoming a resilient city by reducing oil demand and emissions through congestion reduction, vehicle efficiency, and managing electric demand. Urban automation requires a variety of testing environments which are captured by the following sub-projects and as defined by the National Highway Traffic Safety Administration (NHTSA) levels of automation:

#### **Sub-project #1: Automation of Red-Line eBRT system**

Set for early 2017, the nation’s first all-electric BRT (eBRT) Red Line is an ideal platform to model automation for public transit. The Indianapolis Smart City initiative would identify and finance the support and infrastructure needed to implement and operate a fully automated and electric Red Line. Advantages to automating all-electric BRT:

1. Buses will operate in a dedicated lane (lane divider lines or physical barriers)
2. The Smart Corridor will include sophisticated ITS which could be leveraged for V2I communication that will improve autonomous technology performance
3. Provide smoother ride for users that is competitive with light rail systems
4. Improve safety along an active, dense, multi-modal corridor

#### **Sub-project #2: Automation of Bluelndy route from the Airport to Downtown**

The second sub-project would be automating a high frequency route of the Bluelndy electric car sharing service from the airport to a set station in Indianapolis’ downtown central

business district. The vision is to automate a set number of BlueIndy cars to at least NHTSA Level 3 which would allow drivers to experience a high level of autonomous driving while they travel from the airport to downtown.

The initial BlueIndy autonomous drive cycle will include a mix of highway and urban roads that will showcase the various benefits of autonomous technology like lane change control at high speeds, as well as self-parking and speed control in dense urban areas.

Advantages to automating all electric car sharing (BlueIndy):

- BlueIndy cars operate in a nodal network on largely set routes (station to station)
- Seamless technology integration: cars are connected and equipped with GPS and advanced wireless telematics that allows vehicles to be remotely monitored
- The vehicles, charging stations, rental kiosks, telematics systems, and even insurance are all in place and owned and operated by Bolloré Group so there will be fewer technology integration and legal liability challenges. The Bolloré Group has been a very cooperative automotive OEM for the city of Indianapolis.

### **Sub-project #3: Airport Shuttle Automation**

The Airport Shuttle Automation project would be focused on an immediate implementation of a NHTSA Level 4 automation commercial project established and set up in a controlled, protected, and safe commercial environment. The goal of this project would be to implement a fully autonomous shuttle system using electric buses in a closed loop environment. The Indianapolis International Airport currently uses fossil fuel-powered buses to move travelers between the airport to the remote parking lots, as well as the many shipping and distribution centers surrounding the airport. The parking shuttles operate in fixed routes through the parking lots while the shipping companies like FedEx, which has its second largest U.S. hub in Indianapolis, move goods between the airport and its distribution centers.

### **Sub-project #4: BlueIndy Vehicle-to-Grid (V2G)**

Plans for implementing V2G are part of the BlueIndy contract with the city of Indianapolis and the telematics and data collection necessary for V2G are already in place. This required plan will allow us to use Smart Corridors to eventually deploy a smart grid infrastructure that integrates ICT information with the grid to sense and intelligently act on real-time energy flow information. Leveraging this study would lay the groundwork for launching the BlueIndy system into the portfolio of assets for Indianapolis Power & Light (IPL)/AES supply and demand management activities, as well as peak loading conditions.

To expand on the Grid Frequency Regulation (GFR)/V2G project concepts in Indianapolis, the BlueIndy car share system provides ideal conditions for implementing a GFR and V2G systems. The 500 electric car share vehicles in the BlueIndy system total a potential of 15 megawatt hours of storage capacity. A percentage of this energy storage (i.e., 50 percent, 80 percent, etc.) can provide a high level of readiness for bidirectional flow of energy to the electrical grid. Private electric vehicle users of the V2G technology would be able to receive credits to their Transportation Savings Account through the App described in Element 4.

### **Implementation and Operation**

On the Red Line project, moving from NHTSA Level 1 to NHTSA Level 4 automation will need to be phased in order to ensure safety, reduce financial risk, and optimize service delivery. In order to meet the automation goals of the Red Line, technology deployment for full automation will be phased to meet the standards of the USDOT, IndyGo, and technology partners.

One drawback to BRT is the ease with which level boarding can be implemented. The proposed guidance technology in the first phase of this project will improve service delivery. An example of this technology was recently tested on the EmX BRT system in Eugene, Oregon.

### Transportation Challenge Addressed

Automation could directly address the recent DOT estimates in combined cost of over \$1 trillion per year lost through automotive vehicle crashes (\$836 billion per year), urban congestion (\$121 billion), wasted fuel (2.9 billion gallons – cost and GHGs), and time (5.5 billion hours traffic delay per year)<sup>1</sup>. The city's investments have already saved 377 MCO2 and BlueIndy's fleet logged 7,000 trips. If V2G electric car users could take advantage of dynamic pricing and save money, electric vehicle use could grow exponentially. These incentives could make car ownership possible for residents who previously could not afford it.

Innovations in engineering, ITS, and automobile design have continued to reduce severe injury and fatality crashes across the nation. Despite these controls, vehicles continue to be the leading cause of death for our young people ages 11 and 16-24<sup>2</sup>. In Indianapolis, the situation for pedestrians is especially dire; recently identified as a FHWA Focus City due to disproportionately high rate of bicycle and pedestrian fatalities, the number of pedestrian fatalities rose significantly from 2014 to 2015.

#### Indianapolis Pedestrian Crash Statistics<sup>3</sup>

	Total Injuries	Total Fatalities	Crashes	Property Damage
2010	<b>7,006</b>	<b>74</b>	<b>27,577</b>	<b>22,342</b>
2011	<b>6,804</b>	<b>85</b>	<b>27,459</b>	<b>22,378</b>
2012	<b>7,518</b>	<b>80</b>	<b>29,021</b>	<b>23,423</b>
2013	<b>7,039</b>	<b>81</b>	<b>28,749</b>	<b>23,445</b>
2014	<b>7,598</b>	<b>81</b>	<b>30,415</b>	<b>24,865</b>
2015	<b>8,185</b>	<b>89</b>	<b>34,216</b>	<b>28,122</b>

The proposed Smart Corridors are among the largest, most travelled, or highest crash corridors for all users where everyone could most benefit from improved safety through automatic braking and other connected vehicle technologies, potentially reducing crashes by 81 percent<sup>4</sup>. A Smart Corridor where users, vehicles, and infrastructure interface to warn users or respond

to movement will be added to Indy's arsenal of traditional safety measures like improved sidewalk infrastructure, lowering design speed, and installing crosswalks and pedestrian cues.

### 1.2 Element 2: ITS Architecture and Real-Time Data Integration

The exponential growth of on demand mobility options like Uber and Lyft have revolutionized not only how people travel, but how they access, plan, and pay for transportation. The idea of transportation as solely brick and mortar is dissolving and users and operators depend on our invisible infrastructure for their daily travel needs. ITS is the foundation of Smart Corridors that optimize personal mobility and engage residents while maximizing overall person throughput.

The system would create a “live” transportation model for managing travel demand that utilizes user data and intelligent infrastructure. The feedback loop from user data and intelligent infrastructure would allow operators to remotely control traffic operations using ITS technologies like signal timing, LED lane striping, and signs.

<sup>1</sup> USDOT Smart Cities Challenge Forum, Afternoon Breakout Group, 15 December 2015.

<sup>2</sup> Centers for Disease Control and Prevention, Leading Cause of Death and NHTSA, Quick Facts 2014

<sup>3</sup> Aries Portal, 2015, <https://www.ariesportal.com/VCRS/SearchWizard.aspx?Refresh=1>

<sup>4</sup> USDOT, Beyond Traffic: Trends and Choices 2045, 2014.

Operators could remotely control traffic operations and dynamic pricing using ITS technology like signal timing, LED lane striping, signs, and the mobile application. Indianapolis' Smart Corridors differ because they can serve as testing grounds for new ITS equipment and to establish best practices for pairing existing infrastructure and technologies.

### **Implementation and Operation**

There are a variety of investments needed to integrate advanced ITS and big data into real-time traffic management using a cloud computing system:

Smart Corridor ITS Objectives	Technology Solution
Establish common, open source data operating & visualization platform	Integrated sensors, processors, and wireless transmitters for data capture, existing conditions, etc.
Integrate data from all partners and infrastructure	Wireless transmission media (e.g. DSRC)
Make travel, city info available to public	Public Wi-Fi access along corridors
Optimize traffic flow using cloud connected sensor and feedback loop	Centralize system monitoring into a Transportation Management Center; Dynamic lanes allow bi-directional traffic on one-way streets; Integrated signal timing; Dynamic signage; sensor based lighting

The Smart Corridors will require a sophisticated ICT platform and significant investment in ITS hardware. This pilot will upgrade Indianapolis' 20th century ITS infrastructure and require a transportation management center (TMC) and staff capable of achieving the desired data and operating system integration. The TMC will connect INDOT's TMC and local emergency service and operations providers. Congestion management will initially require an excellent timing schedule based on established traffic patterns accounting for time of day and eventually integrate real-time information into the traffic management center. Using these base models, the connected infrastructure will learn how to autonomously adapt to traffic movement.

Smart Corridors will require monitoring and sophisticated data management and storage systems. Currently, traffic monitoring and remote programming is limited on the local network. Indiana Department of Transportation (INDOT) operates a human-in-loop system that allows real-time response and will be an excellent example and resource.

### **Transportation Challenge Addressed**

While the growth of traffic congestion continues to be a major concern for freight and passenger transportation nationally, it is not the primary challenge in central Indiana. In fact, in 2014 the TomTom Traffic Index ranked Indianapolis the 50th most congested city in America, behind many of its peer cities including Columbus, Ohio; Minneapolis, Minn.; Denver, Colo.; and Nashville, Tenn.

