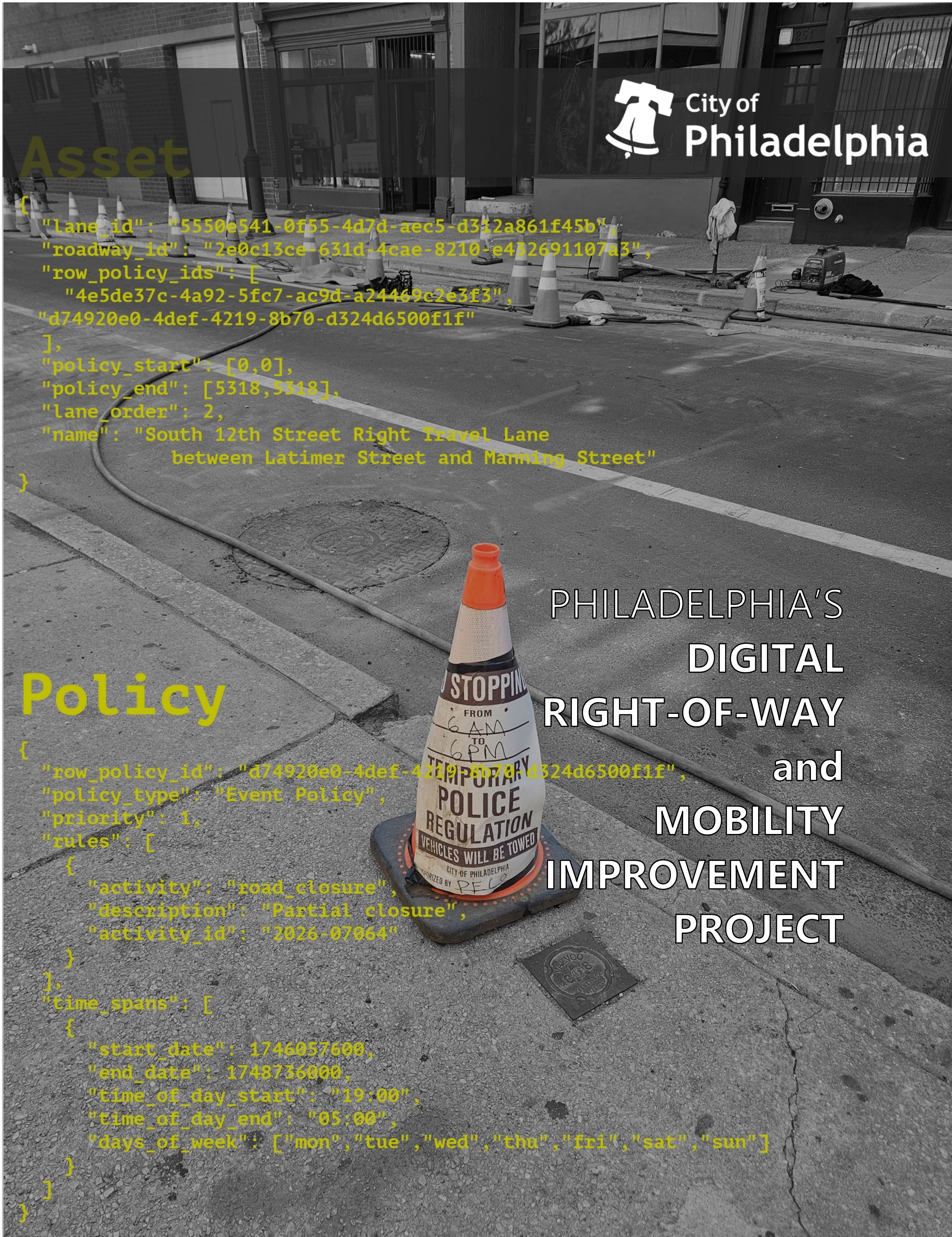

City of Philadelphia

Asset


```
{
  "lane_id": "5550e541-0f55-4d7d-aec5-d312a861f45b",
  "roadway_id": "2e0c13ce-631d-4cae-8210-e432691107a3",
  "row_policy_ids": [
    "4e5de37c-4a92-5fc7-ac9d-a24469c2e3f3",
 "d74920e0-4def-4219-8b70-d324d6500f1f"
  ],
  "policy_start": [0,0],
  "policy_end": [5318,5318],
  "lane_order": 2,
  "name": "South 12th Street Right Travel Lane
           between Latimer Street and Manning Street"
}
```


PHILADELPHIA'S DIGITAL RIGHT-OF-WAY and MOBILITY IMPROVEMENT PROJECT

Policy


```
{
  "row_policy_id": "d74920e0-4def-4219-8b70-d324d6500f1f",
  "policy_type": "Event Policy",
  "priority": 1,
  "rules": [
    {
      "activity": "road_closure",
      "description": "Partial closure",
      "activity_id": "2026-07064"
    }
  ],
  "time_spans": [
    {
      "start_date": 1746057600,
      "end_date": 1748736000,
      "time_of_day_start": "19:00",
      "time_of_day_end": "05:00",
      "days_of_week": ["mon","tue","wed","thu","fri","sat","sun"]
    }
  ]
}
```

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Strengthening Mobility and Revolutionizing Transportation (SMART) Grant
Stage 1

Final Implementation Report

PROJECT TITLE
Philadelphia Digital Right-of-Way and Mobility Improvement Project

RECIPIENT NAME
City of Philadelphia

FISCAL YEAR OF AWARD
2022

PERIOD OF PERFORMANCE
September 2023 – December 2025

RECIPIENT NAME
City of Philadelphia

DATE
May 14, 2026

Cover photo source: Smart Cities

Contents

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Table of Acronyms

ACRONYM	FULL TERM
ADA	Americans with Disabilities Act
API	Application Programming Interface
BIL	Bipartisan Infrastructure Law
CDS	Curb Data Specification
DBE	Disadvantaged Business Enterprise
DMP	Data Management Plan
FTE	Full Time Employee
GIS	Geographic Information System
GPS	Global Positioning System
IT	Information Technology
ITS	Intelligent Transportation Society
MDS	Mobility Data Specification
MDO	(City of Philadelphia) Managing Director's Office
MIRE	Model Inventory of Roadway Elements
MVP	Minimum Viable Product
ODA	Open Data Automation
OIT	(City of Philadelphia) Office of Innovation and Technology
OMF	Open Mobility Foundation
OTIS	(City of Philadelphia) Office of Transportation and Infrastructure Systems
PPA	Philadelphia Parking Authority
PTE	Part-Time Employee
QA/QC	Quality Assurance / Quality Control
RFP	Request for Proposals
ROW	Right-of-Way
ROWDS	Right-of-Way Data Specification
SaaS	Software as a Service
SEPTA	Southeastern Pennsylvania Transportation Authority
SMART	Strengthening Mobility and Revolutionizing Transportation
TRB	Transportation Research Board
TESC	Transportation Engineering and Safety Conference
TSP	Transit Signal Priority
UZA	Urbanized Area
USDOT	United States Department of Transportation

EXECUTIVE SUMMARY

With exponential growth in ride-hailing and delivery services, as well as in construction activity over the past decade, demand for parking and sidewalk space has increased, putting greater pressure on the systems that enable access to these spaces while complying with applicable regulations. The digital systems introduced to improve existing workflows are unable to fully leverage the technology landscape due to gaps in mapping technology. This Project aims to develop those missing pieces and complement existing systems and workflows.

Project Name:	Digital Right-of-Way (ROW) and Mobility Improvement Project
Recipient Name:	City of Philadelphia
Fiscal Year of Award:	2022
Performance Period:	September 2023 – December 2025
Federal Award:	$2,000,000
Location:	Northeastern quadrant of the Center City in downtown Philadelphia

Goals:

- Develop and test a user-centered system to enable digital ROW management
- Develop a new specification to digitize ROW assets, regulations, events, and metrics
- Inform future policy development to digitize ROW management

Technologies developed or tested using Smart Grant funding:

1. **Right-of-Way Data Specification (ROWDS)** – *an open-source data specification that enables digitally encoding ROW assets & policies*

2. **Road Rules**[1] (by INRIX) – *a Right-of-Way management applications demonstrating operational use of ROWDS and digitally managing and deploying information about ROW assets and policies.*

3. **Next-Gen TSP** - *Cloud-based Transit Signal Priority Technology leveraging fiber connectivity of upgraded signal controllers along a transit corridor.*

4. **Digital Signages** – *Solar-powered displays that leverage E-ink technology and digitized curbside parking regulations, including information about temporary closures, to show a user only relevant parking regulations for a given time of day, curb location, and day of the week.*

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[1] The software is referred to interchangeably as "Road Rules", "Smart ROW software", and "ROW management software" throughout this report.

Key Findings:

- **ROWDS works as a specification.** The Right of Way Data Specification can be deployed to digitize assets and policies for any given ROW at a spatial resolution of per-lane, per-running-foot, and per-unit of time. A prototype dataset covering the Center City study area was successfully generated.

- **Near-term operationalization is possible for specific use cases.** ROWDS in its current form can be operationalized for street-closure permitting and curb-space management, as demonstrated by the permit intake workflow developed during Stage 1.

- **Data quality is the critical limiting factor.** The ROWDS specification is ready; the data is not yet at a level where it could be operationalized without risk. Ensuring data quality requires City staff involvement and cannot be delegated entirely to vendors.

- **ROW workflows must be remapped, not just digitized.** Existing workflows carry bureaucratic overhead that does not translate well to digital systems. Stage 2 must include deliberate workflow redesign.

- **A cloud-based TSP system works in the Philadelphia environment.** The City and LYT successfully demonstrated that the LYT system can connect and communicate with the upgraded signal controllers. The LYT system achieved 100% connectivity with SEPTA's Swiftly transit data platform with zero disconnections.

- **Digital signages reduce user interpretation burden** but require further product development (larger displays, lower mounting heights, wholesale replacement of analog signs) to have meaningful operational impact.

PART 1: INTRODUCTION

CONTEXT AND NEED

For decades, cities have managed their streets or the right-of-way (ROW) using regulations encoded as text and conveyed to users as text for compliance and enforcement through physical signage and rate cards. Philadelphia has been no different. Any user trying to park a vehicle or request a street closure in the ROW would engage with Philadelphia's regulations in the same way they have for years, bearing the burden of knowing and understanding them well and determining whether they comply with these regulations when using the ROW.

Figure 1. Parking Sign in Philadelphia. Source: Smart Cities

Philadelphia's Digital Right-of-Way and Mobility Improvement Project (henceforth referred to as *the Project*) is an attempt to make ROW regulations and ROW uses digitally accessible to people by allowing their phones and vehicles to communicate directly with Philadelphia's digital ROW regulations. The Project's multi-pronged approach is designed to bring about significant, sustainable institutional changes across multiple city functions over the long term and to design a digital foundation that can flexibly and sustainably handle changes in technology landscapes over time.

One of the primary drivers of this *Project* has been rethinking how the right-of-way is managed from a **user's perspective**. Most government communication on the street is designed to protect agencies from legal liability. Unfortunately, very little effort goes into understanding the user experience for people trying to park or navigate the City's streets. Treating the streets as a "product," this *Project* starts with the experience of a right-of-way user – anyone trying to drive, park, bike, roll or walk in the street – and tests technologies that can communicate directly with their cars, bikes or smart devices.

The secondary focus of this Project is to develop and implement a Right-of-way Data Specification (ROWDS) that operationalizes the Model Inventory of Roadway Elements (MIRE) 2.1. Here, the Project goes beyond simply inventorying assets and translate them into policies or regulations that people's smart devices can consume directly over the internet.

Lastly, the Project is broken down into four smaller projects, each addressing a different dimension of the problem of digitizing ROW management. This approach helped engage a range of vendors for each effort, each specializing in that field, improving the quality of deliverables and increasing efficiency in procurement timelines. The sum of the four projects or parts has been much more effective at identifying key areas of integration and research for future exploration.

The City of Philadelphia (City) received a $2 million award in the first round of USDOT SMART grant funding for the Philadelphia Digital Right-of-Way (ROW) and Mobility Improvement Project (referred to as the Project). The Stage 1 Project is a 112-block area located within the City of Philadelphia, PA, Urbanized Area (UZA) in Congressional District PA-03 (see Figure 1) and is situated in the eastern portion of Center City. The Project area is bounded by Spring Garden Street to the north, South Street to the south, Broad Street to the west, and 6th Street to the east. The boundary is primarily guided by three factors: constrained curb and ROW access, economic conditions, and travel patterns. The Stage 2 Project area will cover the entire City.

