Minneapolis
City of Lakes

An Open Data Approach to Curbside Management

SMART Grant Stage One Implementation Report

FINAL

U.S. Department of Transportation SMART Grant Recipient: City of Minneapolis

Fiscal Year of Award: 2022

Period of Performance: September 15th, 2023 - September 15th, 2025 (extension granted)

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Date of Original Submittal: January 14, 2026

Date of Amended Report: March 10, 2026

1. Executive Summary

Project Goals and Objectives: Minneapolis's Open Data Approach to Curbside Management SMART grant project enabled the creation of a digital ecosystem for city-wide responsive and data-driven curb management. The city will integrate its asset management systems, a constantly updated digital inventory of curbspace (i.e., a "digital twin"), and real-time data from curb users and the tools used to operate, manage, and monitor the city's curbs.

Project goals include facilitating meaningful engagement, collecting high-quality data, integrating the data, and creating an application programming interface (API). We heard from key stakeholders through focus groups and interviews to understand their curb-related challenges and needs. We gathered quantitative data through cameras, field observations, surveys, and existing datasets, and integrated the information with the city's digital twin. We developed open-source curb, event, and metric APIs to communicate policies and real-time curb activity while ensuring privacy and providing curb information to public and private partners.

Location: Minneapolis, MN – 18th Street to 29th Street along Nicollet Avenue

Key Partners: The city worked with local and regional freight operators, residents, commuters, and businesses located along the Nicollet Ave corridor. Additional partners include the Open Mobility Foundation, Umojo, INRIX, ParkMobile, OpenGov, and Minneapolis Community Technical College (MCTC), which provide technical assistance. Bolton & Menk and Whittier Alliance provide engagement assistance, while Walker Consultants provided project planning and management, stakeholder engagement, evaluation, and reporting assistance.

Prototype Scope: Minneapolis created a digital twin of its curbspace and integrated curb data from various vendors in a standardized curb data specification. The project tested data collection methods by installing fifty-two (52) 4G LTE solar-powered computer vision cameras and ten (10) air-quality sensors across the study area and gathered stakeholder input through focus groups with six (6) major freight carriers and interviews with more than thirty (30) local businesses. Findings revealed widespread curb-use non-compliance and challenges drivers face in locating safe parking, underscoring the need to update permit, pricing, and signage policies.

Potential Stage 2 At-Scale Implementation: Building on Stage 1, we will scale operational strategies by installing sensors and cameras to measure curb usage in five (5) additional neighborhoods, develop a curb data management software platform to ingest curb asset inventory and usage data and house interactive planning tools and APIs, providing third-party private-sector applications with real-time availability, occupancy, and pricing information, and adopting a scaled, data-driven approach that uses data and business input to inform necessary plans, policies, and legislation to govern modernized curb planning and policies.

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2. Introduction and Project Overview

Project Description

Our Stage 1 proof-of-concept project focused on the corridor known as "Eat Street," Nicollet Avenue, from 18th Street to 29th Street. This one-mile corridor was chosen for its vibrancy, diversity of people and curb uses, and various curb demands and user types. The corridor follows a former streetcar route in South Minneapolis, which contributed to the corridor's mix of commercial retail, multifamily tenants, offices, and several nearby schools.

Our Stage 1 SMART project had several major work streams:

- Curb inventory and use data collection and evaluation
- Systems integration
- API development/hosting
- Local, regional, and national curb user stakeholder engagement
- Internal capacity and digital literacy

Harnessing emerging curb monitoring technology, developing curb data tools, engaging with stakeholders, and building internal capacity to conduct data and policy-driven curbside management are necessary for us to move forward in this journey. All of these were central to the Stage 1 SMART project, with the goal of developing a digital data-driven curb management platform and ecosystem.

We are excited to pivot to Stage 2 as we scale our efforts citywide and implement long-term technologies, systems, and processes, while also helping to educate and inform other cities and industry partners.

Our Stage 2 project, to be conducted in collaboration with fellow SMART grant recipient, the City of Seattle, will scale our efforts in three primary ways:

1. **Install sensor and camera technology to** continuously measure curb usage in at least five additional neighborhoods across Minneapolis.

2. **Leverage Stage 1 learnings to develop a curb data management** software platform to ingest curb asset inventory and usage data and house interactive planning tools and application programming Interfaces (APIs) providing third-party private-sector applications with real-time availability, occupancy, and pricing information.

3. **Adopt a scaled, data-driven approach to managing the curb and improving curb access.** Utilize data and business engagement to inform necessary plans, policies, and legislation for programs that govern modernized curb planning and policies.

Real-world issues and challenges that would be addressed with at-scale implementation

Our at-scale implementation in Stage 2, in partnership with the City of Seattle, intends to address the following issues and challenges in managing and operating curb space in urban environments:

IMPLEMENTING DATA-DRIVEN CURB ACCESS MANAGEMENT

This is the core mission of our SMART grant work: to build, operate, and maintain a nimble, scalable digital platform and ecosystem that facilitates flexible, responsive, and data-driven curb management across Minneapolis, enabling seamless data sharing with curb users. This ecosystem brings together the city's asset management tracking and maintenance system, a comprehensive and constantly updated digital inventory (i.e., "digital twin) of the city's curb space, and real-time information ingested from curb users (as users are willing or required to share data) and an array of devices and sensors used to operate, manage, and monitor the city's streets and curb space, such as:

- Parking meter pay stations
- Mobile payment applications
- Enforcement platforms
- In-ground and mounted sensors
- Roving or stationary cameras

These devices provide a wealth of information related to vehicle type, dwell time, curb occupancy, vehicle speeds, revenue, moving and parking violations, air quality hotspots, and other relevant details. Data is ingested in real or near real-time and aggregated to provide powerful data analytics on key performance indicators that are important and neighborhood-specific. All data entering or exiting the ecosystem will be open-sourced and based on the Curb Data Specification (CDS) data standard. The digital curb management ecosystem will advance the following initiatives for the City of Minneapolis and others developing similar systems solutions:

- **Integrating internal curb and asset management systems:** The digital ecosystem integrates the city's asset management platform, OpenGov, into the CDS data standard and with the rest of the curb inventory and the city's digital asset management platform. It creates tools and processes for maintaining the city's assets and digital curb inventory while maintaining cross-communication and ongoing updates after any changes are made.

- **Monitoring curb activity to tailor curb operations and policy:** Before beginning SMART project work, the city did not have a dynamic picture of localized (i.e., space-by-space) curb use patterns, outside of payment transactions coming from meter pay stations and mobile payments. This data will be used by city personnel to tailor curb operations and policy to drive desired curb outcomes, including efficiency and access, in all of the city's unique districts and neighborhoods. The data-driven curbside management ecosystem enables fine-grained performance evaluation of curb operations and management strategies, allowing for adjustments and calibration.

- **Providing valuable information to guide curb users:** The ecosystem enables the sharing of information to curb users about the composition, availability, and current status of curb space via the CDS Curbs, Events, and Metrics Automatic Programming Interfaces (APIs). Intended curb users include the public, emergency response, and local, regional, and national freight companies. More information in the hands of users means improved system access, optimized routing, enhanced system resilience, increased safety, and enhanced traffic and emergency response. Curb data sharing is not common practice across North America. At scale, city-led curb information sharing will normalize curb data sharing with curb users under a consistent data specification, educate drivers and curb users, and create an industry market and protocol for sharing and ingesting curb data.

- **Improving desired curb access outcomes and managing undesirable behavior:** The digital ecosystem allows us to identify and mitigate undesirable curb use behavior, such as excessive dwell times and double parking, and the associated negative impacts on safety, access, and traffic congestion. At the same time, the platform allows tailoring operations and policies to facilitate and incentivize safe, improved compliance with curbside regulations and efficient curb use.

- **Advancing citywide goals:** The platform is a central tool in advancing a variety of citywide sustainability, safety, and community-building goals:
    - **Generating economic benefits for private sector users**, such as freight carriers, and incentivizing partnerships by providing more dedicated curb space, better access, and information through digital tools that inform route planning. This will lead to the adoption of Curb Data Specification (CDS)-based curb data to improve efficiency and driver safety with at least three operators.

    - **Cultivate economic benefits for local businesses** through more efficient deliveries and a reliable flow of goods. Document the proven benefits to small businesses from these efficiencies, which are poorly understood beyond anecdotal comments.

- **Improving safety and transit reliability** for pedestrians, cyclists, and all travelers by reducing illegal curb behavior (i.e., fewer obstructions of travel, transit, and bike lanes). Seattle will address drivers using the center turn lane by modifying Commercial Vehicle Loading Zones (CVLZ) on the Broadway-Pike-Pine corridor with business engagement and Urban Freight Lab at the University of Washington (UFL) machine learning analytics. Minneapolis will strive to increase bus speeds by 15% to improve transit reliability in disadvantaged communities.

- **Reducing traffic congestion** by improving commercial load zones and curb availability, leading to less cruising and congestion.