With a congestion level at 13 percent, Indianapolis does stand out from many of its peers in an important way: the majority of our congestion is disproportionately experienced on local roads (23 percent) versus highways (5 percent)<sup>5</sup>. While nationally vehicle miles traveled (VMT) on local roads is outpacing freeway travel which has been declining since 2010<sup>6</sup>, in Indianapolis, significant congestion occurs on the local system because we are an “event” town. From the Super Bowl to the NCAA Basketball tournament, regional and national conferences, Indiana Black Expo, and other events we welcome an estimated 26 million visitors annually<sup>7</sup>. Moving large amounts of people in and out of the downtown is important from a security, economic, and user perspective.

However, transportation management approaches remain lacking; strategies during these events range from additional police to roadway closures. Off-ramp and state road signal timing is on a time of day control coordinated with Indy’s Department of Public Works (DPW) and INDOT (who owns and maintains it) to manage events and rush hour traffic. Real-time ITS coordination is limited; by summer 2016 only 230 of Indy’s 1,200 traffic signals will be connected by fiber optics. These strategies are no longer possible as downtown Indianapolis is evolving from an event location or evening destination to a neighborhood. Since 2008, over 5,400 residential units have been completed, with a total investment of about \$793 million in the city<sup>7</sup>. Big data and ITS offer a promising solution to managing congestion, improving air quality, and improving safety. Origin destination information from the user application could predict travel behaviors and adjust pricing accordingly and real-time data collections will provide information for operators, planners, and the public. As pressure on the local system grows, the capital for maintenance, operations, and construction have remained level or declined. Real-time data and pricing could provide a new direction in the financing, planning, and construction of transportation investments.

Smart Corridors will help Indy’s “inclusive” goal by building regional assets for residents. By providing free public Wi-Fi along these corridors, including the BRT network, residents will be able to connect to more resources. The recently completed Alternatives Analysis report for the Red Line corridor notes that within a walking distance of the stations, there were 9,200 low-income households, 3,300 of which did not own an automobile. Over 1,000 Section 8 units and two major public housing complexes are also within this walking threshold. This project will connect these residents and more to information, technology, and mobility choices.

### **1.3 Element 3: User Portal/Mobile Application**

Development in Indy favors automobile use; 91.6 percent of people drive to work with 81.8 percent of them driving alone.<sup>8</sup> To decrease VMT, emissions, and improve health outcomes, we need to increase multi-modal options and their density. Making these options accessible and seamless is a key strategy for realizing mode shift and helps Indy meet its goals of a connected, healthy, and inclusive city. The user interface will allow users to safely access transportation and connect to the city. We envision an on-demand mobility service that enhances personal mobility by integrating all available travel options under a united payment platform.

<sup>5</sup> (TomTom International BV, [http://www.tomtom.com/en\\_us/trafficindex/#/list](http://www.tomtom.com/en_us/trafficindex/#/list)).

<sup>6</sup> Texas Transportation Institute, 2015 Urban Mobility Scorecard

<sup>7</sup> Visit Indy, <http://www.visitindy.com>

<sup>8</sup> U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates



Smart Corridor App Mock-up showing various options for the user to choose with other user preferences and incentives from multi-modal platforms.

The application will reduce congestion by providing economic incentives to providers and users through a Transportation Savings Account, similar to health savings account with employer or enrollee contributions. Users traveling from point A-B will be able to see real-time traffic and incidents, mode choices, etc. while receiving offers to take an alternate modes or routes to relieve congestion on the overall system. Key functions of the application include:

- Integrated mode choice and trip chaining capability
- Unified payment platform and cell-phone enabled payment
- User reporting/crowdsourced data capture
- Dynamic pricing captured through a Transportation Savings Account
- Dynamic routing and real-time availability

### **Implementation and Operation**

Multiple technology platforms are expanding into mobility app space like RideScout and Metropias. Our research partner, from Human Centered Computing in the IU School of Informatics and Computing will lead the user experience and user interface elements for the Smart Corridor. The Smart Corridor app may include modifications to existing platforms or the development of a new open source model that can be maintained and improved by the private sector. Important to the features and functionality of the app is tailoring the data collection and processing to inform transportation security, planning, and operations.

Allowing users and operators to view real-time data and engage will create the synergy needed for innovative transportation management. Other features could include community information for current locations like median housing costs, schools, etc. – advertising opportunities could be a substantial part of the financial sustainability for app maintenance.

### **Transportation Challenge Addressed**

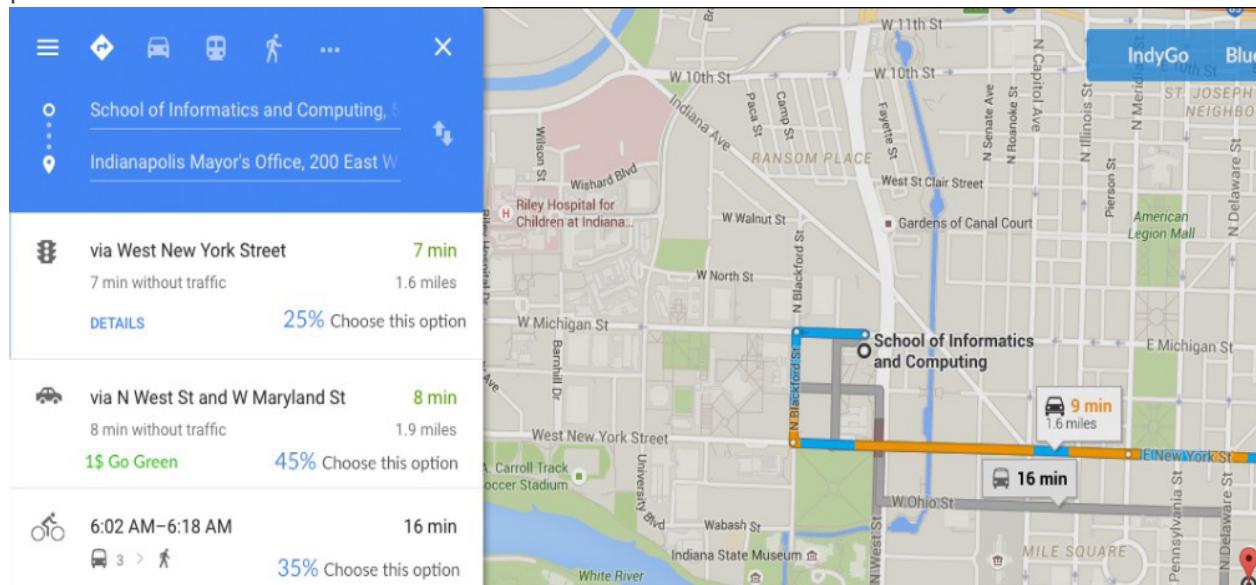
Smart cities mean connected, engaged citizens. While transportation choices and operators are quickly multiplying, public awareness and access to these options can be invisible. People are unable to evaluate the competitiveness of each mode and make choices based on what is best for their overall needs. The Smart Corridor app makes mobility seamless, accessible, and offers incentives for those who live car-free or are transit dependent helping Indy become more inclusive. The platform allows user reported safety concerns to inform investments and improve response times. This information will be integrated into our asset management program and help prioritize investments. By engaging and connecting our residents around the infrastructure that supports them, we improve mobility for everyone. The app catalyzes the growth of ride-sharing or car-lite options and will improving air quality by reducing emissions for the region.

#### 1.4 Element 4: Live Modeling Traffic Modeling and Dynamic Trip Pricing

Dynamic pricing is a method to allow market forces to respond to peaks and valleys in supply or demand for a product or service. Each industry takes a slightly different approach to repricing based on its needs and the demand for the product. Similar to the Octopus model in Hong Kong, Indianapolis will use dynamic pricing across the transportation sector to reduce congestion and more efficiently use our transportation system. The user app will connect to a transportation savings account (TSA) that provides economic incentives for trips that lower emissions like ride-sharing, electric vehicles, or bicycling. Since transportation demand exceeds funding and without a system of toll collection, we have little opportunity to directly use dynamic pricing in the traditional sense. Therefore, we propose to focus on two proxies through the user app – transit and parking – which will be expanded to include all modes after initial deployment.

Dynamic pricing in parking has recently made waves based on pioneering work on on-street parking by Donald Shoup. Indianapolis proposes to employ this model of dynamic pricing across the downtown area for both the on-street parking as well as the privately owned parking garages. The goal is to manage demand on our roadways. The partnership with private garages will allow parking costs across all of downtown to fluctuate with time into and out of the garage, encouraging drivers to travel at non-peak hours whenever possible. In the larger context of an entire transportation system, transit is better equipped to handle large spikes in demand than most other modes of transport, and cities should encourage as much travel as possible be made by transit during peak hours. Therefore, Indianapolis is proposing to incentivize transit travel during those peak periods by *lowering* the cost of the fare. For example, a regular bus fare may be \$1.75 each way, but if a rider boards during the peak time frame, the fare is only \$0.75. Users will be incentivized to use different modes by providing discounted rates.

In the future this pricing model could track the “true” costs or estimates of infrastructure to users using data analytics from multiple agencies to aid in data-driven decision making. When planning or evaluating projects, the city could evaluate this use and cost data to help prioritize investments.



This mock-up highlights the menu on the left and color coded real-time traffic scenario. The same image can show bike routes, Bluelndy car parking/charging stations, etc.

