City of Philadelphia

Right-of-Way Data Typology and Process Mapping

Final Report and Deliverable Summary

December 15, 2025

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Introduction

The City of Philadelphia has embarked on the Philadelphia Digital Right-of-Way and Mobility Improvement Project as part of the U.S. Department of Transportation's Strengthening Mobility and Revolutionizing Transportation (SMART) Grant initiative. A key component of this project is the development of a comprehensive Right-of-Way Data Specification (ROWDS). This data specification is designed to translate the physical and regulatory characteristics of the right-of-way to a digital and mappable format. ROWDS provides cities, private operators, and technology providers a centralized and internally consistent dataset that describes both physical infrastructure (e.g., roadways, traffic lanes, sidewalks, traffic signals, and features such as benches, trees, EV chargers) as well as regulatory conditions (e.g., speed limits, turning restrictions, curb regulations, temporary closures).

ROWDS makes it possible to manage the right-of-way holistically and ensure that the City's transportation network is effectively managed in response to increasing demands on street, sidewalk, and curb space. ROWDS expands beyond curbside regulations to encompass all roadway segments, intersections, policies, assets, and physical objects within the right-of-way. The goal of providing integrated, standardized right-of-way data is not just to simplify the storage of data by providing guidance. ROWDS has the potential to enable a wide variety of use cases, including:

- **Urban Planning:** Ability to model and simulate changes to roadway configurations and public spaces.
- **Asset Management:** Making it easier to maintain comprehensive inventories of right-of-way objects and infrastructure.
- **Multimodal Integration:** Supporting micromobility, transit, freight, and personal vehicles in a coordinated way.
- **Public Engagement:** Sharing open data about right-of-way policies and assets with residents, private sector stakeholders in the built environment, and application developers.
- **Event Management:** Providing a unified mechanism for defining temporary rules, closures, and infrastructure changes for special events.

ROWDS and Data Capture

Having a proper data structure is a key step to making sure data is being used more effectively but it is also important to ensure cities can actually collect and generate the data in the given structure. Hence, a component of this project looks to capture right-of-way data in a selected project area in the City of Philadelphia to showcase what actual data looks like in ROWDS as well as provide a proof of concept of how this data can be mapped city wide. This data will also be used to test out the use cases of ROWDS in the City’s processes.

ROWDS and Existing Standards

Since the early 2000s, a variety of data standards have emerged to help transportation agencies manage and publish information about their systems. Standardized schemas for transportation assets and operational data make it possible to develop common application programming interfaces (APIs), the mechanism through which software applications communicate with each other and share and access data. When standards are widely adopted, software developers can build applications that use a common universal data language, without the burden of integrating and transforming locally specific data. For instance, by offering a well-defined digital representation of transit schedules, the General Transit Feed Specification (GTFS) has allowed application developers to create trip-planning products that work in cities across the entire world.

ROWDS was developed with many of these existing data standards in mind – including those for curbs, mobility patterns, and road rules, that are being used to represent different elements of the roadway – and guided the Project Team in continuing to build off best practices in the data standards space. A brief description of some of these standards is provided below.

- **Curb Data Specification (CDS):** Developed by the Open Mobility Foundation, the Curb Data Specification is a standardized framework for APIs for digitizing curbside regulations, enabling cities to manage and share real-time curb use data for parking, loading zones, and other curbside activities. This standard is comprehensive and serves as the basis for handling curb-related data.
- **Mobility Data Specification (MDS)**: Also developed and maintained by the Open Mobility Foundation, the Mobility Data Specification is a framework and set of APIs that facilitate data exchange between cities and mobility service providers (such as shared bikes, scooters, and ride-hailing services). This specification guided the documentation of specific elements of the roadway related to these so-called "micromobility" services.
- **OpenStreetMap (OSM)**: OpenStreetMap provides map data for public use and is built by a community of mappers that contribute and maintain data about roads, trails, key destinations, transit stops, buildings, points-of-interest and other data. OSM data is updated regularly by the public and therefore can be a more reliable source for local knowledge. Because the OSM map is global and frequently updated, this data was used to create many features used in the SMART grant pilot.
- **General Transit Feed Specification (GTFS):** Originally developed as a collaboration between TriMet in Portland, Oregon and Google, the GTFS provides a standard for transit schedules. GTFS is used by third-party software applications for numerous uses, including trip planning, timetable creation, mobile data, data visualization, accessibility, and analysis tools for planning. This standard served as the basis for handling transit-related data, including bus stops and accessibility information.
- **General Bikeshare Feed Specification (GBFS)**: Developed under the North American Bikeshare & Scooter share Association (NABSA), GBFS was created to provide a data standard for shared mobility options. GBFS provides information about station status, system alerts and information, and vehicle status and type. This standard will be used to guide the development of the data specification for bikeshare within the city. This mostly relates to ROW Objects.
- **INRIX Road Rules**: Developed by the mapping and traffic software company INRIX, Road Rules is an internal data standard used by INRIX software to help cities digitize and host their road, curb, and sidewalk assets. This includes a wide range of policies, assets, and zones in the right of way space. This standard has adopted CDS for curb-related information.

It is worth noting that two of these standards, CDS and MDS, are managed by the Open Mobility Foundation – an organization also involved with this project and several other SMART Grant projects through the SMART Curb Collaborative – helping cities share lessons and advice on how to digitally manage their right-of-way and create mobility data in a digital format. Due to their leadership in this space, the OMF would be the ideal candidate organization for adopting and maintaining ROWDS. More on this in the Next Steps section.

ROWDS and City Processes

ROWDS opens the possibility of having a single source of georeferenced truth about activity occurring or permitted in the right-of-way. The permit review process at the Streets Department – which covers activities such as excavation, temporary loading zones, and crane placement – is a strong candidate for application of ROWDS. The current permit review process is essential to evaluating the legal and operational soundness of a proposed activity in the right-of-way, as well as permit costing. This review process, which typically involves a variety of information that is evaluated for consistency across multiple sources of information, presents an opportunity to streamline workflows.

Currently, the review process involves reviewing information that varies greatly in the level of detail and format depending on application requirements. This means that applications can range from narrative descriptions to detailed site plans. The analysis of this information is complex, as it includes an evaluation of comprehensiveness and accuracy; detection of conflict with other activities; verification of consistency with regulatory requirements; and coordination to ensure continued mobility. As a result, the review process often necessitates several manual steps across multiple systems for referencing written and mapped information. For instance, some permit applications require cross-referencing information from a permit application with data only available through Philadelphia's Atlas platform Guaranteed Pavement Information System, which has no direct integration with the existing permitting system. The permit review process may also require coordination across multiple teams within the department, as well as external departments and quasi-city agencies, including traffic engineers, Southeastern Pennsylvania Transportation Authority (SEPTA), and other city-wide departments are sometimes needed. There are multiple sources of truth that sometimes must be used by multiple reviewers.

Because of these complexities, a large portion of this project focused on developing a better understanding of these processes, conceptualizing how ROWDS can be used to streamline this work, and generating recommendations for future ROW management software to improve these processes.

ROWDS and Management Software

It is also worth mentioning that alongside the creation of ROWDS, mapping of data, and understanding of processes, a separate project was undertaken by the City to develop a software that integrates all of the data needed to digitally manage the right-of-way. The data created and recommendations made within the Data Topology component project will be directly implemented by this software. The ROW software is an updated version of INRIX's Road Rules, referenced throughout this report.

Report Overview

This report provides an in-depth review of the Right-of-Way Data Specification (ROWDS) that was created as part of this project, how data can be generated in this format, and how it can be applied to City processes. The report is structured as follows:

1. **Proposed Right-of-Way Data Specification:**
    - Provides an overview of the endpoints included in the ROWDS, including policies, events, and physical objects
    - Describes how ROWDS endpoints correspond with each other
2. Data Proof of Concept
    - Provides an in-depth description of the data collection and conversion process for the pilot area

3. Current Right-of-Way Permitting Process
   - Provides an overview of the City's current Right-of-Way permitting process
   - Discusses the challenges and potential opportunities for improving the Right-of-Way permitting process
4. Impacts and Improvements to the Permitting Process
   - Provides examples of how the ROWDS can be applied to a variety of previous permit requests received by the City
5. Next Steps
   - Discusses how data collection can be expanded, how new data can be integrated and maintained, and how ROWDS can be refined in the future

1 Proposed Right-of-Way Data Specification

At its heart, ROWDS defines a standard format and set of APIs for representing, sharing, and managing data about the public Right-of-Way. The design of the standard leans heavily on the foundation of CDS but expands beyond CDS to encompass all roadway segments, intersections, policies, assets, and physical objects within the right-of-way. The diagrams in this section provide a visual indication of the core elements within the street which are supported by ROWDS.

Figure 1 - The Right-of-Way and its Elements

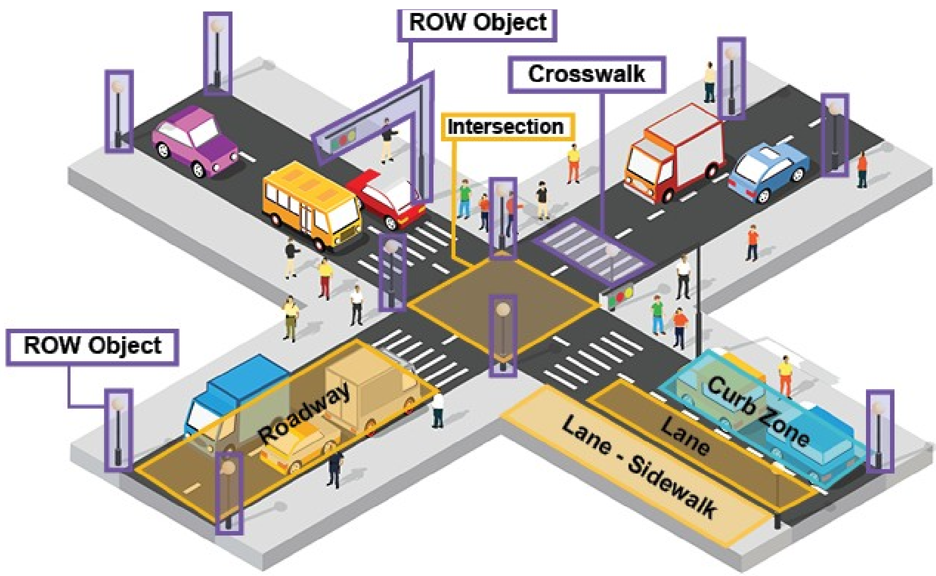
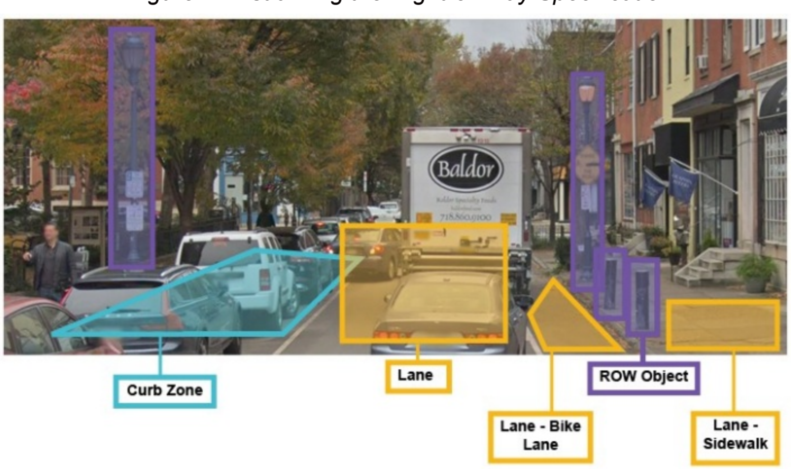


Figure 2: Visualizing the Right-of-Way Specification



To operationalize the standard, ROWDS defines a set of Application Programming Interfaces (API) and endpoints within those APIs, which allow information to flow between organizations managing and using the right of way. For this project, ROWDS consists of two core APIs – **Right-of-Way** and **Events**. The first of these provides the standards to digitally publish data for elements of the right-of-way, while the second provides standards for cities to publish details for time-specific events, which are associated with one or more physical assets. Each of these APIs consists of endpoints as shown in Figure 3. Right-of-Way and Events APIs and Endpoints.

Figure 3. Right-of-Way and Events APIs and Endpoints[1]

ROWDS is structured to be modular, flexible, and ensure clarity, extensibility, and alignment with other mobility data standards. Each API endpoint defines a clear entity (e.g. Roadway, Policy, Object) with required and optional attributes. Entities can reference one another to show real-world connectivity (e.g. Lanes within Roadways, Policies applying to Objects). All spatial elements are represented in standard geographic formats (e.g. GeoJSON). Policies and operational conditions can be defined for specific time periods, including recurring schedules. The design is also modular and flexible. It allows agencies and organizations to implement only the components of the API that meet their operational and policy needs. For example, a city may choose to publish only Roadways and Policies, while another may additionally include Objects and Areas to meet their specific use cases.

