US Ignite Smart City, Big Data Playbook:

On June 19, 2018, US Ignite hosted a Smart City, Big Data workshop with the city of Portland, Oregon, and other municipal, university, industry, and nonprofit partners. The workshop highlighted use cases for sensor-driven data and offered communities a chance to share information on applying new types of data analysis toward efforts at improving local transportation, public safety, housing, and more.

BACKGROUND

The increasing flow of data in smart cities is both good news and bad. New data sets provide insight, which can lead to safer, healthier, more livable communities. However, with more information streaming from new sensors and cameras every day, these stores of data are also rapidly becoming more difficult to manage. Ericsson predicts that IoT devices will outnumber mobile phones starting in 2018, which gives just an inkling of how fast the connected world is changing.

Meanwhile, Cisco estimates that the volume of data produced globally – data generated by people, machines, and other connected things – will almost quadruple by 2021, reaching 850 zettabytes compared to 220 ZB in 2016.

Most smart cities are not dealing in big data today. Communities are largely in the early deployment stage of smart city projects, collecting discrete measurements from sensors like how many cars pass through an intersection or how air quality is rated at a given location at different hours throughout the day. Even that level of information can be difficult for local governments to handle however, particularly coupled with a move toward open data platforms.

And the challenge will only grow.

Because the analysis and application of big data among cities is still in its infancy, this playbook examines some of the initial use cases for data-driven initiatives, including what value they can deliver, and what pioneering communities have learned from early deployments. This guide offers information about early project successes, as well as details about new pilot programs now underway. The second half of the playbook also recommends specific tools and techniques for managing data, using real-world experiences to point the way toward smart city big data strategies for the future.

EARLY DATA SUCCESSES

Transportation and public safety are two areas where communities are finding early success analyzing sensor data and applying new insights to improve local conditions. Below, case studies from Seattle and Denver respectively illustrate how data can be used to reduce vehicle travel times and inform policing strategies related to high-risk traffic intersections.

SCOOT IN SEATTLE:

The Mercer Corridor in Seattle is notorious for its traffic congestion. To address the issue, the city's department of transportation introduced an initiative called Split Cycle Offset Optimization Technique – or SCOOT – to attempt to improve vehicle flow. The project involves a series of sensor nodes placed at 32 intersections on Mercer Street between 3rd Avenue West and I-5. With embedded Bluetooth, Wi-Fi, video, and other environmental sensor capabilities, the nodes detect vehicles traveling both east and west along the corridor across all lanes. The system then uses the data collected – including information about traffic volume, vehicle speeds, and direction of travel – to make stoplight signal adjustments in real time.

SCOOT is particularly helpful for adjusting traffic flows when a sporting event or concert adds to road congestion. However, even a typical trip down the Mercer Corridor is significantly faster today than it was before the city launched SCOOT. With dynamic signaling, the average time to travel the corridor has dropped to 17 minutes from a previous average of 32 minutes.

SCOOT combines detection, analysis, prediction, and responsive signal operations to deliver effective management of traffic as well as reduced emissions and fuel consumption.

Key Takeaways:

- By defining a problem and designing a solution specific to the challenge, Seattle was able to realize a relatively rapid return on investment for its SCOOT initiative.
- The success of SCOOT is predicated not on the fact that Seattle was able to collect new data, but on the fact that it has been able to act on that data in real time.

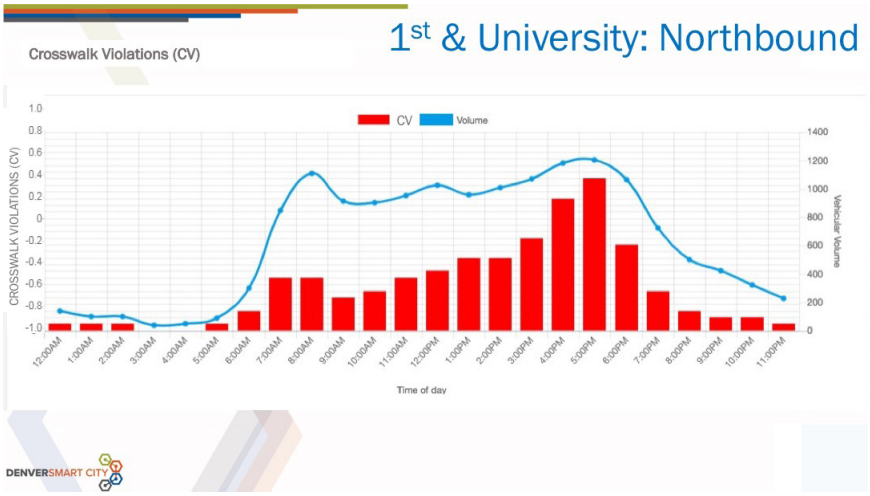
DENVER CROSSWALKS:

The City & County of Denver (Denver) is not only using sensors to collect new traffic data, it's also looking for patterns in the data that will help it improve public safety at high-risk intersections. To do this, officials are pairing up different data sets and drawing insights from information that previously wasn't analyzed side by side.

In particular, Denver has started to compare vehicle crosswalk violations to periods of time with high traffic volumes. Crosswalk violations – where cars stop in the crosswalk while the light is red – are important to examine because they indicate a greater likelihood that cars will run a red light, increasing the risk for a T-bone crash, the deadliest type of collision. Initially officials assumed that the two variables would directly correlate at every intersection during rush hour times. However, a look at sample data from a congested intersection showed that crosswalk violations only spike in the afternoon hours in one direction, while traffic volume goes up during rush hour in both the morning and the afternoon.

There are many factors causing drivers to stop their cars in the crosswalk during a red light including weather, proximity to home, and overflow traffic from congestion elsewhere. The information is important to engineers and safety employees working in Public Works and the Denver Police Department. It informs them on how to best implement actions such as increasing yellow signal times or ticketing to encourage stopping before the crosswalk.

A crucial next step for this project is to gather, visualize, and verify more data to both implement targeted measures to reduce risk when and where these conditions occur, and to test if intervention has a positive effect.



With the knowledge of when crosswalk violations are most prevalent, departments, such as public works and police, can target their resources accordingly, making more efficient use of labor and equipment. While Denver doesn't have sensors at every traffic light, officials are looking to take what they've learned from initial data collection, gather more data, and verify it, with the goal of making improvements to specific intersections and developing a methodology to examine others with similar characteristics.

Note: More details on Denver's data analysis capabilities are available in the Denver spotlight section at the end of this playbook.

Key Takeaways:

- As Denver shows, sensor-based data can help city departments allocate resources more effectively.
- Information can be extrapolated from sensor data to draw reasonable conclusions about similar environments, even where those environments aren't being actively monitored. This paradigm shift can, over time, create an operations environment that is able to be both reactive and proactive.

PILOTS IN PROGRESS

While Seattle and Denver illustrate early smart city successes, many projects in those communities and others are still in a highly experimental phase. Sensors have been deployed only recently, the data sets need further validation, the pilots are small scale, and the costs for deployment and sustainability are just now being explored. The limitations aren't all bad, however. It's in this early phase of testing that communities can uncover where challenges exist, what resources are required, and what potential value from data-driven projects is there to be gained.

PORTLAND TRAFFIC SAFETY SENSOR PROJECT

As part of its larger Smart City PDX initiative, the city of Portland has begun a traffic safety sensor project with a goal to reduce road risk and gain a better understanding of how to invest effectively in transportation infrastructure. For a city of its size, Portland has a relatively high rate of pedestrian injuries and fatalities on roadways. City leaders expect the new sensor project to help them identify danger areas sooner and enable more proactive decision-making with regard to pedestrian safety.

Working with a consortium that includes Current by GE, AT&T, and Intel, Portland launched the traffic safety sensor project in June 2018. It includes 200 streetlight-based CityIQ™ sensors from Current by GE that are being installed in three of the highest crash corridors in the region. The sensors have begun collecting data on: traffic speeds, vehicle direction and volume, parking activity, pedestrian speeds, pedestrian direction and volume, and environmental conditions.