## Synergies Lead to Data-driven Decision-making and Smart Investments

The Smart Corridor user application would incentivize routing based on mode and provide a captive audience or optimal modal mix for new technologies. Can vehicle throughput be maximized if all variables are controlled (signals, flow, etc.)? Is separated bicycle infrastructure alone the best investment for reducing bicycle crashes or does connected vehicle technology (V2I) need to be installed to maximize its benefits? In a corridor with real time information on personal experience (dynamic pricing, happiness based on social media/user experience survey, travel time); existing conditions (traffic, travel demand behaviors, crash information); infrastructure costs/impact (budget expenditure, infrastructure life cycle maintenance and operations costs), environmental impact (air quality, emissions, and infrastructure wear), how will the public choose how to travel?

## Implementation and Operation

Clearly, this transit incentive program would result in lost revenue for the transit agency. However, the pairing of the parking and transit programs would allow the additional fees collected for peak hour parking to be used to offset the lost revenue to the transit agency, making the overall program sustainable. This program would require a significant investment in sensors to monitor real-time demand, communications systems to notify drivers and users of changing costs, and sophisticated fare collection systems for both parking garages and the transit fleet. This Smart Cities grant would be used to build out that infrastructure necessary to implement the plan.

We will develop the dynamic pricing model using regression analysis as such a model can establish relationship between predictors such as distance, traffic patterns, and predicting the response variable, the average fare at a given time. One possible approach would be to use multiple linear regression model,  $y=b_0+b_1x+\dots+b_nx^n+i$ , where  $y$  is the predicted fare at a given time;  $b_0$  is the base fare; and  $b_1$  through  $b_n$  represent coefficients of predictor variables that are chosen such as distance, traffic, demand, etc. And in order to tie in the mission of promoting a smart city, we could include a negative coefficient on a variable(s) that indicate the level of environmental preservation.

Dynamic pricing offers exciting opportunities to test behavior, travel patterns, and emission reduction strategies. The system could support the expansion of car-pooling through the Central Indiana Regional Transportation Authority (CIRTA) by implementing choice recommendations from Deloitte University's Smart Mobility Report<sup>9</sup> like providing financial incentives for car-pooling providers or on-demand commercial providers to increase their number of shared rides. Data could lead to infrastructure investments that support ride-sharing, like HOV lanes along Smart Corridors or reserving prime parking to incentivize cleaner transportation options.

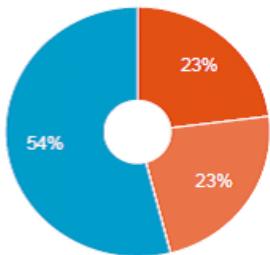
Indianapolis will update its zoning code to allow and support shared transportation facilities on public and private property to remove institutional barriers that discourage on-demand and shared mobility services and use.

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<sup>9</sup> Viechnicki, Dr. Peter, Khuperkar, Abhijit, Fishman, Tiffany Dovey & Eggers, William D., Deloitte University Press, Smart mobility: Reducing congestion and fostering faster, greener, and cheaper transportation options, 18 May 2015.

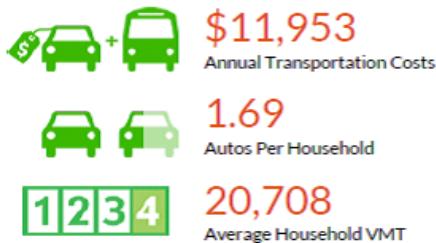
**Average Housing + Transportation Costs % Income**  
 Factoring in both housing *and* transportation costs provides a more comprehensive way of thinking about the cost of housing and true affordability.

- Housing
- Transportation
- Remaining Income



#### Transportation Costs

In dispersed areas, people need to own more vehicles and rely upon driving them farther distances which also drives up the cost of living.



Source: Center for Neighborhood Technology, Housing and Transportation Fact Sheet: Indianapolis city (Balance), <http://htaindex.cnt.org/fact-sheets/>

#### *Challenge Addressed: Transportation Gap and Economic Mobility*

The USDOT identified Indianapolis as a pilot site for the LadderSTEP program. The Red Line BRT investment will connect thousands of job and residents and serve as a building block for improving the economic mobility of residents. LadderSTEP serves to catalyze construction and focus on building connections, workforce capacity, and supporting revitalization.

Smart Corridors would build on this effort by supporting mobility options while providing discounted fare during peak commuting hours. Working with employers to establish TSAs and increase shared mobility choices, Smart Corridors will provide greater access to economic opportunity to residents. Next to housing, transportation costs are often the second highest cost burden placed on an average household. In Indianapolis, the housing and transportation costs for most residents are 46 percent of their income<sup>10</sup>. By supporting the sharing economy and diversifying trip options through open source data and policy incentives, we are improving mobility for all City of Indianapolis residents. This model could allow the city to set and price VMT reduction goals once patterns are established on the cost of emission reduction and individual choice.

## 2.0 Indianapolis: Characteristics of a USDOT Smart City

Indianapolis is a consolidated city-county with a 2014 population estimate of 934,243 residents<sup>11</sup>. However, portions of the county are known as excluded cities and retain substantial political and administrative powers, and the portion of the population in Indianapolis proper (known as “Indianapolis, city balance” in Census terms) is estimated at 848,788<sup>12</sup>. Unlike many of its rust-belt peers, Indianapolis continues to grow, and has done so throughout its history.

<sup>10</sup> The Center for Neighborhood Technology’s Housing and Transportation (H+T®) Affordability Index

<sup>11</sup> U.S. Census Bureau. <http://quickfacts.census.gov/qfd/states/18/18097.html>

<sup>12</sup> U.S. Census Bureau. <http://quickfacts.census.gov/qfd/states/18/1836003.html>

This growth can largely be attributed to the city-county consolidation, which captured four decades of population and tax base growth. While Indy has grown, consolidation disguised the disinvestment and abandonment of the urban core (known as Center Township), which has lost 59% of its population since the peak in 1950. The exciting opportunity is, like many cities, Indy's urban core is on the rebound. According to Census figures, over the past six years, Center Township has grown for the first time since 1950, and the most urbanized portions of Central Indiana (all of which are in Indy) are the only places growing faster since 2010 than they were before.

On the economic front, the national decline in manufacturing hit Indy later than many cities. Since 2003, Indy lost nearly 19,000 manufacturing jobs, stripping many families and entire neighborhoods of their economic purpose. Recent research from Harvard's Equality of Opportunity Project shows Indy ranks 48 among the largest 50 American cities in terms of economic mobility<sup>13</sup>, and research from the Brookings Institute showing that the Indy metro area has seen an 81.7% increase in poverty, one of the fastest growth rates in the nation<sup>14</sup>. As accessible jobs left neighborhoods, new jobs have emerged much farther away, meaning families typically take a pay cut for a lower-level job while increasing transportation costs just to get there. This is one reason the U.S. DOT selected Indy to participate in the Ladders of Opportunity program (LadderSTEP) and why Indy city leaders have focused, and continue to do so in this application, in promoting more robust transportation choices that improve residents' access to economic opportunities throughout the region.

In 2002, Marion County accounted for just 2.7 percent of the region's population growth. But over the course of the next ten years, Marion County consistently captured an ever-increasing share, rising to 41 percent of the metropolitan area's growth in 2012. These trends mirror those that have been observed in other highly-competitive metropolitan areas. Over the last 25 years, we've had more than \$12.5 billion in investment in downtown.

### 3.0 Other Smart City Characteristics

#### Indianapolis' Smart City Infrastructure

In the spirit of Indianapolis' successful history of large-scale infrastructure improvements and economic investments, IndyGo is currently pursuing the Red Line Rapid Transit project. The Red Line will be the first all-electric BRT in the nation and the first rapid transit service in Indiana. The complete line is envisioned as a 35-mile BRT corridor, to be completed in three phases first of which is in the Indianapolis Regional Center (downtown and vicinity). The Red Line will serve as the backbone to the planned regional transit network, connecting neighborhoods from all walks of life, universities, and other major commercial hubs through the downtown urban core of the city. While operating in its own lane, along a dedicated route with traffic control technologies and frequent stops, this eBRT system is ideal for developing autonomous vehicle technologies.

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<sup>13</sup> More Challenges to Economic Mobility in Indiana. <http://iiwf.blogspot.com/2013/08/more-challenges-to-economic-mobility-in.html>.

<sup>14</sup> The Growth and Spread of Concentrated Poverty. <http://www.brookings.edu/research/interactives/2014/concentrated-poverty#/M26900>.

Indianapolis has been at the forefront of the transportation electrification movement for a number of years. Energy Systems Network (ESN), a non-profit organization headquartered in Indianapolis, has been focused on accelerating the energy technology sector since 2009, when it launched an initiative called Project Plug-IN. ESN gathered partners from a variety of industries and backgrounds to work together to begin a deployment of electric vehicle and smart grid technologies in central Indiana. Using this approach, Project Plug-IN launched nearly 200 charging stations in central Indiana by 2011. Those initial deployment efforts led to the growth in electrified transportation detailed below.