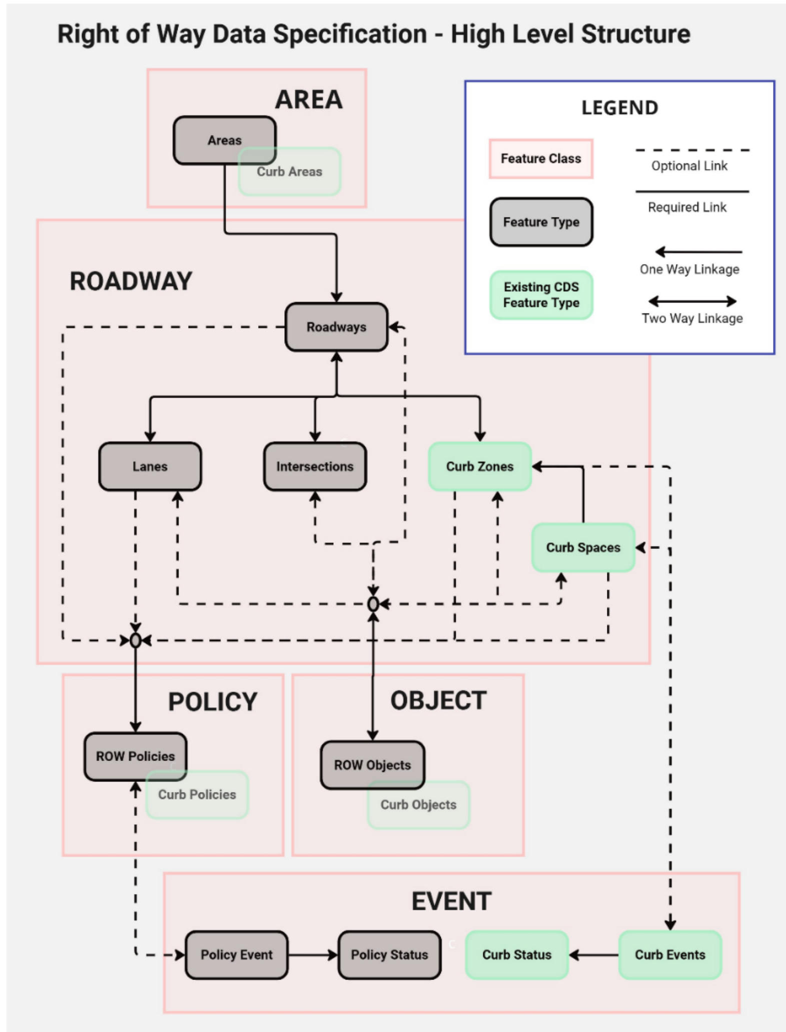
A high level of overview of the specification design is shown in Figure 4. A key requirement for the specification is the ability to capture the detailed relationships between right-of-way entities in order to efficiently answer questions such as “which bus stops are on this street” or “what movements are permitted or prohibited in this particular traffic lane”. These relationships are shown in the diagram as arrows. These connections can be one-way or two-way depending on the relationship. For example, every lane is connected to a roadway and vice versa, however a roadway need not be connected to an area.

As many elements of ROWDS already exist in some capacity in CDS, these endpoints are indicated on the high-level overview of the diagram as well. In particular, ROWDS includes proposals to generalize CDS’s Curb Policies into ROW Policies and Curb Objects into ROW Objects. Meanwhile, Curb Zones, Curb Spaces, Curb Events, and Curb Status endpoints are adopted wholesale from CDS without proposed changes.

[1] An API endpoint refers to a specific address from which software is able to request data or through which software can send data back to a server, in a structure specified by the API design and definition. In case of ROWDS, different endpoints are used to communicate about different Right-of-Way elements covered by the standards.

The endpoints are summarized below, including key required and optional attributes. Full definitions and available attributes can be viewed on the ROWDS GitHub page[2] and in Appendix A: Right-of-Way Data Specification GitHub Page. Most items covered by the specification have common fields that are not discussed in detail to avoid repetition. These include metadata fields – such as the date and time that the entity was first published and the date and time it was last updated. Many objects may have Policies attached to them, which specify one or more rules about the allowed/unallowed usage of that particular right-of-way element. Such objects can also store historic policies (using the “previous policies” field) which have been removed from the object. It should also be noted that the unit of measurement for length and width dimensions is typically defined in centimeters.

Figure 4 - ROWDS High Level Structure



1.1 Roadways, Lanes, Intersections, Curb

Roadways make up the network used by vehicles, pedestrians, and other mobility operators to move around the world. Roadways consist of several elements that, together, form this network. At a base level, a set of Roadways (links) and Intersections (nodes) is needed to create a road network. Additional details along each roadway, such as Lanes, or Sidewalks, Curb Zones, and Curb Spaces, can be included if this information is available and/or applicable. Roadways also support Location References, which may be based on a locally defined linear referencing system.

[2] https://github.com/openmobilityfoundation/ROW-data-specification

1.1.1 Roadway

A Roadway is a portion of the right-of-way that is intended for the movement of vehicles, including both motorized vehicles and non-motorized vehicles, such as bicycles. A single Roadway is a segment and should span a single city-block and feature a defined Intersection on each end (or a dead-end, where applicable). A Roadway typically consists of one or more travel lanes, and may include shoulders, turn lanes, and medians, but excludes any elements outside the curbs on either side of the Roadway. Each Roadway is assigned a unique identifier, which should remain constant over time unless the geography of the actual road represented by the Roadway changes substantially.

Figure 5. Five Lane Roadway (Market Street Between 11th Street and 10th Street)

Required attributes include unique ID, the spatial extent of the roadway, and lists of the associated Curb Zones, lanes, intersections, and Right-of-Way Policies. Optional attributes include geometric information (for instance, the length and width of the carriageway), and the type of roadway – such as whether the street is an arterial, local street, pedestrian street, etc. These are designed to correspond with functional class definitions used in OpenStreetMap. Users may also optionally tag each roadway as a bridge, tunnel, overpass, or underpass as needed. Other key optional attributes include the name of the street, IDs of cross streets, direction of traffic.

1.1.2 Lane

A Lane is a designated section of a Roadway where vehicles, pedestrians or other users are allowed to travel in a specific direction. Lanes may be defined for vehicles, bicycles, or – in the case of Sidewalks – pedestrians. A Lane should be at most one vehicle wide and is typically defined by pavement markings or curbs. Lanes exist fully within a single Roadway and shouldn't span multiple Roadway segments. Because certain Policy types can differ across the Lanes within a given Roadway, Lanes may have their own unique set of policies that cover what types of vehicles are permitted, turning-movements, speed-limits, etc.

Figure 6. Parking Lane (Left), Vehicle Travel Lane (Center), Sidewalk (Right), (Walnut Street Between 9th Street and 8th Street)

Required attributes for Lanes include a unique ID, which Roadway ID the Lane exists in, and the associated Curb Zones, Lanes, Intersections, and any Right-of-Way Policies that apply. For Policies affecting Lanes, users may also define the start and end points to which a Policy applies, measured in centimeters from the beginning of the lane. This feature is useful in cases where, for instance, a general travel lane becomes a turn lane as it approaches an intersection. Key optional attributes include a list of any policies that previously applied, linear references, the name of the street that the roadway is on, associated intersections, length and width dimensions, striping, pavement condition, and direction of traffic. Note that a Sidewalk is considered a lane if it is adjacent to the roadway.

Required attributes include unique ID, the IDs of associated roadways, Right-of-Way Objects, and Right-of-Way Policies (and start/endpoints thereof), and the lane's place in the lane order. Additionally, attributes must include the timestamps for when the object was published and last updated.

Optional attributes include the lane's geometry, the ID of associated intersections, length and width dimensions, street side and traffic direction, lane striping and pavement condition, a human-readable name, and references to previous policies or other locations.

1.1.3 Intersection

An Intersection is the meeting point of two or more roadways, and where roadway segments end or start. Because they are essential to defining Roadways, Intersections are mandatory as part of a minimal implementation of the ROWDS. Just as Roadways must start and begin with Intersections, each Intersection must have at least two Roadways at their start and end points. Intersections can be composed of several components such as crosswalks, corner radii, and traffic signals, but not all information may be detailed.

Figure 7. Four Way Intersection (Locust Street and S 11th Street)

Like roadways and lanes, required attributes for intersections include a unique ID and indicators of geometry and location, and a list of applicable Policies. Optional attributes describe the regulation of the intersection in more detail, and what past policies are linked, Intersections may also be classified by the type of traffic controls used to manage traffic at the intersection, such as stop signs, traffic signals, roundabouts, dual carriageway, and diamond.

1.1.4 Curb Zones

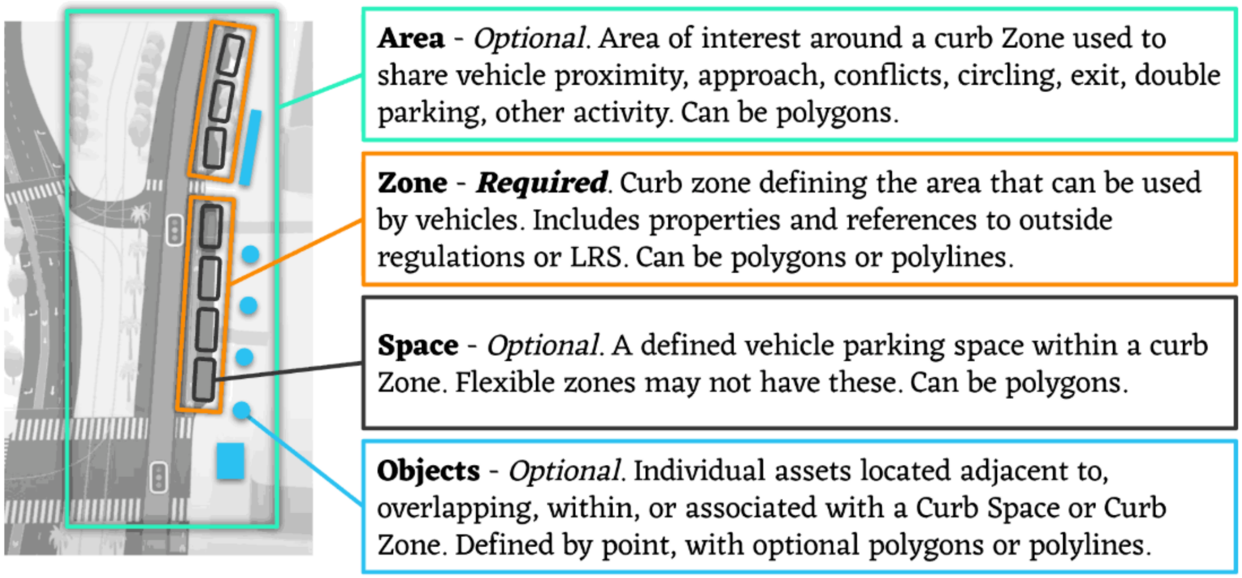
ROWDS represents Curb Zones in accordance with the Open Mobility Foundation's CDS Curbs API[3], but proposes extending the Curb Zone object with two key attributes to capture geographic relationships:

- The unique ID of the Roadway on which the Curb Zone is situated.
- An array (list) of unique identifiers for any Right-of-Way Objects associated specifically with that Curb Zone, used to link the Zone with relevant objects located within or adjacent to the Zone. This is similar to CDS's field for Curb Objects – but incorporates ROWDS more generalized concept of Right-of-Way Objects. An example of a relevant object would be an EV Charging station serving the Curb Zone.

Per CDS, a Curb Zone is a geographical entity representing a single region along the curb, along with metadata about that region and the policies that apply to its use by vehicles. It is commonly used to represent an individual parking lane governed by a single set of regulations. The regulations applicable to Curb Zones are represented through a list of unique IDs corresponding to Policy entities. More details on Policies is provided in Section 1.2 below.

[3] https://github.com/openmobilityfoundation/curb-data-specification/blob/main/curbs/README.md#curb-zone

Figure 8. Various Spatial Elements Defined Within the CDS Curbs API



What constitutes an individual Curb Zone is determined by the city, but there is a standard list of key requirements:

- Always have a common regulation along their entire extent (i.e., if at certain times of day, half of a given stretch of curb is a loading zone and the other half is metered parking, that stretch of curb must be divided into at least two Curb Zones).
- Never span multiple blocks - an entire Curb Zone must be on the same Roadway and be between the same two Intersections, alleys, or service roads (also considered Roadways/Intersections).
- Never overlap other Curb Zones in the same dataset with overlapping validity times.
- Be assigned a unique ID, in the form of a UUID. This ID should remain consistent as long as the Curb Zone's geography remains substantially the same. Policies may be updated without changing the ID.
- It should not be possible to legally park a single vehicle in two different Curb Zone at the same time (i.e., a given non-demarcated parking area or loading zone should be represented as a single curb location), unless this conflicts with the requirements above.

Required attributes for Curb Zones include a unique ID, indicators of geometry and location, links to relevant policy objects, and timestamps for publishing and updates. Optional attributes cover the number of parking spaces, adjacent roadway objects, and historical information.

1.1.5 Curb Spaces

ROWDS represents Curb Spaces in accordance with Open Mobility Foundation's CDS Curbs API[4]. A Curb Space is a defined vehicle parking or loading (or other use) spot along the curb for use by one vehicle at a time. Curb spaces are optional in the CDS. ROWDS proposes extending the Curb Space objects with two key attributes to capture geographic relationships:

[4] https://github.com/openmobilityfoundation/curb-data-specification/blob/main/curbs/README.md#curb-space

- The unique ID of the Roadway on which the Curb Zone is situated.
- An array (list) of unique identifiers for any Right-of-Way Objects associated specifically with that Curb Space. Where a Curb Zone might have multiple parking meters associated with it, a Space would likely list only a single ID corresponding to an individual meter.

Valid Curb Spaces must exist within a single Curb Zone and not overlap with any other Spaces. Required attributes include a unique ID, the geometry of the Space, and the ID of the Curb Zone in which the space is situated, and publishing history. Optional attributes include space numbers, availability information, and custom attributes required by the agency.

1.2 Right-of-Way Policies and Rules

1.2.1 Right-of-Way Policy

Policy objects represent sets of rules that allow users to define and represent a full set of regulations within the right-of-way. The design of the Policy object borrows heavily from how policies are handled by Curb Policies in CDS but extends the specification to handle not only rules and regulations that apply to parking, but also to the management of Roadways and Lanes as well.