Although Portland has only begun to assess the new information available from traffic sensors, the project team has already encountered an early challenge impacting deployment strategy. Specifically, city leaders were concerned about the privacy implications of including video surveillance in the project scope. Video is a powerful tool for tracking vehicle and pedestrian movements, but it can also be used to monitor citizens for reasons other than traffic safety, with the potential for civil rights abuse.

The Portland team ultimately decided to activate the video cameras on the city's new traffic sensors, but footage is deleted almost immediately after it's recorded, and there is no access available to the live video feeds. Instead, the system uses edge processing capabilities to analyze footage for traffic safety issues on site in real time. That analysis is then provided to city officials for further action, but without the raw video itself.

Takeaways:

- The Portland deployment isn't a solution in search of a problem. The city recognized a significant problem with pedestrian safety and is now using new technology to address that issue.
- It is possible to come up with creative solutions to privacy concerns around real-time video surveillance.

TRACKING BERRIES IN INDEPENDENCE

The city of Independence in Oregon is a rural community that wants to be an example of how small towns can jump the digital divide and leverage technology to create economic benefit. As a result, the community is launching a pilot project in partnership with Intel to create an interface between urban technology and rural agriculture. The pilot will focus on field-to-fork tracking of berries from local farms.

In the project, small sensors will be placed in totes of berries laid out on pallets in farm fields. The sensors will monitor both the location of the berries as they're transported to processing stations and a final distribution center, and environmental conditions during transit. The vertically-integrated packing company Rogue Ales plans to use the data to track the progress of berry picking and processing, and to set alerts that help optimize crop yield throughout the harvesting process.

For Independence, the pilot also presents an opportunity to integrate blockchain technology for additional applications around shipping logistics and food safety certifications. Project partners are working with the Department of Agriculture and hope to expand on the initiative in the future.

Takeaways:

- Small towns can benefit from new sensor-based technologies, although the applications may be different.
- Because of limited resources, small communities need to focus on investments with near-term, tangible benefits.

SEATTLE ARRAY OF THINGS

Like the city of Chicago, Seattle is participating in the Array of Things project, an initiative born out of a joint effort between Argonne National Laboratory and the University of Chicago. Array of Things uses modular sensor boxes that collect information on temperature, light, air quality, ambient sound, pedestrian and vehicle traffic, and more. In Chicago, the city wants to use the data to offer information to citizens like how to find a well-populated walking route late at night, and when there are highly localized weather conditions – like icy sidewalks – to be wary of.

However, the situation in Seattle is different. While Chicago has hundreds of sensor nodes to work with, Seattle has run into equipment supply issues and also hasn't yet figured out the best way to put the hardware to use.

For now, Seattle's Array of Things equipment is living at the University of Washington and being used for student research. This may change, but Kate Garman, Technology Policy Advisor to the Office of the Mayor in Seattle, says that what she's learned from the Array of Things project is that without scale and a well-defined use case, it's hard to glean new insight just by deploying sensors. The lesson is an important one because it will help define how Seattle initiates new projects going forward.

Takeaways:

- Scale can be the difference between success and failure in a smart city project.
- Without a defined use case, even a well-designed sensor platform may languish.

WORKING WITH DATA – LESSONS LEARNED

Beyond discussing use cases and sensor deployments, community leaders at the Smart City, Big Data workshop presented lessons they've learned from working with data; not just what information is the most useful and how to collect it but how to manage it thereafter. This includes working with disparate data sets, coordinating across multiple municipal departments, evaluating the needs of citizens, working with vendors, and testing new technologies. In many ways the challenges are similar to the difficulties of enterprise data management in any commercial organization. However, communities nearly always make do with fewer resources than their private sector counterparts.

Below are the recommendations shared by participants in the Smart City, Big Data workshop for more effective management of municipal data.

USE OPEN DATA AS A CONSTRAINT

The open data movement has gained traction at the municipal level over the last several years, but much of the information communities save is still written down on paper or stored in spreadsheets on a local server. John Clary, Supervisor of Data and Technology Services for the Austin Transportation Department, points out that this makes it difficult to share data across multiple departments, and therefore difficult to put valuable information – whether from new traffic safety sensors or historical records in city archives – to widespread use.