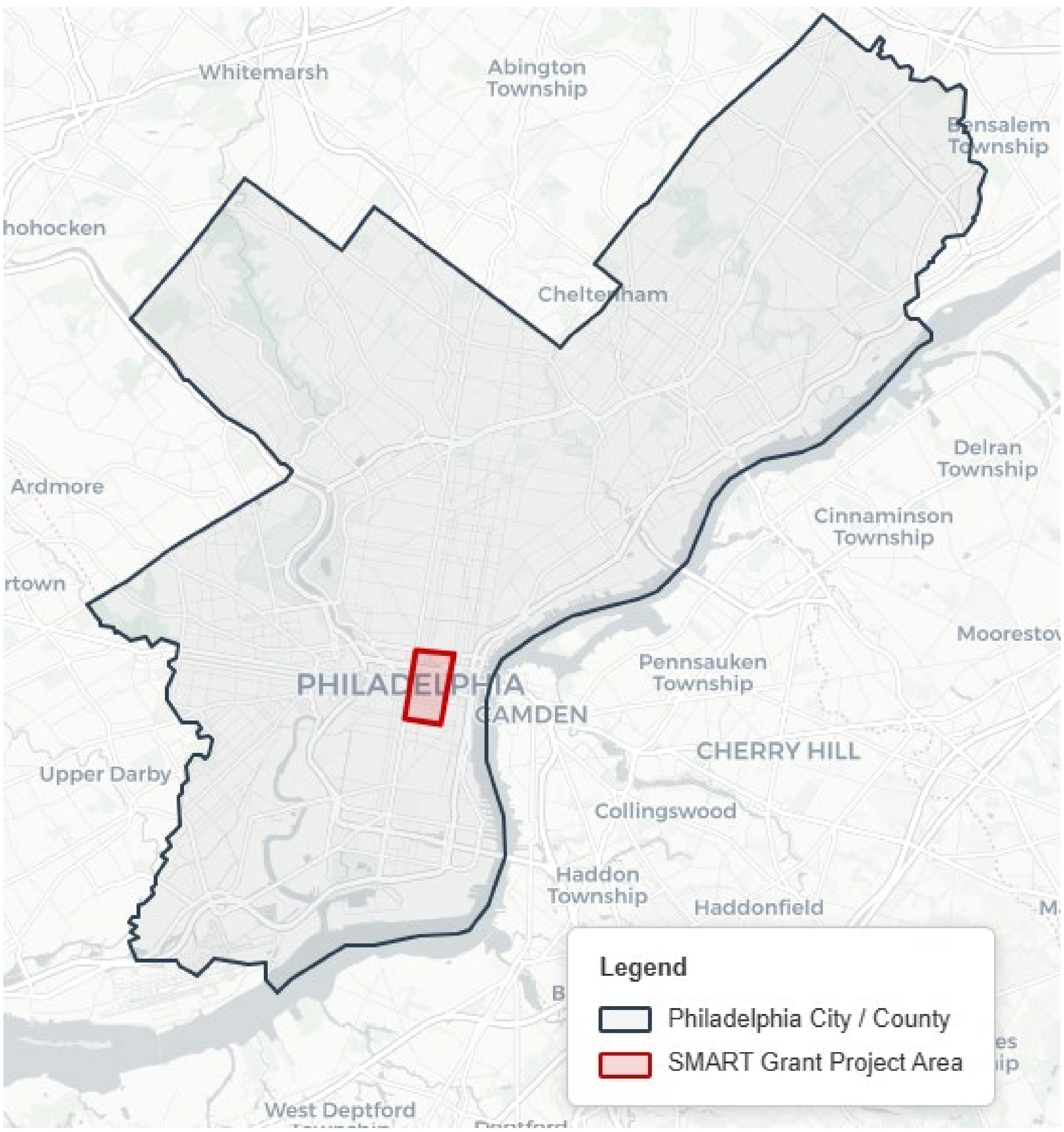

Figure 2. SMART Grant Stage 1 Pilot area in downtown Philadelphia. Source: Smart Cities

USERS AND CHALLENGES

Inspiration for this Project comes from lessons learned in another project. The City of Philadelphia's Smart Cities team conducted a six-month pilot project in Fall 2022 called the Smart Loading Zone Pilot Project[2]. This pilot project successfully demonstrated the use of digital technologies that enabled users to reserve and access a loading zone via mobile applications. The regulatory agencies were able to digitally inventory, visualize, modify, publish, and enforce regulations for 22 loading zones in the pilot area using a web application. They were also able to gather data about who used the loading zones and for how long.

One of the most important findings of this pilot project was that regulating agencies must rethink who the target users of a digital ROW ecosystem are. The pilot project team recommended a pivot to reorient the **target user** group from "curb-space" users to **"right-of-way" users**: drivers of all types, pedestrians, cyclists, and contractors and others conducting work in the ROW Such a pivot would allow regulating agencies to address a broader set of city functions (e.g., not just loading but also other curb uses and uses beyond the curb) using the same or similar technology platforms. This would also allow the "market" to develop more robust solutions with larger addressable markets, leveraging economies of scale.

The **target user** for this Project is not just someone trying to park in the parking lane or a loading zone. The **target user** also includes someone seeking a parking lane closure to load food into their cafe, someone requesting a block party permit to restrict all vehicular traffic for a few hours, or a plumber seeking a sidewalk closure to access the service line under the sidewalk. The reason for choosing a broad cohort of ROW users as the **target user** group is that each of them is trying to perform the same function: reserving ***a small part of the ROW for permissible use for a limited time.***

This broader cohort of **target users** has traditionally been engaged and managed through separate agencies and workflows. In Philadelphia, parking functions are managed by the Philadelphia Parking Authority (PPA), and street-closure permits and regulatory functions are managed by the Streets Department. Together, these are referred to as "regulating agencies." These regulating agencies use separate systems, and in an analog world, this has worked well. To bring about further operational efficiencies, both agencies have independently implemented digital systems that mirror their analog workflows, such as payment portals and mapping services. But in the digital world, economies of scale can be leveraged to bring all **target users** *and* regulating agencies to the same system and deliver an entirely new, and much better, user experience. This Project is an attempt to do so by solving some complex technical challenges using new technology implementations and evaluating such implementations against real-world use by **target users** in a small pilot geography.

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[2] https://www.phila.gov/media/20250106140146/Pilot-Eval-Report-_Final.pdf

The Project focused on solving **four (4) technical challenges** and used four (4) separate procurement efforts to address each challenge. These four challenges are as follows:

1. **Data Topology and Process Map** – The first and most important technical challenge was creating a new *data topology*: a way to digitally map different parts of the Right-of-Way at a resolution that meets the operational needs of regulating agencies and improves the user experience for all stakeholders. Although the City and partners initially set out to create a new data topology, **the Project efforts ultimately led to the development of an entirely new data specification: Right of Way Data Specification (ROWDS)**.

2. **Smart Right-of-Way (ROW) Software** – Data is only as good as its usability; the City uniquely worked with two major software providers in the curb/ROW management space, with one (Arcadis) generating ROW data and the other (INRIX) ensuring the usability of that data and ingesting it into Road Rules, **proving that a Software-as-a-Service could be customized to enable real-time visualization and editing for not just the curb but the entire ROW**, at the operational resolution and spatial granularity necessary for digital ROW management (as opposed to just curb management), all within a very short timeframe.

3. **Digital Signages** – The ROW Software, as configured and customized by INRIX, showed that City ROW managers could view and edit ROW policies in real time via an API; the Digital Signages demonstrate that this or a similar API can be used to **display ROW policies in real time to the public**. At the outset of the Project, the status quo was that a curb or ROW user needed to read through *all* policies displayed on physical signs and then correctly interpret that signage to determine whether their intended use (usually parking) was permissible at that time and place. The Digital Signages demonstrated an attempt to remove such ambiguity by showing 1) the current policy, 2) the next upcoming policy, and 3) any *overriding* policies based on closures, events, and permits.

4. **Next Gen TSP** – This proof-of-concept pilot tested whether a centralized, cloud-based system could work in the Philadelphia environment. The City successfully upgraded 80 controllers that meet the standards required to implement this type of Next-Gen TSP and tested the new system on one transit corridor.

These four technical challenges have been strategically crafted to ensure a robust, sustainable set of solutions that deliver real value for all stakeholders and enable multiple vendors to participate in supporting federal and local curb and ROW access goals.

OMF COLLABORATION & PARTNERSHIPS

A key and unique part of the Project was the collaboration with other cities to develop strategies, plan deployments, and conduct evaluations on Curb Management. In SMART Grant Stage 1, these efforts are formally supported by the Open Mobility Foundation (OMF) for Philadelphia and other cities. The value of this collaboration cannot be overstated. Efficient, coordinated communication and consulting support for technical challenges were of great value to the Project and to ensuring that lessons learned by one city were shared across other cities, obviating, to a large extent, any need to "reinvent the wheel."

Going beyond this effort, the Open Mobility Foundation (OMF) will also be a close partner in Stage 2 or any other future endeavors in this area, leveraging its membership and open-source software development expertise to advance ROWDS to a level of maturity that enables adoption by a number of cities and companies for operational deployment in the near future.

This Project set a very high benchmark among infrastructure projects in terms of speed, efficiency and the levels of collaborative work produced. Within the City of Philadelphia and its partners, four agencies worked together to deliver the Project. Further, at least six vendors, including one nonprofit (OMF), were onboarded to provide technology and project coordination support.

In addition to OMF, Stage 1 partners included the OMF-led SMART Curb Collaborative cohort (**Boston**, **Buffalo**, **Los Angeles**, **Miami-Dade County**, **Minneapolis**, **Portland**, **San Francisco**, **San José**, and **Seattle**); **Arcadis** with subconsultants **Cambridge Systems** and **Cyclomedia**; **INRIX**; **LYT**; and **SenSen**. City of Philadelphia participants included the **Streets Department**, the **Office of Innovation and Technology**, the **Office of Transportation and Infrastructure Systems**, the **Managing Director's Office**, and the **Southeastern Pennsylvania Transit Authority** (SEPTA).

PROJECT ACTIVITIES

Stage 1 was organized around four distinct technical workstreams, each procured separately: Data Topology and Process Mapping, Smart Right-of-Way Software, Digital Signages, and Next-Gen Transit Signal Priority. The first three were sequentially dependent. Data topology and data generation needed to be completed (to an extent) before Road Rules could ingest it, and data had to be QA/QC'ed and fully understood before it could be displayed to the public on Digital Signages. Meanwhile, TSP represented a parallel proof-of-concept within the same geography. The milestones table below documents the planned and actual completion dates for each major phase of work across all four workstreams.

The dominant theme of the project timeline is procurement. The first vendor contracts were not conformed until Q4 2024 and Q1 2025, and substantive vendor work did not begin until January 2025. This compressed the *active* implementation phase to approximately eleven months within a 27 month performance period. Table 1, below, documents where delays originated, how timelines were revised across successive quarterly reports, and where the project ultimately landed relative to its original milestones. The performance period extension through December 2025, granted by USDOT, was the mechanism that allowed all four workstreams to reach minimum viable product by the end of the Project Performance Period.

Table 1: Key Stage One Milestones

#	STAGE ONE MILESTONE	PLANNED COMPLETION	ACTUAL COMPLETION	MILESTONE COMMENTS
1	Complete City-side grant profiling	Q4 2023	Q4 2023	Profiling completed January 4, 2024 within one month of planned date.
2	Post RFPs Data Topology and Process Mapping, Smart ROW Software, TSP Enhancement	Q4 2023	Q2 2024	Approximately five months delayed due to extensive compliance and procurement coordination across multiple City departments navigating *direct* BIL grant requirements for the first time.
3	Select vendors	Q4 2023	Q3 2024	Selection committees comprised of Subject Matter Experts from OIT, Smart Cities, CityGeo, Streets ROW Unit, OTIS, and Streets IT evaluated finalists for all three RFPs and identified first-choice vendors Arcadis, INRIX, and LYT.
4	Conform contracts	Q1 2024	Q4 2024 - Q1 2025	Contract negotiations were protracted by internal process discussions between multiple City departments on BIL contract provisions and best method for handling negotiations. INRIX conformed Q4 2024; LYT and Arcadis conformed Q1 2025.
5	Vendors and City commence work on Data Topology and Process Mapping, Smart ROW Software, and TSP Enhancement	Q2 2024	Q1 2025	Kickoff meetings held and biweekly project cadence established with Arcadis and INRIX in January 2025. Work commenced approximately eight months behind original schedule and more than a year after signing of Grant Agreement.
6	Procure Digital Signages	Q4 2024	Q2 2025	Procurement pathway shifted from Best Value RFP to Office Automation reseller bid. Digital Signages ordered Q2 2025, delivered Q4 2025.