Taken together, all of the Right-of-Way Policy objects associated with an entity in ROWDS should define the full extent of regulations affecting that entity at a particular time. Policies themselves do not specify the exact rules that apply but rather represent a collection of Rules (see the section on Rules below). Each entity defined in the ROWDS specification will list all the Policies associated with it by a unique ID, with all Policies being defined in the central database.

The required attributes of a valid Policy include a unique ID, publishing history, a policy type (discussed below), the priority of that policy (used to determine which policy prevails in the event of conflicting policies), and a list of Rules which make up the Policy. The policy may also specify the different Time Spans (periods) during which the policy applies, and the source (e.g. a department) of the policy.

As an example, a Right-of-Way Policy may specify that a Bus Lane is in effect for a lane from 7am to 7pm, Monday through Friday. General traffic is allowed to continue making right turns. In that case, that Lane would feature two Policies, applicable during those time periods. The first would be a Movement type policy, with a rule specifying that only buses may travel using that lane. The second would be a Turning type policy, specifying a positive rule that all vehicles may make right turns.

1.2.1.1 Policy Types

Because ROWDS seeks to represent a much broader range of policies than are represented in CDS, each Policy is defined as belonging to one of five types. Depending on the type of Policy, different sets of Rules may need to be included in the policy.

- **Turning Policies**: This covers all policies involving turning onto or from various roadways or lanes.
- **Movement Policies**: This covers all policies relating to speed, special zones, or freedom of movement of a vehicle. This includes community safety zones, speed limits, and car free zones.
- **Event Policies**: This covers all events that can affect a roadway element, including construction, road closures, special events, or permits. Generally, event policies take highest priority.

- **Managed Right-of-Way Policies**: This covers all policies that relate to the management of a roadway or lane with respect to the types of users that may be permitted or disallowed from using a Right-of-way element.
- **Curb Policies**: This covers all rules that allow or prohibit a particular set of users from using a particular curb at a particular time or times. These data objects are defined by CDS.

1.2.2 Rules

Rules contain detailed information about who is allowed to do what and for what length of time within the right-of-way. Rules contain the detailed regulations that are established by a given Policy. Because Policies are collections of Rules, a single Rule may be associated with more than one Policy.

A rule needs to specify the type of activity that is permitted or forbidden by regulation. The types of activities should be clearly linked to the type of Policy that leverages them. Each activity should be given a unique ID, referenced by the rule. Rules may also be given human-readable descriptions.

A typical ROWDS implementation could be used to specify activities including:

- Speed limits (minimums and maximums).
- Permitted turning movements (left, right, through, U-turns).
- Weight and height limits for commercial vehicles.
- Parking activities (parking, loading, standing, stopping), parking charges as well as other parking rules setting such as limits on length of time for allowable stays within Curb Zones and Spaces. These are designed to be compatible with CDS.
- Toll rates, parking rates, and other user charges.

Rates for curbs usages are already well-defined by the CDS Rate object[5]. For tolling, ROWDS proposes an extension of rates with attributes that allow definition of common tolling rates including a base rate, distance-based rates, distance units (miles, kilometers), a minimum number of distance units, and an incremental amount to use for rounding.

An important feature borrowed from CDS is the ability to apply rules to specific groups of users and activities, called “Managed Users” in ROWDS. An allowed/disallowed activity may be optionally specifically targeted to a given list of managed user types. Because regulations are often targeted to specific modes, vehicles, space types, or activities that take place in the right-of-way, ROWDS is designed to allow data managers to flexibly define this critical field. Rules can be applied on the basis of:

- Vehicle types: e.g. cars, high-occupancy-vehicles, buses, pedestrians, bicycles, etc.
- Vehicle properties: e.g. accessible vehicles, autonomous vehicles, combustion vehicles, human-powered, etc.
- Usage purposes: including parking construction, activities governed by permits, emergencies, deliveries, ridesharing or taxi operations, school travel, special events, utility work, waste management etc.
- Tolling regime: for tolled or high-occupancy-toll lanes.

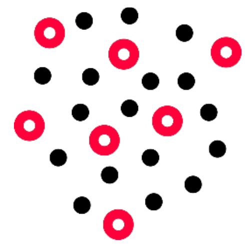
If no managed users are specified, the rule is presumed to apply to all roadway users regardless of mode, vehicle type, or purpose. It is important to note that the managed users in the proposed ROWDS specification is an abstraction that covers multiple concepts in the current version of Curb Data Specification, allowing for a broader

[5] https://github.com/openmobilityfoundation/curb-data-specification/blob/main/curbs/README.md#rate

set of rules to be applied. CDS concepts combined into the managed user field include Activities[6], User Classes[7], and Purposes[8].

ROWDS allows users to define many complex regulations covering a wide range of activities and users. The full set definition and example applications of Rules may be found in the ROWDS website[9] and in Appendix A: Right-of-Way Data Specification GitHub Page.

1.3 Right-of-Way Objects



Objects are any physical assets that exist in public space that may need to be represented but are not otherwise defined in the ROWDS. The concept of Objects in ROWDS borrows heavily from – and extends the definition of – Curb Objects in CDS[10]. The inclusion of any or specific Objects is completely optional.

The required attributes of a Right-of-Way Object include a unique ID, mappable geometry, the type of object it represents, and its publishing history. The Right-of-Way Object may also be linked to other ROWDS entities such as Roadways, Lanes/Sidewalks, and Intersections to facilitate querying based on spatial relationships to the other features on a map. Policies may be applied directly to objects as needed, but normally, it is preferred to apply Policies to the physical space such as a Roadway or Curb Zone in which an object is located.

Right-of-Way Objects are extremely flexible and can be used to map nearly any type of physical element found within or alongside the public Right-of-way. Examples of object types include signs, bike racks, parking meters, trees, bollards, street lighting, and more. ROWDS provides a long list of well-known values for object types. See the full specification on the website or in Appendix A.

1.4 Areas

Areas are an optional feature class designed for ROWDS implementers to define large geographic areas of interest, such as a neighborhood or district. Areas are extremely flexible and may be updated as needed. They may overlap with or nest within other areas. These are not meant to represent entire cities, and in general should be no larger than a typical neighborhood.

Areas facilitate geographic querying for many ROWDS entities that may be related within the fabric of a city. As a simple example in the context of parking management, Areas would allow users to query the Curb Zones in a specific neighborhood. An Area could also be used to define one or more key corridors of special interest.

Each area must contain a unique ID, a mappable geometry representing the Area, the list of Roadway IDs covered by the area, and its publishing history. Areas also allow the application of blanket Policies that may not be defined on each Roadway (for example – a City Center speed limit).

[6] https://github.com/openmobilityfoundation/curb-data-specification/tree/main/curbs#activities
[7] https://github.com/openmobilityfoundation/curb-data-specification/tree/main/curbs#user-classes
[8] https://github.com/openmobilityfoundation/curb-data-specification/tree/main/curbs#purposes
[9] https://github.com/openmobilityfoundation/ROW-data-specification/tree/main/rightofway#rule
[10] https://github.com/openmobilityfoundation/curb-data-specification/blob/main/curbs/README.md#curb-object

1.5 Events

The Right-of-Way endpoints in ROWDS described above provide a geographic data model describing what assets and objects exist in the public realm and the rules for the allowable usage of those assets. ROWDS also calls for an Events endpoint specifically designed to track real-time and historic information the *actual usage* of these assets by public and private actors.

Events describe what is happening in the right-of-way and their temporal and spatial connections to right-of-way elements, such as roadways, lanes, curbs, sidewalks, etc. Events provide users with data on what activities are taking place in the built environment, where they are taking place, and when. It is envisaged that event data could be populated from a wide range of sources, such as sensors, payment systems, in-person observations by agency personnel, drones, and other sources.

The proposed specification would extend the Curb Data Specification's Events API, which provides a concrete example of events[11]. CDS provides the concept of a *Curb Event*. While highly generalized, the simplest use case for a Curb Event is to record the details of parking events. A roadway user parking in a Curb Zone/space a specific time would be recorded as a single event, and a second event would be recorded for the end of their parking session. The system also provides fields for information about the vehicle itself, such as the type of vehicle, parking permits associated with the vehicle, and vehicle characteristics (e.g. size, color). Payment details for a parking session are also recorded as part of a Curb Event. These detailed events allow CDS-powered applications to calculate parking occupancies and turnover and determine whether vehicles using the curb are parked legally or illegally.[12]

For the purposes of the Philadelphia SMART Grant prototyping effort, the scope of ROWDS Events endpoint was limited to designing a data model specifically to extend CDS concept of Curb Events with *Policy Events* and *Policy Status*, containing information about events that are permitted by temporary or recurring policies.

A future permitting system should, ideally, be able to track and serve information to help with efficient management of City space and, critically, *management* of activities. Even when a permit is issued for a period of time – for example, a month – it may not be actively used efficiently for a variety of reasons, including delays, change orders, and availability of staff or equipment. Alternatively, some activities may violate the specific conditions attached to a permit. The specific use case for this extension is to link permitted street closure and right-of-way encroachments to information about the construction or special event activities requiring these permissions. These objects are described below.

[11] https://github.com/openmobilityfoundation/curb-data-specification/tree/main/events
[12] As noted, Curb Events supports recording many different types of events beyond parking sessions, including violations, ticket issuance, simple vehicle detection events, and communications equipment used to record events coming online or falling offline.

1.5.1 Policy Events

ROWDS defines a Policy Event as a record of activity that relates to an Event Policy Type within the right-of-way. It is used to record what activities related to a Policy are taking place and their location. A core requirement for Policy Events is that they must be associated with a Right-of-Way Policy. This is essential for linking Policy Events back to one or more defined Right-of-Way Objects, such as a specific roadway or lane, as both are related to the same Policy object. A Policy Event must also have a unique ID, an event type, location, enforced or active time, publication date, and source type. For example, a planned lane closure along a given street for construction, or a complete road closure for a street festival. The source type indicates whether the event was retrieved from a data provider, an individual on-site recording the event, a work order, or a source not previously mentioned.

One Policy Event is recorded for each stage associated with an activity and is associated with a single, required timepoint. The required Event Type field is used to say whether the event represents the fact that:

- An application has been submitted;
- An application has been approved;
- An activity has started;
- An activity was paused;
- An activity was resumed;
- An activity has ended (permanently).

A single, logical activity will thus often have multiple events associated with it, which together form a *session*. An optional Session ID field can be used to tie multiple events back to the same basic activity. For instance, a single Session ID may be used to link together the start and end times of an excavation activity, which could take place over multiple days or weeks.

1.5.2 Policy Status

Policy Status is an optional object that describes at a higher level whether a permit is actively being used. While Policy Events record the detailed changes in an activity over time and contain multiple records for when an activity associated with a permit starts and stops – the Policy Status provides a summary of the *latest* details of recorded Policy Events. It boils down the complex sequences of Events into a simpler categorical data structure about current usage.

Policy Status object has only two fields – both are required. The first is a timestamp for when the Status was last updated. The second is the Policy Status Type which may be:

- In Review – Indicates that a permit application has been submitted and is under review;
- Approved – Indicates that the permit application has been approved and can be applied to the right-of-way;
- Active – Indicates a permit policy is within its active, approved period of validity, but no specific activities are underway;
- In Use – Indicates that the activities allowed by the permit are currently happening;
- Complete – Indicates that the permit policy is still within its period of validity, but the activities for which the permit was needed been completed;
- Closed – Indicates the permit period has closed and the policy is no longer in effect.

1.5.3 Example of Event and Status Updates

The advantage of implementing the Status object is to provide a more direct answer to the question "what is happening now" with respect to a policy. It operates by providing a summary layer over a whole series of events, which would otherwise need to be analyzed in detail to answer that question. The table below reflects an example of how Policy Events could be recorded along with how the Policy Status should be updated for a fictional, small construction project.

Table 1. Policy Event and Policy Status Updates

Timepoint	Stage	Event Type Recorded	Policy Status Type Updated
1	Contractor applies for permit	"submitted"	"in_review"
2	Permit is approved by City	"approval_given"	"approved"
3	First permitted date for activities commences	n/a	"active"
4	Construction begins	"event_start"	"in_use"
5	Construction pauses for holiday	"event_paused"	"active"
6	Constructions resumes after holiday	"event_resumed"	"in_use"
7	Construction is completed	"event_end"	"complete"
8	Last permitted date for activities passes	"event_end"	"closed"

2 Data Proof of Concept

In order to demonstrate the potential of the ROWDS for this SMART Grant prototype, the Project Team generated a ROWDS-compliant dataset for a pilot study area in Center City Philadelphia. The study 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.

Source data were collected from multiple mapping databases, enriched, and transformed into JSON-files conforming to the specification. To create the ROWDS data, the Project Team relied on official city-generated datasets where possible, but other data sources, including collecting new data, were used where existing data was not available. This initial study served to identify gaps in city-hosted data sources and create an initial holistic source of data for Right-of-Way Objects in the study area.

Figure 9. Bounds of the Pilot Area

2.1 Data Collection Process

Over 50 different data types had to be captured as part of the mapping of the right-of-way for this project. Fortunately, several of these data types had similar data sources, allowing for similar processes to be used to take data and convert it into the final data format. The following section highlights the various data objects generated for the final data deliverables, as well as the processes used to generate this data. A summary of all this information can be found in the associated Right-of-Way Data Tracking Table found in Appendix B.