- **Increasing access for all users** through improving transit speeds and reliability, increasing curb turnover, and maintaining stable curb utilization.

Building and promoting internal digital literacy:

We will hire new in-house staff and develop a workforce pipeline of transportation technology experts. In addition to feeding the city's workforce with digital professionals, we will work with a local technical institution to implement a curriculum and training program for the ongoing hiring and training of digitally literate professionals in the region. The plan is to offer this as a blueprint that can be replicated nationwide.

Cultivating and maintaining productive stakeholder relationships:

Our at-scale implementation will build on the meaningful relationships we have cultivated in Stage 1 with business owners, community groups, agency stakeholders, freight companies, and others to solidify a network of stakeholders with whom we will collaborate on an ongoing basis for information gathering and sharing in the name of promoting positive outcomes for our streets and curbs.

Advancing the industry and educating other cities:

The impacts of our at-scale implementation will extend beyond Minneapolis. We will do the following:

- **Develop a detailed toolkit for other cities** to learn how to transition to digital curbs, no matter where they are on their curb management journey. This roadmap will cover topics such as developing a useful and pragmatic data plan, navigating equipment vendors, acquiring, installing, operating, and maintaining physical curb monitoring equipment, building digital literacy, utilizing data standards, collaborating with utilities, and other relevant areas. The roadmap will include not just the "how," but will leave other cities with actual code that can be used as the foundation for cities to build their own models.

- **Integrate data sharing and standards** across cities and private sector users to provide easily accessible data, normalize the use of data standards, and prove the economic

benefits of coordination to support widespread adoption of data standards and the ingestion of curb data by curb users

Geographic area and communities serviced at scale

Recognizing that different neighborhoods have varying intensities of curb management needs, and the need to be fiscally responsible, such that the most sophisticated technologies are deployed to corridors and neighborhoods with the greatest need, Minneapolis selected six (6) corridors/areas for at-scale implementation (See Figure 1). Our at-scale implementation will be expanded citywide beyond Nicollet Avenue, to include three (3) districts and three (3) corridors in the most vibrant and highly utilized curb space in the city:

- **Downtown:** Dense and multidimensional, downtown Minneapolis is the center of commerce, community, culture, entertainment, and events for Minneapolis, the state, and the region. The area spans nearly one square mile and features a diverse range of curb users and premier destinations, including U.S. Bank Stadium, Target Center, and Nicollet Mall.

- **Dinkytown:** On the doorstep of the University of Minnesota's main campus, Dinkytown is a vibrant area with some of the city's most diverse mix of land uses and restaurants. Development is of a variety of scales, and Dinkytown's center is 14th Avenue SE. Several bikeways and bus routes connect the area to the rest of Minneapolis.

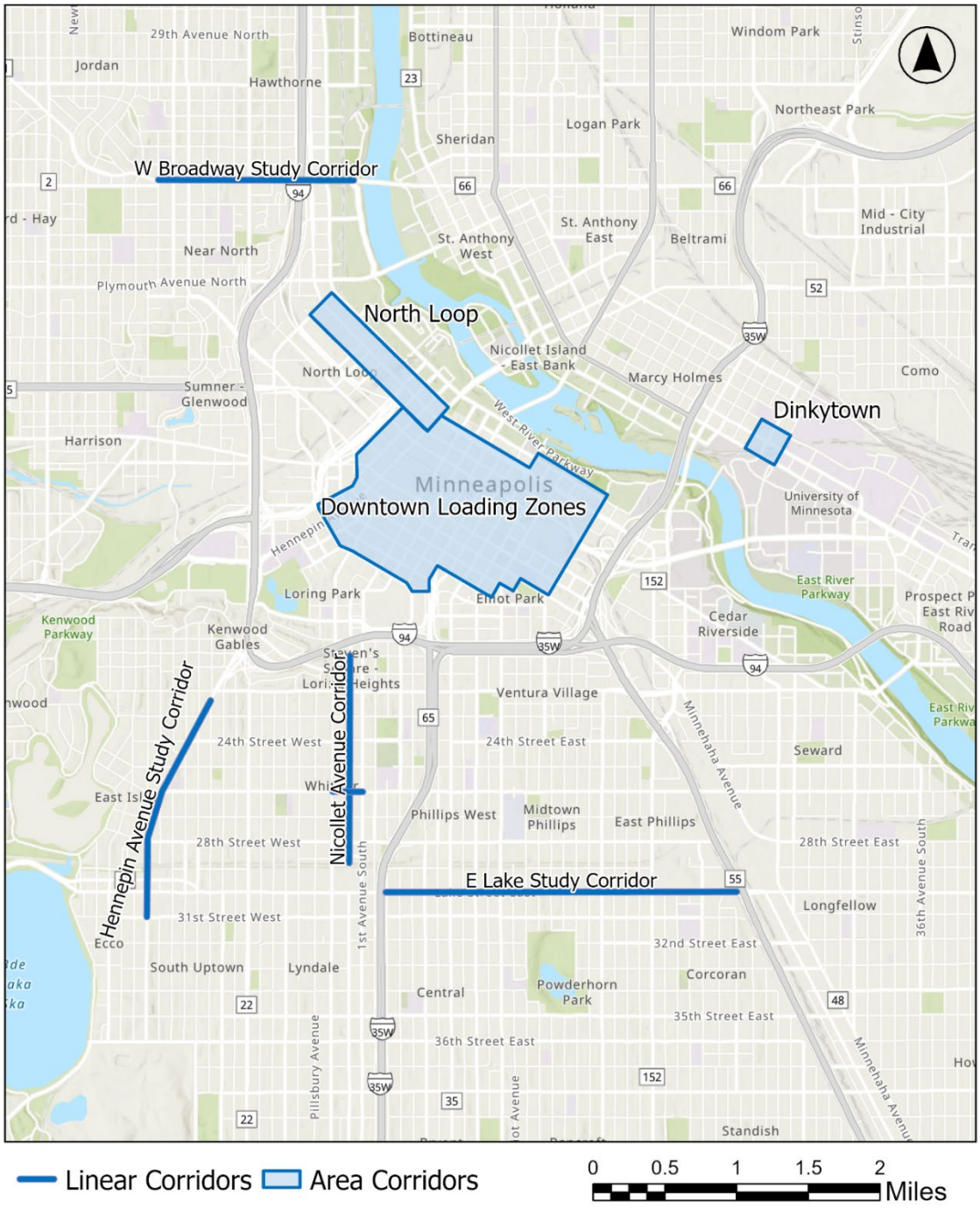
- **North Loop:** The North Loop is the densest mixed-use neighborhood with heavy event traffic from nearby Target Field, office, residential, and an array of popular event, dining, and entertainment destinations. High demand and the historic nature of the transportation and urban form in the neighborhood make it challenging for freight, passenger pick-up/drop-off, and delivery vehicles to access.

- **East Lake Street:** East Lake Street is the primary commercial corridor connecting Uptown to Midtown Minneapolis and St. Paul to the east, and we will scale along the stretch from I-35W to Highway 55 (Minnehaha Avenue). This vibrant corridor features a diverse array of multicultural restaurants, shops, and community destinations. The Lake Street Bus Rapid Transit (METRO B Line) began service in the summer of 2025 and connects Minneapolis to St. Paul along this east-west corridor.

- **South Hennepin Avenue:** A mixed-use corridor linking Downtown Minneapolis with Uptown, South Hennepin Avenue is a hub for entertaining, shopping, and nightlife. The E-line BRT, with a dedicated lane, began serving this corridor in December 2025.

- **West Broadway Avenue:** An important east-west mixed-use corridor in North Minneapolis, West Broadway Avenue includes a mix of uses, is well served by transit, and is a major truck route.

Figure 1: At-scale (Stage 2) Focus Area Corridors



Source: City of Minneapolis

Technologies being deployed:

Technologies we have deployed in Stage 1 and will deploy at scale in Stage 2 include technologies in the following categories:

Solar-powered Cameras: We contracted with technology solutions provider Umojo to purchase and install fifty-two (52) 4G LTE solar-powered computer vision cameras to collect curb use and activity data. Cameras were installed along the entire Nicollet Avenue corridor in the Summer of 2024. The cameras take a snapshot every 60 seconds, and the artificial intelligence-enabled backend system processes the images, aggregating curb use data and trends on an integrated performance monitoring platform.



Source: Walker Consultants

Camera performance has been inconsistent in Stage 1, primarily due to issues with solar and battery storage. We are working with Umojo to replace all 52 solar-powered cameras with 57 hard-wired cameras connected to the city's electrical infrastructure, aiming to improve performance (i.e., enhanced battery life and the ability to capture images at shorter intervals).