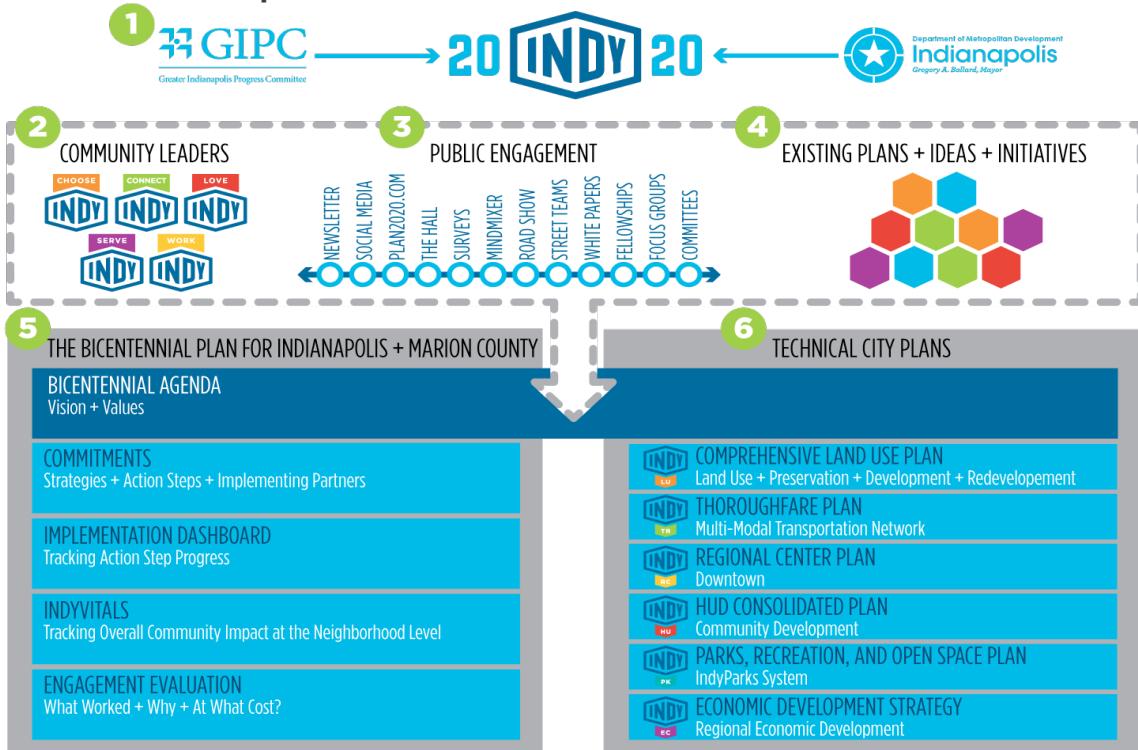
In early 2014, the city of Indianapolis contracted with French multinational conglomerate the Bolloré Group to provide and build out a fully electric car sharing service in Indianapolis. Launched publicly in September 2015, the system has accrued over 1,000 members in the first four months of operation and logged more than 7,000 trips with 60 operable stations. The system will continue to build out through 2016 and will finish with a planned 200 stations (five charging stations each) and 500 cars for a total of 1,000 charging stations capable of 13 MWh of storage.

In 2013, the City of Indianapolis entered into an agreement to deploy up to 425 plug-in sedans in the city's fleet replacing older, less efficient gas-only vehicles. Today there are more than 225 plug-in cars deployed, giving the City of Indianapolis one of the largest fleets of plug-in vehicles in the nation. Each car is saving the city approximately \$2,000 per year in avoided fuel and maintenance costs. This has resulted in over 42,300 gallons of gasoline and 377 MTCO<sub>2</sub> saved. Further savings can be gained by utilizing automated safety systems on the vehicles to reduce chances of accidents as well as leveraging the large cumulative energy storage capacity of the vehicles as a whole through a holistic, integrated systems approach with the grid and built environment.

### **An Environment Conducive to Smart Corridors**

The Red Line is one part of a significant rethinking of what an Indianapolis transit system should be and demonstrates how Indy's environment is conducive to implementing the Smart Corridor project. For over five years, the Indianapolis region has been working on a transit vision, dubbed Indy Connect. In early 2016, IndyGo will be unveiling the first step in Indy Connect, a five-year implementation plan to improve the transit system in the core city of Indianapolis. This plan would be put to the public as a referendum in November 2016. This planning process has deliberately made the choice of deploying new resources into areas of highest density and ridership potential rather than attempting to cover more area. Key components of the plan include Red, Blue and Purple Rapid transit lines and significantly enhanced local service with more frequency, improved travel time, and extended night and weekend hours.

## Committed Leadership



Indy's leadership is committed to Smart Corridors and long term strategies for improving the region as Plan 2020 demonstrated. Smart Corridors is informed by Plan 2020, a pioneering planning process to define the next century for the city that has been driven by an extraordinary team of nearly 200 community leaders. The plan is a collaboration between the Greater Indianapolis Progress Committee, Department of Metropolitan Development (DMD), DPW, the Indy Chamber, and community leaders to make Indianapolis a better place to live, work and visit. The Plan 2020 initiative includes a visionary yet strategic Bicentennial Plan for Indianapolis as well as updates to six local government plans.

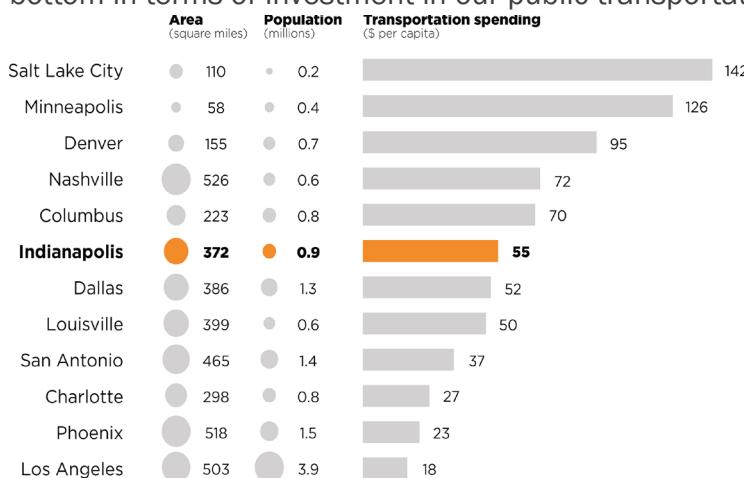
### **Commitment to Smarter Land Use & Affordable Housing**

Indy's ability to maximize transportation investments has been the key to the success of many large scale projects. IndyGo's Red Line BRT system will connect hundreds of thousands of jobs and community members. To maximize this investment and housing security for all residents along the route, the City is adopting Transit Oriented Development (TOD) overlays to support appropriate land use, zoning, and development.

TRANSIT ORIENTED DEVELOPMENT IMPLEMENTATION			
COMPREHENSIVE PLAN ELEMENT	2015	2016	2017
LAND USE	RED LINE TOD STRATEGIC PLAN IDENTIFY TOD TYPOLOGIES EXISTING PROPOSED LAND USE MAP CHANGES TO POLICY	PLAN 2020 UPDATE IDENTIFY NEW BASE LAND USES DELINATE TOD OVERLAY BOUNDARY CHANGES TO MAP	ZONING CHANGES MUS/MU4 DISTRICT PLANS REZONING CHANGES TO LAW
HOUSING STRATEGY	RED LINE TOD STRATEGIC PLAN AFFORDABILITY STRATEGY PUBLIC INVESTMENT PRIORITY	MARION COUNTY HOUSING STRATEGY COUNTYWIDE SYSTEMS PUBLIC/PRIVATE/NON-PROFIT PRIORITY	

The TOD Strategic Plan, produced by the Indianapolis Metropolitan Planning Organization (MPO) supports community development that includes a mixture of housing, office, retail and city living amenities integrated into a walkable neighborhood and located within a half-mile of quality public transportation to increase accessibility to jobs. This year the City will expand on both of these efforts, developing a neighborhood housing strategy for the entire County that uses data-driven inputs to coordinate public, non-profit, philanthropic, and private sector community development investment, as well as a new county-wide land use plan that includes a focus on increasing density in select villages, introducing transit-oriented development, and connecting land use recommendations to adequate public infrastructure. This work will ultimately set the stage for new mixed-use district zoning categories provided by Indy's new zoning ordinance, IndyRezone.

Similar to many U.S. metropolitans, Indy's existing transportation infrastructure requires greater investment capital than the operation and maintenance budget will allow. In spite of this, Indianapolis continues to spend less per capita than many of our peer cities approximately \$50 million annually or \$125,000 per square mile<sup>15</sup> and ranks near the bottom in terms of investment in our public transportation system.



Source: State of Walkability Report: Indianapolis Pedestrian Plan, to be released 2016

IndyGo is currently funded primarily with property taxes. However, in recent years, the state of Indiana instituted a cap on the percent of assessed value that can be captured in a tax, essentially capping IndyGo revenues to grow only with the growth in property values, preventing any growth in our service. Therefore, in November 2016, IndyGo is pursuing a referendum to direct a portion of income taxes to the agency. The developing referendum demonstrates the political and community commitment to increasing mobility options.

### **Commitment to Sharing Economy**

Indiana's low-regulatory environment and the growing tech cluster in Central Indiana have benefited the sharing economy. A commitment to the sharing economy is evidenced by the inclusion of the topic in the Plan 2020 initiative's Bicentennial Agenda, the vision and values component of the Comprehensive Plan for Indianapolis and Marion County. In the transportation options portion of the vision, "continue to create an environment that supports the sharing economy including car and bike sharing" is listed as a must-do activity.

<sup>15</sup> State of Walkability Report, Indianapolis Pedestrian Plan, to be released March 2016.

### **Pacers Bikeshare Impact**

**(4/22/14- 12/31/15)**

- Annual Memberships Purchased: 2,674
- Day Passes Purchased: 53,114
- Calories Burned: 17,536,505
- **Carbon Offset: 418,283 lbs.**
- **Total Trips: 205,935**
- **Miles: 441,836**

(Indianapolis Cultural Trail, Inc.)

The City has a data-sharing relationship with ride-sharing service Uber. Pacers Bikeshare, currently serving the award-winning Indianapolis Cultural Trail and with expansion plans for other destinations and cultural districts connected by a growing bicycle and greenway trail network, has been highly successful, surpassing 100,000 rides in its first year. In 2015, Pacers Bikeshare boasted 116,000 trips and 240,000 miles ridden saving 227,335 pounds of carbon. In 2015, the City also launched North America's largest all-electric, point-to-point car sharing program BlueIndy slated to have 500 cars at 200 stations by 2016.