2.1.1 Data Objects

As part of this project, the City of Philadelphia specified 50 different data objects to be captured within the right of way. As part of the Existing Conditions and Gap Analysis report, these 50 data objects were reviewed, and it was decided which objects would be captured only in the specification, captured as part of the data deliverable, and whether existing data existed to help capture the relevant information. Details on each of these data objects, including information on how each of these data objects were processed and how they are included in the ROWDS is included in Appendix B. A summary of the information included is noted below:

- **Data Type Info:** Includes the original grouping of data objects from the City as well as names and descriptions.
- **Data Source:** Lists from where the data asset was originally sourced, whether new data was collected, and the final file names.
- **Conversion Process:** Details the method for converting the original data set into the INRIX Road Rules data format. This section also notes if an asset that was originally intended to stand alone was combined with another more encompassing asset. For example, pedestrian flashing beacons were originally intended to stand alone as their own asset but were ultimately aggregated into the "traffic calming devices" asset.
- **Other Notes:** Any other considerations for the asset, including challenges with converting the dataset, fields that were originally missing but added later, or additional processing that may be considered later.
- **Right-of-Way Specification Documentation:** Notes where this data object exists within the ROWDS as well as the processes required to convert this data into ROWDS.

2.1.2 Data Sources and Conversion

Several data sources were required to create a comprehensive digital twin of the right-of-way. Data sources included OpenDataPhilly, Open Street Map (OSM), and Cyclomedia imagery. These sources ranged from providing specific locations and attributes of street poles and parking meters, to the layout of whole transit and bikeshare networks.

Given that data was collected from a variety of sources, several data conversion processes were required to ensure that all data assets were recorded as JSONs and followed the final data schema specifications. At a high level, data was received or downloaded from the source as a shapefile, csv, GeoJSON, or JSON. From there, Python scripts were used to transform data into the schema for the given asset type.

Note that data was initially converted into the INRIX Road Rules format, but similar processes can be used to convert the data into the ROWDS. A summary of the processes used are provided below, according to the specific data source, with additional details in Appendix B.:

- **Open Data Sources:**
  - **Open Data Philly:** Data was downloaded in JSON format, and a Python script was used to transform the data into the INRIX data schema format.
  - **OpenStreetMap (OSM):** Roadway data was extracted from Open Street Map, which has information regarding road centerlines, travel lanes, directional attributes, and a variety of other attributes. A roadway file was generated using a combination of GIS tools and OSM data points. This data was then reviewed through an extensive quality control process, which included comparing the data to a combination of Cyclomedia roadway data and street view imagery to ensure accuracy.
  - **Other Sources:** Although some data objects were primarily sourced from one open dataset, specific attributes or policy information may have come from other sources. For example, roadway data came from OSM but road closure information about those roadways was sourced from the city's StreetSmartPHL tool. These combinations of data overlays are noted in Appendix B where relevant.
- **Generated:** Some data sets had to be generated from other available data, including fire lanes, parking lanes, and curb policies. For these assets, the data conversion process began with viewing satellite imagery

to determine where fire lanes and Curb Zones begin and end. In some cases, satellite imagery of signage, curb cuts, and other objects were also used to break up the curb into CDS Curb Zones. Additionally, this step could be used to extract relevant data to create CDS curb policies.

- **Cyclomedia:** The City's Cyclomedia imagery data was used to extract data for many assets in the right-of-way. Cyclomedia captures panoramic photography along with 3D LiDAR data. Using computer vision techniques in combination with processing this 3D point-cloud data, Cyclomedia is able to extract individual features from the imagery dataset with a high degree of geographic precision (within several inches)[13], specifying the presence and location of assets at a granular level, such as individual street signs. Data sourced from Cyclomedia was both derived from an "automated extraction" process utilizing machine learning and manually created using the Cyclomedia Streetsmart platform.
  - **Automated**: Cyclomedia data derived through the "automated extraction" process was delivered directly as full datasets and only needed a Python script to ensure that the JSON's schema matched the INRIX schema format. More information on automated extraction for parking signage follows below.
  - **Manual:** Alternatively, some assets such as bollards and trees, had to be manually extracted from Cyclomedia imagery, by manually adding points to the map using GIS software. In these instances, the Project Team viewed street level imagery, added a point directly to the map representing the location of the asset, and recorded the required attributes. Once this dataset had been created as a shapefile, a Python script was used to transform it into a JSON file and ensure that its schema corresponded to the INRIX schema.
- **Out of Scope:** Certain features, such as pavement condition, traffic cameras, and bollards are technically accommodated by the ROWDS specification, but were excluded from the ultimately delivered pilot data set. Other built-environment features, such as retaining walls, land use, and off-street parking are out of scope for the ROWDS specification and were not included.

2.1.3 Data Quality Control and Accuracy

Arcadis is ISO 9001-compliant and has deployed its Quality Management System (QMS) across the firm and in the various work we complete. We are committed to Quality Assurance (QA) and Quality Control (QC) practices that support the standard certification which includes external and internal audits of our projects. This holds true for this project, which had a robust QA/QC process for all data objects created to ensure accuracy and completeness. A detailed breakdown and documentation is provided in Appendix B, but some high-level takeaways are noted below:

- **Spot Check Reviews:** All data objects had spot check reviews completed which involved ensuring data seemed complete across the pilot area as well as checking a random sample of the data to ensure attributes were consistent and accurate. These spot checks also included comparing with Street View imagery where applicable.
- **Custom QC Processes:** Some data objects had additional, custom QC processes added in to ensure some of the unique information for that data object was correct. For example, sidewalk data was reviewed to ensure consistent representation of geometries after it was noted that depending on the quality of imagery captured data may be inconsistent.
- **INRIX Software Review:** As INRIX ingested all the data that was being generated into their software, they also performed a review of the data and flagged any specific issues that would affect how they handle the

[13] https://www.cyclomedia.com/us/resources/blog/cyclomedia-street-smartr-vs-google-street-view

data. For example, certain ID matches were required for overlaying permit data onto the various right-of-way assets that may not have been necessary for just the data itself.

In general, it is also worth noting that not all data could be validated from a second source or directly in the field, so data was assumed to be accurate from its original source. For example, several of the data objects from open data sets or OpenStreetMap could be reviewed for consistency, but ultimately the accuracy of their locations was assumed to be correct based on what OSM provided.

A subset of data objects that required additional processes and QC to ensure a high level of accuracy was parking signage extracted from Cyclomedia to be used for generating the curb inventory. Unlike a light pole or stop sign that was simply extracted as an asset with its relevant location, parking signage had to have the relevant regulatory and directional information pulled from the text on the sign itself to map out curb restrictions. This process is highlighted below. Some of these steps were unique to the City of Philadelphia and had to be created as part of this project, but they are now ready to be used at-scale.

Cyclomedia Parking Sign Processing

As mentioned, ensuring high quality imagery and a high level of accuracy for parking signage data was particularly important as this data was being used for generating all Curb Zones, parking inventory, and curbside rules & regulations. Therefore, the central objective of the below processes to convert Cyclomedia parking sign imagery to the finalized ROWDS schema, was to ensure data accuracy. The workflow evolved significantly; from a single-view detection model (Iteration 1) to a multi-view, best-frame selection system (Iteration 2). Each iteration is designed to reduce false positives, recover missed detections, and filter out non-applicable assets. The final pipeline integrates automated detection, geometric reasoning, and human-guided verification to maximize correctness and minimize noise in the dataset.

This section summarizes how each part of the pipeline protects accuracy and how the full system achieved measurable improvements across the dataset. These improvements are quantified below. The pipeline is designed as a series of accuracy filters, where each stage removes uncertainty and reinforces correctness.

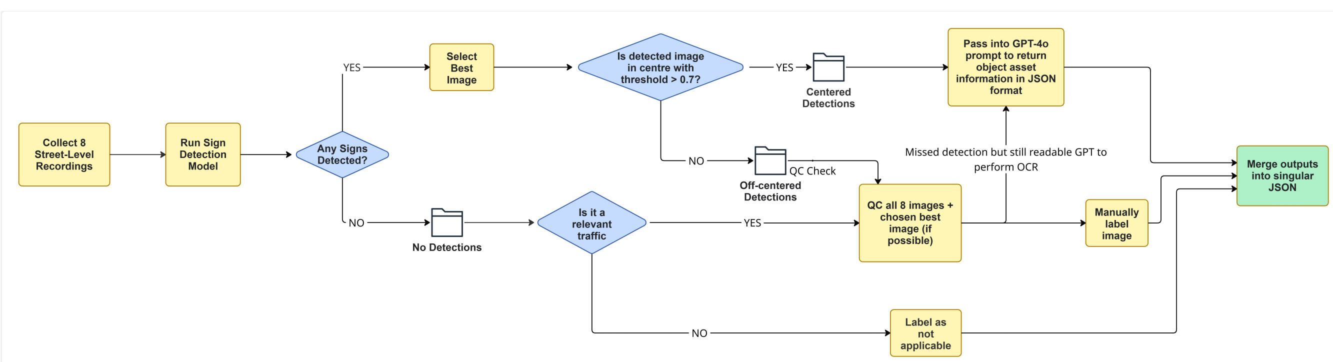
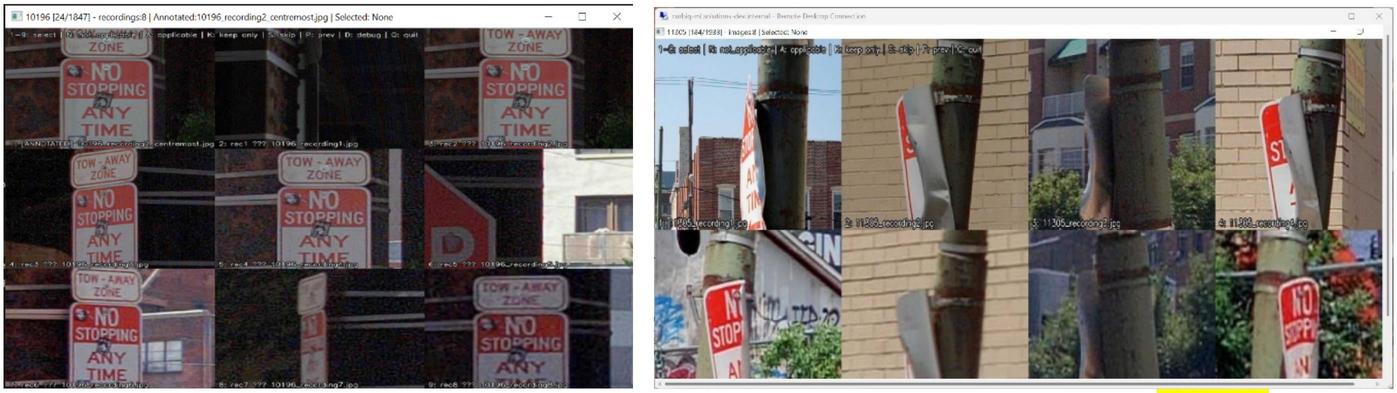


Figure 10: Multi View: Off-centered detection recordings example; Left Figure - original image (top middle) shows no sign visible but by capturing multiple viewpoints, we are able to capture the sign in another recording. Right Figure – a more challenging instance with several angles having unsuccessful views of the sign.



Multi-Recording Input Collection: Each asset includes up to 8 street-level recordings as seen in Figure 10. This inherently raises accuracy by ensuring that if a sign is angled, blocked, partially visible, or out of the frame in one recording, another recording may fully capture it. This step alone addressed one of the largest accuracy problems observed when the model was initially developed, using single-viewpoint images of each recorded location.

Model Detection and Centrepoint Filtering: From here, the sign actually had to be detected within the image. The sign detection part of the pipeline utilized YOLOv5, a commonly used object detection model in machine learning, trained on already existing sign imagery in our database. To ensure the correct sign is chosen, the pipeline applies strict selection logic:

1. Pick detections whose bounding box contains the image center point
2. If none, select the detection closest to the center
3. Break ties using the highest confidence score (Note: a sign is considered detected if its score is greater than or equal to 0.70 – this confidence score ranges from 0 to 1 and is generated from the model)

This geometric approach ensures the model consistently selects the main regulatory sign, rather than street name blades, banners, address plates, background signage, overlapping signs, or other non-relevant imagery. This center point logic produced one of the largest boosts in precision between Iteration 1 and Iteration 2.

Best Image Selection Across 8 Recordings: Once all 8 frames are processed, the pipeline selects one best recording per sign object based on confidence score, center point containment, and center distance. This ensures the dataset retains the single most accurate and readable sign image. It also prevents poor-quality views from diluting the dataset or reducing model precision.

Separation Into Centered, Off-Center, and No-Detection Buckets: With a sign image selected for each data object, objects then had to be classified into different folders based on set criteria so different policy (sign text) extractions can be applied. Each image was classified into:

- Centered detections → fully automated, highest accuracy
- Non-centered detections → partially automated, requiring QC
- No detections → reviewed for relevance or non-applicability

This system ensures only high-quality detections enter the automated pipeline while ambiguous cases are escalated to human QC.

Manual QC and Not-Applicable Filtering: For ambiguous cases (poor angle, clutter, low visibility), an additional script was developed which displays all 8 frames at once, making it easy to determine:

- Is there a real traffic sign?
- Is the asset not a traffic sign at all?
- Was the sign simply occluded or mis-oriented?

Figure 11: Off-centered detection recordings example, model selected the tow-away sign as the sign of interest (incorrect)

This step is critical for downstream model accuracy; non-applicable items must be excluded, so the model is not penalized for correctly ignoring irrelevant signs. As the sign detection model cannot distinguish parking-specific signage from other street-level signs, as it was only trained to identify any sign **not** their type, this manual step is critical for creating a clean, curb-policy-relevant dataset. Manual QC was applied specifically to the no-detection and non-centered detection folders to (a) filter out non-applicable signs, (b) correctly label applicable signs that would likely be unreadable by GPT-OCR, and (c) recover valid signs from any of the eight recordings that the automated winner-selection logic did not choose, ensuring those readable frames were still passed into the GPT-OCR stage. An example of a sign requiring manual labelling for the off-centered detections can be seen in Figure 11.