"Open is a great constraint for us," says Clary. He notes that usually if departments don't make their data open, the reason is because they know there's data missing, that it's difficult to extract, or simply that it's messy. On the other hand, if those departments know that data has to be open, it forces greater discipline.

Some critics may point out that there's a risk of exposing sensitive data by making it open, but Clary suggests that if data is sensitive, then it shouldn't be saved in an unprotected file in the first place. If data is safe enough to be stored in an unsecured digital or physical document, most of the time it's safe enough to share on an open portal.

The tools for making data widely accessible are also widely available. IT managers can connect a backend database of information to standard public-facing web forms with customizable business rules.

At the far end of the open data spectrum, there are some communities that are beginning to experiment with creating collaborative data marketplaces. These combine municipal data with additional private sector and even crowdsourced information via a shared platform that spreads infrastructure costs across multiple public and private sector participants.

A data marketplace requires careful controls over information access, but it also opens the door to new models of data sharing, including systems for data licensing and innovative approaches to data monetization. As Dr. Ken Figueredo, IoT Strategy Industry Advisor with InterDigital explains, the concept goes well beyond the open data movement for cities; a marketplace builds on the foundation and discipline set in place with open data portals while providing municipalities with the policies and tools to extend and improve the economic payback from their data assets and smart city services.

Source: Chordant, an InterDigital business; adapted from ATIS, Smart Cities Data Sharing Framework, March 2018

The Big Data journey for municipalities illustrates the scope of data assets that municipalities and their service-delivery partners will need to integrate over time. Initially, data exchanges will emerge to share data within municipal bodies. However, to benefit from open innovation, citizen-inspired, and private sector ideas, many municipalities will evolve to a data marketplace model that provides the foundation for a vibrant public-private data ecosystem for smart city services. The key issue for cities embarking on any open data initiative is to anticipate the requirements that will arise over the course of this journey.

KEEP YOUR OPTIONS OPEN

Optionality is key to making smart city initiatives and data systems sustainable over the long term, which is why even though Portland has teamed up specifically with AT&T, GE, and Intel for its traffic safety sensor project, Smart Cities Manager Kevin Martin says the city is still looking at sensor equipment from additional vendors. Martin wants Portland to be able to adapt as new solutions come along and not be hemmed in by one early technology decision.

From a data perspective, Austin's Clary considers it another way. He asks all of his vendors for access to their application programming interface (API) documents. APIs provide data flexibility so that if Clary wants to port information from one system to another, it's possible to do so.

In the same way that vendors can lock in municipal partners with closed hardware or software solutions, they can lock customers in with data that's not easily transferrable between and among different data management systems.

DON'T OVERLOOK DATA PRIVACY ISSUES

There's significant concern when it comes to smart cities and data privacy issues, and it's not just around high-profile scenarios like the use of facial recognition software by law enforcement groups. Communities are finding that even with data that appears innocuous, there are often unexpected reactions when it's collected, analyzed, and shared.

For example, Denver Smart City Program Manager Emily Silverman notes a case where the city has secured funding to deploy sensors to review air quality in different school zones. The goal is to analyze the data and look for ways to improve environments with lower air quality, but there's potential concern from some schools over worries that data showing air quality issues illustrates the impact of being located in an industrial area and could negatively affect public perceptions.

Similarly, Dr. Figueredo with InterDigital tells a story about government education officials not wanting to share data on student obesity with a county health department in Virginia. As with the air quality issue, Dr. Figueredo says there is a fear of stigmatizing schools with higher obesity rates even when the information is only being passed from one government department to another. Situations such as this illustrate the importance of trustworthy data management policies and automated data sharing systems in making open data accessible and usable.

Video surveillance ratchets up tension further because of the potential for civil rights abuses. Hence the reason Portland has decided not to store the video it records through new traffic cameras.

However, even Portland's Kevin Martin points out that deleting data because of privacy concerns isn't a blanket solution. There's value to consider too, like the fact that communities may be able to generate revenue by sharing less-sensitive data (like traffic patterns) with private companies in return for a licensing fee.