#	STAGE ONE MILESTONE	PLANNED COMPLETION	ACTUAL COMPLETION	MILESTONE COMMENTS
7	Deploy and integrate all technologies (Smart ROW Software, TSP Enhancement, Digital Signages, Signal Upgrades)	Q3 2024	Q4 2025	Data Topology and ROW Software went from *vendor* QA/QC in Q3 2025 to demonstration of minimum viable product version of Road Rules and hosting of ROWDS on OMF's GitHub in Q4 2025; Digital Signages bench tested, policies templatized, and deployed Q4 2025.
8	Complete community and stakeholder engagement	Q3 2024	Q4 2025	City did not complete extensive *public* community engagement but did complete stakeholder engagement both through discussions with peers at conferences and convenings and through the Process Mapping aspect of Arcadis' work with Streets Department.
9	Complete evaluations	Q3 2024	Q4 2025	Completed evaluations of ROWDS, audited vendor data, evaluated ROW management capability in Road Rules, and evaluated Digital Signages' ability to display curb and ROW policies dynamically. City staff continued these efforts through the end of the reporting period.
10	Final Stage 1 concluded and prepared for scale-up	Q1 2025	Q4 2025	Minimum Viable Product of each technology established and evaluated in or before Q4 2025. "Technologies" *exceeding* MVP by this time: Right of Way Data Specification.

MEDIA AND PUBLICATION

Through the City's partnership with OMF and several partner agencies, the Project has been presented at the following public webinars and in-person presentations:

- Transportation Engineering and Safety Conference (TESC) – Data Driven Solutions in Southeast PA – presented on December 11, 2024 at Penn State University, Collegeville, PA
- Transportation Research Board (TRB) Annual Meeting Working Breakfast – Data in Motion: Defining the Right-of-Way – presented on January 7th 2025
- Intelligent Transportation Society of America (ITS America) World Congress, Atlanta - https://www.itsamericaevents.com/world-congress/en-us/program/full-program/full-program-details.4398.243103.usdot-lessons-learned-from-the-smart-grants-program.html - presented on August 26th 2025.
- GeoExchange – Local program that brings together GIS professionals from the City of Philadelphia – presented on October 9th 2025.
- Central Philadelphia Development Corporation – Transportation and Infrastructure SubCommittee – presented on July 15th 2025.

Below is a list of media and publications related to this project:

- https://www.phila.gov/2023-03-22-city-receives-usdot-smart-grant-for-smartcityphl-project/
- https://www.openmobilityfoundation.org/showcase-philadelphia/
- https://transportationtodaynews.com/news/29982-philly-receives-smart-grant-from-u-s-department-of-transportation/
- https://inrix.com/press-releases/philly-right-of-way/
- https://www.phila.gov/media/20250106140146/Pilot-Eval-Report- Final.pdf

CHANGES FROM ORIGINAL PROPOSAL

The Stage 1 Project achieved its three primary goals. The manner in which those goals were achieved differed from the original proposal in several important respects, described below.

- **Performance Period Extension:** The original performance period ran from September 2023 through March 2025. The City received an extension through December 2025 to accommodate delays described below.

- **Procurement Delays:** The most significant departure from the original proposal timeline was a delay of approximately six months in completing vendor procurement. As the first *direct* federal grant received by the City of Philadelphia under the Bipartisan Infrastructure Law, the Project required multiple City departments to review the Grant Terms and Conditions to ensure simultaneous compliance with grant terms and City contracting and procurement procedures. These processes required extensive coordination between the Law Department, Procurement Department, OIT's Contracts Unit, The Office of Economic Opportunity, and Streets Department, and were not fully resolved until April 2024, or *six months* into the performance period.

- **Arcadis/INRIX Schema Pivot:** The original proposal contemplated generating ROW data directly in a new data topology to be developed in Stage 1, and then demonstrating and operationalizing that topology through software. Due to the aforementioned contracting and procurement delays, the Project team made a deliberate pivot: Arcadis generated ROW data in INRIX's Road Rules schema (rather than a to-be-developed ROWDS schema) in order to enable timely demonstration of the Road Rules platform within the performance period. Arcadis independently drafted ROWDS, and the City independently, but with substantial input from Arcadis, converted the Arcadis-generated data into ROWDS format. This pivot had the unintended benefit of producing two independent versions of the data – one in INRIX schema and one in ROWDS – which together demonstrate the interoperability potential of an open standard.

- **ROWDS as an Emergent Deliverable:** The original proposal described the goal of creating a "data topology." The result exceeded this goal: the City, in collaboration with Arcadis, INRIX, and the Open Mobility Foundation, developed ROWDS: a full data specification with defined endpoints, field definitions, data types, and example implementations. This was not anticipated in the original proposal and represents a significant additional deliverable.

- **Digital Signages Scope:** The original proposal contemplated approximately 30 digital signages. The City procured 40 signs and deployed 38. Two are held in reserve for any additional configuration/display testing and as potential replacements in case any of the deployed units are damaged or require long-term maintenance or repairs. One important and valuable unintended benefit of having *anything* resembling a singular dataset about the configuration of the ROW and ROW objects (albeit only in INRIX' Road Rules schema at the time) was the ability for City staff to heavily lean on that initial as-generated ROW data in the process of developing a siting model for the signs.

- **Community Engagement:** The original proposal and Evaluation Plan contemplated *public* community engagement activities including feedback mechanisms and possible collaboration with local academic institutions. These activities were not conducted within the performance period due to resource constraints and the prioritization of technical deliverables. This represents a gap relative to the original proposal that should be addressed in Stage 2.

- **University Partnership:** The original Evaluation Plan referenced possible collaboration with a local academic institution. The University of Washington's Urban Freight Lab participated in the SMART Curb Collaborative, and Philadelphia delivered its intermediate data in Curb Data Specification format as retrieved from INRIX' APIs to the Urban Freight Lab. No local academic partner was engaged for the Philadelphia project within Stage 1.

PART 2: PROOF-OF-CONCEPT / PROTOTYPE EVALUATION

Because there are four separate technical challenges addressed here through four different technologies and development paths, it is critical to examine each in its own context before evaluating their performance.

DATA TOPOLOGY AND PROCESS MAP

Before diving into the data topology efforts and the resulting prototype specification, it is important to clarify the resolution or spatial granularity currently used by the City's regulating agencies and partners. Both street closure permits and metered parking spaces operate on a cost-per-foot-of-a-lane and per-unit-of-time basis. For instance, a parking lane closure is charged at $2.50 per foot per week (for businesses and contractors). The following rate chart in Table 2 shows costs for different types of lane closures using a similar resolution.

Table 2. Lane and Full Street Closure Schedule for the City of Philadelphia (Businesses and Contractors only). Source: https://www.phila.gov/services/streets-sidewalks-alleys/street-closures/apply-for-a-street-closure-permit-for-construction/

Closure type	Rate – Center City or University City	Rate – Other areas	Maximum duration
Parking lane closure	$2.50 per foot per week*	$1.50 per foot per week*	1 year
Travel lane or bicycle lane closure	$3.50 per foot per week*	$2.00 per foot per week*	1 year
Full closure – 5 days or fewer	$250 per block per day	$250 per block per day	5 days
Full closure – More than 5 days	$1,500 per block per week**	$750 per block per week**	1 year

Further, it is important to define what is meant by *data topology* in the context of the Project, what the state of the City's data topology was at Project outset, and how the Project laid the groundwork for a much more granular topology.

A *data topology* is the way a data set defines the structure of the information it aims to capture. For instance, the data topology for a data set showing the location of electric poles could be points on a map, but if a data set needs to capture tree canopies, the appropriate data topology will be a circle or polygon tied to a point. Currently, the City's regulating agencies and partners use a "Street Centerline" dataset that has a data topology limited to representing a street's entire width and length with a single line. In other words, if a request for a parking lane closure of 15 feet and a sidewalk closure of 5 feet were to be made for the same time and day on the same block, both users would have to select the same street centerline representing the entire block's length and width.

Then each user would have to use words in an open text field to describe the exact location for which they are seeking closure, and the regulating agencies would have to interpret that text to determine exactly where on that block the user needs or wants a closure. This process is inherently prone to input errors, miscommunication or misinterpretation, and a great deal of subjectivity in a process that should be, in theory, entirely objective.

The City worked with Arcadis and its partners, Cambridge Systems and Cyclomedia, to develop a new data topology that supports capturing information at a spatial granularity or resolution of "*per lane, per foot*," enabling regulatory agencies to receive a user's request with the precise geography for which they intend to seek a closure. The outcome is the development of ROWDS, a new "recipe" for structuring ROW data.

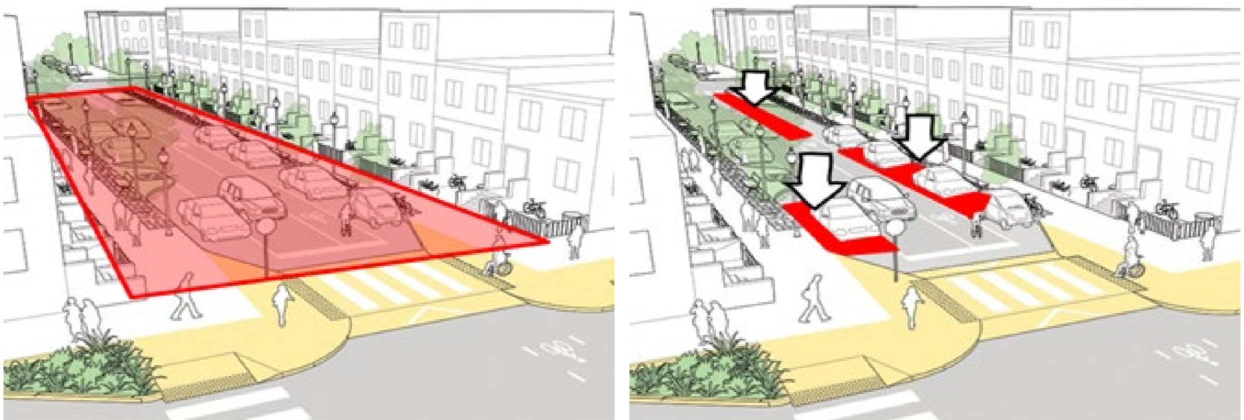

Figure 3. Comparing existing and Future Data Topologies in terms of Spatial Granularity. Source for the underlying image of streetscape: https://nacto.org/wp-content/themes/sink_nacto/views/design-guides/retrofit/urban-street-design-guide/images/neighborhood-street/neighborhood-street-1.jpg

The original intent of the Project was for the selected vendor to demonstrate the use and applicability of this new data topology by mapping the ROW data for the selected pilot area and delivering it to the City in a standard digital format aligned with the new data topology. However, due to delays primarily related to procurement, shifting timelines required a pivot to having Arcadis and Cyclomedia map the Pilot Area into INRIX' Road Rules schema (more on this later) to enable the timely production of an updated version of Road Rules.

The goal of this effort was not to replace the "Street Centerline" dataset currently used by the regulating agencies, but to complement it and enable new, strategic ways to use digital technologies to improve user experiences. The Project has successfully demonstrated that it is possible to generate such a complementary dataset in a very short timeframe and with extremely constrained resources.