We continue working with Xcel Energy, the electrical utility provider, and Umojo to solve this issue. Throughout the past year, we have collaborated with Xcel Energy to develop workflows that will enable Minneapolis to install hard-wired cameras across all Stage 2 focus areas, in addition to the Nicollet Avenue corridor. The cameras will use a National Electrical Manufacturers Association (NEMA)-approved tap for power hookup. Minneapolis and Xcel Energy were unable to reach an agreement far enough in advance of the end of the Stage 1 period of performance, which limited the city's ability to derive comprehensive data from the cameras during Stage 1. The two parties have an understanding and agreed upon workflows that will allow Minneapolis to proceed with hard-wiring in Stage 2. We anticipate all future deployments of mounted camera-based sensors to be hard-wired.

Light detection and ranging (LiDAR) curb inventory scan: We procured an outside vendor, Umojo, to conduct a LiDAR "scan" of curb space and create a digital map (i.e., digital twin) of the curb inventory and regulations along Nicollet Avenue and downtown Minneapolis. The curb inventory serves as the foundation for Stage 1 project work, at-scale implementation, and

beyond. The inventory serves as the source of truth for curb rules and regulations. These regulations serve as the basis for comparing monitored curb activity.

We have worked to integrate the curb inventory with our internal city asset management platform, OpenGov, standardize the data specification across the systems, and establish a process for updating the curb digital twin when changes are made in the field.

Air quality sensors: With the help of vendor Ambilabs, we placed ten AQMesh air quality sensors, mid-block, on every block along the corridor. The monitors create a baseline by taking readings every 10 minutes of vehicle-related air pollutants, including Total Volatile Organic Compounds (TVOC), Nitric Oxide (NO), Nitrogen Dioxide (NO2), Nitrogen Oxides (NOx, which includes NO and NO2), Ozone (O3), Temperature, and Humidity (as a percentage).

ParkMobile Insights: In the fall of 2025, we deployed five (5) LiDAR sensors from solutions provider ParkMobile, paid for by Stage 1 grant funds. These sensors attach directly to city fleet vehicles using large magnets and draw power by plugging into in-vehicle power sources. As vehicles drive around and conduct their normal business throughout the day and week, they collect data on parking occupancy. The data is aggregated on ParkMobile's dashboard, and an algorithm is used to predict typical curb occupancies at different times of the day and days of the week. To serve as a baseline for understanding curb use behavior to enable accurate and useful data points from its scanning devices, ParkMobile conducted its own inventory of curb assets.

In-ground sensors: Paid for from non-grant funds, we have 134 in-ground sensors from provider RISETEK. These sensors, which have a 5-second detection time and are functional in all weather, provide a means to cross-compare with camera-based sensors and will be part of our at-scale implementation.

SYSTEMS INTEGRATION

Curb digital twin: With the help of Umojo, we have created a detailed "digital twin" or representation of our pilot corridor's curbside inventory, including all associated curb policies and regulations. A digital curb map was created using ESRI ArcGIS and is integrated with real-time curb monitoring data from solar cameras installed along the corridor. Through additional work with INRIX, we have built a full digital twin for curb space across the entire city. This will be the foundation of our work in Stage 2.

Integrated internal curb and asset management systems: The digital ecosystem integrates the city's asset management (e.g., signs, meters, street light poles, EV charging stations) platform, OpenGov, into the CDS data standard and with the rest of the curb inventory and the city's digital asset management platform.

After working extensively with OpenGov to open potential integrations and automations in their software, we were then able to ideate a workflow that would collect changes made in the

asset management system each night, aggregating them into actions that would modify, remove, or generate curb zones automatically. The final integration work was performed by INRIX, which also utilized the APIs of our parking payment system vendor, Flowbird, to ensure that all paid parking zone regulations and rates were included in the new "Evergreen Curb Map Engine". The result is an automated system, with daily reconciliation and authentication performed by an administrator, that maintains our curb map indefinitely.

Digital ecosystem: Other relevant city parking and transportation data have also been integrated with curb inventory data and are housed on a backend curb asset management platform. This digital ecosystem translates all data into the Open Mobility Foundation's Curb Data Specification (CDS), and this data will be leveraged to represent the CDS Curbs, Events, and Metrics APIs (discussed more below).

COMMERCE DELIVERY AND LOGISTICS

Application programming interfaces (APIs): A primary objective of our data-driven curb management work is to collect and maintain a curb inventory and a real-time data set related to curb use and the surrounding transportation context to be able to share data with curb users to inform routing and deliveries, thereby improving outcomes like less double-parking and reduced congestion from less circling of delivery vehicles. We will accomplish this by posting the CDS Curbs, Events, and Metrics APIs for those utilizing the curb space, including freight operators, taxi and rideshare companies, and the general public.

The city's OpenData CDS API specification is continuing to evolve and change. The real-time data requirements of the Events API have been the most difficult to make public-facing and ready for stakeholder testing. Throughout the project, we have identified and brought forward practical issues with the beta CDS standard to the OMF, including how to address double-parking and parking in non-valid spaces, logging enforcement actions, and integrating events with transaction data. While these have been addressed with the release of CDS version 1.1.0 in October 2025, challenges associated with the Event API integration have caused some delays in linking up datasets between the city and data collection vendor throughout the second half of the project. As tweaks were made to address these issues and prepare for CDS 1.1 release, the data export format had to be changed multiple times. Minneapolis will collaborate with data collection providers in Stage 2 to develop a more robust Events API, which should be more straightforward to use with CDS 1.1.

We did not implement changeable curbside dynamic message signs in Stage 1, but we intend to do so in Stage 2 at scale. We are investigating the installation of changeable message signs at the curbside. These dynamic signs would be able to be controlled remotely, allowing them to change the rules and regulations at the curb throughout the day and week based on curb demand and traffic conditions. Using e-ink, they should be functional and visible in all weather conditions.

We intend to deploy this technology at scale in Stage 2. We will leverage our digital data-driven management ecosystem to understand curb use and demand conditions, real-time traffic and road closures, and event information. The rules and regulations displayed on the dynamic signs will be informed by the digital twin of parking rules and policies, as well as a real-time understanding of curb use and demand conditions from sensors, payment, and enforcement applications (including communication about parking regulations), with the goal of increasing compliance. Signs would also integrate with the city's operations management system to provide information about snow emergencies or other traffic information. The dynamic curb signs will allow us to communicate curb use changes to users based on these ongoing data feeds.

Goals and desired outcomes for at-scale implementation

Our primary mission for at-scale implementation is to establish an ***integrated data-driven ecosystem of digital systems***, including a curb inventory, asset management system, and data feeds from a myriad of devices that the city deploys to manage its transportation and curb infrastructure. All parts of the system will be integrated under a common data language, and mechanisms will be in place to ensure the system is updated when changes are made in the field. The system will ingest and publish data via open APIs to create transparency and understanding of curb assets and transportation, as well as curb system performance, in real-time.

This system will enable us to operate and manage curb facilities across the city in a nimble and responsive manner, adapting to fluctuating needs throughout the day and week (including conditions such as events, road closures, and acute curb demand fluctuations). It will also help us shape our curb policies and operational strategies. Examples of leveraging the digital ecosystem to shape policy and operations include pulling data from the system to understand demand in specific areas, identifying the need for additional commercial loading zone space, calibrating on-street parking rate changes, or determining the boundaries or regulations surrounding residential parking areas.

We intend to utilize the system to conduct predictive analytics, understanding potential curb and transportation behavior resulting from scenarios that may include new development, road closures, and curb space reallocation.

Providing curb spaces for specific users when and where they need these spaces, and sharing real-time information about curb regulations and availability will help improve curb access, thereby driving positive measurable change according to a variety of related factors: reduced traffic congestion and double parking, reduced double parking, improved street and sidewalk safety, and overall better curbspace turnover helping improve commerce and quality of life outcomes.

Another important goal of our at-scale deployment is establishing ***lasting partnerships*** with business, community, interest, and neighborhood groups, organizations, and other governing and public service agencies that rely on thriving and accessible curb space across the city. These stakeholders will form a network that will be sustained moving forward to maintain open communication about neighborhood-specific curb access needs, use, changes, and policies.

We will also establish partnerships across both cities with large curb users, including goods distributors, local, regional, and national freight companies, as well as others requiring access to curb space, such as those centered on transit, pedestrian, and bicycle, ADA, and passenger pick-up and drop-off activities. These partnerships will allow us to better understand curb needs and challenges, and communicate meaningful data and information to improve curb access and safety outcomes.

The last critical goal of at-scale implementation ***is internal and external promotion and education around digital literacy, data standards, and data-driven curb management***. Through our work, we strive to make the CDS data standard commonplace among cities and technology providers. We will develop an internal workforce pipeline to train the next generation of digitally literate city staff in installing, maintaining, and operating sensor-based infrastructure and backend data systems that power our digital, data-driven ecosystem.

Industry promotion and education will establish our project's lasting legacy. We will connect with and promote our work to industry organizations related to freight, curb management, and rideshare operations. Additionally, we will establish a toolkit and training manual to guide cities across the spectrum on the path to digital literacy and data-driven curb management.