More broadly, if all data is locked away or deleted, then there's little that even municipalities can do to use that information to improve existing conditions.

Municipal leaders should work to consider as many potential consequences – both good and bad – as possible when moving forward with data-driven initiatives. Unfortunately, there's no simple answer to data privacy concerns, but leaders should weigh the pros and cons of any proposed strategy and then draft policy decisions according to the needs and priorities of their communities.

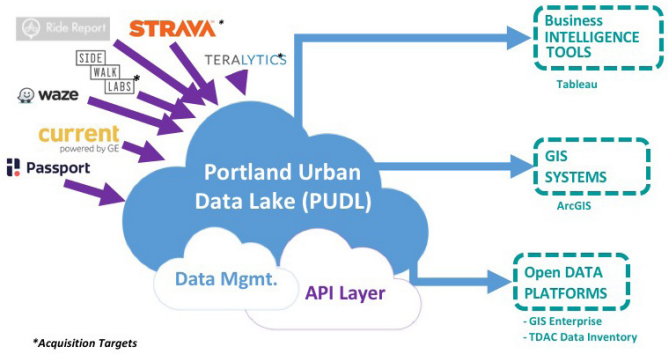
MAKE THE MOST OF THE CLOUD

Smart communities are rapidly learning that they need a cloud-based platform to manage all of the new data being collected from sensors and other connected devices. In Portland, leaders have launched the Portland Urban Data Lake (PUDL) pilot, which is being designed as an initiative to store, integrate, and analyze data from a variety of sources. The PUDL platform will include granular permissions control, embedded analytics capabilities, and a foundational set of standardized APIs for integrating new data sets and tools. Data sets can be municipally sourced, or they can come from commercial partners like Waze or Ride Report.

What the Portland team has discovered, however, is that there isn't an out-of-the-box solution that meets the PUDL project's needs. Instead they plan to create their own customized platform, but with the help of an existing software framework and a developer ecosystem that will continue to produce new tools and functionality over time. The team is evaluating both Amazon Web Services and Microsoft's Azure cloud service. Either of these cloud partners should be able to support the PUDL project as Portland envisions it.

Price is a determining factor. Smart Cities Manager Kevin Martin notes that Portland's funds are limited, and that as much as possible, the city would like to reduce costs by offering itself up as a reference customer to either Amazon or Microsoft. Since both companies are looking to prove their value in the smart city space, the hope is that being able to tout Portland as a test case will prove appealing.

We will benefit from PUDL's ability to manage and Interpret the BIG DATA we have/may acquire



Note: Denver has gone through a similar process to Portland of creating a cloud-based data management platform and is further along in its development. A full account of Denver's experience and the current status of its data management platform is included in a spotlight section at the end of this playbook.

KNOW YOUR DATA TOOLS

Because municipal governments are often lacking resources, innovative leaders are finding creative ways to address data management by looking to free and low-cost software and to tools requiring minimal developer expertise. Austin's Clary recommends several open source solutions including the Waze Connected Citizen Program for sharing mobility data, the Mobility Data Specification for data sharing around dockless bikes and scooters, and the data visualization software Mapboard developed out of Philadelphia.

In Independence, Oregon, Economic Development Director Shawn Irvine says his town was able to win a smart city challenge conducted by the open FIWARE software community out of Europe, which then gave Independence access to a virtual control room platform for smart communities known as WiseTown. The town has used WiseTown for free as an event management tool. In particular, the software has been valuable for the community's annual 4th of July celebration.

Not everything is free, but when developer expertise is an issue, Clary also recommends low-code and no-code software options. Among the solutions he cites are database software Knack, collaboration software Podio, and app builder software Zoho Creator.

DON'T FORGET THE HUMAN FACTOR

Data alone won't solve community problems. People need to be the guiding force in how data-driven projects are implemented. Participants in the Smart Cities, Big Data workshop recommend: the notion of open data champions who can create momentum for new data projects; the use of governance boards to ensure data initiatives serve the public interest; and the importance of community engagement for making sure citizens get the most out of these data-driven programs.