### ***Commitment to Open Data***

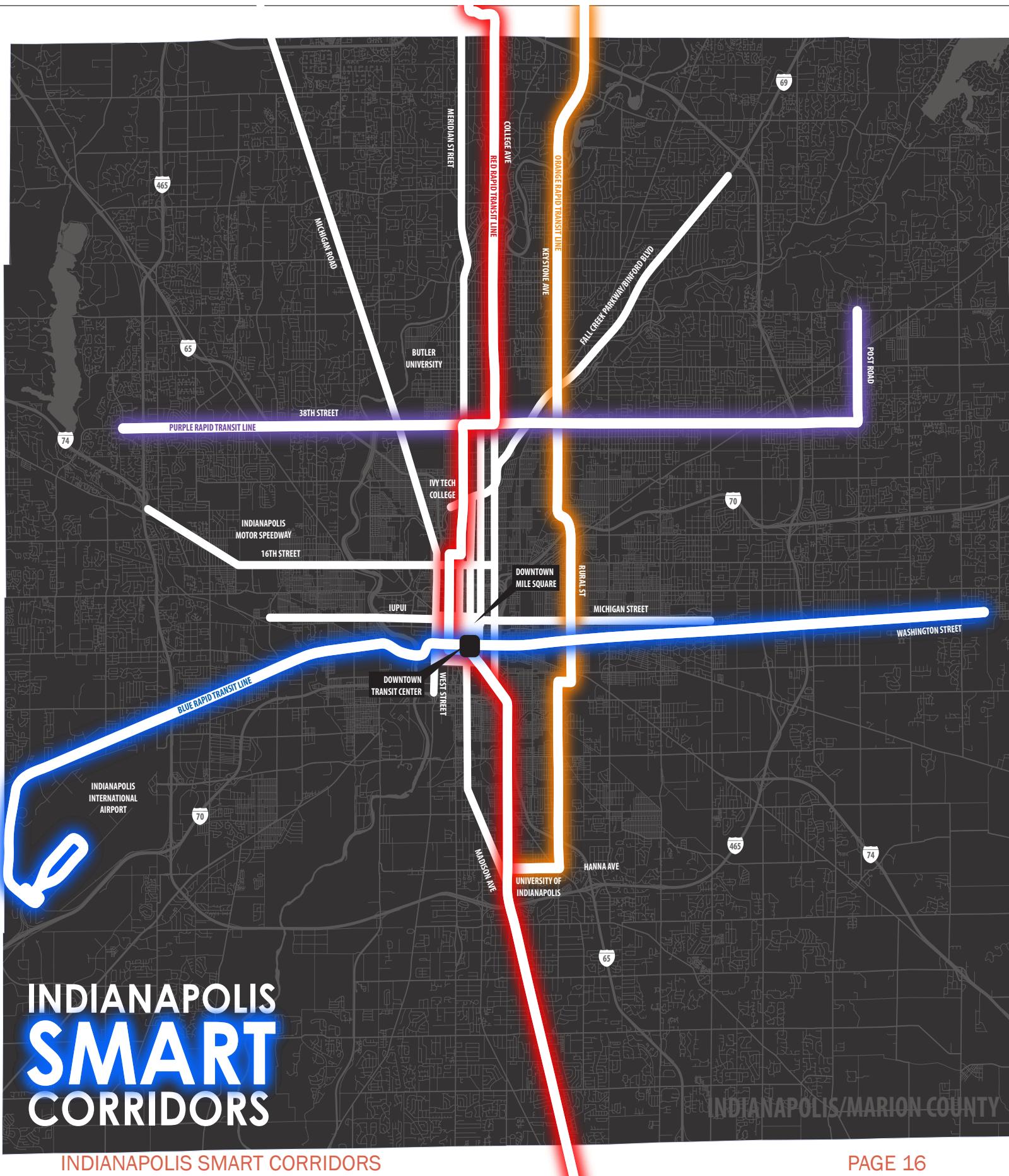
Indy is ramping up its focus on open data, with the City's Plan 2020 Initiative funding a fellowship to integrate open data policy into municipal government and including a focus on the topic in the initiative's Bicentennial Agenda, the vision and values component of the Comprehensive Plan for Indianapolis and Marion County. The plan includes a commitment to open data platforms as one of fifteen pillars, stating:

“We must produce an environment where the sharing of ideas and resources across industries fuels our future economy. We must ensure that our virtual connectivity is not only at a competitive capacity but accessible to all. We must support civic advancement and new business by sharing data, allowing both the public and private sectors to create new applications and find new solutions. This ensures a government that is communicating internally and externally, providing opportunities for efficiencies and transparency.”

One of the first regional data portals in the nation was recently launched to facilitate data flows across political boundaries, and the State of Indiana's Management and Performance Hub and Transparency Portal provide tremendous platforms for broader data-driven management decisions. For policing, Indianapolis just opened the Real-Time Data Center, a hub that connects patrol-level information, city-wide surveillance cameras, and data analytics to respond to and predict evolving criminal patterns. This focus on data-driven decision making in the largest department in city government is itself the outgrowth of a Code for America fellowship program that added transparency to police complaints, officer-involved shootings, and use of force through the Project Comport program, which is now integrated into the Regional Data Portal.

The region's commitment to open data is broader than simply the public sector, however. The Open Indy Brigade, a Code for America brigade, has been a driving force in civic data, including Plan 2020 and the regional data portal. A diverse and growing tech sector, anchored by global names like Salesforce (ExactTarget), Interactive Intelligence, Angie's List, and award-winning start-ups like Rook Security and TinderBox, provides a rich pool of talent to support civic data. This private-sector commitment is also evident at the Indy Chamber, who is actively involved in sponsoring hack-a-thons focusing on improving government efficiency and supporting the ideas of the Plan 2020 vision.

## 4.0 Smart Corridor Annotated Site Map



## 5.0 Alignment with USDOT's 12 Vision Element

### **Element 1: Urban Automation**

Indy's Smart Corridor approach to urban automation (UA) is building automated all-electric BRT, airport shuttle, and car share supported by smart infrastructure. This urban platform or "sandbox" offers an historical opportunity to accelerate the integration of the nation's largest and most advanced electric car sharing and eBRT systems with cutting edge automation and connected vehicle technologies in an environment that will reach millions of consumers.

Investing in UA technology across mobility options can reduce operational costs to providers and connected infrastructure can relay improved safety information. Deployment of NHTSA Level 3 automation on Bluelndy car share vehicles will realize cost savings due to the existing technology systems. Integrating autonomous technology into the Bluelndy system can occur seamlessly as the vehicles are already operating in an intelligent, connected, and monitored system. Automated eBRT will be tied into signal timing to improve congestion along the corridor, and Wi-Fi connections will be provided to users that can collect information to evaluate system performance, improve access, and increase safety.

Examples of technology and solutions available from corporate partners AT&T, IBM, & Ericsson to implement this include:

- Connected Vehicle Cloud that integrates with an ITS package
- Transformation Services to help integrate standalone applications to transform data into information for real-time interworking and intelligent insight across applications and organizations.
- Data Analytics to enable controlled access and use of data from cellular and non-cellular devices, creating value through cross-industry use of data.

### **Element 2: Connected Vehicles**

Smart Corridors will provide the ICT structure to allow users and vehicles and infrastructure to "talk" to one another and each other. Communications technology solutions proposed include:

- Installation of free Wi-Fi along Smart Corridors
- Wireless transmission media (i.e. Dedicated short range communications DSRC)
- Cellular data sharing

Connected to the Internet of Things (IoT), drivers can choose alternative routes or parking by using data analytics and routing information (optimized by the user application). Connected vehicle technology could revolutionize safety of all roadway users. Smart-sensor based infrastructure could improve safety by holding signals for pedestrians crossing the street or warn connected vehicles of bicyclists in their blind spot.

V2I technology could send existing data streams to allow operators to identify infrastructure problems or gaps and emergency management personnel to respond to hazards or detect crashes in real time. In response to incidents or potential hazards like weather, connected technology could allow transportation management centers TMCs to automatically reroute trucks or vehicles carrying hazardous materials onto appropriate corridors by sending information to in-car controllers. V2I solutions deployed along the Red Line will save costs as these corridors have planned roadwork and intersection redesigns. Research partner IUPUI's current relevant projects include 1) Integrating vehicle to vehicle communication and pedestrian autonomous emergency braking and 2) Development of Pedestrian/bicyclist Crash Scenarios and Vehicle Performance Testing.

### **Element 3: Intelligent, Sensor-Based Infrastructure**

Sensors in infrastructure could alert operators during congestion events and reroute users via the mobile app to alternative routes or modes. Technology solutions proposed to support Smart Infrastructure include integrated sensors, processors and wireless transmitters for data capture on existing conditions and environmental information (e.g. pavement markers, lighting, bus stop, and crosswalks). The pilot Smart Corridors have planned infrastructure work in the short term including ITS upgrades and intersection redesigns so their installation can be coordinated with the current project work saving project costs.

### **Element 4: Urban Analytics**

A large amount of dynamic, real-time data will be generated from traffic monitoring sensors and vehicle location and schedule information. A team of faculty from the IU School of Informatics & Computing and Purdue School of Science, Department of Computer Science are partners on this project. This data will undergo pre-analytics to clean, integrate structure, store and secure. For this pre-analytics stage, we will develop and implement various data management and data security algorithms that will work on large real-time streaming data. Research partner IUPUI's current relevant projects include 1) TrafficAnalyzer: A Real-time Traffic Stream Processing and Analyzing System, Supported by IBM and 2) Development of Key Technologies for Big Data Analysis and Management Software Based on Next Generation Memory, Supported by ETRI.