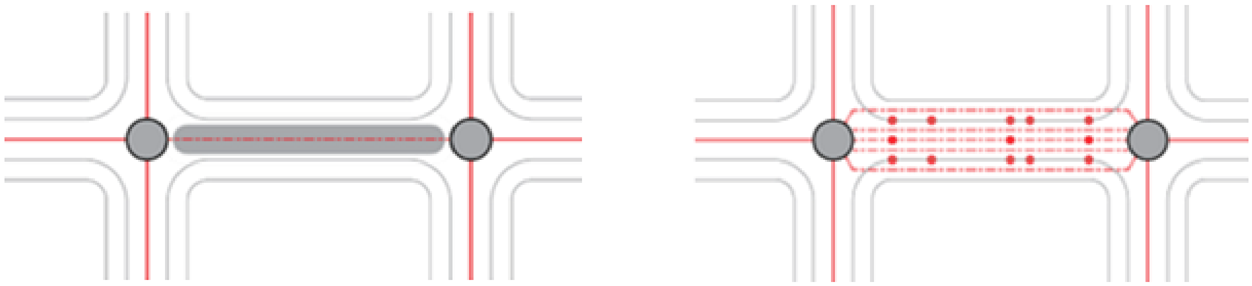

Figure 4. Current and future data topologies. Using a single line, the current Streets Centerline data (left) represents the travel lanes between two intersections. The Project aims to develop a new data model (right) to capture travel lanes, parking lanes, bike lanes, sidewalks, light poles, signposts, fire hydrants, trees, and other physical assets that the City must track and monitor. The focus of this new data model will be to enable the digital management of regulations based on asset location. Source: Smart Cities

The City had three goals for this portion of the overall Project:

- Establish the topology of a new base map to precisely capture events along each sidewalk, parking, travel, or bike lane;
- Assess existing processes that interact with ROW-based information;
- Develop an understanding of how technologies deployed in the rest of Stage 1, and ultimately in Stage 2, must publish information to avoid heavily disrupting legacy systems and processes.

A key goal of the Data Topology and Process Mapping work was to expand data fields and the related data intake, management, and publication processes for those fields beyond what was already covered in the Open Mobility Foundation's (OMF) Curb Data Specification (CDS). With the inception of ROWDS, the City and Arcadis added fields missing from CDS in its current state, extending it to parts of the ROW beyond just the curb. This goal was based on lessons from the Smart Loading pilot: namely, that the digitization effort must not be limited to the curb to make it operationally relevant to the Streets Department and certain other agencies.

The City and Arcadis reviewed available data sources, and Arcadis and its partners conducted open-data extraction from a variety of sources, including OpenStreetMap and OpenDataPhilly, resulting in a detailed **Existing Conditions and Gap Analysis Report**. To collect any missing ROW data, Arcadis relied on Cyclomedia's pre-existing imagery of Philadelphia's ROW to generate a highly granular, up-to-date ROW inventory. Curb-level surveying methodologies were used for on-site data verification and quality control. Arcadis then led the effort to define a comprehensive ROW Data Topology. Finally, Arcadis and Cambridge Systems extracted insights from the Existing Conditions and Gap Analysis Report to develop recommendations and guidelines for integrating the new ROW dataset into the City's workflows and departmental processes.

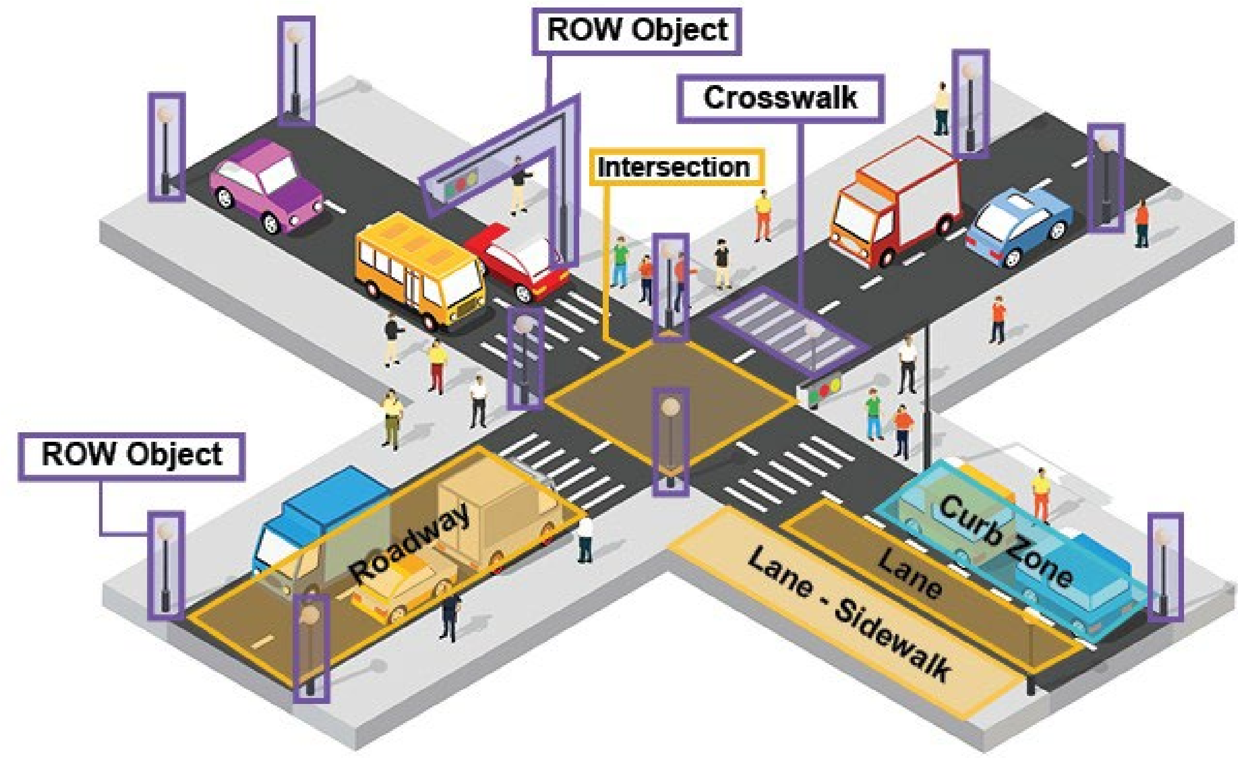

Figure 5. Visualizing Right-of-Way Data Specifications. Source: Smart Cities

The deliverables from the Stage 1 Data Topology and Process Mapping were:

- **Cleaned ROW Datasets for Analysis**: all existing datasets related to the ROW were cleaned using Open Data Automation (ODA) processes, ready for completion of existing conditions and gap analysis.
- **Existing Conditions and Gap Analysis Report**: a detailed report highlighting the existing conditions of the ROW data, what information was still missing or unusable, and recommendations to fill the gaps in this missing data.
- **Extracted ROW Data for Missing Information**: a complete database of extracted ROW data from Cyclomedia imagery, to help both verify existing ROW datasets and fill in any gaps in the data identified in the deliverable above.
- **Verified Existing ROW Data**: verification that existing ROW data was accurate in select locations of the project area.
- **A Comprehensive ROW Data Topology**: a robust data standard with relevant formats, attributes, and definitions, to define the ROW and all associated information, assets, and infrastructure - ROWDS. This includes relevant documentation defining the standard.
- **Complete ROW Dataset in the Defined Data Topology**: all collected and existing data in the defined ROW data topology.

- **ROW Data, Software, Processes, and Integrations Report**: a comprehensive report outlining all the City processes and software that deal with ROW data, an assessment of how automated and digital these areas are, and recommendations on how to update these methodologies to accommodate the new ROW data.

The Data Topology and the Process Map were compiled for the Stage 1 Project area only. However, scaling up the methodology and incorporating the lessons learned in Stage 1 should not be cost-prohibitive in Stage 2 or any similar scope expansion for two primary reasons: the first giant leap of creating a new data specification is already complete, and it now need only be tweaked as the City scales the *amount* of data living in the specification's format; and the proportion of overall work that will need to be done by vendors should shrink versus the proportion that should be handled by the City directly.

For more on the Data Topology and Process Mapping aspect of the Project, see the file *Arcadis – ROW Data Typology and Process Mapping – Final Report.pdf*, included in the same dataset as this report.

SMART RIGHT-OF-WAY SOFTWARE

The original intent of the Project was to first develop a comprehensive data topology and then deploy it through software tools that enable regulatory agencies and the general public to interact with this topology and test digital management of the ROW. However, due to the aforementioned delays, a pivot was also required. In conjunction with the City's professional services partner, Arcadis, and the City's software vendor, INRIX, a decision was made to prioritize showcasing *a version of a granular dataset* using **INRIX's Road Rules platform**. Since the Project Team anticipated that developing the full ROWDS specification would take substantial time on its own, INRIX provided its Road Rules schema, and Arcadis prepared the initially generated ROW data into that format. INRIX then ingested that data and demonstrated the ability to display it interactively through Road Rules.

*Of the above, a **fully functional version of Road Rules,** enabling regulating agencies to visualize, monitor, edit, and publish ROW regulations, was achieved within the Project performance period.* Both the City and Arcadis had snippets of the Project area in some version of ROWDS within the Project performance period. The City has continued to refine its own version of the data in ROWDS since the end of the Project performance period, through ongoing conversations with Arcadis, INRIX, and the OMF.

Figure 6. Road Rules Demonstration: Lane-level mapping and editing; Tagging of impacted Geo-assets. Source: INRIX

At a minimum, a *prototype* of each of the other items was also established, as follows in Table 3 below:

Table 3: Desired Capabilities and Results for ROW Management Software

DESIRED CAPABILITY	RESULT
Digitization of all assets and regulations using an open-source specification developed in partnership with the OMF.	**Achieved.**[3] The City developed a full dataset on its own in ROWDS format based on the data as-generated in a variety of other sources, including INRIX' Road Rules schema. In the future, INRIX could either ingest into Road Rules directly from ROWDS, or could back-port ROWDS data into INRIX' Road Rules schema.
A platform (web application) for regulating agencies to visualize, monitor, edit, and publish the ROW regulations	**Achieved.** See above and in various markdown files in *ROWDS Examples.zip* in the same dataset as this report for details about the version of Road Rules that was developed.

[3] The data is in ROWDS format and has been QA/QC'ed by City staff post-transformation processes, but given the limited resources dedicated to this task, the portion of the data QA/QC'ed is on the order of magnitude of five-ten examples of each ROWDS asset or endpoint type. It is not at a level where it could be operationalized without risk. The City is embarking on an entirely separate Automated Pavement Inspection Solution project that will present a near-term opportunity to further QA/QC the SMART data, and further populate the ROWDS data prototype.

DESIRED CAPABILITY	RESULT
A publicly accessible web application to allow **target users** to seek closures and parking permits while communicating precise locations and enable regulating agencies to receive such requests through existing systems for approval	**Prototyped.** Target users could use Road Rules with different permission levels and settings, and potentially a slightly modified User Interface. Due to time and resource constraints, and the aforementioned required pivot(s), the Project could not have members of the *public* test for this purpose.
Integration using APIs into existing digital systems being used by regulating agencies	**Prototyped.** The City was able to directly query INRIX' APIs for ROW feature IDs or a variety of geometries and receive payloads of requested relevant information. The Project identified a variety of existing City systems that could integrate with these APIs in a scaled-up deployment.

Through the ROW Software component of the Project, INRIX configured its existing SaaS solution, Road Rules, to visualize the locations of street-level assets such as signals, crosswalks, parking meters, trees, travel lanes, pavement, and other relevant assets. During Stage 1, INRIX worked with the City to configure its software to meet the City's use cases and needs, specifically in the following areas:

- **Collaborative Software Development**: This process included direct feedback from City staff on product direction, technical product, and engineering development, as well as requirements for configuration based on the assets and formats developed during the Data Topology and Process Mapping process. This process concluded with the successful ingestion and integration of said data sets into Road Rules. Working with both Arcadis and INRIX, the City finalized the list of ROW asset/object types that were to be tracked throughout the implementation phase.
- **Vendor SaaS APIs**
  A key element of this effort is the ability to disseminate ROW information to third parties, the public, and to City-managed digital assets like signage, etc. At Project start, INRIX' Road Rules could already transform some ROW features and policies into standardized APIs. By Project end, INRIX was able to operationalize this data such that City staff were able to edit ROW assets (e.g. lanes) and policies in Road Rules.
- **Evaluation**
  The vendor will work with the City to deliver a final Stage 1 Pilot Report including a summary of pre-defined metrics and lessons learned during the Stage 1 implementation. The vendor will also deliver all Stage 1 data to the City in agreed-upon formats comporting with the Data Management Plan.

For more on the Smart ROW Software aspect of the Project, see the file *INRIX – Philadelphia Digital ROW Tech Report.pdf*, included in the same dataset as this report.

DIGITAL SIGNAGES

The ROW Software procured through the Project will enable the digital publishing of regulations and curbside uses through open-source public APIs (Application Programming Interface or a link to communicate with software technologies over the internet). The goal of the Digital Signages aspect of the Project was to use the published digital curbside regulations and display them on the curbside using digital signages on e-ink displays.