Communities Impacted by At-Scale Implementation

Stage 1 deployment was centered on the one-mile Nicollet Avenue corridor, known as "Eat Street," between 18th Street and the Midtown Greenway. Approximately 2,780 people reside within one block of the corridor, located in the center of the Whittier neighborhood. The Whittier neighborhood is home to over 14,000 people, the largest and second-densest neighborhood in Minneapolis. 82% of Whittier residents are renters.

As its name implies, Eat Street is renowned for its culinary institutions, including locally and nationally recognized restaurants that specialize in German, Greek, Vietnamese, Chinese, Caribbean, Cajun, Thai, Mexican, Japanese, and pan-Latin cuisines. Other popular businesses in the area include a live-event venue, coffeehouses, a climbing gym, a food hall, several schools and daycares, and the street is located a few blocks away from the Minneapolis Institute of Art.

Serving Local Businesses and Diverse Users

The goal is to make curb space safer, more efficient, and more innovative. As cities continue to see a rise in population and activity—people living, shopping, dining, and enjoying entertainment—the pressure on curb space intensifies. This, in turn, impacts travel lanes, sidewalks, and ultimately, local businesses, which are increasingly reliant on frequent deliveries. Balancing different types of mobility, improving parking and curbside efficiency, enhancing safety and signage, integrating real-time navigation technology, considering community mobility preferences, and managing external factors like construction and seasonal changes are essential for enhancing community mobility and business operations. The feedback received during Stage 1 highlights the importance of designing a curbside policy that balances community mobility preferences, safety, and efficiency, reflecting the City of Minneapolis' unique character and diverse needs, thereby increasing access for the many different curb users.

Parking congestion, particularly from a combination of transportation modes such as cars, delivery trucks, and gig drivers, is a significant issue. Businesses and community members are advocating for more efficient and clearly defined curbside management to ensure safe parking for customers and smooth access for deliveries. Updating curb regulations, especially to inform drivers of loading and offloading delivery time limits, improving curb space turnover during congested periods, and improving signage—particularly for short-term parking—are essential for both business functionality and public safety.

Stage 2 will expand the geographic scope of this work, improving safety and transit reliability for pedestrians, cyclists, and all travelers by reducing illegal curb behavior (i.e., fewer obstructions of travel, transit, and bike lanes).

By utilizing curb data from sensor technology to reallocate curb use, better map bus obstructions, and provide various communication tools, such as our occupancy maps, adaptive e-ink street signage, and overhead variable message signs, Minneapolis will strive to reduce

curb violations in at-scale corridors. With fewer curb violations and less circling for available parking spaces, we aim to increase bus speeds by 15% in designated corridors, improving transit reliability for surrounding communities.

Involving Stakeholders and Communities

The project team conducted an extensive engagement process, utilizing a variety of outreach methods—including community meetings, focus groups, pop-ups, surveys, and one-on-one interviews—to ensure broad participation and gather diverse perspectives. Over 4,300 stakeholders shared their feedback through 78 engagement activities. Key insights highlighted several priorities for improving the city's curbside environment, including:

- **Safety improvements** to reduce conflicts between pedestrians, bikes, and vehicles.
- **Efficient delivery zones** to address double-parking and access challenges.
- **Real-time navigation tools standardized across cities to** assist gig drivers and delivery companies.
- **Tailored parking access** for customers, employees, and high-turnover users.
- **Sustainable curb solutions**, such as EV charging stations and year-round usability enhancements.

Stage 2 stakeholder engagement will continue to foster these conversations and build a network of stakeholders that can be leveraged for ongoing discussions around curbside management for years to come. We will work closely with stakeholders during the data and gap analysis to develop appropriate curb changes.

In Stage 2, we will formalize stakeholder partnerships with commercial goods delivery carriers. During Stage 1, we built trust by explaining the program and its benefits. We learned that local and national freight companies are now updating their delivery routing systems, including reducing customer delivery windows. They want to collaborate with us to use API data for route planning. For national freight companies, widespread adoption of API data across cities is necessary to make it logistically and economically feasible for their bottom line. Furthermore, some of our stakeholders are regional rather than national decision-makers. The diversity of in-vehicle technology tools being used across freight companies, fleets, and drivers makes data integration more challenging. In Stage 2, we will leverage our collective power to engage with these decision-makers to develop usable tools that work for drivers.

Scale of Stage 1 Deployment & Anticipated Scale of At-Scale Implementation

Stage 1 encompassed three primary work areas:

1. Curb data collection and systems integration
2. Stakeholder engagement
3. Internal capacity, digital literacy, and development of a digital data-driven curb management platform and ecosystem

A successful at-scale implementation will require the continued and expanded deployment of staff, hardware, APIs, and community partnerships, as described below.

Curb data collection and systems integration

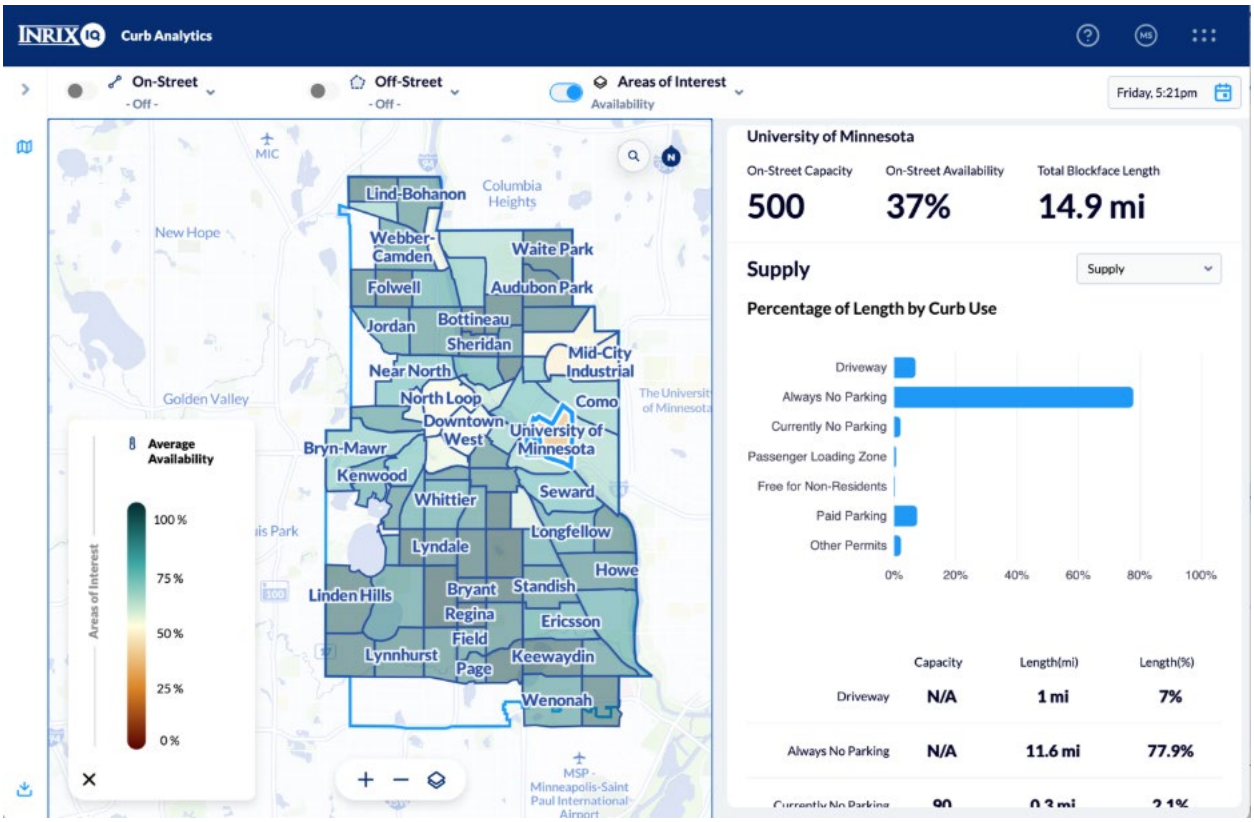
STAGE 1 DEPLOYMENT:

Before being awarded Stage 1 funding, Minneapolis had taken initial steps toward curb data collection and systems integration by installing 134 in-ground sensors on Nicollet Avenue between 24th and 27th Streets, as well as along one block of 26th Street to the east and west of Nicollet. The sensors, procured from vendor RISETEK, have a 5-second detection time and are functional in all weather conditions. The in-ground sensors collect data about violations, parking space occupancy, and dwell times.

The city issued a public RFP and evaluated proposals based on previous experience, cost, data storage, data reliability, and the ability to act quickly to install and collect data. The city contracted with Umojo to purchase and install fifty-two (52) 4G solar-powered computer vision cameras to collect curb use data and inventory using LiDAR. Cameras were installed along the entire Nicollet Avenue corridor in the Summer of 2024. The cameras use Artificial Intelligence (AI) to detect objects (vehicles), classify vehicles by vehicle type, and estimate vehicle size and position to assign a space to each parking session. Two (2) to three (3) cameras were installed per blockface, and cellular networks were used to transmit data. We are using Umojo's NexCity curb inventory digital platform to view aggregated curb use data extracted from the cameras.