This image highlights one of the challenges the model faced when selecting the “best” image. With multiple signs stacked, there was difficulty choosing the best one, especially when the image did not show the full sign. Hence the need for this manual QC step to ensure a usable image is selected.

Having a person who is familiar with the sign imagery and context of the task manually QC’d and labelled these blocked signs to effectively capture all the regulations from the dataset. In cases where the sign was completely obstructed or it was not a Traffic Sign being captured (i.e., highway or location signs), the assets were labelled as “not applicable”. Signs that were partially blocked by foliage were inferred based on the color of the sign and letters that could be captured by the team and labelled manually.

GPT-OCR Extraction and Structured JSON Output: After the best images are generated and valid signs are recovered from the no detection and off-centered detection folders, each sign is passed into an OpenAI-powered OCR prompt to extract structured regulatory information (Figure 12). This stage converts the visual content of the sign into a clean, machine-readable JSON object in ROWDS.

Figure 12: Successfully detected and cropped sign passed into GPT4.0, with respective response.

The GPT-OCR layer produces:

- structured text fields (reason, time windows, days of week)
- directional information (arrows, exceptions)

- additional posted text
- a standardized JSON entry linked to the original sign object
- corrected or overridden values when manual QC is involved

This final step transforms the high-quality cropped detections into a unified, consistent dataset suitable for asset layer generation and digital curb inventory creation.

Data Accuracy Summary

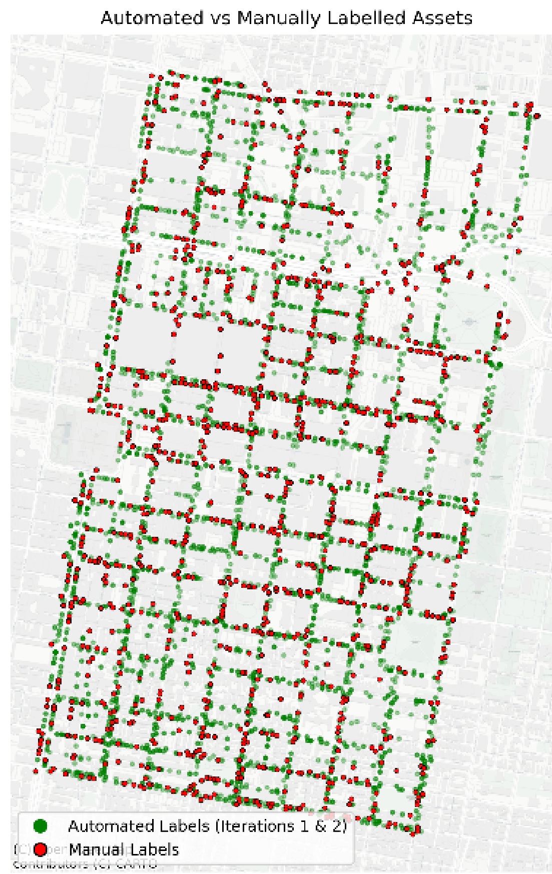
The accuracy of the curb-sign detection pipeline improved substantially across the two iterations of processing. Iteration 1, which relied on a single rendered image per asset, faced significant limitations due to viewpoint, obstruction, and image quality. Iteration 2 introduced a multi-recording pipeline with up to eight images per asset, dramatically increasing sign capture reliability through best-view selection, center point filtering, and structured QC workflows. To illustrate this improvement, the table below summarizes the key accuracy metrics from both iterations.

Table 2: Data Accuracy of Parking Signage Capture

Metric	Iteration 1 (Single View)	Iteration 2 (Multi-View)	Notes
Total assets processed	**7,918**	**7,918**	Iteration 2 runs only on remaining assets that were not successful in the Single View (hence the smaller amount)
Successful detections (usable, no manual intervention)	**2,948**	(2,948+1,728) **4,676**	Iteration 2 value combines centered and successful off-center detections
Not-applicable assets (manually verified)	—	**1,389**	Includes assets not meant to have a sign
Manually Labelled Assets	—	**1,826**	
Off Centered	—	879	Model gave a higher confidence score to an incorrect sign, therefore not picking the actual “best” image; typical if signs are stacked
No Detections	—	947	Missed by model typically due to low quality images or signs
Effective Automation Success	37.2%	**71.6%**	Model success only applied to parking signs (not omitted signs)
Automation Success	37.2%	**76.6%**	Combines successful detections from both iterations and includes omitted signs (as model could still detect these)
Assets Processed	N/A	**100%**	Between automation and manual QC, all signs were processed

The results of this model are visualized in Figure 13, showcasing areas where manual intervention was required. This analysis highlights underlying trends where certain corridors or streets where signage was more difficult to read. This could be attributed to several elements such as more traffic blocking signs on busy streets, or older signage that may be more difficult to read, that result in less automatic capture. Further analysis can be done on these trends when scaling this collection city wide.

Figure 13: Overlay of signs automatically vs manually labelled

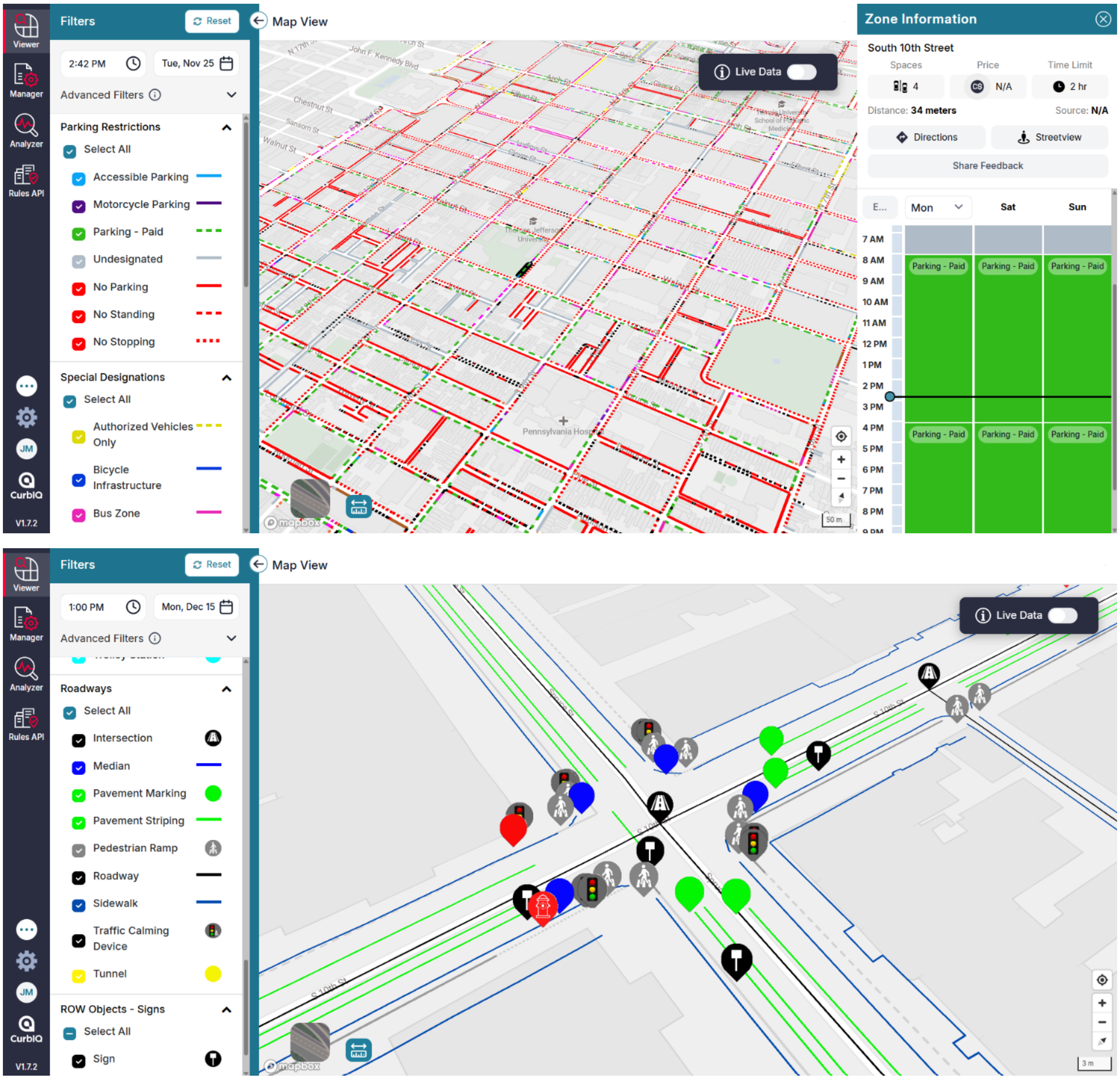


Overall, the multi-viewpoint pipeline substantially improved the time, reliability and accuracy of the traffic sign extraction. While Iteration 1 suffered from single-view limitations such as sign angle, obstruction, and inconsistent rendering quality, Iteration 2's eight-recording approach allowed the pipeline to consistently recover clearer, more front-facing views, significantly increasing effective detection and reducing ambiguity. Cyclomedia imagery and how the data is processed still has room for improvement, with the opportunity to limit the amount of manual labelling that needs to be completed. This includes addressing small text, glare, shadows, back-of-sign views, and physical obstructions. Potential improvements to using Cyclomedia for image capture are covered in greater detail under Next Steps section, see Section 5 below. However, the multi-view approach, center point filtering, and manual QC helped offset these issues and produce a much cleaner dataset.

2.2 Final Data Packages

With these processes run, QC completed, a final set of data deliverables was created that represent the roadway and its associated rules, objects, and features in a digital format. These files were all provided in INRIX Road Rules format and will be converted into the ROWDS format by the software team. To visualize some of this data, the Project Team uploaded several of the data objects to the CurbIQ platform, with screenshots shown below. Temporary access to the platform will also be provided to the City.

Figure 14 - Collected Curb Data (top) and Roadway Data (bottom) Snapshot on CurbIQ platform



3 Current Right-of-Way Permitting Process

Along with the data collection and standard to host the data being created, it was also important to have a clear understanding of the City's existing processes and how this data can fit into those processes. A particular focus for this project was the right-of-way permitting process.

The City of Philadelphia identified the processes for reviewing and approving permit applications for temporary right-of-way modifications as an important potential use case for improved digital mapping. This is because the permitting process relies heavily on piecing together information about what assets will be impacted by encroachment into or closure of portions of the public right-of-way.

At its core, the permitting process asks three questions about a proposed closure:

1. Is the closure being planned in a safe manner?
2. What else is happening in the City that might conflict with the closure?
3. Is the permit allowable?

A base understanding of what exists in the real world is crucial to making these decisions digitally. Consolidating mappable assets into a flexible, unified system was deemed to have a high potential to improve efficiency to the permitting process, which is a core function of the Philadelphia Streets Department's Right-of-Way Unit.

To explore this application of ROWDS, the Project Team gathered information about the existing workflows and processes used by the Streets Department through multiple venues. First, the team conducted a "ride-along" interview via video conference. In this interview, the team observed a Streets Department employee going through each step of a permit review and approval process. The Team also had the opportunity to ask clarifying questions about the process.

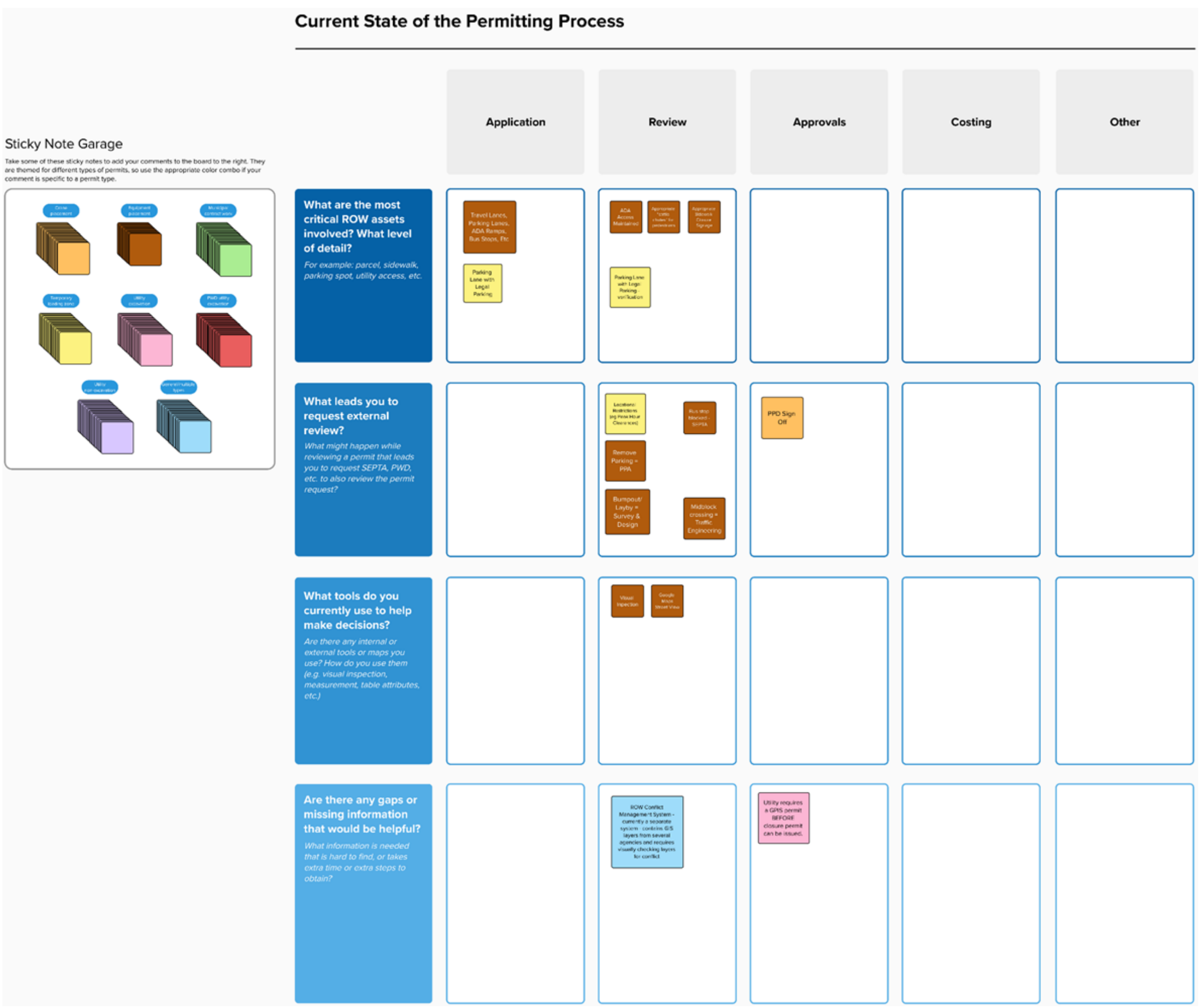
The Right-of-Way Unit is responsible for the review and approval of applications of the following permit types, which vary greatly in logistical complexity and their corresponding impact to City streets. The most common types of permits are Temporary Loading Zones (for moving trucks, skiffs/containers, and other items); Utility Work requiring excavation into City streets and sidewalks; Utility Works not requiring excavation; Equipment Placement for construction projects; Temporary Loading No Parking regulations; Crane Placement for construction projects; and Municipal Contract Work to construct or restore street elements. As one can see from Table 2, thousands of these permit requests exist across the City at a given time, and at this scale any improvements to how they are coordinated or processed could result in major cost and time savings for the City.