Figure 7. A Digital Sign on South 8th Street. In this image, taken before 8 AM, the sign is displaying a parking policy that the curb user would typically have to infer: *that parking is free outside the hours stated on the analog sign. Source: Smart Cities*

The City worked with SenSen and their partner Mercury Innovation to scope, site, install, and test 40 Digital Signages. It is worth highlighting that the siting process incorporated some of the new data generated under the other aspects of the project. The data from Arcadis and Cyclomedia, however raw or unaudited it was at the time the siting process began, was invaluable in terms of identifying curb zones with complex policies where signs with dynamic displays would add the most value for the curb user. This process would have taken much more time, possibly leading to a cancellation of the entire Digital Signages branch of the overall Project, if Smart Cities had needed to rely on extant data sources about curb policies and sign locations.

The siting model was as follows: within the Project area, any curb zone with more than one parking policy was considered for evaluation; curb zones that only have one policy, e.g. “No Stopping Any Time” are not useful candidates for displaying curb policies dynamically. Sites (individual poles upon which Digital Signages could be mounted) were scored as follows in Table 4, with binary scoring for each criteria:

Table 4: Digital Signages Siting Model

CRITERIA	SCORE
More than two policies	1
Sign post not damaged	1
Solar: not in shadow of tall building	1
Solar: not under tree	1

Then, Smart Cities looked through each block face, evaluating both the average score of the sites along the block face as well as the total number of sites at each block face, desiring to give blocks with multiple curb zones and complex policies a “complete treatment” rather than favoring blocks with e.g. only two perfect-scoring sites.

The Digital Signages vendor, SenSen, advised the City to consider eliminating east-west running streets from the model due to concerns of solar availability. Smart Cities in part included the signs along east-west running Arch Street to challenge this notion; it was deemed better to discover whether this was indeed an issue during Stage 1, before scale-up. The two blocks of Arch Street were also chosen in part due to the overall limited universe of blocks in the Project area with multiple viable sites *and* a complex array of policies. As of the time of this writing, no major solar availability concerns have surfaced.

All but one of the requirements for the Digital Signages were achieved or partially achieved, as outlined in Table 5 below:

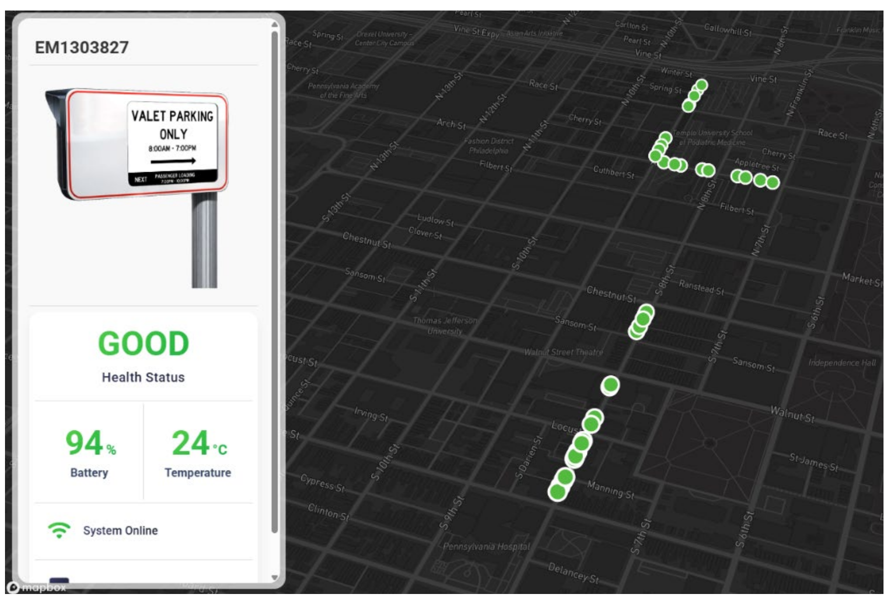

Figure 8: The Digital Signages SaaS portal. Shows the status of a device on South 8th Street, as well as a map showing all devices functioning. Source: SenSen

Table 5: Desired Capabilities and Results for Digital Signages

DESIRED CAPABILITY	RESULT
Ruggedized and rated for outdoors and vandalism-resistant	**Achieved**. The e-ink signs procured and installed during Stage 1 are rated for outdoor deployment and were selected in part for their durability characteristics. There have been no incidents involving impact or vandalism up through the date of this report, but the devices contain accelerometers so both the vendor and City staff will know if and when such incidents occur and will be able to document it.
Powered by photovoltaic cells or some other source of durable independent power	**Achieved**. The signs are solar-powered, eliminating the need for hardwired electrical connections and enabling flexible siting without utility coordination. The vendor noted that the devices may not receive enough sunlight on east-west oriented streets, and the City deliberately sited some of the devices on Arch Street to test this. No device has yet displayed any lack of function due to solar or power constraints.
Cellular modem	**Achieved.** The signs communicate via cellular modem, enabling remote content updates without physical access to the sign.
Capable of displaying a live-updating web-page	**Not Achieved.** The signs, for the time being, display pre-rendered templates encapsulating all curb policies for the sites at which the signs are deployed. True real-time updating of the information on the signs requires a much higher refresh rate and therefore significantly more data usage than was scoped for this portion of the Project.
Dashboard or other interface allowing City personnel to monitor status of signs on an individual basis and by specific location or designated area	**Partially achieved.** A monitoring and editing interface was provided as part of the Stage 1 deployment, and the City can use the portal to deploy templates on a per-location, at- specified-times basis, with the ability to "override" standard policies, e.g. when there is a temporary closure for an event. Full integration of a workflow starting with the Master Lane Closure API and outputting to the sign displays was not completed during Stage 1 and should be scoped for Stage 2.

Such signages reduce the amount of information a user needs to read since only time-relevant regulations will be displayed. These signages also improved accessibility to digital tools since not everyone has a smartphone, smart vehicle, or the requisite level of digital literacy to consume the digital regulations the ROW Software will publish online.

Figure 9: A view of the Digital Signages display templates in the vendor's portal. These are the templates for a Digital Sign sited at a curb zone with six different policy rollovers throughout the week. Source: SenSen

TRANSIT SIGNAL PRIORITY ENHANCEMENTS

The City, in partnership with LYT, deployed innovative transit signal priority (TSP) communication technology to enhance transit operations in conjunction with digital ROW management improvements. The City's current TSP system is outdated, analog and effectively obsolete. In the time since the previous TSP installation, breakthroughs in technology such as large-scale data processing, GPS tracking, and interconnected signal platforms have developed, changing the landscape for TSP. These advances will allow the City and SEPTA to develop new, innovative strategies for implementing TSP in a manner that ensures faster and more reliable service. Bus riders represent over half of SEPTA's total ridership, and the majority of SEPTA operations are within Philadelphia. With this logic, TSP improvements have the potential to affect 100+ million bus trips per year when deployed at scale. Additionally, advanced TSP has the potential to help streamline traffic operations more broadly, saving time for all road users.

The goal of the Next-Gen TSP proof-of-concept was to test whether a centralized, cloud-based system could work in the Philadelphia environment. The City has successfully upgraded 80 controllers that meet the standards required to implement this type of Next-Gen TSP. On January 12, 2026, the City and its Next-Gen TSP vendor for this project, LYT, successfully showed through a field test that the LYT system can connect and communicate with the upgraded controller.

LYT connected to real-time transit vehicle location data using SEPTA’s transit data platform, Swiftly. The connectivity is 100% with zero disconnections since gaining access. The LYT system is capable of providing key performance measurements such as arrival-on-green/red, signal delay, and TSP success. These measures can be compared and contextualized with analysis of SEPTA real-time vehicle data, which provides metrics such as speed (in 25-meter increments), corridor travel times, and bus bunching.

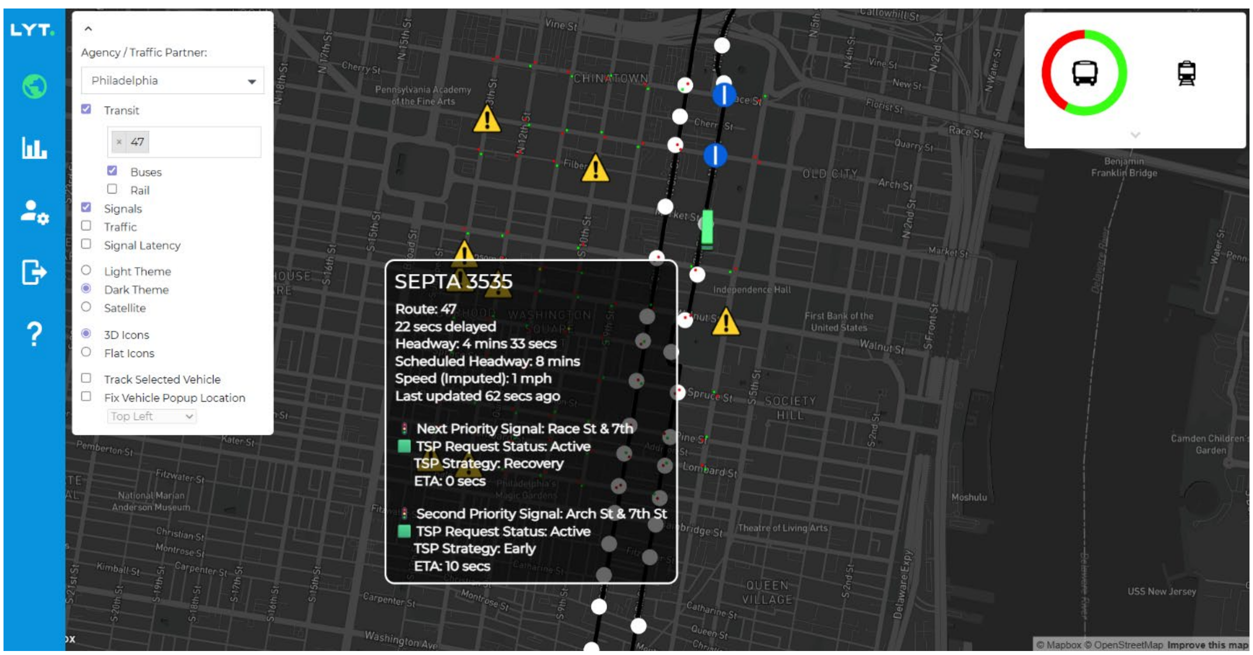

Figure 10: LYT's Transit Portal. Source: LYT.

It is anticipated that Stage 2 deployment would feature further integrations between not only TSP and the Smart RoW Software directly, but also between the TSP system and web-based applications built upon the underlying API developed throughout Stage 1 Project.

FINDINGS AND RELATION TO GOALS

The goal of this project was to find, deploy, and test a range of technologies that together could offer a system to digitally manage the ROW.

Table 6: Performance Measures, Targets, And Findings

EVALUATION QUESTION	PERFORMANCE MEASURE	PERFORMANCE TARGET	FINDINGS
Can a ROW basemap with granularity beyond the centerline level be established and integrated with new and legacy systems?	ROW managers' ability to add, alter, or query information about the ROW at a granular level	ROW managers report better user experience; enhanced data that can be queried through APIs	Achieved. A prototype ROWDS dataset covering the Center City study area was generated at lane-level granularity. City staff were able to view, query, and edit ROW asset and policy data through Road Rules. ROWDS data was made available via INRIX's APIs.
Safety and Reliability: Does availability of better data about the ROW lead to fewer conflicts?	# of conflicts, incidents, injuries, deaths in ROW in project area	Statistically significant reduction	Not yet measurable. No public-facing technology was deployed within the performance period.
Resiliency: Does better ROW data lead to better emergency response?	Congestion caused by sudden ROW changes; first responder routing ability	Reduced congestion; faster response times	Not yet measurable. See above. Integration with first responder systems was not completed in Stage 1.
Access: Does better ROW data improve transit outcomes for communities?	Community feedback	Community members report improved outcomes	Not yet measurable. Community engagement activities were not conducted within the performance period. TSP enhancements are anticipated to benefit bus riders, who are disproportionately from lower-income communities, but deployment occurred near the close of the performance period.