### **Element 5: User Focused Mobility Services and Choices**

The Smart Corridor on-demand mobility service will all available travel options under a unified payment platform that offer economic incentives for trips that reduce emissions. Once deployed, this system could reduce cost to operators for maintaining separate payment systems and user applications. Revenue generated from dynamic pricing could support ongoing maintenance and operation of the application or be applied to projects identified through crowdsourced data.

### **Element 6: Urban Delivery and Logistics**

By piloting automated vehicle technology and V2I, Indy could optimize freight routes on our system. The Indianapolis MPO is finishing a regional freight study that prioritizes local arterial and state systems as key freight corridors. Using ICT, TMCs could channel freight vehicles to priority corridors by communicating with drivers or alert them of weight and height restrictions.

### **Element 7: Strategic Business Models and Partnering**

In addition to the core team members for this application, ESN has also assembled a world-class team of global leaders in connected mobility and automation. This group includes members from: AES, Bolloré Group, BOSCH, Clemson University International Center for Automotive Research (CU-ICAR), Delphi Automotive, Duke Energy, Indiana Department of Transportation, Indiana Bureau of Motor Vehicles, Indianapolis Power & Light, Purdue University, Toshiba, TechAssure, and Transportation Active Safety Institute (TASI). Each of these partners is committed to working with ESN and the City of Indianapolis to plan, execute, and report on the nation's most advanced ecosystem of multi-modal electrified, connected, autonomous vehicles through the Indianapolis Smart Corridors initiative.

Employers and universities in Indianapolis, as in many cities, provide on-demand parallel transportation through bus or van services for their residents, students and employees. The maintenance, operation, and capital expenditure for these closed loop systems is high while providing little to no support to regional mobility. If these system operators could incentivize their consumers to connect to existing ride-share options while ensuring user safety, these systems could be phased out or generate income by providing rides through an on-demand ride model.

### **Element 8: Smart Grid, Roadway Electrification, and Electric Vehicles**

Deployment of Indy's smart grid solutions will have significant cost savings by leveraging existing electrified infrastructure and investment. Implementing V2G capability can help providers manage electric demand and allow consumers to participate in peak shaving. Indianapolis will have 15 MWh of energy storage connected to the grid through a single customer once this program is completed. V2G technology and wireless charging capabilities could tap into the dynamic pricing model. Not only would wireless charging help reduce peak electric demand, but the application could electric vehicle users could capitalize by taking advantage of surge pricing within the app while the vehicle is stopped or parked.

### **Element 9: Connected, Involved Citizens**

Providing open, accessible data in a user-friendly format will allow residents to discover innovative applications of that information. The user application could connect citizens to crowdsourced reporting applications and community information. For example, if a user is traveling along a street, they could connect to local historical sites, take a guided tour, access popular restaurants, and access city information.

### **Element 10: Architecture and Standards**

Smart Corridors will use all existing standards, systems, and processes approved for connected vehicles and ITS systems. The partnership with IUPUI will allow us to integrate these systems with other city systems which may include police navigation, emergency medical services, and weather stations. For example, a flood forecasted by weather outlets could link to the city's impervious surface map, detect high risk areas and dispatch responders to those locations for evacuation. All existing tools including CVRIA, National ITS Architecture and other ITS standards to model this integration and deployment. Indy's approach and partnership with a major research institution will allow for training and deployment across the country.

### **Element 11: Low-cost, Efficient, Resilient Information and Communications Technology**

One of the most important factors in the proposed mobile smart city is the collection and processing of huge dynamic sensor and vehicle data. We will design integrated security architecture and develop a resilient secure system that will enable the secure data collection, transportation, storage, management and processing of smart city data. This system will provide one common operating platform to inform the city's data-driven decision making. In detail, we propose and will develop 1) Secure sensor and vehicular data collection and aggregation 2) Secure and integral data transmission and 3) Access control and controlled data sharing.

### **Element 12: Smart Land Use through Connected Infrastructure**

Indy's adoption of TOD overlays and affordability strategies to support appropriate land use, zoning, and development demonstrates our commitment to increasing density and improving housing choice. The TOD Strategic Plan supports community development that includes a mixture of housing, office, retail and city living amenities integrated into a walkable neighborhood and located within a half-mile of quality public transportation to increase accessibility to jobs.

The Smart Corridor project will allow us to take this focus a step further- analytics will allow us to evaluate mode mix by land use and transportation options to prioritize investments and provide optimal mobility choices. Additionally, smart infrastructure like roadway sensors could detect where cars are driving so we can reserve more realistic right-of-way for projects or allocated unused space to bicycle infrastructure, sidewalks, or HOV lanes.

## **6.0 Risk Identification & Solutions**

Data integration is a fundamental, yet challenging, component of this Smart Corridor model. The data integration system will combine various types of data including geographic location, speed, count, and behavior patterns, from multiple sources into integrated sets and provide users with a unified view of these data. In this project, we will incorporate both batch-oriented techniques for query performance and real-time data integration to eliminate the annoyance of out-of-date data. We will use both batch-oriented technique such as extraction, transformation, and loading (ETL) and popular real-time techniques such as Data Federation.

Dynamic pricing and e-payments require providers to have integrated systems, payment platforms, and an agreed upon price structure. Financial structures and reserves will be established to ensure providers cash flow and fare box recovery is not too disrupted during deployment. A financial institution will be identified to manage the transportation savings accounts and ensure financial stability in the long term. Additionally, users without bank accounts or credit access must be able to use the system.

Creating a TMC and upgrading to a shared-use platform will require detailed roles and responsibilities, maintenance plans, and dedicated ongoing funding sources in cooperation with technology partners. The upgrade and deployment of ITS infrastructure will require an integrated work plan with the Red Line and detailed traffic pattern information to establish baseline system management.

Creating a digital interface requires we ensure participation from all users like people without cell phone access, visual impairments, and older adults. By working with community foundations, advocacy groups, and others, Indy will create programs to ensure Smart Corridors are accessible to all through education, subsidies, or integrated technology programs.

## 7.0 Partners and Stakeholders

Plan 2020 captured the values and goals for Indy. Equally important, it created the partnerships with major institutions and engaged them in thinking about a dynamic future. It financed innovative projects and research and provided opportunities for young community members to apply their talents to solving Indy's challenges and finding opportunities. Lead by Indy's **Department of Metropolitan Development**, this Smart Cities Coalition was made possible by this foundational project.

The City of Indianapolis' **Department of Public Works (DPW)** builds and maintains public infrastructure, park land, manages solid waste collection and the city's entire fleet—striving always to provide effective, efficient customer service to citizens and visitors to Indianapolis, Marion County and ensuring a healthy, safe, and natural environment.

The faculty and researchers from **Indiana University Bloomington and Indiana University Purdue University Indianapolis (IUPUI)** will be collaborating on all four major aspects of the proposed Smart Corridor project. This unique partnership will ensure the evaluation and replicability of the Smart Corridor approach and technology. The Indiana University is a major multi-campus public research institution, grounded in the liberal arts and sciences, and a world leader in professional, medical, and technological education. The IUPUI campus, with over 26,000 students, is adjacent to downtown Indianapolis. **The Indiana University School of Informatics and Computing** is the first completely new school in the United States devoted exclusively to Informatics and a range of its sub-disciplines. With its formative national role in creating the nation's largest Informatics Program on the Bloomington and Indianapolis campuses, the School is the broadest and one of the largest information/computing schools in the U.S. **The Purdue University School of Engineering and Technology** at IUPUI working on project's autonomous vehicle element offers cutting-edge academics and a research catalyst. These centers are focused on solving some of the world's most pressing challenges in areas such as health care, energy, and transportation, while educating a technically savvy workforce. This team has a wealth of expertise in this area, as evidenced by the **Transportation Active Safety Institute's (TASI)** success. TASI's goal is to partner with university, industry and government to conduct research and development in advanced active safety technologies, and perform evaluation and assessment of active safety systems. TASI has many faculties and full time researchers with expertise from electrical engineering, mechanical engineering, human factor engineering, medicine, and public policy.

Successful implementation of the Element 1: Commercial Integration of Autonomous and Connected Vehicle Technology will require a diverse set of experienced and committed partners from industry, academia, and government. Fortunately, headquartered in Indianapolis, is **Energy Systems Network (ESN)** – a unique non-profit organization led by a board of CEOs and presidents of several of the world's largest energy and transportation companies. Their mission is to "leverage ESN's global network of renowned thought leaders, and provide integrated, energy, economic, and environmental solutions with the "capacity to endure" for improving the quality of life for all people." ESN is highly focused on developing and implementing public-private partnerships in the alternative energy technology sector as demonstrated by leadership in Project Plug-IN™ resulting in more than \$60 million invested in plug-in electric vehicle projects in Indianapolis. This work has all been accomplished by drawing on the technical, operations, finance, and policy expertise of a network of global thought leaders coordinated by ESN.

**Delphi Automotive** is a leading global technology company of automotive and commercial vehicle markets. Delphi delivers solutions that help make vehicles safe, green, and connected. Its product lines range including the automotive industry, commercial vehicle industry, testing services, commercializing and licensing disruptive technologies, and others. Of significant interest to the Smart Corridor project is Delphi's wide range of active safety technologies, such as intelligent cameras, sensors, lane departure warning systems and parking guidance systems. With Delphi's support, the best-of-class technologies will enhance the vehicle automation pilots in Element 1.

Local utility support integration of a project of this scale is critical in ensuring full system integration. **Indianapolis Power & Light** is the local utility for the Indianapolis area (Marion County) to more than 480,000 residential, commercial, and industrial customers. IPL has been a leader in EV infrastructure readiness as the first utility to offer time-of-use (TOU) rates to incentivize EV usage in homes and businesses in 2011. In addition to deploying public EV charging infrastructure, they are a key partner in preparing the grid for the deployment of charging stations for the Bluelndy car sharing service.