Table 3: Summary of Permit Requests in the City of Philadelphia for The Provided Time Period

Permit Type	Count	Min Duration (Days)	Max Duration (Days)	Ave. Duration (Days)
Temporary Loading Zone	53,950	0	365	0
Utility Work Excavation	14,883	0	28,858	38
Utility Work Non-Excavation	9,696	0	456	80
Equipment Placement	8,024	0	427	48
Temporary No Parking	5,186	0	366	4
Crane Placement	2,067	0	140	0
Municipal Contract Work	1,208	0	24,577	133
Temporary Passenger Loading Zone	726	0	365	10
Tower Crane Placement	14	0	94	17
Banner Installation	10	1	365	223
Helicopter Lift	9	0	4	0
Festival & Special Event	3	0	8	3

Second, a follow up workshop was held in June 2025 with multiple members of the Streets Department. This workshop was focused on expanding on learnings from the interview process. Participants were provided with access to a whiteboarding exercise. This focused on soliciting additional details about what most critical assets participants consider when reviewing different application types; what conditions require external review or input from other City departments; what digital tools, software, and maps they currently use in their processes; and what gaps in information would most help make their process more efficient.

Figure 15. Permitting Process Workshop Whiteboard

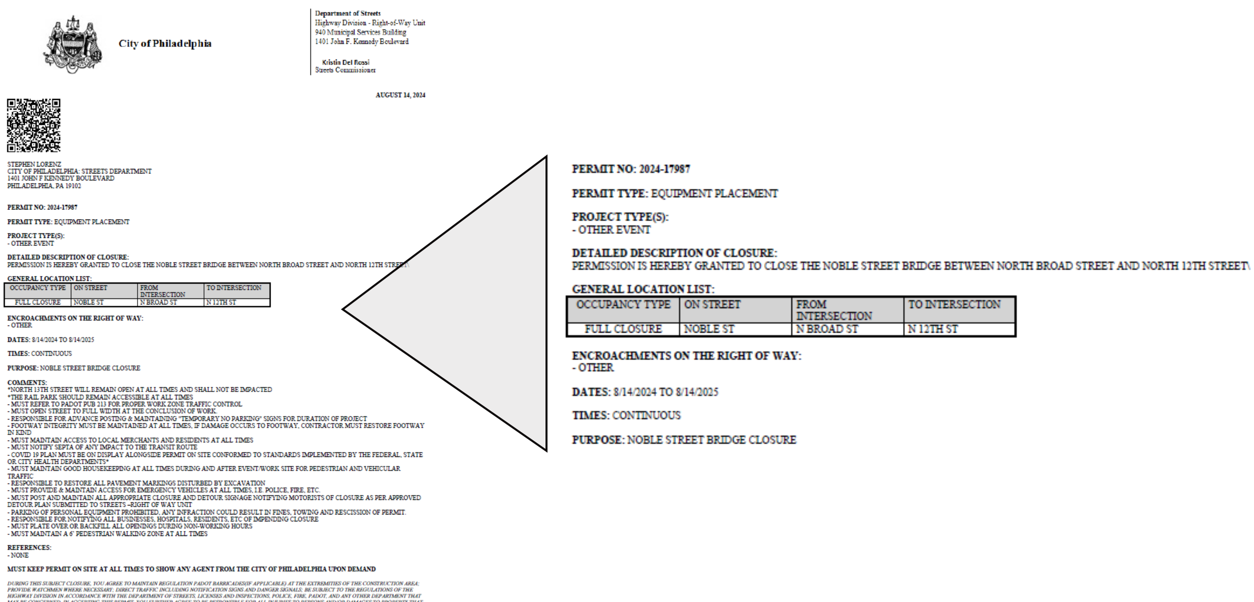


Based on these stakeholder engagement exercises, the project team developed summary process maps that informed discussions on the specific ways in which ROWDS could benefit this important government function.

3.1 Permit Review Process

The review process varies by permits in terms of specific details and level of detail. More complex permits that may have greater impact on surroundings, such as Equipment Placement, tend to require more information than less complex permits, such as Temporary Loading Zones. Additional examples are provided in Appendix C.

Figure 16. Equipment Placement Permit Example


City of Philadelphia

Department of Streets
Highway Division - Right-of-Way Unit
940 Municipal Services Building
1401 John F. Kennedy Boulevard

AUGUST 14, 2024

PERMIT NO: 2024-17987

PERMIT TYPE: EQUIPMENT PLACEMENT

PROJECT TYPE(S):
- OTHER EVENT

DETAILED DESCRIPTION OF CLOSURE:
PERMISSION IS HEREBY GRANTED TO CLOSE THE NOBLE STREET BRIDGE BETWEEN NORTH BROAD STREET AND NORTH 12TH STREET

GENERAL LOCATION LIST:

OCCUPANCY TYPE	ON STREET	FROM INTERSECTION	TO INTERSECTION
FULL CLOSURE	NOBLE ST	N BROAD ST	N 12TH ST

ENCROACHMENTS ON THE RIGHT OF WAY:
- OTHER

DATES: 8/14/2024 TO 8/14/2025

TIMES: CONTINUOUS

PURPOSE: NOBLE STREET BRIDGE CLOSURE

MUST KEEP PERMIT ON SITE AT ALL TIMES TO SHOW ANY AGENT FROM THE CITY OF PHILADELPHIA UPON DEMAND

Review applicants generally submit letters describing planned works, along with textual descriptions and design drawings. The review process involves several forms of information that can be geospatially represented. Data reviewed by permitting staff includes:

- Street addresses that are provided as text in the permit application submission.
- Site plan drawings provided in the permit application submission, showing plans for encroachments and temporary plans to support the maintenance and protection of traffic.
- Written description of where regulations and policies apply and proposed temporary policies to support construction activities (for example: “Sidewalk Closed – Use Other Side”).

Streets department staff must contextualize and verify these descriptions and design documents. They ensure that dimensions are represented accurately, identify bus routes and transit stations that will be impacted, and check whether any additional public works are likely to overlap or conflict with the permitted activity.

To accomplish these tasks, Right-of-Way Unit personnel must cross reference the application documents with other geographic data sources. In many cases, measurements are verified using tools built into these mapping platforms. Tools referenced by the Streets Department during stakeholder engagement include:

- Google Maps and Street View
- Philadelphia Atlas GIS Portal – The City’s digital property map containing information on property assessments, deeds, licenses and inspections, zoning, and election districts, and other information.

- The City's Right-of-Way Decision Tool – A system designed to highlight geospatial and temporal information across active and planned permits.
- Guaranteed Pavement Information System (GPIS) – A City system designed for coordinating street repaving and to ensure that excavation works result in suitable resurfacing after completion. GPIS is also administered by the Streets Department Right-of-Way unit, although separately from the group that permits street closures.

The Streets permitting process generally follows these steps:

Submission	• Applicants for street closure permits are submitted through an online portal. • The application must include proper supporting documentation, including a letter describing the work, and where required, design documents and site plans. • Depending on the type of right-of-way permit requested, an upstream permit from the Department of Licenses and Inspections (L&I) or from the GPIS system. • If the applicant is requesting a closure, the application request must explain how pedestrians, transit users, or vehicular traffic are being diverted.
Initial Review	• Verifies the point of contact for the application materials. • Confirms that the application materials completely satisfy requirements for the proposed development. • Identifies the location of the proposed development. Within the internal administrative system, staff provide inputs regarding all the streets involved, the from-street, the to-street; whether a partial or full footway is required, and linear footage of the impacted right-of-way. • Verifies that the site plan and permit applications are consistent with each other. • If reported dimensions appear inconsistent with the site plan or any other application materials, staff may manually enter a street address in Atlas, a mapping platform, and proceed to calculate measurements. • Determines whether review is needed from other specialized staff, such as the traffic engineering, ADA, and surveying, as well as other organizations, such as the Philadelphia Parking Authority (PPA) or Southeastern Pennsylvania Transit Authority (SEPTA).
Analysis	• Evaluates the application materials for impacts to pedestrians, transit, traffic, parking, and any other activity that is overlapping. Staff may use the Right-of-Way Unit Decision Tool to compare the request to other current permits. • Ensures proper placement of temporary traffic control devices. • Ensures ADA compliance. • Confirms the necessity of roadway or sidewalk closures.
Permit Creation	• Verify measurements and record encroachments into the right-of-way. • Enters descriptive information about the location of proposed work per the application. • Apply additional Comments notifying the applicant of additional specific rules that must be followed as a condition of the permit. These are typically copied from text

	document templates, with key fields to fill in based on the application details. • Identify relevant external contacts requiring notice of the application.
Costing	• Calculates cost for permits. Each encroachment has a unit-cost (either per-event, per-item, per-foot, etc.) that must be multiplied by the extent of the encroachment gathered from the application details. • Costing takes place in a separate application from other permitting. • Mark decision as “awaiting payment”. • Notify the applicant that payment is due within five days.
Payment and Final Approval	• Update decision to “approved”. • Email confirmation of the decision to the applicant.

3.2 Challenges and Opportunities in the Current Review Process

Consideration of Many Asset Types and Rules

Stakeholders in the Streets Department must review many physical aspects of the right-of-way to determine whether to approve a permit. Key asset types mentioned during engagement process included travel lanes, parking lanes, ADA ramps, bus stops, and parking lanes with legal parking. In the review section of the process, they mentioned analyzing the maintenance of ADA access, inclusion of a “cattle chute” for pedestrians, appropriate sidewalk closure signage, and verification of a parking lane with legal parking.

Stakeholders also mentioned policies that impact some right-of-way reviews, including critical arterial streets (e.g. Broad Street and Walnut Street) with special peak-hour parking restrictions that restrict curb lane usage during rush hours periods that need to be considered.

Multiple Software Systems

The burden of cross-referencing information between applications is relatively high for Streets Department staff. One participant noted having “seven applications open on my screen right now,” indicating that unifying various information sources could greatly improve user experience for their permitting workflows.

Feedback mentioned referring to visual inspection of aerial maps, use of Google Maps and Google Street View, as well as the City of Philadelphia Atlas GIS portal in order to verify information included in an application and to measure geographical features for costing permits.

Staff also rely heavily on the Right-of-Way Decision Tool, an intranet web application that was discussed further in response to the final question about gaps and missing information. This intranet site is provided to permit reviewers to locate existing approved permits and other data layers. However, Streets staff mentioned that it can only be used for conflict resolution via visual comparison, not automated integration. Staff also mentioned that the tool has data quality issues and is prone to being unstable when too many data layers are turned on. While staff indicate this is an important tool for reviewing permit applications, it can be further enhanced to improve efficiency and accuracy.

Lack of Integration Across Permitting Systems

System integration is perhaps the greatest challenge mentioned by staff. Some activities require permits from multiple departments or units that must be coordinated, and it can be difficult to match these together. Staff mentioned that the Department of Licenses and Inspections base its geographies on parcels, while other departments use centerline miles, and yet other sources of information, like GPIS, use street segments bounded by intersections. In the case of GPIS, queries must also match the order in which the start/end intersections are coded. For example, permits on a particular roadway between 8th Street and 9th Street would not return the needed information if the works were entered as occurring between 9th Street and 8th Street. Associated permits are generally hard to locate, such as on larger projects where multiple contractors are pulling permits for the same project.

Missing Information and Manual Data Entry

Streets Department staff noted it was rare that they get 100% of the information that they need to accurately review a permit application without follow up. Free-entry fields open the possibility for manual errors in data entry by staff or applicants and can result in related permit details not being recorded accurately and requiring manual verification. Standardized fields that allow data to flow through systems seamlessly and prepopulate already verified information could help to streamline the process.

4 Impacts and Improvements to the Permitting Process

ROWDS was designed with the broad goal of providing a draft specification that could facilitate building "digital twins" of the entire public right-of-way. And, while developing a fully-fledged permitting software is outside the scope of the specification itself, ROWDS does contain features that could be leveraged to develop a much more streamlined application.