EVALUATION QUESTION	PERFORMANCE MEASURE	PERFORMANCE TARGET	FINDINGS
Pollution: Does better ROW data reduce transit-related emissions?	Instances of circling, idling	Statistically significant reduction	No baseline measurement of circling and idling was conducted by the City as part of the SMART Grant Project, but data about such behavior was collected as part of the previous Smart Loading Zone project, available at: https://www.phila.gov/documents/smart-loading-zones-project-materials/
Partnerships: Does better ROW data increase coordination between City agencies?	Feedback from City agencies and departments	Greater interagency coordination	Partially achieved. The Project involved active participation MDO, Streets Department, OTIS, and OIT. OMF coordination with the Curb Collaborative cohort provided regular inter-city knowledge sharing.
Integration: Can new and legacy systems integrate with a more granular ROW basemap?	Interoperability of legacy systems and Smart ROW software	Legacy systems and deployed technologies communicate with Smart ROW software	Partially achieved. INRIX Road Rules successfully ingested Arcadis-generated ROW data and demonstrated API-based data publishing. Direct integration with City legacy systems (permitting, event/road closure announcements) was prototyped but not fully operationalized within Stage 1.

DEMONSTRATED IMPROVEMENT IN STATUTORY AREAS

Stage 1 primarily delivered digital infrastructure, not operations. As a result, measurable improvements in most statutory areas are not yet available: no public-facing system was deployed, no before-and-after traffic or safety data was collected, and no legacy workflows were replaced. Stage 1 built the preconditions for statutory improvements that Stage 2 is designed to deliver. The four statutory areas highlighted below are the ones where Stage 1 made concrete, demonstrable progress rather than solely laying the digital groundwork, and even within those four, the improvements are best understood as directional and foundational rather than quantified.

(II) Improve the safety and integration of transportation facilities and systems for pedestrians, bicyclists, and the broader traveling public. The sidewalk lane model treats sidewalks as first-class ROWDS lanes rather than afterthoughts, and linking pedestrian ramps and crosswalk objects in one inventory represents a meaningful advance in how Philadelphia's pedestrian infrastructure is digitally represented. The permit validation workflow in the attached markdown files in this dataset at *ROWDS Examples.zip* is a concrete example of how ROWDS improves safety outcomes by catching misapplied ROW restrictions before they affect vulnerable users.

(VI) Improve the reliability of existing transportation facilities and systems. The TSP deployment and controller upgrades represent the most tangible reliability improvement delivered during Stage 1. Eighty upgraded controllers and a demonstrated LYT-to-controller connection are real infrastructure changes with real effects on bus performance.

(VII) Promote connectivity between and among connected vehicles, roadway infrastructure, pedestrians, bicyclists, the public, and transportation systems. This is the area where Stage 1 delivered most directly. ROWDS itself is fundamentally a connectivity specification and API-first data model designed to make ROW information machine-readable and consumable by any system that needs it. The prototype dataset, the Road Rules configuration, the Events API, and the Digital Signage deployment all represent concrete steps toward a connected ROW. This is the main statutory area in which the Project delivered results, but they are significant results.

(VIII) Incentivize private sector investments or partnerships. The Project directly engaged Arcadis, INRIX, LYT, and SenSen, as private sector partners, and did so under novel BIL procurement terms. Each of these partners, and many of their partners and subcontractors (with the exception of LYT) are in the Open Mobility Foundation orbit. Arcadis, INRIX, and SenSen (through its parent Blue Systems), are all expected to be naturally active participants in any further development of ROWDS as stewarded by the OMF. This framework sets Philadelphia and other OMF member cities up for success in terms of both 1) avoiding vendor lock-in and 2) building out this holistic ROW open-source, open data ecosystem in a way that provides access to the maximum number of players in terms of customizing existing applications and developing new applications for specific ROW-related use cases. A common, peer-reviewed, nonprofit-stewarded data specification and sample data also help set the stage for broadening the one- or two-way exchanges of information between municipalities and private sector operators in the automated vehicle, ride sharing, micromobility, and delivery robot arenas.

PART 3: ANTICIPATED COSTS AND BENEFITS OF AT-SCALE IMPLEMENTATION

Although the project area for Stage 1 represents a very small fraction of the city's area, most of the technologies being developed or deployed in the Project now have very small marginal costs for scaling to a citywide scope. The development of a robust street closure permitting system with the right operational resolution or spatial granularity is worth, on its own, millions of dollars in permit revenues for the city of Philadelphia. There are additional qualitative benefits of improved user experience for the public and City employees, the latter of whom will now be able to use the time they spent deciphering people's ROW-related requests to more creative or meaningful tasks.

Of the four technologies deployed in Stage 1, two are already applicable citywide even within the Stage 1 Project: Data Topology and Process Mapping work will create the "recipe" (schema) for citywide use and will not require further development or funding in Stage 2; the City will simply apply the new topology (ROWDS) to the rest of the ROW outside the Stage 1 pilot area. The City will explore other funding opportunities to support a larger rollout of TSP enhancements since they have high marginal costs and offer limited scope in supporting a digital ROW management ecosystem. A citywide at-scale implementation will only require about $10 million to cover the cost of critical system integrations with legacy systems that are sustainable and tested for vulnerabilities.

ANTICIPATED AND ESTIMATED IMPACTS OF AT-SCALE IMPLEMENTATION

At the citywide scale of implementation for the SMART Grant, only two of the four technologies should be scaled up: Smart ROW Software and Digital Signages. Because the Data Topology and Process Map consists of a recipe and a system-wide process map, its output is already citywide and does not require scaling. The goal of Next Gen TSP was to create a test case to seek funding from other sources, and it will not be continued as part of future phases of this Project.

Safety and Reliability:

Without having *operationalized* ROWDS or Road Rules beyond Stage 1, it would be speculative and inappropriate to venture a guess at the estimated *magnitude* of the impacts of at-scale implementation in the area of Safety and Reliability. However, in a binary sense (decrease, increase), it is anticipated that, at scale:

- Instances of conflict in the ROW between all ROW users would decrease
- Instances of conflict in the ROW between non-transit uses (e.g. the Philadelphia Water Department and the electric company both attempt to work on the same portion of roadway at the same time) would decrease
- Instances of conflict between transit and non-transit uses would decrease

Resiliency:

The integrations between legacy systems and the Smart ROW Software to be completed during Stage 1 of the Project, based upon the results of the Data Topology and Process Mapping process, are not anticipated to directly implicate e.g. first responders. However, partnering with e.g. the Philadelphia Fire Department and/or Philadelphia Police Department in Stage 2 to integrate any of their legacy systems with the Smart ROW Software and evaluating the benefits of that integration in terms of e.g. response times and/or response outcomes is not out of the question.

Access:

The Stage 1 Project prototyped technologies that will improve freight access to residents and businesses in areas with severely constrained curb and ROW access. A ROWDS-based digital ROW management system (e.g. Road Rules) capable of integration with, and publication of data to, public-facing applications is anticipated to lead to **lower dwell times and higher turnover, resulting in more efficient (and safer) freight deliveries**. This digital infrastructure is also crucial to inducing fleet ROW users to shift to cleaner and safer last-mile delivery modes such as cargo bikes and, in the longer term, sidewalk delivery robots.

Pollution:

The Project will support a shift in both freight and passenger movement as follows in the long-term: the Project will enable ROW managers to more proactively manage the ROW, including loading zones and passenger pick-up/drop-off zones. Any modal shift in freight and passenger movement will rely heavily on ROW managers' ability to both make data-driven decisions about which ROW policies should apply where, and to quickly promulgate those policy changes through digital interfaces. On the user side, these modal shifts will only result in reduction of congestion or air pollution or improved energy efficiency if all ROW users, but especially motor vehicles of all types, are able to query the aforementioned data and operationalize that data by reserving specific portions of the ROW for specific allowed uses in a real-time manner that avoids conflicts and their biproducts, such as circling and idling.

Partnerships:

Without having *operationalized* ROWDS or Road Rules in Stage 1, it would be speculative and inappropriate to venture a guess at the estimated *magnitude* of the impacts of at-scale implementation in the area of Partnerships. However, in a binary sense (decrease, increase), it is anticipated that, at scale:

- Increase the level of coordination between City agencies and departments and close City partners such as SEPTA due to standardized digitized curb data and integrated systems

- Provide city-wide curb regulation data in an increasing number of formats and with a higher level of fidelity to support the proliferation of APIs based on e.g. CDS

Integration:

The ability to integrate a wide variety of systems through standardized, machine-readable ROW information is arguably the most consequential long-term benefit of ROWDS and the broader digital ROW management ecosystem developed during Stage 1. A common data specification removes the bilateral negotiation that currently makes every system-to-system integration a custom engineering effort. When ROW data exists in a standardized format, any system that speaks that language can consume it. This includes permitting platforms, asset management systems, transit operations tools, connected vehicle systems, navigation applications, and possibly emergency management or dispatch systems can all draw from the same source of truth without requiring point-to-point integrations between each pair of systems. This is the fundamental value proposition of open standards, and distinguishes ROWDS from a data project intended for consumption by only one city, or worse, only within one city department.

During Stage 1, the City demonstrated a "slice" of what could ultimately be the full set of ROWDS-based integrations. This slice included automated ROWDS data generation, ROW data ingestion into a ROW management software, use of the ROW management software, public-facing displays of ROW policies derived from the ROWDS data, and even a mockup of the automated workflow necessary to take an issued permit in PDF format to a machine-readable set of ROWDS policies and events. At scale, without having fully operationalized ROWDS or Road Rules beyond Stage 1, it would be speculative and inappropriate to venture a guess at the estimated magnitude of integration impacts. However, in a binary sense (decrease, increase), it is anticipated that, at scale:

- Interoperability amongst and between new and legacy systems would increase, as ROWDS provides a common language for ROW data that eliminates the need for custom translations between each pair of systems
- Duplication of effort and inconsistencies in ROW use or management would decrease as integrated systems replace parallel, siloed workflows across Streets, OTIS, OIT, and SEPTA
- The number of City systems capable of consuming or publishing ROW data via API would increase, including the Streets Department's permitting system, Cityworks, the LaneClosure Master API, and eventually public-facing applications
- The barrier to entry for private sector vendors seeking to build applications on top of Philadelphia's ROW data would decrease

Workforce development:

The Project did not anticipate impacts in this area, nor did any impacts in this area arise.

The Stage 1 Project established the foundational data infrastructure and technology deployments that, at scale, will deliver measurable improvements across all eleven federal statutory goal areas. The following describes how each area will be addressed through at-scale implementation.

Table 7. Stage 2 Alignment with Statutory Goal Areas

STATUTORY GOAL AREA	STAGE 2 OBJECTIVES
(I) Reduce congestion and delays for commerce and the traveling public.	The permit intake workflow prototyped during Stage 1 demonstrates that permit data can be automatically ingested, validated against the ROW dataset, and translated into ROWDS-compliant Event Policy objects. Combined with a check-in/check-out system or sensor deployment, this foundation enables automatic flagging of discrepancies between authorized and actual ROW activity, mitigating some of the underlying causes of cascading delays for commercial traffic and the traveling public. While ROWDS is not a navigation specification, its data is consumable by public-facing navigation applications, and Digital Signages displaying real-time ROW policy information reduce the time users spend interpreting conflicting or outdated signage at the curb.
(II) Improve the safety and integration of transportation facilities and systems for pedestrians, bicyclists, and the broader traveling public.	ROWDS is the first data model in which sidewalks, bike lanes, travel lanes, and curb zones are represented as co-equal, spatially explicit elements of a unified ROW dataset rather than separate siloed inventories. At scale, this enables automatic flagging of ROW conflicts, e.g. simultaneous permit requests that would close sidewalks on both sides of the same street. Road Rules or similar software can be further configured so that a ROW manager sets rules for how conflicts are flagged and how competing requests are prioritized, ensuring policy conflicts between ROW users are visible and resolvable before they become safety incidents in the field.
(III) Improve access to jobs, education, and essential services, including health care.	Cloud-based Transit Signal Priority directly reduces bus travel times on corridors serving essential destinations, compounding at scale into more reliable access to employment, medical appointments, and educational institutions for SEPTA's most transit-dependent riders. Bus detour modernization, discussed but not fully explored during Stage 1, is an additional ROWDS use case that should be scoped for Stage 2.
(IV) Connect or expand access for underserved or disadvantaged populations and reduce transportation costs.	The Center City study area includes corridors that serve disadvantaged communities. At scale, the prototype dataset and specification which it follows become tools for ensuring no work conflicts with upgrades to ADA ramps, pedestrian signals, and other infrastructure in the neighborhoods where they are most needed. A digital permitting system that reduces ROW conflicts also reduces the frequency with which sidewalks and bike lanes are closed without adequate notice or accessible detour routing.