Josh Keeling, Supervisor of Customer Energy Solutions at Portland General Electric (PGE), also has advice for generating enthusiasm around data initiatives. Create a useful application, he says, and then let people play with it. At PGE, Keeling's team created a virtual power plant app that lets operators manipulate power flow to consumer appliances like water heaters where there's no risk involved. The PGE team can use the app to optimize distribution, ramping power up and down at different times to match demand.

Once people get their hands on a useful app, it gets easier to experiment with new tools and functions. This is also what drives interest in data projects, says Keeling, increasing adoption and overall value to the whole community.

SPOTLIGHT SECTION: THE DENVER DATA STORY

The City & County of Denver (Denver) has forged ahead with one of the most ambitious data-driven smart city projects to date. Its early success is a combination of creating a viable funding strategy, choosing the right technology partners, addressing challenges head on, and understanding exactly how new data initiatives can benefit Denver residents and citizens. This is the Denver story.

FUNDING HISTORY

Denver earned federal grant money from the Department of Transportation in late 2016 as part of the Advanced Transportation & Congestion Management Technologies Deployment (ATCMTD) program. The award was for $6 million, with the city committing to use that money to focus on connected pedestrians, connected freight, and connected fleet management. The grant also required 50/50 matching funds from the city for a total program budget of $12 million over four years.

While working on the agreements to secure the ATCMTD funding, Denver leadership decided to begin its smart cities work by focusing on building a foundation in the Information and Communication Technology (ICT) space. Additional internal funding of $500,000 was enough of a catalyst to kickstart the development of an Enterprise Data Management (EDM) system, which had been outlined in Denver's application for the US DOT Smart City Challenge earlier in the year. That EDM is now operational and is being used to collect, store, and analyze transportation and other data, which will inform decisions in the future on the use of community resources for mobility, safety, environmental, and quality of life opportunities.

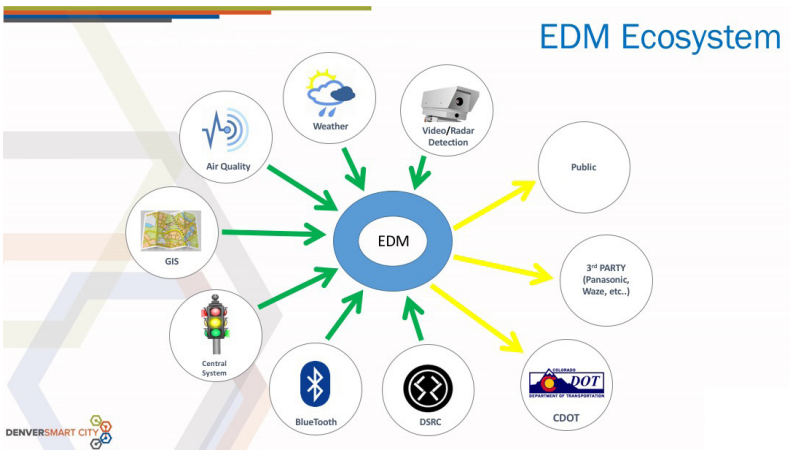
CHOOSING A PLATFORM

One of the first steps to developing Denver's EDM was selecting a cloud-based solution to host the city's data and provide the tools necessary to normalize and analyze disparate data sets. The Denver team evaluated many options and ultimately selected Microsoft Azure as its platform.

There were several reasons for the decision. The city's current contract and work with Microsoft followed on a Technology Services practice of facilitating the integration of legacy infrastructure to build a seamless ecosystem. In addition, in the assessment of James Lindauer, Lead IoT Architect for Denver, MS Azure is more configurable than other platforms, which Lindauer sees as requiring heavier customization work to tailor to a user's specific needs.

CREATING AN EDM ARCHITECTURE

After choosing Microsoft as a cloud partner, the Denver team built an EDM architecture to manage both data in motion and data at rest. This includes inputs from: video and radar detection systems, weather data sets, air quality sensors, GIS mapping technology, traffic lights, Bluetooth devices, and Dedicated Short-Range Communications (DSRC).