In particular, the modular design of ROWDS could provide key benefits to enhance the creation and review of permits:

- A flexible framework for visualizing the entire right of way in a true, two-dimensional planimetric map. ROWDS is not limited to abstracted geometric representations of roadway networks, like centerlines, but capable of representing the full cross-section of the right-of-way as well as most physical objects (and therefore also policy objects) within it.
- A Policy framework designed to represent a temporary event, and the ability to link these directly to digitized assets in the right-of-way. ROWDS enables linking details about temporary policies, such as road closures, the dates and times these policies are active, the specific impacts to what activities are allowed, and the physical assets to which they apply.
- Common geographic identifiers that are systematically applied across a variety of assets, including relationships to linear referencing systems that can make identifying impacted elements easier and more consistent.

The following sections highlight some of the specific impacts that ROWDS could have on the City of Philadelphia's permit process, along with specific examples.

Centralized, Queryable Asset Data

A full implementation of ROWDS in an application would lessen the need to cross reference multiple systems of information, as it enables consolidation of various right-of-way elements and other physical assets to a single user interface. These relationships can support advanced querying and assignment of what right-of-way elements are impacted by a permit. By defining the extents of a permit, it would be possible to immediately identify the various roadways, lanes, parking assets, and any defined objects that would be affected.

Users outside of the Streets Department would be able to easily reference the same source of information facilitating multi-departmental reviews. Such changes to the right-of-way inventory would efficiently propagate through the City's system(s) to quickly inform all stakeholders of the updates. If ROWDS were implemented across multiple systems – such as GPIS as well as street closure permitting – it would also provide a common set of geographic identifiers and objects between these systems.

Example: Loading Zones and Disseminating Data – If the City approves a request from a resident to implement a temporary loading zone outside of an apartment building, there are several staff (or even several different departments, depending on the permit) that could be impacted and who may need to access this information. By centralizing this data, it can be easily accessed, updated, and can streamline sending notifications to the necessary departments.

- **ROWDS Usage:** A City staff member in the permitting department would be creating a Right-of-Way Policy Event to represent the temporary loading zone. This policy event would be connected to the Curb Zone where it is taking place. This Curb Zone is also connected to the roadway and sidewalk via the corresponding roadway ID. In turn, that sidewalk and roadway portion is connected to various related Right-of-Way Objects, including the trees, bus stops, and mailboxes on that block via those objects' linkage to the same roadway ID. Though the primary goal of this project was not focused on operationalizing navigation aids, it is worth imagining the applicability of such information (outside of just temporary loading zones) to use cases such as bus detours, emergency vehicle dispatch, and more.
- **Impact on Processes:** The temporary loading zone may require closure of part of the roadway or sidewalk and the Streets Department can be easily notified through these data linkages. Flags can also be created when there are too many objects in front of the proposed loading zone, such as trees or mailboxes, that may impact the effectiveness of the loading zone. Staff may even find that there may be a better location for this zone further down the block or identify nearby accessible ramps to help with the loading, all of which should help make that curbside work happen more efficiently.

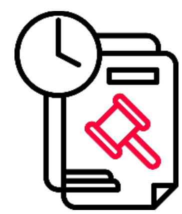
Dynamic, Consistent, Data

In addition to assisting with detection of spatial conflicts, ROWDS can support more consistent detection of temporal conflicts between the activities of different permits. The unified standard governing ROWDS promotes ongoing updates, which would produce data that reflects the most recent conditions in a given area. By storing information about policies that are no longer active, supporting research into – for instance – when a street was last closed for resurfacing.

Example: Utility Work and Coordination – If the city must conduct utility work on a particular roadway that will close it temporarily to cars, the department conducting the work can mark the project and associated closure as active or not.

- **ROWDS Usage:** A city staff in the permitting department would create a new Right-of-Way Policy and designate it as an event policy type to represent the temporary road closure in the work area. The staff member would collect information from the applicant about the project's location and duration. The newly created Right-of-Way Policy would be connected to the roadway, which has a corresponding roadway ID. The roadway ID is also linked to all associated sidewalks and Curb Zones, which would also all be selected in turn. If the closure was only affecting one lane or the sidewalk, this granularity could also be specified in ROWDS.
- **Impact on Processes:** Once the permit is approved, the spatial and temporal information gathered will be fed into the database. The initiation of the construction will serve as the 'event' needed to activate the Right-of-Way Policy created by the permit. The start of this event will automatically update the Streets Department of the temporary closure of the roadway and associated assets, via the appropriate data linkages. This will help the Streets Department and other necessary city departments to better understand how traffic flows may be impacted and for how long, which streets they can operate city vehicles on, or to plan future maintenance around the closure.

Standardized Data with Rich Attribute Information



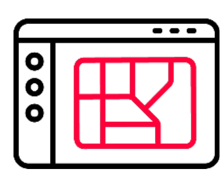
ROWDS ensures that data will be complete and formatted in a manner that supports permit review analysis. Whereas current data does not necessarily provide a predictable set of attributes or make attributes available in a consistent format, coordinated and sustained adherence to the data specification would ensure that certain information is always available. This improves the ease and effectiveness of conflict detection, and analysis of pedestrian and traffic diversions.

ROWDS also encourages data managers to populate fields with physical attributes of assets – such as their length and width. Paired with a database of unit-costs for encroachments, this fosters the ability to directly calculate the quantity and of physical dimensions of right-of-way elements.

Example: Sharing Permit Information - The City will have a standardized data format to collect information from a municipal contractor before approving their construction/restoration permits. This format will allow the city to gather a comprehensive understanding of the city assets and roadways that may be affected by the project.

- **ROWDS Usage:** The City will input information from the application about the project's type, location, and duration of the project into a new Right-of-Way Policy. The creation of this Right-of-Way Policy will automatically select any affected roadways by its roadway ID. In turn, this action will also select any sidewalks, bike lanes, or Curb Zones, as these assets are linked to the affected roadway via the roadway ID. Relevant information about these objects will also be available for City staff to review as they could affect the construction work (e.g. sidewalk with trees or paid parking in lane).
- **Impact on Processes:** With this new process and availability of information, it now becomes much easier to understand details on a given permit or construction notice. Furthermore, details about other ROW assets can easily be passed on to City staff or contractors so workers know all relevant details about the area they are working in.

Intuitive Visualization



Permitting is guided by official policies and procedures, but expert human review of applications is critical to ensure that impacts to City streets balance the needs of construction and events with the safe and efficient use of public space.

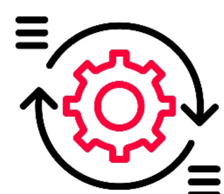
ROWDS supports building rich, intuitive visualizations of geospatial and temporal information. While some components of permit review are already mapped, there is still an opportunity to visualize more physical assets, as well as the policies that apply to the right-of-way and these assets.

High quality mapping applications designed to output ROWDS-compliant data could reduce the time burden of performing manual tasks in maps, such as identifying cross streets, measuring, and inspection of context. For example, digitizing sidewalks, crosswalks, and ADA pedestrian ramps in the same format and digital standard could make ensuring that a site-development project has duly considered the safety of pedestrians around a construction zone.

Example: Visualizing Requests and ROW Assets – If the City is looking to close roadways to accommodate equipment for construction or maintenance, the associated permit request can be more-readily shared with other city departments in a visual format (like a map) if all the information has been digitally created in ROWDS. This can make it much easier for other departments to understand what this permit request involves and how it affects their work.

- **ROWDS Usage:** All elements of the right-of-way are associated with a specific location (latitude and longitude) or a linear reference (X meters from Y street) as part of ROWDS. This allows for all this data to be mapped onto a visualization software wherein various objects can be easily compared and ROW policies overlaid onto the data.
- **Impact on Processes:** With all these elements digitally mapped and accessible to visualize, understanding where a permit is actually being applied and what right-of-way elements are affected becomes much easier for City staff. Seeing where additional signage may be required, the best locations for equipment placement, and if there are any additional objects not previously considered that may be in the way of the work – these are all steps that become easier with data visualization. Other departments who are looking to understand what is involved with a given permit request can now also get a quick overview by viewing the permit request on a map, as opposed to reading through a text-heavy request.

Potential for Automations



ROWDS provides a system for digitizing a large number of feature types and attributes as well as detailed spatial and temporal relationships between entities. Because of this, the data standard could support including many time-saving automations in a new permitting application.

By coding a closure permit as a ROWDS Policy and applying that Policy to a sidewalk Lane object, for instance, it would be possible to devise a system that automatically ensures that permit comments related to sidewalks are included as conditions of the permit.

Similarly, by applying a closure Policy to a Roadway object, the application could automatically query a list of bus stops and transit stations associated with that Roadway and generate a notification to forward along to the local transit agency for review.

Example: Crane Permits and Automations – If a crane is being used for construction and a roadway or sidewalk must be closed to accommodate it, the user can update the ROWDS Policy and apply it to the sidewalk that will be affected. This will in turn apply the policy to the other Right-of-Way and Curb Objects, including parking meters, bus stops, and bike parking that may be affected while the sidewalk is closed. Once the Policy is removed, these objects will be automatically restored to their normal status.

- **ROWDS Usage:** A City staff member in the permitting department would create a Right-of-Way Policy to represent the temporary closure (the event). This Right-of-Way Policy would be connected to the Curb Zone where it is taking place. This Curb Zone is also connected to the roadway and sidewalk via the corresponding roadway ID. In turn, that sidewalk and roadway portion is connected to the Right-of-Way Objects via the roadway ID. These connections can all be automated or configured to provide automatic alerts to City staff as needed.
- **Impact on Processes:** Once the permit is approved by the city, the affected city assets will also be flagged as impacted by the temporary closure. The start of construction (the event) will activate the Right-of-Way Policy and update the appropriate city departments. A second event signaling the end of construction could also update the Right-of-Way Policy to note that it has ended and proceed to update the affected assets as "open" again. All these steps that were previously not tracked or had to be manually completed are now all done automatically. This will help the city to maintain up-to-date information on the statuses of its assets and closures, allowing them to more effectively approve permit requests and monitor operations.

Aligning Permits with Actual Usage

A common issue with permits is that they may be issued for longer than actually required to complete a job. Through the Policy Events API, ROWDS provides the ability of agency officials to track when permits are actively being used and when those activities have been completed, as well as allowing agencies to then follow up. Event tracking could also be used for understanding utilization purposes if data is collected regularly. For instance, if permit allows noisy activities only on Weekdays from 8:00am to 5:00pm, but such activities are recorded outside of those hours, this violation could be recorded and citations issued asynchronously.

Example: Minimizing Road Closures for Work – Suppose a permit allows for a street closure of up to one month for excavation, but the actual excavation is completed in just a week. A combination of the Policy and Policy Events in ROWDS could be used to define the permit and associated activities, with observations used to record the actual time the work takes place.

- **ROWDS Usage:** A contractor would request a permit via the City's permitting systems, generating a new Policy object and a Policy Event with the type "submitted". City staff would then review the and approve the permit, creating a new Policy Event with the type "approval given", and the Policy would be applied to the relevant right-of-way elements. Once the active date range of the permit kicks in, automated or manual processes are used to observe the excavation activity. Once the actual excavation begins, a new Policy Event with the type "event_start" is created. The excavation is completed a week later, and a fourth event with the type "event_end" is completed. City staff keep track of this Policy using the Policy Status – which is then changed to "complete". The Status remains this way until such time as the permit would expire.
- **Impact on Processes:** Staff are able to track that construction has begun and finished well within the allowed time frame of the permit. Because the construction was recorded as finishing ahead of the dates and times allowed by the permit Policy, software automations can flag that this activity has been completed with many days still left on the permit. Staff can follow up with contractors to verify if the work was finished, and the permit can potentially be relinquished earlier, returning the street to normal usage, or allowing other permits or special uses that would previously have been blocked by a permit whose purpose was already completed. Staff can also conduct analysis of the dates/times between for work completion compared to what is allowed by policy, in order to provide insights that can help "right-size" how much time is allowed for similar permits in the future.

5 Next Steps

The work completed for this project is very much intended to be a proof-of-concept or template that can be applied at-scale across the City. This holds true for the data collection processes used to create right-of-way data, the standard created to format this data, and the process improvements recommended to utilize this data in day-to-day operations. The next steps outlined below are written to be a guideline on how the City can continue this work and see lasting impacts on how they manage their right-of-way.

Expansion of Right-of-Way Data

Cyclomedia's street-level imagery, LiDAR, and feature extraction workflows were central to generating many of the physical right-of-way datasets used in this project. The combination of high-resolution imagery, automated detection models, and structured attribution provided a detailed and accurate foundation for several ROWDS data classes. However, the work completed for this project was just a small area - some recommendations on why and how this can be expanded upon, as well as what is already in place to be ready to scale, are outlined below.

Citywide Expansion of Right-of-Way Asset Data: The extraction work completed for this project shows that Cyclomedia can reliably identify and attribute a wide range of right-of-way features at scale. Extracted assets included curbs, curb cuts, traffic signs, sign supports, ADA ramps, streetlights, traffic signals, pavement markings, driveways, sidewalks, manholes, fire hydrants, and catch basins. Each feature includes standardized geometry, associated attributes, and a direct Street Smart URL for visualization. Expanding this approach across the full city would create a comprehensive and consistently structured dataset that aligns with the ROWDS object model.

Scaling Automated Extraction for ROWDS Features: Cyclomedia configured its Insights360 platform with project-specific classification rules, attribute picklists, and logic checks that ensured each extracted feature was tagged consistently. Automated multi-view detection was first applied to imagery and LiDAR, followed by analyst refinement within a shared 3D quality control environment. This combined workflow supports high accuracy, consistent attribution, and a repeatable process aligned with the detailed data dictionary used for this project.