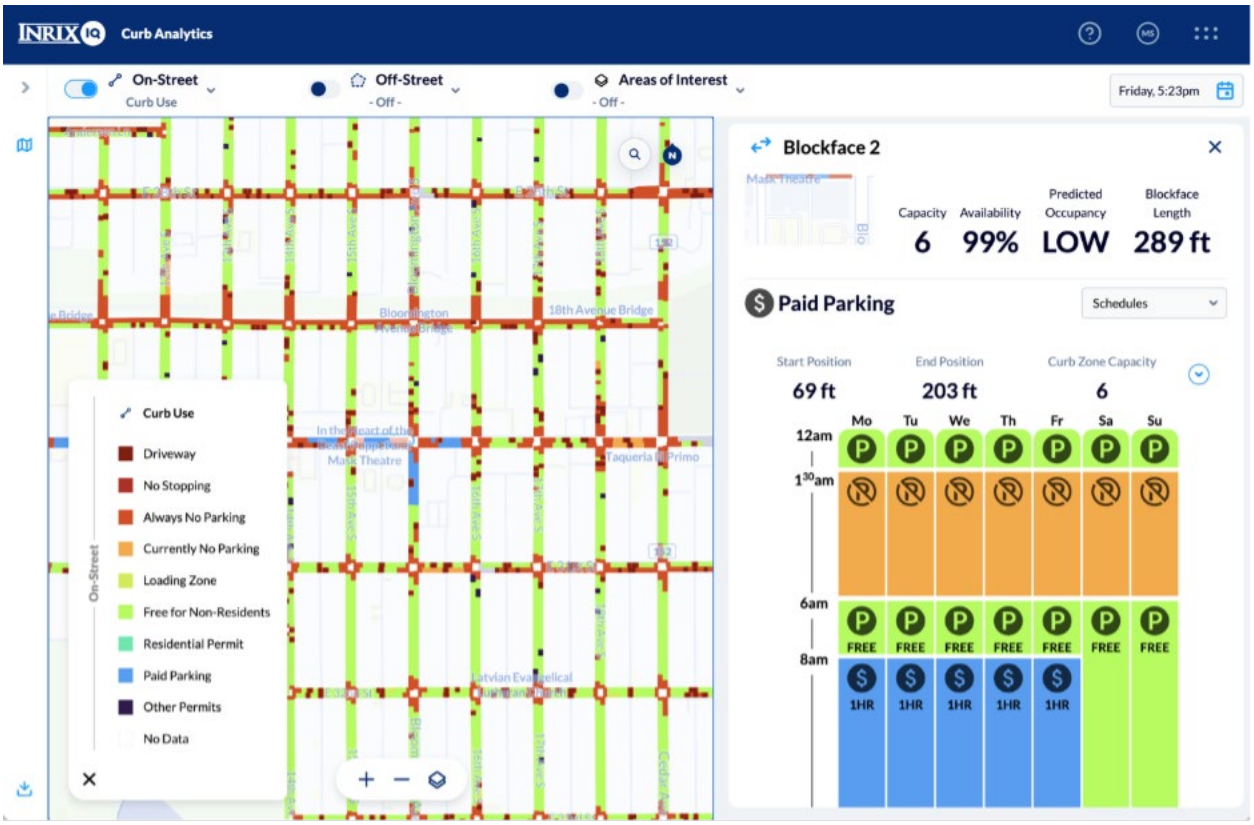
INRIX collected a citywide inventory of static curb geometries and policies. This effort included digital mapping and in-person ground truthing. The data was also visualized in INRIX's Curb Analytics software and included on-street availability and occupancy estimates powered by INRIX's floating vehicle data (See Figure 2 and Figure 3). The static curb data was shared via the Curb Data Specification (CDS) API with the city, as well as private entities that were consuming this data as part of their standard operations. This included freight and logistics providers, mapping software companies, and rideshare operators. As part of its ongoing work with Minneapolis, INRIX performs a quarterly ground truthing exercise to increase accuracy and reliability, while also capturing updates to curb rules.

Figure 2: INRIX Curb Analytics, Average Availability by Area



Source: INRIX

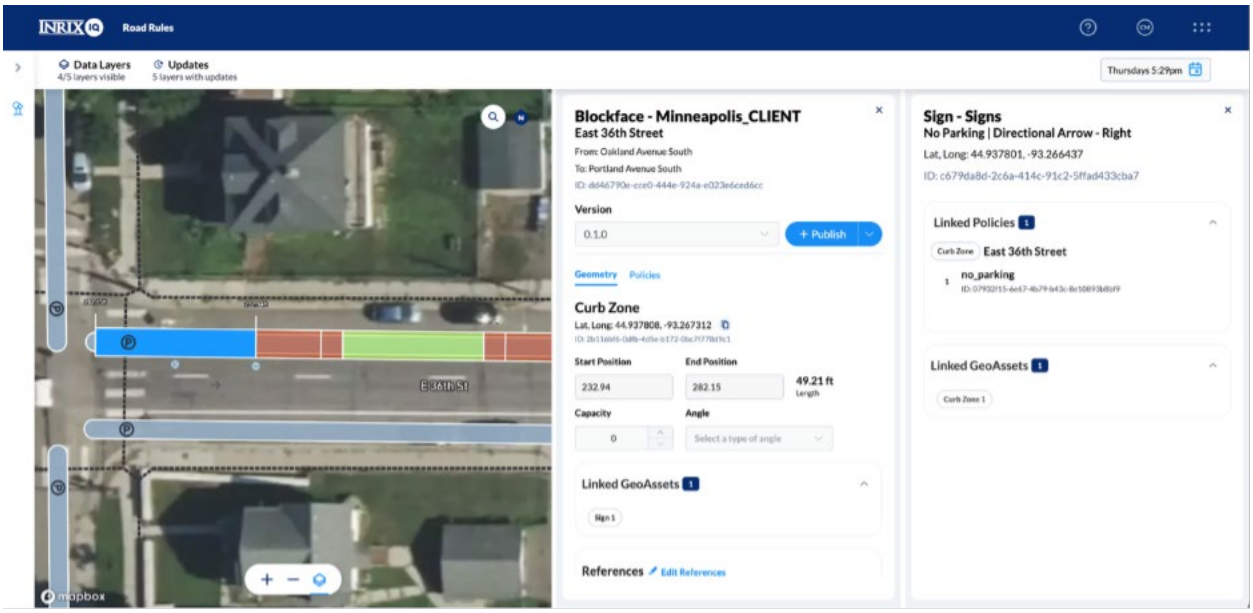
Figure 3: INRIX Curb Analytics, Curb Use by Blockface Map



Source: INRIX

INRIX also represented the curb data in its Road Rules Right of Way Manager software and is in the process of integrating the city's sign and meter inventory (See Figure 4). As part of this process, INRIX worked to integrate with the city's OpenGov (signs) and Flowbird (meter) APIs. This enables INRIX's automated and semi-automated updating process, by which any changes to signs or meters are represented in curbs, keeping the static geometry and policies up to date.

Figure 4: INRIX Road Rules, Blockface Curb Regulations



Source: INRIX

Through vehicle-mounted sensors, we are utilizing vendor Flowbird/Arrive to conduct an ongoing city-wide LiDAR scan, which will serve as a final data set for inventory validation and geospatial accuracy. This will enable us to refine the true regulatory signage positions and verify the presence of any potentially anomalous signs in the asset management database. The sensors collect parking occupancy data, which is compared with inventory to produce parking availability predictive analytics by time of day and day of the week.

To monitor progress toward reducing air pollution at-scale, Minneapolis purchased and placed ten (10) AQMesh air quality sensors midblock on every block along the corridor. The monitors create a baseline by taking readings every 10 minutes of vehicle-related air pollutants, including Total Volatile Organic Compounds (TVOC), Nitric Oxide (NO), Nitrogen Dioxide (NO2), Nitrogen Oxides (NOx, which includes NO and NO2), Ozone (O3), Temperature, and Humidity (as a percentage).

AT-SCALE DEPLOYMENT:

In Stage 2, curb activity will be monitored for each of the six (6) focus areas, while continuing to collect data for the Nicollet Avenue South corridor. In Stage 1, we learned the importance of redundancy, given the potential for severe weather, outages, and system errors. Therefore, we plan to install both in-ground sensors and camera sensors for some focus areas. In total, we plan to install 750 in-ground sensors across four (4) corridors, and 345 camera sensors across all six (6) corridors. All cameras will require fixed mounts that tap into the electrical grid.

To continue to monitor changes in air quality, Minneapolis plans to purchase fifty (50) fixed air quality sensors to be installed across the city's six (6) project focus areas.

Additionally, we plan to install digital 'smart' signage along five (5) focus areas to test API integrations with Minneapolis' digital curb management. A total of eighty-two (82) digital signs are planned.