STATUTORY GOAL AREA	STAGE 2 OBJECTIVES
(V) Contribute to medium- and long-term economic competitiveness.	Philadelphia's ability to attract and keep logistics operators, construction contractors, and other ROW users depends in part on the predictability and efficiency of the permitting and closure management process. A digitized, API-accessible ROW dataset makes Philadelphia a more attractive operating environment for private sector actors who increasingly rely on machine-readable infrastructure data for scheduling and compliance.
(VI) Improve the reliability of existing transportation facilities and systems.	A major source of unreliability in Philadelphia's surface transportation network is lack of adequate advance notice, or readily available notice, about construction, utility work, events, and emergency incidents that close lanes, sidewalks, or intersections. A ROWDS-based permitting system, connected to the City's LaneClosure Master API and eventually to Cityworks, provides the operational visibility needed to anticipate, sequence, and mitigate ROW conflicts before they affect travelers.
(VII) Promote connectivity between and among connected vehicles, roadway infrastructure, pedestrians, bicyclists, the public, and transportation systems.	ROWDS is designed from the ground up as an API-first data standard. At scale, the ROW API and Events API provide machine-readable, real-time-updateable data about every lane, intersection, curb zone, and ROW policy in the City, consumable by connected vehicle systems, navigation applications, transit operations platforms, and mobility-as-a-service providers. The Digital Signage deployment tested during Stage 1 represents the physical layer of this connectivity: communicating policy information to users at the point of decision, in real time, without requiring a smartphone or data connection.
(VIII) Incentivize private sector investments or partnerships, including working with mobile and fixed telecommunication service providers, to the extent practicable.	At scale, a transparent, data-driven ROW management system reduces the friction and uncertainty that currently discourages private investment in street-level infrastructure. Vendors operating in the ROW, including utility companies, telecommunications providers, mobility operators, and construction contractors, all benefit from a system that makes ROW availability, restrictions, and policy status queryable via API rather than dependent on phone calls and paper permits.
(IX) Improve energy efficiency or reduce pollution.	A ROWDS-based permitting system reduces ROW conflicts that generate idling, circling, and double parking. Real-time ROW policy data, consumable by navigation and logistics applications, gives drivers and fleet operators the information needed to avoid occupied zones before they arrive rather than after. Digital Signages leave less interpretation of curb or ROW policies up to drivers, enabling them to more quickly make the determination “I can park here,” rather than potentially circling for another spot due to ambiguity.

STATUTORY GOAL AREA	STAGE 2 OBJECTIVES
(X) Increase the resiliency of the transportation system.	A digitized, machine-readable ROW dataset is a resilience asset. In an emergency, the ability to rapidly identify available ROW capacity, reroute traffic and transit, and communicate policy changes via API and Digital Signages is the difference between a managed response and a chaotic one. The ROWDS Events API was designed explicitly to handle time-sensitive, real-world ROW state changes, and its event lifecycle model (submitted → approved → active → closed) maps directly onto the workflow of emergency ROW management. At scale, integration with the City's emergency operations systems would make this capability operational rather than theoretical.
(XI) Improve emergency response.	The ROW object inventory generated during Stage 1 could provide first responders with machine-readable data about the physical infrastructure of the street environment that is currently available only in fragmented, agency-specific formats. At scale, a complete, current, API-accessible inventory of ROW objects, like fire hydrants, linked to their associated roadways, lanes, and intersections enables more precise emergency routing and better coordination between responding agencies. TSP infrastructure can also be extended to support emergency vehicle preemption to improve emergency response times across the signal network.

EXPECTED COST-BENEFIT

Quantifying the cost-benefit for Stage 2 with precision is not possible at the time of this writing, and any attempt to do so with confidence would be misleading. The technologies developed and deployed during Stage 1 were prototypes and proof-of-concept deployments, not fully operationalized systems. No legacy workflows were replaced, no permit revenues were processed through ROWDS, and no before-and-after measurements of ROW conflict frequency, dwell time, or circling behavior were collected within the Project scope. Stage 1 produced the *preconditions* for a cost-benefit analysis: a specification (ROWDS), a prototype dataset, and a minimum-viable-product software configuration for housing, displaying, and editing said ROW data. These are not benefits unto themselves, but necessary foundational elements for building an integrated system or systems capable of delivering those benefits.

That said, the cost side of the ledger is clear: the City spent more than $1.8 million in federal funding and delivered, among other things, an entirely new open data specification for the Right of Way, a prototype dataset covering roadway segments, lanes, intersection, and an abundance of Right of Way objects, a configured instance of commercial ROW management software, 40 digital signages, and a demonstrated cloud-based TSP system. The marginal cost of extending this foundation citywide is estimated at approximately $10 million, primarily for legacy system integrations. This is a modest figure relative to the operational value of a functioning digital ROW management system.

For context, the City's street closure permitting program alone generates permit revenues on a per-foot, per-week basis across thousands of lane closures per year. A digital system capable of automating even a portion of permit intake, validating closure geometry against the ROW dataset, and flagging conflicts before they occur would recover its integration costs through permit revenue and staff time savings alone, to say nothing of the downstream benefits in congestion reduction, transit reliability, and emergency response.

The benefit case is best understood qualitatively at this stage: reduced information asymmetry between ROW users and regulating agencies; fewer conflicts between simultaneous closures of sidewalks, bike lanes, and travel lanes; more reliable bus service through TSP on upgraded corridors; reduced circling, idling, and double parking as real-time ROW policy data becomes consumable by navigation and logistics applications; and a data infrastructure that positions Philadelphia to participate in and benefit from the growing ecosystem of connected vehicle, autonomous vehicle, and last-mile delivery applications that depend on machine-readable ROW data. Each of these benefits is real, directionally certain, and supported by the statutory goal area analysis in the preceding section. Translating them into dollar figures will require integrating, iterative testing with user feedback, and operationalizing use cases outside of ROW permitting, all of which would occur in Stage 2 atop the digital foundation built during Stage 1.

PRELIMINARY BASELINE DATA

There are two dimensions of baseline data to consider in this Project: what was the City's digital ROW inventory prior to this Project; and what was the status quo in the ROW in terms of the various metrics identified in the Evaluation Plan (included in this dataset at *Philadelphia SMART Grant Evaluation Plan.pdf*), for example instances of circling, idling, and conflicts in the ROW (e.g. double parking).

The former category of baseline data – digital ROW inventory – warrants the most discussion as this Project was ultimately about creating a version of the digital foundation needed to modernize ROW management. At a high level, the baseline[4] digital inventory at Project outset, in the Project Area, was as follows:

- 4,114 signs in Curb Data Specification (CDS)
- 3,547 curb zones in CDS
- 459 curb policies in CDS

At Project conclusion, the digital inventory is as follows:

[4] For more information and data about the Smart Loading Zone Pilot, the predecessor to Philadelphia's SMART Grant Project, please see the materials at https://www.phila.gov/documents/smart-loading-zones-project-materials/.

- 11,316 signs in Right-of-Way Data Specification (ROWDS)
- 5,5551 curb zones in CDS
- 202 curb policies and 25 row policies in CDS and ROWDS
- 813 roadway segments in ROWDS
- 2,909 lanes (including sidewalks) in ROWDS
- 432 intersections in ROWDS
- 32,158 Right-of-Way objects (besides signs), such as manholes, bollards, pedestrian ramps, all in ROWDS

PART 4: CHALLENGES & LESSONS LEARNED

Stage 1 of the Philadelphia Digital Right-of-Way and Mobility Improvement Project was technically ambitious and ultimately successful, but it was not without significant challenges. Those challenges fell into four broad categories: procurement, specification development, data quality, and TSP implementation. What they share in common is that none were purely technical in nature; each was rooted in institutional, organizational, or capacity constraints that no amount of technical skill alone could resolve.

The Project team's delivery of three technological Minimum Viable Products and then some, in addition to an entire new data specification prototype for the entire Right-of-Way despite these constraints is itself a finding: progress on multiple simultaneous fronts is tangible and possible even with limited resources. The Project Team considers the following Challenges and Lessons Learned to be a deliverable, insofar as they are invaluable to informing even the earliest of planning efforts for a Stage 2 SMART Grant or any other scale-up of these technologies. Requests for Proposals, and Scopes of Work would be drastically altered going forward based on these lessons. The Procurement Department, Law Department, the Office of Innovation and Technology, and other entities involved in the early stages of technology procurement would be consulted differently and made aware of these hard-learned lessons up front.

PROCUREMENT AS A TECHNICAL CONSTRAINT

The City's procurement process, while ultimately successful, imposed a rigid sequencing on the Project's technical work. Vendors could not begin work until contracts were signed; contracts could not be signed until procurement was complete; and procurement could not begin until the grant was formally executed. Throughout this document a six-month procurement delay is frequently mentioned. In total, however, the Project faced what was essentially a combined *year* of procurement *and contracting* delays. This six-month gap at the start of the performance period compressed the time available for technical work and forced trade-offs that would not have been necessary with a shorter procurement timeline. Future projects of this type should explore pre-procurement activities such as market research, requirements development, and data inventory, that can be completed without vendor contracts and that reduce the ramp-up time once procurement is complete. A final and important note on this topic: when it is assumed that all or nearly all work will be completed by vendors, the City must wait until any given vendor is under contract before doing *any* work. Under tight grant timelines, this is an untenable situation, and it is therefore imperative that the City build and sustain at least *some* in-house capacity for ROW digitization.

The greatest challenge faced by the Project team in Stage 1 was trying to figure out how the City of Philadelphia ensures it complies with the terms of a grant agreement. This Project was one of the first projects that the City of Philadelphia received as a direct federal grant and it was the first one with contract terms that were specifically created within the Bipartisan Infrastructure Law.

Even though the Project team had the *technical* skills to deliver the project on time, over six months into the performance period they were still struggling to navigate the challenges of local procurement policies that did not align well with the grant agreement terms. For instance, the Smart Cities team, even after receiving guidance from USDOT staff on the matter of Disadvantaged Business Enterprise (DBE) participation requirements that typically come with Federal Highway Administration grants, needed to seek outside assistance and guidance from a DBE expert form the Philadelphia International Airport on how the terms of the SMART Grant differed from those the City was more used to seeing. The Project team had to understand the unique requirements per the grant contract and craft specific procurement processes to ensure that the City complied with said requirements without the need to set up a new program or rely on non-City agencies to cover them.

Getting new policies and language introduced into the procurement processes took time and capacity was not anticipated and for which therefore no resources were pre-allocated. The greatest early achievement of the Project team was to have crafted processes and workflows for other BIL-funded projects to navigate the challenges of direct federal grants and grant contracts.

SPECIFICATION DEVELOPMENT COMPLEXITY

Developing ROWDS in parallel with generating a prototype dataset proved to be a significant undertaking. The specification evolved iteratively as real-world data generation surfaced gaps and edge cases. Good examples of this are: the treatment of sidewalks as lanes; the unanswered but at least raised question of "What is a crosswalk in ROWDS?"; and the modeling of event (closure/permit) policies with temporal components. This iterative process, while ultimately productive, created version management challenges and required frequent re-processing of already-generated data. Some of these versioning challenges stemmed from the fact that a GitHub repository for ROWDS was not created at the outset of the project, but rather in March of 2025, with the first new endpoints (ROWDS endpoints, as opposed to CDS) not appearing until June of 2025. Future specification development efforts should anticipate this iterative dynamic and plan for multiple data regeneration passes, but can also lean on the OMF-stewarded GitHub repository, which will eventually be made public.[5]

With more resources and time, more feedback would have been solicited on ROWDS, and more sets of eyes would have been available to review, test, "break," and raise questions about ROWDS. Smart Cities staff considers the development of *any* version of an entirely new data specification to be a

[5] OMF has a defined process for versioning specifications that begins with an exploratory process for potential new specifications such as ROWDS. Thus, a clear timeline for the publication of the ROWDS *GitHub* repository is not available at the time of this writing. But, see the exported Right of Way README and Events README in this dataset *from* that repository for reference.

major success, let alone one that exists in a near-publishable format as a result of substantial efforts by Arcadis and *one* Smart Cities staff member.