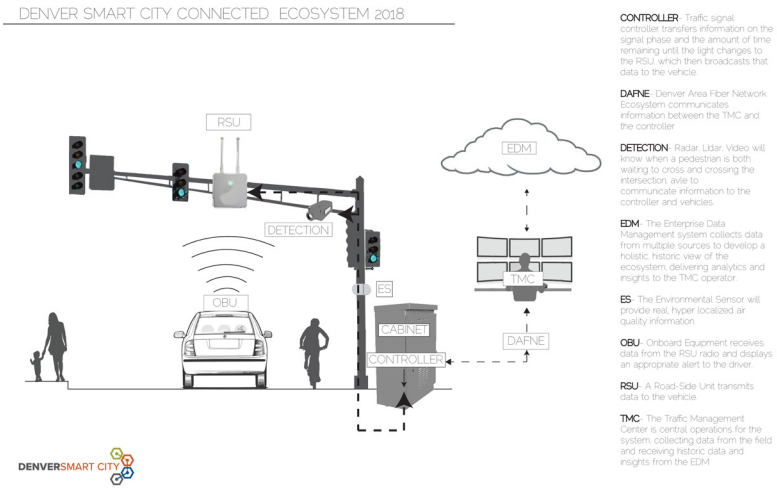
The team is using Microsoft's Power BI data analytics tools to slice and dice the information in the system and to provide a dashboard interface on top of the data. The entire EDM is housed separately from other municipal IT systems today to give developers a chance to experiment with the data and analytics capabilities. Already, there is almost a terabyte of data in the EDM. In the future, the city will be able to output select data sets to the Colorado Department of Transportation, third-party companies, and the public.

THE PATH AHEAD

Lindauer views Denver's data journey as moving from data aggregation to data intelligence, with the end state architecture facilitating full interoperability among municipal data systems and leveraging predictive analysis with artificial intelligence and machine learning algorithms built upon the specific agency use cases. While Denver has barely entered the data aggregation phase, developers already know what needs to happen next from an intelligence perspective. With enough information in the EDM, Denver can apply analytics tools to understand what's happening in the local environment, why it's happening, what's likely to happen next, and eventually how they can positively influence outcomes around safety, congestion, and the environment.

Initial use cases include leveraging the EDM to understand travel times through different transportation corridors, to understand real-time traffic and safety alerts, to target specific interventions, and to measure the efficacy of each intervention.

As far as the Denver team is concerned, although data is key to the foundation of their smart city program, it is not the only important component. Denver's fiber area network provides the connectivity backbone to scale smart city applications and services across the city environment, and the city's Internet-of-Things deployments provide real time sensory information to deliver immediate insight at the local level. Ultimately, the Denver smart city program is focused on leveraging these strategic assets to improve city infrastructure and services.



Importantly, the city does not intend to use its smart city data management system only for transportation issues. (This is informed by best practices from USDOT and other research and advisory organizations.) Work is already underway to measure and collect data from air quality sensors that can also be added to the system. And with more collaboration and community engagement in the future, the value of the EDM will only grow.

Denver looks to transition the EDM from development to production mode over the next couple of years.

CONCLUSIONS

Denver is constructing a platform that will manage input from numerous data sources (including IoT sensors) and enable analytics across data sets. As a pioneer, the city offers several lessons learned for communities that may want to follow a similar path in the future.

- **Know your assets: fiber plays a critical role**
  As the volume of data that Denver collects continues to grow, the fiber infrastructure in the city is becoming increasingly important for transmitting data and making it available for analysis. If a city has a fiber network, it should be utilized to allow the city to develop and deploy its smart city strategy, which is key due to smart cities' position as an emerging industry with both many unknowns and many opportunities. If a city does not have fiber, it should be able to identify other key assets it has in current state or wants to have in future state.

- **Data ownership and data sharing policies can't be an afterthought**
  Although Denver's EDM system is currently walled off even from the city's own IT systems while in development, the leadership team has still had to negotiate with IoT and cloud vendors to ensure that the city maintains sole ownership of its data. Denver wants decisions about data sharing in the future to be governed by the city's own security and privacy requirements and not by vendor policy.