Supporting Additional ROWDS Endpoints Through LiDAR Geometry: The LiDAR collected for this project supports precise geometric extraction of roadway edges, sidewalk boundaries, ramp extents, pavement striping, and other linear features. These geometric elements map directly to several ROWDS endpoints including Roadways, Lanes, Intersections, and Curb Zones. As the City refines and expands ROWDS, this geometry provides a strong base for more detailed spatial representations of the right-of-way.

Annual Captures to Support Ongoing Maintenance and Updates: Cyclomedia already performs annual imagery, and LiDAR captures for the City. This provides a consistent and regularly updated source of high-quality reference data that departments can use to monitor evolving right-of-way conditions and keep ROWDS-compliant datasets current. The combination of annual recapture and structured extraction enables long-term maintenance of accurate, field-validated asset information.

Enhancing Curb, Signage, and Asset Accuracy for Citywide Inventory: The feature extraction delivered for this project followed detailed attribute definitions including sign dimensions, MUTCD classifications, striping patterns, curb characteristics, ramp types, and sidewalk geometry. These structured attributes support accurate generation of ROWDS objects such as Curb Policies, Curb Zones, and physical ROW Objects. Applying this structured methodology citywide would produce a fully attributed, policy-ready curb inventory suitable for integration with permitting and mobility planning workflows. The lessons learned from this initial round of data collection will help shape and inform improvements to these processes in future collection.

Integration Into Existing City Systems and ROW Management Tools: Philadelphia already has access to Cyclomedia's Street Smart platform, allowing City staff to immediately view, measure, and validate extracted features in 360-degree imagery. All extracted features are linked to a unique Street Smart URL, enabling rapid inspection and confirmation of asset locations. Street Smart's integrations with ArcGIS Online, ArcGIS Pro, and City enterprise GIS systems support seamless operational use of ROWDS-compliant datasets and make it easier for departments to adopt these data into day-to-day processes and future ROW management tools.

Alignment With Ongoing Standard Development: The structured schemas and attribution rules used in the extraction process align closely with the goals of ROWDS and can continue to inform its development. The detailed data dictionary created for this project highlights standard field types, geometric definitions, and attribute requirements that can guide consistency across feature classes. As ROWDS expands through collaboration with other cities and organizations, Cyclomedia's structured extraction schema provides a mature and well-documented foundation for representing physical right-of-way elements. This will help make transition from Cyclomedia to ROWDS that much easier.

Refine the Right-of-Way Data Standard

Although a relatively thorough process was used to generate the Right of Way Data Specification standard for this project, including analysis of existing standards, stakeholder engagement, and applying the standard to actual use cases, any successful standard needs to be scrutinized, reviewed by peer cities and operators, improved, supported, and adopted outside of just one organization. That is why with the completion of this project, the Project Team and City of Philadelphia intend to review the specification with the Open Mobility Foundation, with the hope that the ownership of this standard can be adopted by the OMF, similar to the Mobility Data Specification or Curb Data Specification. This includes opening of this standard for discussion and improvement to OMF members and associated working groups, future versioning, expansion of use cases, and more. Through the initial development of ROWDS, many ideas and directions for development were identified that could not be fully explored. Some of these ideas are listed below to emphasize the potential breadth and value this specification could have.

- Combination of MDS and CDS fully into ROWDS to have one governing standard for all operations in the right-of-way. Although a large undertaking, this could help streamline future digitization of this information and make it easier for cities to adopt digital standards.
- CDS Curb Objects and ROWDS Right-of-Way Objects could ultimately be combined into one grouping; these were left separate in this project, as it would result in a breaking change with CDS.
- Building out ROW Events to handle a wide range of activities that occur in the right-of-way including traffic counts, pedestrian counts, car queuing, traffic incidents, and more.
- A logical, long-term application of ROWDS is to support navigation applications. The requirements of such applications would likely have an impact on how details for Roadway, Lane, and Intersection (and their policy) information is structured. Conversely, navigation or routing apps could be updated to ingest and operationalize information in ROWDS format.

- Intersections contain a wide range of rules that could be captured within ROWDS including signal timing, pedestrian advances, and on demand signal changes.
- Continuing to align this standard alongside other standards like OSM and GTFS. Although some initial considerations were made, as these other specifications and ROWDS evolve, it is paramount to ensure that they can work well alongside each other to help promote adoption, opposed to having conflicting fields or use cases.

In general, this version of ROWDS can be thought of as an alpha or initial version of the specification, with the opportunity to grow in future.

Implement Solutions to Integrate & Maintain this Data

Having well-understood means of storing and representing complex right-of-way data is a critical first step in digitizing and streamlining workflows. However, to truly transform these workflows, the standardized data must be integrated into existing processes and incorporated into new software applications from the ground up. Centralizing this data within a dedicated ROW management platform would significantly simplify operations. A comprehensive management software that can effectively ingest standardized data, support established workflows, and facilitate the sharing of relevant information across departments could provide substantial benefits to the City at scale.

Another important component of the SMART Grant initiative is focused on developing these capabilities further, including leveraging external data sources such as those provided by INRIX to enhance the functionality and value of the system. Furthermore, maintaining the accuracy and currency of ROW data is essential; if the data becomes outdated, its utility in supporting city processes diminishes. Automating data maintenance wherever possible can alleviate the burden on city personnel by enabling updates to be drawn from various open data sources, updated field surveys such as those from Cyclomedia, and vendor data feeds, thereby ensuring that the ROW data remains reliable and actionable.

Build Adoption of Data into Department Processes

To advance the effective adoption of ROWDS, collaboration with the City's IT and GIS groups is essential for building centralized databases containing sample data. This approach will help familiarize City data professionals with best practices in data management and the specific schemas required for ROWDS compliance. In parallel, it is important to work closely with the Streets Department to pilot the use of Right-of-Way Policies and Policy Events in managing permit application processes. To minimize disruptions to ongoing departmental activities, it is recommended that additional staff, preferably from data or analytics functions, be temporarily assigned to shadow existing processes. This "shadowing" will enable the identification of necessary adjustments and the development of recommendations for further improvement based on real-world usage of ROWDS concepts.

Following these initial trials, the next step is to scale the sample ROWDS data implementation to encompass the entire City of Philadelphia. This will involve appointing a Product Manager responsible for gathering requirements and defining a minimum viable mapping product that addresses a defined set of use cases from one or two additional City departments, beyond the permitting applications of the Streets Department’s Right-of-Way Unit. The creation of a comprehensive, ROWDS-compliant city map will require leveraging municipal data sources, open-source mapping datasets, and data from partner organizations such as Cyclomedia to extract the necessary geospatial features.

Finally, ensuring the ongoing relevance and accuracy of ROWDS data will require identifying resources and designing robust data engineering solutions to maintain the dataset. Because the built environment is constantly evolving, with new private and public projects regularly altering the allocation and use of the right-of-way, it is crucial to develop and implement new data pipelines that can keep ROWDS-compliant data current and reliable for all users.

Reiterate and Innovate/Fail Forward

Recognizing that ROWDS is an ambitious project aimed at generalizing the Curb Data Specification, the prototype developed for the City of Philadelphia's SMART Grant should be considered an initial "alpha" release, intended primarily for testing and further iteration. To ensure the successful evolution of ROWDS, it is essential to collaborate with the Open Mobility Foundation (OMF) and participating city partners to determine the future stewardship and governance of the specification. At a minimum, establishing a charter is necessary to outline a product roadmap, assign responsibilities for ongoing updates, and define stage gates for a first major release.

Through its involvement in the SMART Grant, the City of Philadelphia is uniquely positioned to lead the development of a roadmap for ROWDS. Nevertheless, the specification would also benefit from guidance provided by a small Product Leadership committee, ideally comprised of representatives from various partner cities within the SMART Curbs Collaborative. This committee would play a key role in determining processes for issue resolution, identifying participants and securing funding for future development, and defining the core functional requirements for a broader, beta release. Such a beta release should be designed to enable experimental adoption by cities that may not be directly engaged in developing the specification.

To facilitate this iterative process, it is important to target additional proof-of-concept mapping applications using sample ROWDS data, enabling business users to work directly with the data. This direct engagement allows for more robust feedback to further refine and enhance the specification. Transportation planners and engineers, in particular, are expected to find valuable use cases for the detailed planimetric data contained in ROWDS, which can be delivered through familiar tools such as ArcGIS Online mapping systems or custom web-mapping applications.

Finally, based on trial applications conducted with City of Philadelphia departmental staff, it will be important to document any limitations or challenges encountered in implementing or scaling the data specification. While ROWDS has been thoughtfully designed to be as general as possible, it is acknowledged that some features critical to users may be challenging to represent or may require minor adjustments to the specification to better accommodate operational needs.

Conclusion

The implementation of ROWDS as a data standard for right-of-way management represents a significant step forward in the modernization of permitting processes. By enabling the digital representation of assets, policies, and events, and by supporting advanced automation and seamless integration across different systems, ROWDS can help municipalities streamline operations, reduce administrative burden, and improve safety and coordination for all right-of-way activities. As cities continue to face increasing complexity in their urban environments, adopting robust digital standards such as ROWDS will be essential to ensuring efficient, transparent, and responsive public infrastructure management.

Appendix A: Right-of-Way Data Specification GitHub Page

Appendix B: Right-of-Way Data Tracking Table

Appendix C: Additional Permit Example

Temporary Loading Zone Permit Example

City of Philadelphia

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Kristin Del Rossi
Streets Commissioner

APRIL 14, 2025

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317 N BROAD ST APT 307
PHILADELPHIA, PA 19107

PERMIT NO: 2025-06080

PERMIT TYPE: TEMPORARY LOADING ZONE

PROJECT TYPE(S):
- MOVING/DUMPSTER

DETAILED DESCRIPTION OF CLOSURE:
PERMISSION IS HEREBY GRANTED TO CLOSE A 40' ZONE OF PARKING LANE FOR 317 N BROAD ST APT 307, ON WOOD ST.

GENERAL LOCATION LIST:

OCCUPANCY TYPE	ON STREET	FROM INTERSECTION	TO INTERSECTION
LANE	WOOD ST	N BROAD ST	N 13TH ST

ENCROACHMENTS ON THE RIGHT OF WAY:
- STORAGE CONTAINER

DATES: 4/16/2025 TO 4/20/2025

TIMES: CONTINUOUS

PURPOSE: TEMPORARY LOADING AND UNLOADING – MOVING RELATED - STORAGE CONTAINER

COMMENTS:
WEBSUBMIT: THE PERMIT LOCATION: 317 N BROAD ST APT 307, NO OF PODS : 2
TEMPORARY NO PARKING SIGNS MUST BE POSTED IN ADVANCE*
ALL EQUIPMENT MUST BE PLACED IN PARKING LANE AND TIGHT TO CURB WITH PROTECTION FOR STREET SURFACE PROVIDED*
IMPORTANT NOTE: BY CITY CODE POD ARE NOT PERMITTED TO STAY ON SITE LONGER THAN 5 DAYS.
- MUST OPEN STREET TO FULL WIDTH AT THE CONCLUSION OF WORK
- MUST MAINTAIN GOOD HOUSEKEEPING AT ALL TIMES DURING AND AFTER EVENT/WORK SITE FOR PEDESTRIAN AND VEHICULAR TRAFFIC
- MUST MAINTAIN A 6' PEDESTRIAN WALKING ZONE AT ALL TIMES
- RESPONSIBLE FOR ADVANCE POSTING & MAINTAINING TEMPORARY NO PARKING SIGNS TO UTILIZE THE CURB LANE FOR VEHICULAR TRAFFIC
- MUST MAINTAIN A MINIMUM OF ONE TRAVEL LANE AT ALL TIMES IN BOTH DIRECTION
- PROHIBIT OVERRIDE EXISTING AUTHORIZED OR HANDICAP PARKING AREAS
- MUST PROVIDE & MAINTAIN ACCESS FOR EMERGENCY VEHICLES AT ALL TIMES, I.E. POLICE, FIRE, ETC.
- EQUIPMENT MUST BE PLACED IN PARKING LANE AND TIGHT TO CURB ONLY WITH PROTECTION FOR STREET SURFACE

REFERENCES:
- NONE

MUST KEEP PERMIT ON SITE AT ALL TIMES TO SHOW ANY AGENT FROM THE CITY OF PHILADELPHIA UPON DEMAND

DURING THIS SUBJECT CLOSURE, YOU AGREE TO MAINTAIN REGULATION PADOT BARRICADES(IF APPLICABLE) AT THE EXTREMITIES OF THE CONSTRUCTION AREA; PROVIDE WATCHMEN WHERE NECESSARY; DIRECT TRAFFIC INCLUDING NOTIFICATION SIGNS AND DANGER SIGNALS; BE SUBJECT TO THE REGULATIONS OF THE HIGHWAY DIVISION IN ACCORDANCE WITH THE DEPARTMENT OF STREETS, LICENSES AND INSPECTIONS, POLICE, FIRE, PADOT, AND ANY OTHER DEPARTMENT THAT MAY BE CONCERNED. IN ACCEPTING THIS PERMIT, YOU FURTHER AGREE TO BE RESPONSIBLE FOR ALL INJURIES TO PERSONS AND/OR DAMAGES TO PROPERTY THAT MAY BE CAUSED BY THE STREET CLOSURE, AND TO HOLD THE CITY OF PHILADELPHIA HARMLESS IN THE EVENT OF AN ACCIDENT OR MISHAP. UPON EXPIRATION OF THIS PERMIT, THE BARRICADES, SIGNS, ETC., MUST BE REMOVED, AND THE STREET LEFT IN A CLEAN AND SAFE CONDITION.