Stakeholder Engagement

STAGE 1 DEPLOYMENT:

Minneapolis' engagement efforts for the SMART Curbs Grant Stage 1, focused on Nicollet Avenue between 18th and 29th Streets, took place between March 2024 and March 2025. The project aimed to understand how businesses, freight and delivery services, and the broader community use curb space in this busy area. Engagement activities sought to capture stakeholders' experiences and opinions on improving curbside access, logistics, and safety, with a specific focus on parking preferences, mobility options, and infrastructure improvements. Key participants included Minneapolis residents and visitors, local and national freight and delivery companies, Nicollet Avenue business owners, Whittier Alliance, Hennepin County Emergency Services, as well as the Minnesota Uber/Lyft Drivers Association (MULDA), and many others, who contributed valuable perspectives.

The project educated the community about the importance of curb management and ensured that stakeholders received project information in a clear and accessible manner. It also focused on understanding how businesses use the curb and the challenges they face, as well as learning how freight and delivery companies plan their routes. This information helped explore opportunities for testing new curb management communication technology with these companies. Gathering meaningful feedback from stakeholders was crucial to developing a curb management plan that the community could support. Additionally, the project aimed to ensure that stakeholder questions and concerns were addressed, while also fostering and strengthening relationships among Minneapolis, the project team, and stakeholders.

From March 2024 to March 2025, a comprehensive engagement effort reached over 4,300 city stakeholders to gather insights on curbside usage and mobility needs. Through targeted outreach, newsletters, and pop-up events, the project collected perspectives from residents, visitors, businesses, and delivery professionals, offering a detailed view of the current challenges and opportunities along city curbs. The outreach revealed that while the community values accessible transit and mobility options, there is limited awareness of curb regulations, with over 55% of participants unfamiliar with the existing rules. For most, trips involved a short 2–5-minute walk on weekday evenings and 2-8 minutes on weekends; however, safety concerns surrounding pedestrian-vehicle interactions were common. Parking was also a consistent issue, with many participants noting that they avoid Nicollet for evening parking due to congestion and safety concerns caused by the heavy mix of transportation modes on a narrow street, including bus and rideshare stops, scooters, freight deliveries, bikes, school buses, gig driver pick-ups, and other vehicles.

Freight & Delivery: The project engaged nine (9) local and national freight companies through four focus groups, a survey directed to delivery drivers, and driver ridealongs. These discussions revealed that short-stop package deliveries often require double parking, while food and liquor deliveries require more strategic parking arrangements. Survey results indicated delivery drivers often park in loading zones, the middle of Nicollet, or right-turn lanes due to space constraints. Safety for drivers and adherence to non-obstructive parking remain key concerns.

Business Community: Through several interviews and focus groups with local businesses, as well as the distribution of a survey, key insights into the challenges surrounding curbside usage, deliveries, and parking on Nicollet Avenue were gathered. The businesses interviewed included Nicollet Pharmacy, Nicollet Market, Colonial Market, Christo's, KhunNai Thai Cuisine, Black Forest Inn, TT Market, Nicollet Halal Market, Shuang Hur Supermarket, Good Grocer, Centro Nicollet, and Vertical Endeavors. Overall, businesses expressed a need for practical, data-driven solutions to improve curb access, enhance delivery efficiency, and manage the growing demand for limited parking, thereby supporting both business operations and customer experience.



Source: Bolton & Menk

Minneapolis Business Associations: Engagement with 15 business associations through the City of Minneapolis revealed key curbside management and mobility challenges along major corridors, such as Nicollet Avenue. Whittier Alliance represented Nicollet Avenue businesses. A central concern is the lack of comprehensive data on how customers and employees access destinations, which is essential for understanding parking demand and usage. Additionally, businesses face ongoing disruptions due to road construction, detours, and unclear transit options that complicate transportation and accessibility. These associations emphasized the importance of robust data collection and analysis in developing effective curbside management solutions that can also enhance sustainability and improve transit options.

Nicollet Avenue Community: The project team engaged over 4,000 Nicollet Avenue community members, finding strong support for accessible transit. However, safety concerns and parking congestion from mixed transportation modes were common. The team also held conversations with the Minneapolis Advisory Committee on People with Disabilities to address accessibility issues and stressed the importance of ongoing stakeholder engagement for the project's next stages.



Source: Bolton & Menk

Gig Driving Community: The project team engaged with DoorDash, which showed interest in collaborating on real-time curb space availability for drivers under the USDOT SMART Grants project. The team also met with the Minneapolis Uber/Lyft Drivers Association (MULDA) to address challenges such as poor snow plowing, limited alley access, and technology issues. A pop-up event at KhunNai Thai Cuisine aimed to engage gig drivers, but language barriers and time constraints limited survey participation.



Source: City of Minneapolis

City & Metro Services: The project team engaged with Hennepin EMS, Metro Transit, and Minneapolis Waste & Recycling to address infrastructure challenges on Nicollet Avenue. EMS emphasized the need for clear pathways, dedicated lanes, and curb ramps for efficient responses. Metro Transit raised concerns about curb obstructions and suggested improvements, such as in-lane stops. Waste & Recycling highlighted issues with alley access and road closures affecting waste collection.

AT-SCALE DEPLOYMENT:

We will build on the progress made in Stage 1 by further engaging local and national freight carriers. We aim to develop a partnership with two (2) to three (3) private vendors to deliver digital curb information tools that inform their first- and last-mile delivery route planning. In Stage 2, we plan to formalize the relationships developed in Stage 1 to create usable tools that cater to the highly diverse operators (in terms of age, education, language, and employment type) across Minneapolis and Seattle.

Community engagement at scale will focus on listening and education, incorporating similar outreach tactics, such as focus groups and direct outreach. We want to hear from each of the communities where deployment occurs about safety, accessibility, and concerns when using curb space. We also want to educate the community about how we collect data, what the data is used for, and how data-derived decisions will be made regarding curb space.

Internal capacity, digital literacy, and development of a digital data-driven curb management platform and ecosystem

STAGE 1 DEPLOYMENT:

CDS 1.0 (a beta version) launched in January 2022, which was the result of a two-year-long development process between public and private sector collaborators. The City of Minneapolis, along with other OMF members, played a crucial role in testing the first CDS deployment, which led to upgrades to the specification. An updated CDS 1.1 was released in November 2025. John Lundstrom, project manager for Stage 1 of the SMART grant, is one of eight public-sector members of the CDS Steering Committee. Through his involvement in the Steering Committee, John was able to quickly communicate issues identified in Minneapolis to other members, as well as learn from them and apply those lessons to Minneapolis.

In addition to OMF membership, Public Works and Information Technology staff have enhanced their digital literacy by attending the SMART Collaborative Sustainable Mobility & Urban Freight Logistics Study Tour, participating in Minnesota Center for Transportation Studies freight and logistics symposia, and regularly engaging in OMF meetings and webinars.

Internal capacity-building involved leveraging in-house staffing and technology to enhance the city's knowledge and skillset in curb data mapping. This meant utilizing existing city staff and technology as much as possible. The city has a dedicated Geographic Information System ("GIS") team embedded within the city's central IT department that supports the GIS services and software for the city enterprise. This team is familiar with and currently administers this technology for the city. The city leveraged an Enterprise Service Bus (ESB), which enables flexibility in integrating and standardizing API development/publishing. The ESB was procured during Stage 2 (outside of Stage 2 funding), enabling the team to dive into developing workflows and build internal literacy for the ESB while developing the CDS APIs.

From a digital literacy training perspective, City of Minneapolis Public Works worked with the Minneapolis Community and Technical College (MCTC) to develop a curriculum around the use and development of APIs, CDS, and digital infrastructure. It is anticipated that this partnership will lead to direct hiring opportunities for Stage 2 and beyond.

AT-SCALE DEPLOYMENT:

Minneapolis has identified that three (3) new full-time personnel will be required to conduct at-scale deployment and continued operations. These positions will initially be hired for Stage 2, with the expectation that they continue as regular city-paid positions at the conclusion of Stage 2. These positions are:

- Data Systems Project Manager: responsible for managing internal Public Works data architecture development in support of CDS and API development at-scale
- Data Systems Deputy Project Manager: assists with project management and internal workflows to support integration across various divisions within Public Works
- GIS Technician: builds out internal capabilities to maintain and support digital curb asset management systems

In addition to these new positions, it is estimated that existing staff may need to dedicate a portion of their time toward at-scale deployment, coordination, and monitoring. These roles include:

- Mobility and Curb Manager (15% of time)
- Mobility Planner (15% of time)
- Operations Analyst (50% of time)
- Assistant Parking Systems Manager (15% of time)
- Two interns (part-time positions)

Stage 1 Project Activity Summary

Developing a team

The City of Minneapolis established a public-private team to ensure ongoing project success. Within the city, the Public Works' Traffic and Parking Services Division collaborated with the Information Technology department. The city added capacity by securing Walker Consultants, a national leader in the curb space and technology field, as the team's project manager. Another private firm, Bolton & Menk, was contracted to assist with local engagement activities, joining the team in February 2024.