DATA QUALITY AND VENDOR DEPENDENCY

A third major challenge that emerged during Stage 1 was the difficulty of ensuring data quality when ROW data generation is delegated to a vendor. Arcadis generated a large volume of ROW data in a short timeframe using automated extraction from Cyclomedia imagery and OpenStreetMap. However, the City found that this data required extensive quality control, including: correction of coordinate reference system errors in vendor-delivered geometries; identification and remediation of missing sidewalk lanes; manual correction of linkages between asset classes; and spot-fixes for dozens of individual assets. This level of QC effort was not anticipated in the original project plan and consumed a substantial portion of City staff time. The lesson: data quality in a ROW digitization effort cannot be left *entirely* to vendors. The City must be an active participant in QC, and that participation must be resourced accordingly.

TRANSIT SIGNAL PRIORITY

The Next-Gen TSP implementation team faced the following challenges:

- A slow procurement process delayed the RFP development and release, vendor selection, and contracting.
- The project team was new to the internal security review process, and therefore the process was slower than is typical, delaying the ability to start work.
- Contractor delays and equipment backorders for traffic controllers, which cascaded from delays on other corridor upgrades that were earlier in the procurement and installation queue. This was exacerbated by a limited number of qualified contractors this work.
- A learning curve for programming settings in newer traffic controllers to provide TSP.

The project team had some success in overcoming these challenges, which informed the recommendations in the next section. The project team connected with peers in other cities to learn best practices to overcome challenges with network connectivity. The team also found validity of the initial approach: that the Philadelphia infrastructure can support the NextGen TSP system and see early improvements to transit performance.

Before rolling out its at-scale deployment of Next-Gen TSP, the City should develop a clear plan for programming controllers with TSP settings. There are several viable options for this including, as the signal timing plan development and programming could either be done in-house or contracted. Either solution can work, provided that the City is prepared and has allocated adequate labor in advance. Once the team identified this issue, the City moved forward with working with an external party to develop signal timing plans and relied on in-house staff to implement those plans. The City may choose to take another path in the future, provided that the plan for development and implementation is laid out and communicated to all relevant parties in advance of TSP roll-out. An effective way to clarify who is expected to do this work would be to clearly include signal timing work in the scope during the procurement and contracting process.

While the Next-Gen TSP project team included many of the right people, it was only through talking to various staff that the team learned about others whose knowledge and expertise would have been helpful from the start. By including certain staff on the Streets IT network team from the beginning, the project team could, in the future, minimize challenges in connecting the TSP system to the network. This would also help to break down communication silos across teams, bringing parties with knowledge of different aspects of the Streets IT network together for more streamlined implementation.

The project team also has more clarity on the timeline for the procurement process for this type of project and can set a project timeline that matches the expectations in the procurement process. Similarly, if required to go through the internal security review process in the future, the expansion project team should proactively reach out to the security review team to schedule reviews as early as possible and to stay ahead of the required next steps.

PART 5: DEPLOYMENT READINESS

The Stage 1 Project has helped the Project team highlight the need for more resources to support the deployment of advanced data-intensive systems in the City. The Implementation was led by the Smart Cities Team within the Managing Director's Office, on behalf of the Streets Department and in partnership with the Open Mobility Foundation and SEPTA. The digitization of ROW management is not just an attempt at operational efficiency, but an entirely new way to conduct business for all regulating agencies. An attempt at such a transition is institutionally always challenging since it requires people performing legacy functions to keep doing the same tasks, but to try a new way of doing those tasks, all while "not breaking anything." This becomes even more challenging when the City tests a new product (to say nothing of four different products at once) that may have unresolved issues. Public-facing functions are hard to pause for even a small amount of time for the sake of testing new ideas, and this Project attempted to insert a set of three-to-four new technologies (depending on whether one counts a data specification as a "technology") into legacy workflows through several directions. The technologies were deployed without "breaking" any legacy systems, which Smart Cities often cites as its first benchmark of success. However, Road Rules or any other ROWDS-based ROW management system need to be deeply *operationalized* before the City would know for certain what legacy systems would be "broken" by it, and this is a natural core goal for Stage 2.

But it is worth noting that legacy systems are barely functional as-is. Thus, *anything* that seems to hold potential for improvement is welcomed by all staff members, though more thought needs to be given to how to *regularly* engage those staff members. Thanks to Stage 1 Project, the City is testing its deployment readiness supported by grant funding and will generate a precedent for other cities to try such a change and for Philadelphia to try other such transformational technologies based on lessons learned here.

REQUIREMENTS FOR SUCCESSFUL IMPLEMENTATION

Based on Stage 1 experience, the following requirements are identified for a successful Stage 2 implementation:

- **Dedicated City staffing.** Stage 1 was effectively delivered by one City staff member with part-time support from a wide variety of colleagues. A Stage 2 implementation at citywide scale will require a dedicated team of more than one Full Time Employee (FTE). It would behoove the City to plan for at least one FTE within Smart Cities, and a combination of FTE/PTEs across Streets Department ROW Unit and Streets Department Information Technology Unit, all with a combination of skills in geospatial data, software development, and project management.

- **Vendor data quality standards with City audit rights.** Any Stage 2 data generation contract must include explicit data quality standards, acceptance criteria, and *City audit rights*. Automated QC tooling (such as the HTML auditor developed in Stage 1) should be specified as a deliverable. Ultimately, a vendor stating they will conduct QC is not sufficient for this type of work; City staff with the right background and skills must be able to "pierce the QC veil" iteratively *before* delivery of a prototype, minimum viable product, or similar. The above notwithstanding, Arcadis and INRIX should be commended for their patience and responsiveness in dealing with the City's questions.
- **Open standard commitment.** All data generated under Stage 2 should be in ROWDS format from the outset, not in a vendor-proprietary schema with a subsequent conversion step. The City, the other cities in the Curb Collaborative, and OMF discussed several times and in several formats how to include such language in RFPs, Statements of Work, or contract terms. Any city or other jurisdiction should require vendors to adopt CDS, MDS, and, hopefully someday soon, ROWDS natively.
- **Legacy system integration roadmap.** A clear roadmap for integrating ROWDS data with the Streets Department's permitting system, parking management systems, special events, emergency closures, and SEPTA's operations data should be developed at the start of Stage 2 rather than treated as a future deliverable. Arcadis' partner in this Project, Cambridge Systematics, conducted process mapping with Streets' ROW Unit for a small portion of possible permit types, and via a "ride-along" of the permitting process with one member of Streets' ROW Unit and one [descriptor of session] exercise with a wider array of Streets Department personnel. A similar but greatly scaled up consultant-led effort should begin as soon as possible, if not before Stage 2, and should be tightly scoped and reviewed by senior stakeholders from all relevant stakeholder agencies, offices, departments, quasi-city agencies, and select external stakeholders.
- **Community engagement plan.** A structured community engagement plan, including feedback mechanisms for ROW users and coordination with communities and businesses with heightened ROW use needs, should be developed and resourced at the start of Stage 2.
- **TSP** - The primary requirements to implement the Next-Gen TSP system at scale in Philadelphia are the same requirements to build out a modernized signal system: the city needs upgraded controllers (currently using 2070s running D4 software) and those controllers need to be reliably connected with fiber (or wireless) communications to the traffic control network. The requirements to expand TSP are aligned with the City's other traffic management goals. By prioritizing signal upgrades along corridors that are best-suited for the greatest TSP benefit, the City can ready itself for at-scale implementation. The City has already studied which corridors are best suited to benefit from the investment in TSP. Because the Next-Gen TSP system is centralized, the future at-scale rollout would rely on connecting a TSP server to the traffic controller network, which is part of this pilot project, and should not require anything new on the City's Streets IT network, so this would not pose any additional challenge.

ADDITIONAL INFORMATION REQUIRED FOR FUTURE-PROOFING

The Right of Way Data Specification developed during this Project exists, as of the close of Stage 1, as a working prototype and as such, it still requires the kind of broad review and iterative refinement that produces a durable open standard. The Open Mobility Foundation is the appropriate steward for that next phase. The OMF may form an Exploratory Working Group specifically for ROWDS, which would make the GitHub repository public and open it to review, issue-filing, and commentary by vendors, operators, and other cities working in the ROW digitization space. This is the same process through which the Curb Data Specification (and the Mobility Data Specification) matured, and it is the right path for ROWDS. The City of Philadelphia, as the originating city, should plan to be an active participant in any such working group and should allocate staff time accordingly. Until that process occurs, ROWDS should be understood as a Philadelphia prototype rather than a ratified standard, and any at-scale deployment decisions should account for the likelihood that field names, endpoint structures, and data types will continue to evolve.

Parallel to the OMF process, and potentially in coordination with it, the ROWDS specification and the prototype dataset need to make their rounds through internal City review. Several departments and units have a direct stake in how the ROW is digitally represented and managed: the Streets Department's Right-of-Way Unit, which administers street closure permitting and is the most immediate operational user of any ROW policy management system; the Office of Transportation and Infrastructure Systems (OTIS); the Philadelphia Parking Authority[6]; the Office of Innovation and Technology; and CityGeo. None of these stakeholders had a formal role in reviewing or commenting on ROWDS during Stage 1; the accelerated and/or condensed pace of the Project post-procurement did not permit it. This is a gap that must be closed before any at-scale implementation can proceed.

A structured internal review process, modeled on the OMF's open comment process but adapted for a multi-agency municipal context, should be a Stage 2 prerequisite, or a prerequisite to any scale-up of these efforts.

Integration with the City's asset management system was not achieved during Stage 1, and this represents one of the most significant outstanding requirements for any sustainable ROW data management program. The City currently uses Cityworks as its primary asset management platform for Streets Department assets. No digital ROW policy management system can operate sustainably without a live, bidirectional connection to the asset management system that tracks what physical infrastructure exists, where it is, and what condition it is in. Without this integration, ROWDS data will drift out of sync with ground truth over time, and the permit and policy workflows that ROWDS is designed to support will remain dependent on manual reconciliation. Importantly, Cityworks is not static: a separate Smart Cities pilot project for an Automated Pavement Inspection System is anticipated to include recurring automated sign inventory as a component of its scope, which will generate updated asset data on a regular basis. The ROWDS implementation should be designed

[6] Depending on any prohibitions on use of data for enforcement purposes as attached to any SMART Stage 2 funding.

from the outset to receive and incorporate that data, and the two projects should be coordinated to ensure their data architectures are compatible, at least in the direction of inventory into ROWDS.

Finally, the Events API, while designed and prototyped, was not connected to a live data feed during Stage 1. The permit intake workflow developed by City staff demonstrates that automated Event Policy generation from permit data is technically feasible, but it was demonstrated in a Python notebook environment against a static dataset, not as a running service connected to the City's LaneClosure Master API. Operationalizing that connection, including handling the full permit lifecycle in real time rather than retrospectively, is the most concrete and near-term path to demonstrating ROWDS utility to the Streets Department, and should be prioritized accordingly in Stage 2 planning.

PART 6: WRAP-UP

The City of Philadelphia emerges from Stage 1 of the SMART Grant project having exceeded its lofty and multifarious original technical ambitions while navigating significant institutional and procurement challenges and resource and time constraints. The development of the open data specification ROWDS is a contribution not just to Philadelphia's digital infrastructure but to the national and international field of urban[7] mobility data standards. The ROWDS prototype and the prototype ROWDS dataset, the Road Rules configuration and demonstration, the TSP deployment, and the digital signage deployment and testing together constitute a proof-of-concept that is both technically credible and practically reproducible.

The City's Stage 1 work has been shared with the OMF Curb Collaborative cohort and presented at multiple public forums. The lessons learned – about procurement, data quality, specification development, and the importance of City capacity – are directly applicable to any city seeking to digitize its Right of Way. Any such city or other jurisdiction is highly encouraged to contact the Philadelphia Project Team authors of this dataset.

Stage 2, with adequate funding and staffing, presents a clear and achievable path to citywide digital ROW management. The foundational elements are in place. The work ahead is one of scale, integration, and institutionalization; all of which are well-understood challenges with well-understood solutions. The City is ready to implement ROWDS across multiple use cases and across the entire City, serving a wide variety of ROW users and improving the speed and quality of ROW interactions for and businesses alike.

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[7] There is nothing, other than potentially a lack of immediate need and probably a lack of capacity, from preventing rural or suburban jurisdictions from adopting CDS or ROWDS as well. But let it be noted that the City of Philadelphia itself lacks capacity, and achieved all of the above nonetheless, so the authors encourage rural or suburban jurisdictions to reach out to the City of Philadelphia with any questions they may have regarding their own efforts to digitize their ROWs.