The City and partners will be working with the support of the **Smart Cities Alliance**. AT&T Mobility LLC ("AT&T"), Ericsson Inc. ("Ericsson") and the International Business Machines Corporation ("IBM"). The members of the Smart City Alliance, together with our other vendors, strategic relationships, consultants and subcontractors, will be able to deliver a comprehensive solution as well as the execution experience necessary to deploy projects of this magnitude.

The Smart Corridors' success relies on the coordination and cooperation of all local and state-wide transportation partners. **IndyGo**, a key implementing partner for multiple technology solutions, is the largest public transit agency in the state of Indiana. Their leadership in developing an electric bus fleet and other innovations continues to improve the health of our community.

The **Indianapolis MPO** is the regional entity that plans and programs federal transportation funds for highways, transit, non-motorized transportation, and other means of moving people and goods. The MPO works within federal transportation requirements to guide the development of a multi-modal transportation system within the Metropolitan Planning Area (MPA).

The Chamber's leadership in public transportation and leveraging investments through public-private partnerships will be vital to this programs' broad coalition and financial sustainability. The **Indy Chamber** serves as a voice of progress and improvement in the region, uniting business and community to maintain a strong economy and quality of life, representing roughly 2,000 members and their 200,000+ employees. It provides membership functions and serves as the lead regional economic development entity.

The **Bluelndy** electric car sharing service is another key partner by serving as a test case for vehicle automation. The vehicles are already equipped with much of the necessary technology and communications systems that allow for a smoother transition to a level of automation that would work well for a key route: The Indianapolis International Airport to the downtown area.

The project's success will require a broad coalition that can plan, implement, market, fund, and evaluate the Smart Corridor model. We've identified the stakeholders below as key partners of our broader coalition and will continue to seek their official support.

Transportation Agencies, Researchers, and Advisors	Central Indiana Regional Transit Authority (CIRTA) Indianapolis Cultural Trail, Inc. ParkIndy and Denison Parking Bolloré Group INDOT Uber, Lyft, Taxis Transportation for America Conexus Indiana Motor Truck Association
Technology Sector and Business Incubators:	Google, Waze, Garmin Open Indy Brigade 1776
The Private Sector:	BOSCH ITS Maintenance Contractors FedEx Financial Institutions Eli Lilly
Other Agencies and Advisors:	MIBOR Indianapolis Public Schools
Public Safety Agencies:	Ambulance/Emergency Medical Services Indiana Counterterrorism and Security Council (CTASC) National Weather Service/NOAA Indiana State Police (ISP) Indianapolis Emergency Management Agency Indianapolis Police/Fire/emergency medical services (EMS) Marion County Sheriff Metropolitan Emergency Communications Agency (MECA) Suburban municipality police/fire/emergency medical services (EMS)
Activity Centers:	Indianapolis Airport Authority Indianapolis Motor Speedway Lucas Oil Stadium Indiana Convention Center

## 8.0 Existing Transportation Infrastructure & System Features

Indianapolis' local roadway network is based on a traditional grid with a highway ring serving surrounding neighborhoods around a downtown core known as the Mile Square. The local road network provides the backbone for mobility options including bicycles, pedestrians, transit, shared use mobility, and car sharing which includes:

- Arterial/Thoroughfare Assets: Centerline Miles 1,165 Miles; Lane Miles 3,311
- Local Street Assets: Centerline Miles 2,172 Miles; Lane Miles 4,274 Lane Miles
- NHS/INDOT Jurisdiction: Centerline Miles 159.51 miles

Mode	Provider; Operator	Infrastructure	User Access Points	Public Information	Planned Expansion
Personal Automobile	Department of Public Works (DPW), INDOT	Interstates; State Highways; Local, Collector, Arterial Streets			New roadways and planned arterial system expansion
Bicycling; Bike-share	Pacers Bike-Share	Indianapolis Cultural Trail, Separated and Protected Bike Lanes, Greenways	Stations Downtown & along Cultural Trail	Mobile application provides station locations and available bikes	
Public Transportation (Local & Rapid Bus Service)	IndyGo	Shelters, Benches, Trash Cans, Station Signs	Bus stops and Downtown Transit Center ( <i>opens 2016</i> )	Pamphlets, Website, Call in Number	Real time bus arrival; Bus Rapid Transit Network (BRT)
On-Demand Services	Uber, Lyft, Taxis			Mobile applications, Call-in numbers	
P2P Car-sharing	BlueIndy	300 Electric Vehicle charging stations; enrollment kiosks; 120 all-electric cars (60 Sites)			200 Sites; 500 all-electric cars; 1,000 charging stations
Car-Pooling and Express Bus Service	Central Indiana Regional Transportation Authority (CIRTA)	Vehicles		Website; Software matching; call-in numbers	

## **Transit service - IndyGo**

Despite the City of Indianapolis being the 12th largest city in the United States (U.S. Bureau of the Census, 2010), IndyGo ranks 101st of transit systems in terms of passenger-miles travelled. IndyGo is the primary provider of public transportation in the Indianapolis region. Its service includes 31 local routes and a county-wide paratransit service serving 10.5 million passenger trips annually.

## **Shared-use mobility services**

<p><b>Indianapolis Cultural Trail:</b></p> <p><b>A Legacy of Gene &amp; Marilyn Glick</b></p> <ul style="list-style-type: none"><li>• <b>\$63 million of total project cost</b></li><li>• <b>\$27.5 million of total private funding</b></li><li>• <b>\$35.5 million of total federal transportation funding (\$20.5 million TIGER grant)</b></li><li>• <b>\$1 Billion</b> in increased property values</li></ul>	<p>From 2008 to 2015, Indianapolis went from 0 to 90 miles of bike lanes and separated infrastructure and over 70 miles of trails and greenways. The last eight years have also included the launch of Pacer Bikeshare system, creation of the bicycle commuter hub downtown, and the passage of a comprehensive complete streets ordinance. The Indianapolis Cultural Trail is an eight-mile world-class separated urban bike and pedestrian path in downtown Indianapolis that connects neighborhoods, cultural districts and entertainment amenities while serving as the downtown hub for central Indiana's vast greenway system.</p>
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In early 2014, the city of Indianapolis contracted with the Bolloré Group to provide, build, and operate America's largest fully electric car sharing service in Indianapolis. Launched in September 2015, the \$50 million system has over 1,000 members in the first four service months logging more than 7,000 trips with only 120 electric cars and 300 charging stations at 60 sites which will expand in 2016. Indy is also served by major point-to-point shared use mobility providers including Uber and Lyft.

## **Information and communication technology**

There are 230 traffic signals, primarily located in the core CBD, currently interconnected via fiber optic cable. The system allows real-time monitoring and manipulation of timing plans via a web-based platform. A substantial investment has been made over the past three years to repair and upgrade the original system installed in the late 1990's. An \$800,000 conduit and fiber optic repair project was recently completed, and DPW Operations continues to replace \$1.4 million in traffic signal controller and cabinet hardware. This project is scheduled to be completed summer 2016. The original fiber optic network has been damaged and cut due to utility work, demolition, and construction. This next generation of fiber optic infrastructure investment will need to be closely monitored and enforced through the Department of Code Enforcement (DCE).

## **Intelligent Transportation Systems (TMC and field equipment)**

ITS have been applied throughout the greater Indianapolis area for many years to promote the safe and efficient travel of motorists, transit riders, and cargo. A majority of the ITS infrastructure belongs to INDOT and is utilized along the interstates. Indianapolis TMC is owned and operated by INDOT and is co-located with state police, allowing for seamless roadway incident management and response. They maintain a sophisticated ITS and data management system. Despite state-of-the-art technology and system monitoring on the highways, Indianapolis' ITS deployment is slowly upgrading from legacy systems installed in the 1980s and 1990s.

The City of Indianapolis is responsible for 1,200 traffic signals three basic types: non-interconnected signals, closed loop signal systems, and in the central business district (CBD) interconnected signals. Non-Interconnected Signals are either coordinated using time-based coordination or are too far from any adjacent traffic signal to benefit from any signal progression plan. Of the 1,200 traffic signals approximately 498 (or 42 percent) fall under this category. Closed Loop Signal System interconnected via copper, fiber, or radio and allows limited remote manipulation of the traffic signals. Of all our traffic signals, 472 fall under this category. There are currently 54 closed loop systems. Fall Creek Parkway, a major urban arterial, also features variable lanes that shift based on time of day to accommodate rush hour congestion.

## 9.0 Data Collection, Sharing, and Management

Information Services Agency (ISA) provides data management and services to the city and serves as the central information hub. While there is a centralized resource, current transportation data collection efforts and distribution vary department to department. Development of a public information portal where residents can access zoning, parcel, and right of way information is currently underway. Data collected by the city and partners includes:

- Asset management data (pavement condition)
- Pedestrian and bicycle count data (via sensors and manual collection)
- Transportation plan implementation data (for evaluation)
- Vehicle counts on local roads and federal system
- Crash data (ARIES system based on police reports)
- IndyGo security cameras and passenger counters
- BlueIndy origin-destination information and number of trips
- Pacers Bikeshare trips, mileage, carbon-offset

The format of the city data collected varies; some are converted to geospatial data while others are maintained in separate software systems or spreadsheets. All mapped data in ArcGIS shapefiles are managed and maintained by ISA on a shared server available to any city department. The MPO's count information is available through INDOT's interactive mapping website. Outside of the city government, data sharing processes are less formal. Public transit count information is aggregated and shared monthly with partners via email. Pacers Bikeshare aggregate data is released to the public periodically via a press release. Crash data is available using the online Aries portal and the public must request a login. A data-sharing agreement with Uber and BlueIndy allows the city access to their collected data.