- **Multi-department collaboration is a necessity**
  Conversations between different municipal departments are difficult, and without coordination, Denver would not have been able to fund the EDM program or to begin building out applications with the legitimate ability to address traffic and safety concerns. City workers are experts at what they do, and smart city solutions should build upon their knowledge base.

- **Municipal investment can be a catalyst for federal funding**
  In Denver's case, the city had to raise its own funds before federal grant money was available. Although one doesn't guarantee the other, the promise of local funding is often a requirement before cities are granted access to federal dollars.

- **Consider cloud partners carefully**
  There are a limited number of options for communities seeking a cloud platform provider. However, in addition to evaluating on price, communities should consider platform flexibility, any statewide policies that might affect usage, and interoperability with existing municipal IT systems. A strong vendor management and contracting team needs to be in place to ensure that costs of services are closely monitored.

- **Validate use cases ahead of data collection**
  Denver isn't collecting any data that its stakeholders haven't already confirmed will be valuable for specific use cases. Without that validation ahead of time, Denver would be running the risk of expending resources and costs without a plan for generating a return on investment.

- **Understand and make the most of analytics tools available**
  Collecting data is only the first step in data management. Cities need access to developers who can apply analytics tools to turn raw information into intelligence.

- **Create a sandbox for experimentation**
  Eventually local governments should aim for IT interoperability. However, while these data-driven applications are still so new, it helps to host them separately to avoid the potential of damaging existing systems.

- **Even a lean team can do a lot**
  Even a city as large as Denver faces significant resource constraints. The fact that Denver has been successful with its EDM project so far is a testament to the fact that a lot can be accomplished with a small but effective team if a city focuses its resources on these efforts.

FURTHER RESOURCES

CHART: DATA MANAGEMENT EVOLUTION

US Ignite is collaborating with ATIS (atis.org), an industry-backed forum, through a National Science Foundation EAGER-funded initiative to create a framework for Smart City Data Exchange. This chart, produced by US Ignite, illustrates how communities can progress from current open data initiatives through to the development of marketplaces for data exchange.

	Example Project	Benefits	Barriers	Challenges	Areas for Improvement
Stage 1: Open Data Portal	Data.gov	Starting point for online public data sharing; maintained by the government; improves transparency, accountability and public engagement	Limited data expertise at the local government level; limited number of use cases defined; local governments still function in silos	Variety and volume of data and devices to address; data privacy and security; incomplete data sets; difficulties integrating with third-party data; public engagement	Adaptation for interfacing through APIs; better data availability; licensing standards; consistency and reliability
Stage 2: Data Management Platform	Denver Enterprise Data Management (EDM) platform	Adaptation for interfacing through APIs; better data availability; licensing standards; consistency and reliability	Requires multi-department collaboration; requires data analysis expertise and an effective internal framework for deployment	Identifying, funding, and deploying a cloud-based platform; heterogeneity of data; scalability; privacy; ability to collaborate with private agencies	Process, store, encrypt and make data accessible at the right level; integration with multiple analytics and data visualization tools
	Example Project	**Benefits**	**Barriers**	**Challenges**	**Areas for Improvement**
Stage 3: Data Exchange	City Data Exchange, Copenhagen	Ability to share data at scale beyond municipal borders; larger data sets improve analytics capabilities	Immature market; lack of defined use cases; fragmented data landscape; reluctance to share data in an open forum	Lack of skills and competencies; lack of a solid technical platform	Models for data brokering; establishment of solid use cases; development of regional and national data communities
Stage 4: Data Marketplace	Interdigital, Chordant model	Creates potential for new funding sources to support smart city development	Immature market; data quality issues; integration challenges	Data ownership; liability	Cost modeling; ROI tools; data sharing standards

Quick Start Guide to Data Marketplaces, Chordant, an InterDigital business.
https://www.chordant.io/white_papers/a-quick-start-guide-to-data-marketplaces

Data Sharing Framework for Smart Cities, ATIS.
https://www.atis.org/smart-cities-data-sharing/

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Department of Transportation, Intelligent Transportation Systems Joint Program Office, Enterprise Data Research.
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