Data management plan

Our team developed and submitted our Data Management Plan in December 2023. This included in-depth meetings and discussions to fully develop and articulate our data collection

and management processes and protocols. Our team made suggested edits to the Data Management Plan brought forward by the USDOT.

SMART Collaborative learning

Minneapolis benefited from the ability to learn from and share experiences with other SMART awardees and OMF members. Minneapolis participated in the first in-person meeting of the OMF SMART Collaborative in Seattle in April 2024. In October 2024, two (2) City of Minneapolis team members travelled to Europe to participate in the SMART Collaborative Sustainable Mobility & Urban Freight Logistics Study Tour, generating learnings about logistics, small vehicle deliveries, delivery hubs, and data standards, and learnings from European collaborators.

Manual data collection and observations

Walker Consultants team members spent several days observing the corridor to get a preliminary sense of curb activity prior to hardware deployment. Walker conducted ten (10) vehicle occupancy counts on three days, as well as observed types and durations of loading activity. This activity was conducted in April and May of 2024.

Freight and business engagement

We conducted several meetings with freight companies operating in Minneapolis, during which we had the opportunity to discuss the challenges they faced in making deliveries in the city's busy areas. These meetings were progressive, starting with an understanding of broad issues and leading to more focused discussions around how curb policy and usage data might impact driver/operator workflows. We hosted several recurring meetings with freight operators between July and August 2024.

We had the opportunity to ride along with FedEx drivers in the summer of 2024 to observe how they operate in busy parts of the city.

Curb mapping & digital twin development

We used the same vendor and contract for both camera procurement and for conducting a LiDAR scan to feed the curb digital twin. The vendor, Umojo, hosts the curb digital twin. The city and Umojo collaborated to integrate various data feeds into the digital twin, ensuring that these data feeds adhered to the common curb specification standard. For digital mapping, Umojo mapped the Nicollet corridor, in addition to 40 miles of curb space around Downtown, Dinkytown, and the North Loop. Initial mapping occurred in May 2024; however, initial errors necessitated an additional round of mapping in Summer 2025. After ground-truthing and adjustments to match existing data layers, the curb inventory process was completed and integrated into the Umojo NexCity platform by September 2025.

Installation of solar-powered edge computing cameras

The initial installation of 52 4G LTE solar-powered computer vision cameras was completed in June 2024.

Air quality sensors

Sensors were purchased in early 2024 and deployed to the corridor alongside camera sensor deployment in June 2024.

Loading zone deployment

Based on discussions with local businesses and delivery operators, our team identified and deployed two (2) loading zone locations on the corridor in October 2024. Signage was installed, and cameras were re-aligned to ensure they captured loading activity. Shortly after deployment, one of the loading zones was taken offline for construction activities on an adjacent street, which are ongoing as of October 2025.

To compare data flows across multiple vendors, Minneapolis contracted with INRIX to build out a citywide inventory of the city's curb assets. The first iteration was completed in early 2025, enabling the city to compare data between INRIX's and Umojo's digital inventories. In September, INRIX released a final iteration, having conducted ground-truthing to verify the digital map.

API development

The city's Information Technology department developed a process to ingest data from Umojo's digital twin into Minneapolis' local cloud-hosted server, the Open Data Platform, powered by ESRI. The first export of CDS-formatted data into the Open Data Platform occurred in August 2024. Minneapolis collaborated with the curb data vendor Umojo to refine data discrepancies in the Fall of 2024.

Presently, the Open Data Portal contains CDS datasets, including Policies, Zones, and Space regulations/locations. The datasets provide information about 96 unique zones and 329 spaces along the corridor. This information serves as the source of truth for defining curb metrics and is intended to be regularly updated and expanded in Stage 2 as changes are implemented.

Asset Management and Data Standardization

The city helped coordinate discussions between Umojo and OpenGov, the city's digital asset management host, to ensure that existing asset management processes comply with the city's adoption of the Curb Data Specification. All three entities collaborated to standardize a process for updating curb policies and assets, ensuring that changes are automatically reflected in both the digital twin and the digital asset management map, as per CDS.

Installation of mounted power adapters

Having realized that solar cameras are not viable at scale to capture the necessary data, the city requested that the vendor provide adaptors to directly connect with the power system. Although the cameras were successfully delivered, they were not installed as part of the Stage 1 activities because no agreement had been set in place with the regional power utility, Xcel Energy.

The power adaptors would draw power from streetlight poles. Groups of streetlight poles draw their power from aggregated electrical cabinets monitored by Xcel Energy's electrical meters. Currently, all streetlights utilize a specific electrical rate that can only be applied to public lighting, meaning that the city requires a different rate for all the electrical meters that feed poles with cameras. The power use difference would be negligible, as would the projected cost difference.

Leading up to Stage 2, the City of Minneapolis has initiated the process of proposing a new electrical rate to the Public Utilities Commission of Minnesota, which would serve the hybrid needs of lighting and light-pole-powered sensors, as well as other curbside and traffic monitoring technologies. Xcel has agreed to the following workflow for Stage 2:

- Minneapolis submits a service exception and a map of identified poles.
- Xcel accepts service exceptions and installs meters. Minneapolis installs a cabinet for a metering point if needed.
- Xcel switches streetlights from A32 to A10 service and bills for service as such.

Updates to the Curb Data Specification

Based on discrepancies and issues with the beta CDS identified by Minneapolis and other Curb Collaborative cities, OMF took measures to update the CDS throughout 2024 and 2025, resulting in the release of CDS version 1.1.0 in October 2025. Some of the major updates with version 1.1 include:

- Defining curb objects- signs, meters, EV chargers, street poles;
- Vehicle properties- new properties like make, model, year, color;
- Computer vision- now includes confidence levels for vehicle detection and vehicle property associations;
- Curb zone lines- can now be represented with lines, instead of polygons; and
- Double parking- may now be tracked and shown outside of valid curb spaces.

Project Exposure

Minneapolis' SMART project has garnered national attention, especially following the announcement of its Stage 2 recipient status. The project team has led presentations and a walking tour highlighting the importance of curb management and the use of digital tools. Below are highlights of the project in the media and in presentations.



Source: SMART Project Team

- **Project walking tour, Minnesota State American Planning Association Conference:** The project team led a walking tour of the Nicollet Avenue project corridor during the American Planning Association state conference in September 2024 (See image above) The tour highlighted the relationship between curb access and land use, engaging with the freight and local business communities, and utilizing data to inform decisions about curb management. While walking the length of the corridor, the project team highlighted what technologies were deployed and the data streams they provided. Planners and stakeholders from several Minnesota cities attended the tour.
- **Media attention following notice of Stage 2 grant award:** Several national media outlets reported on Minneapolis and Seattle receiving notice of grant funding for their Stage 2 project, "Smart Curbs for Better Access: A Digital, Data-Driven Approach Across Cities." Media outlets included Parking Today, GovTech, Kurrant, Cities Today, and the Open Mobility Foundation, which partnered with Minneapolis in Stage 1.
- **IPMI presentation:** Minneapolis presented on its SMART curb management work to date at the June 2025 IPMI national conference in Louisville, Kentucky, along with the Cities of Boston and Seattle.
- **University of Minnesota Center for Transportation Studies Freight and Logistics Symposium**: Minneapolis Curb Manager Dillon Fried presented at the Center for Transportation's 28th annual Freight and Logistics Symposium about the city's curb management efforts, including work performed through the SMART grant (See image to the right). Fried also provided updates on the city's progressive Transportation Action Plan, Curbside Access Policy, and Curbside Action Work Plan.
- **NACTO's Building Modern Programs for Dynamic Streets webinar**: Dillon Fried, Minneapolis's curbside



Source: SMART Project Team

manager and SMART grant project lead, presented how Minneapolis is using digital tools and policies to more effectively manage its curb space during a December 2025 NACTO webinar.

Deviations or changes from the original Stage 1 proposal

As discussed in more detail in Part 5 (Challenges & Lessons Learned), the strongest lesson learned in Stage 1 is that having comprehensive and accurate data is foundational for all other steps of the curb management process. Quality data is required in order to:

- Provide a complete picture of curb policies and regulations to public and private users;
- Accurately track events and metrics of the curb;
- Provide APIs to support private companies' curb use;
- Integrate with and cross-reference with existing city systems;
- Make data-informed changes to curb use, allocation, and policies.

Collecting quality data and ensuring continued support for quality data collection took longer than anticipated, delaying progress in the formation and widespread release of APIs and implementing changes to the curb. The following describes the project's deviations from the Stage 1 grant proposal.