Data collection and sharing across departments and partners could provide a detailed picture of how the city is performing and lead to better decision-making. A central information portal providing access to the public and partners will require a data collection and management architecture. The City will lead this initiative bringing together partners and corporations to establish sharing policies and operating procedures. . A corporate partnership with the Smart City Alliance (AT&T Mobility LLC, Ericsson, Inc., and IBM) would allow for providing of information on the tools and cloud-based technology necessary for transportation data collection, monitoring, and integration.

In partnership with IUPUI, a user portal will be established. IUPUI's COMET Lab – an applied interactive media development laboratory in the School of Informatics and Computing – will develop novel, citizen-centered designs for interactive “omnichannel” access, navigation, search and browsing of interactive, real-time Smart Corridor data. Nimble, context-, location-aware and customizable data-driven interactive applications will be available to citizens on a variety of personal user interface channels (including: web, mobile, smart watches) that will enable various user profiles to access, search, explore, gain recommendations and insights from large-scale, real-time traffic data and public information.

## **10.0 Research and Documentation on ITS and Connected Vehicles**

A Regional ITS Architecture, developed by the Indy MPO is already in place, providing the foundation for transportation system integration. IUPUI and the City plans to partner with architecture and standards developers to improve connected vehicle and ITS solutions. These Smart Corridors offer testing opportunities for the technologies of automation or connected vehicles, ITS, and the implementation of real-time data analytics for transportation system management. Vehicle to Infrastructure (V2I) technology deployment will be evaluated throughout the process; system utilization, congestion, air quality, and safety performance measures will be adopted and monitored throughout deployment. Capital and on-going operating costs will be summarized in a Cost-Benefit Analysis report based on selected performance measures.

## **11.0 Goals and Objectives**

The goals for transportation in Indianapolis have been set both from a regional mobility standpoint through the *Marion County Thoroughfare Plan* and from a community-inspired, collaborative-based planning effort known as Plan 2020.

*“Four defining qualities describe not what the Indianapolis community is, but what it wants to become, which is to make Indianapolis a **healthier, more resilient, more inclusive, more competitive city** (Plan2020).”*

The Smart Corridor project will make roadways safer and more accessible for all by using data to make more informed decision about infrastructure investments and management. Monitoring the demonstration project’s effect on safety, mobility, efficiency, sustainability, and climate change will require hardware installation, emissions monitoring equipment, and the selection of robust performance measures. With our university and research partners, ESN, and public transit operators, the City will set up a system, operating procedure, and work flow capable of collecting and monitoring the Smart Corridors’ performance through deployment and into the future.

An Inclusive, Connect, Resilient Indy	Smart Corridor Objective	Actions	Measurable Impact
Become the automated vehicle testing center to improve safety & reduce emissions	<b>Pilot automated vehicle technology with smart infrastructure across vehicle modes</b>	Automation of Red Line Bus Rapid Transit (BRT)	Successful Deployment; creation of a replicable model; # of crashes reduced along Corridors; Reduction of Greenhouse Gas (GHG) emissions and electric demand; Improved system efficiency of the drive cycle by controlling speed, breaking, acceleration
		Improve route efficiency through automation of all-electric car share	Validation of how autonomous technology can support drive cycles that contain both highway and dense urban driving
		Automation of closed loop, airport shuttle	Validation of NHTSA Level 4 automation in drive cycles that include fixed high frequency low speed routes
Implementation of Vehicle to Grid Technology to reduce emissions	<b>Implement Smart Energy management system</b>	Use BlueIndy car-share sites to pilot a V2G system	System utilization; credits earned through Transportation Savings Accounts (TSA)
Maximize individual mobility through cloud based-technology	<b>Create a Mobility on demand (MOD) platform</b>	Provide integrated, smart phone payment system	Successful deployment of app & integrated payment system
		Shared facilities & payment systems; Create Transportation Savings Accounts (TSAs) for users to implement dynamic pricing	Secure financial institution to manage accounts; reduced number of emissions and SOV trips; TSA utilization
		Provide integrated, real-time information on mobility options	Reduced number of single occupancy vehicle (SOV) trips
		Connect citizens to crowdsourced reporting applications and community information	# of reports made
Implement Travel Demand Management (TDM) through Dynamic Pricing	<b>Create Transportation Savings Accounts (TSAs) where users can earn credits for reducing SOV trips</b>	Price parking to reduce consumption and maintain available spots to reduce circulator traffic	Registered users/cash flow
		Implement demand pricing for transit, parking, and peak hour travel	Mode shift; lower peak hour demand; % of parking utilization
Use big data & analytics to improve routing, predict travel behavior, and mode share (e.g. Metropias Pilot)	<b>Integrate Advanced ITS into real-time traffic management</b>	Establish common, open source data operating & visualization platform	# of developers & citizens utilizing data; # and location of start ups
		Integrate data from all partners	# of government agencies utilizing/connected
		Make travel, city info available to public	# of users with Wi-Fi access along Corridors
		Optimize traffic flow using cloud connected sensor and feedback loop	

## 12.0 Capacity to Execute Smart Corridors

### Leadership & Collaboration

Indy's commitment to the vision of Smart Corridors will be executed by the partners who developed this vision collaboratively and are committed to this great city: The City of Indianapolis, IUPUI, ESN, Indianapolis MPO, the Indianapolis Chamber of Commerce, and IndyGo. The City of Indianapolis will provide full-time staff dedicated to overseeing the project's planning, deployment, and monitoring. As our major research partner, IUPUI has identified project leads for the development of technology systems and evaluations of the Smart Corridor technology and data analysis. The City's Smart Corridor project embodies our goal of fostering business innovation, employing advanced energy technologies, and building sustainable transportation. Its success will rely on traditional investments and commitments and the ability to adapt to the unforeseen hurdles that come with breaking new ground.

RebuildIndy is a testament to Indy's ability to manage a project of a similar scale to the proposed Smart Corridor project. RebuildIndy was an initiative under former Mayor Gregory Ballard to restore deteriorating streets, sidewalks and bridges, greenspaces as well as address neighborhood drainage and flooding issues. Delivery of infrastructure projects cut through much of the existing red tape; design time was reduced by 3-4 months while streamlining saved projects up to 20 percent.

This investment continues to transform neighborhoods throughout Indianapolis.

### REBUILDINDY Investment

9,764	ADA Access Ramps
119,511	Linear Feet of Alley Repairs
91	Miles of Bike Lanes
89	Bridges
2	Roundabouts
833,522	Linear Feet of Sidewalks
1,821	Lane Miles of Resurfacing
691	Traffic Signals
152,020	Linear Feet of Trail/Path
14,441	Trees Planted
\$722M	Total RebuildIndy Investment



### Infrastructure Readiness

Indianapolis is unique as the only city in the United States which stands ready to automate transportation systems in a clean and sustainable way leveraging the publicly accessible electrification transportation systems that are already in existence or currently in development including BlueIndy and the eBRT Red Line. Combined, these systems are the result of more than \$50 million invested to date and another nearly \$100 million planned for the Red Line. This offers a generational opportunity to accelerate the integration of the nation's largest and most advanced electric car sharing and eBRT systems with cutting edge automation and connected vehicle technologies in an environment that will reach tens of thousands of consumers. Indianapolis provides an ideal and pragmatic location for autonomous vehicle technology development. Over the last few years, Indianapolis has very quietly become the most connected, electrified city in the U.S. through several key large-scale projects including the largest all electric car-share fleet in the U.S. The opportunity for testing and validation of automated transportation technologies is ripe. IndyGo's vehicle and bus fleet are being converted to an all-electric fleet as well as the City's vehicles.

Despite state-of-the-art technology and system monitoring on the highways, Indianapolis ITS deployment is slowly upgrading from legacy systems installed in the 1980s and 1990s. While there would be multiple systems to integrate and connect, the City is ready to install and upgrade their existing system. Indianapolis is uniquely positioned to upgrade its ITS system due to the national expertise found locally through the INDOT team.

INDOT provides national leadership for TMC models and ITS deployment; INDOT TMC staff travel the nation advising communities on their systems, helping plan for and select new technology, and anticipate and address potential problems. INDOT's partnership will be key to the implementation of a local and connected ITS system. Their national expertise will be especially important while selecting ITS technologies and building the best base model for timing plans from base traffic patterns.

## 13.0 Leveraging Federal Resources

Indianapolis knows how to make targeted investments that improve livability, creating opportunities for its residence and drive economic growth while getting the most from each dollar. Indianapolis has been able to maximize competitively awarded federal transportation dollars on an impressive scale. The Cultural Trail was funded through a large public-private partnership (PPP) led by Central Indiana Community Foundation, the City of Indianapolis, and multiple not-for-profit partners. Research evaluating the economic and community impact found assessed property value within one block of the eight-mile trail increased 148 percent for a total increase of \$1 billion<sup>16</sup>. We will apply this tenacity to developing our PPP for the Smart Corridor project.

As a part of a unique Indiana Utility Regulatory Commission (IURC) rate case settlement for the BlueIndy project, Indianapolis Power and Light (IPL/AES) is currently required to conduct a full study of V2G technology and methodologies utilizing the BlueIndy platform that will match this project.

Using the Smart Cities grant, Indianapolis proposes to develop a production-ready application of BRT docking guidance technology to implement along with the Red Line BRT project. By packaging both the docking precision and electric propulsion into a single project, we believe that the Red Line can be a model for low-cost rapid transit around the world.

The Airport Shuttle Automation project could be replicated to other U.S. airports as well as any company with a campus-to-campus employee shuttle (e.g., Lilly Corporation, Cummins Engine, other Indiana-based corporate companies) or companies who move goods regularly between fixed route nodes.

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<sup>15</sup> State of Walkability Report, Indianapolis Pedestrian Plan, to be released March 2016.