Digital Twin and Curbside Management Platform

The City of Minneapolis Public Works and Information Technology departments aimed to collaboratively develop a curb inventory digital twin and data-driven curbside management platform and ecosystem that would integrate curb policies and metrics with relevant city and vendor data, such as mobile app and pay station transactions, traffic, sewer, and water assets, and geospatial databases. The aim was for the digital twin and platform to be created and managed by city staff, utilizing open-source technology, and capable of ingesting APIs from various internal and external data feeds, then mapping them digitally on an enterprise platform. To achieve our objectives, we have had to rely on private vendors more than we had intended to at the outset of Stage 1 (as described below); however, Stage 2 will expose important aspects of our digital platform and the resulting APIs as open-source elements.

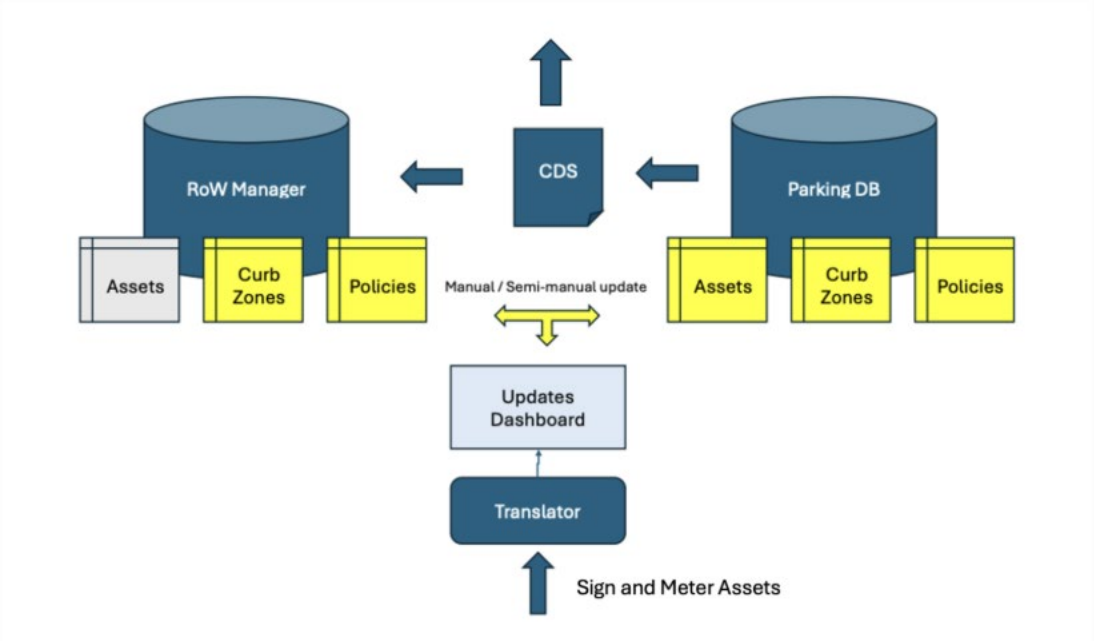
In the first few months of the project, the team collaborated with ESRI, the city's enterprise GIS provider, to explore the platform's capabilities for external integrations and API ingestion. Based on conversations with ESRI and other curb management entities, particularly Park Omaha, it was determined that ESRI's platform would not be capable of handling API ingestion from external data feeds.

Meanwhile, the camera vendor, Umojo, was eager to work with the City of Minneapolis to provide a digital twin using their NexCity dashboard. Umojo cleaned and aggregated camera data into the standard Curb Data Specification, while Minneapolis created an API endpoint to intake APIs.

Minneapolis is relying on INRIX for automated updating of the city's sign and meter inventory. Minneapolis worked with INRIX and OpenGov to establish API connections between the two entities. These tools also allow the city to manually make updates in the event of temporary

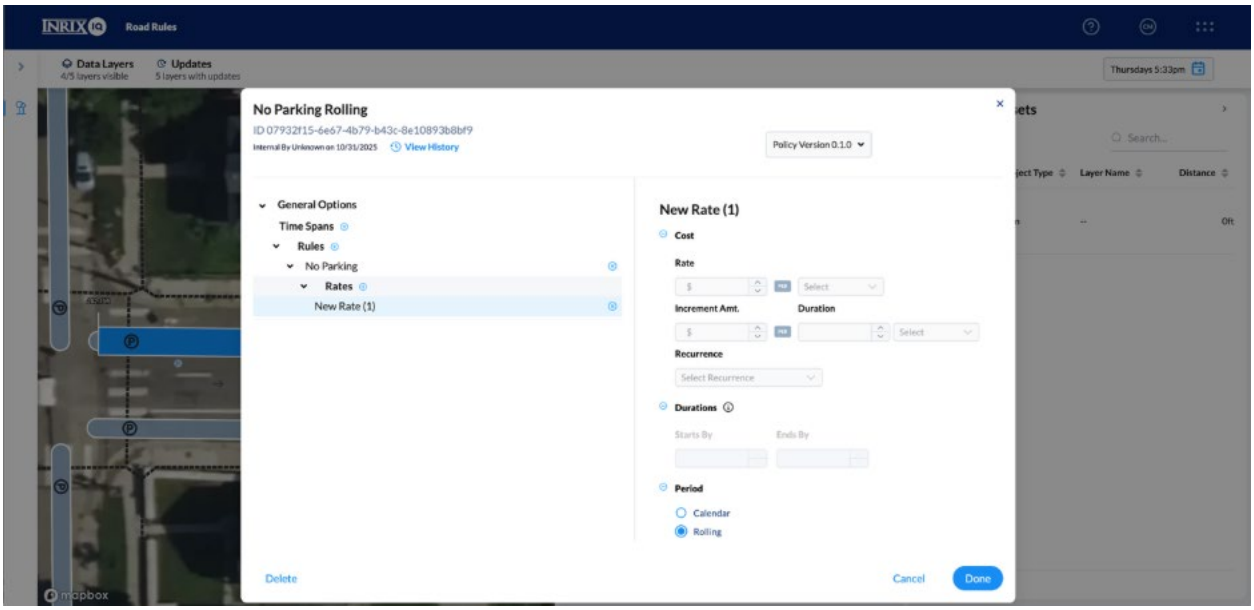
(e.g., event-based) or permanent (e.g., new driveways) changes to the curb that may not already be captured by the asset management system APIs (See Figure 5 and Figure 6).

Figure 5: Automated Process for Updating CDS



Description: INRIX developed an automated process for the San Francisco Municipal Transportation Agency to update its Road Rules Right of Way (RoW).
Source: INRIX

Figure 6: INRIX Road Rules, Rate Change Manual Input Page



Source: INRIX

Widespread release of APIs

Due to delays in establishing data accuracy, digitizing LiDAR scans, and addressing signage and policy discrepancies, Minneapolis was unable to widely release and test APIs in a meaningful way during Stage 1. However, we successfully hosted the CDS Curbs API on the city's Open Data Portal in Stage 1. Plans in Stage 2 include outward sharing of the Curbs, Events, and Metrics APIs to the public and curb users.

Data-driven re-allocation of curb space

Data collected during Stage 1 was useful in developing the city's Curb Access Policy and Curbside Action Workplan, which provides a framework for how Minneapolis will allocate curb space in the future. However, significant changes to curb allocations were not made to Nicollet Avenue. This is due to several factors, including:

- The initial aim was to introduce additional dynamic curb loading zones at hotspots along the corridor, as well as introduce digital signage and API connections to aid in locating available curb locations. Without the API and digital signage, there would be no distinction between traditional loading zones and dynamic loading zones.
- The data that we share with private operators and the public must be accurate and reliable. Due to issues with solar-powered cameras, we are not confident that the camera event data is accurate without NEMA power taps.
- While data was limited due to issues with solar-powered cameras, we found that instead of a single or a few 'hotspots', commercial vehicles park all over the corridor.

- Engagement with freight operators informed us that operator demands are varied, with different delivery durations, loading needs, and dispatch/navigation technologies deployed. Several operators informed us that they do not use digital tools when making deliveries, instead relying on operators to memorize routes or use paper dispatch and route planning. This limits the ability to utilize digital tools to provide accurate and useful information about curb regulations and availability. We gained trust and began educating the operators about the benefits of digital tools that we will introduce in Stage 2.
- Current enforcement strategies do not effectively moderate freight and delivery driver behaviors. This makes policy-setting and space allocation less effective, as operators are aware that they can park in violation of curb and traffic rules without being cited.

With the city's parallel development of a *Curbside Action Workplan's* curb space allocation framework, and improved data collection and sharing mechanisms, Stage 2 will incorporate more re-allocation of curb space and implement dynamic curb operations and management.

3. Proof-of-Concept or Prototype Evaluation Findings

Note: The dataset generated under this SMART Stage 1 project has been submitted to USDOT's ROSA P repository for public release. A DOI will be assigned by ROSA P upon publication.

The December 2023 Evaluation Plan identified key performance measures and targets to assess the effectiveness of the curb management system. Below is a summary of evaluation questions, measures, and findings from Stage 1.

Evaluation Question	Performance Measure	Performance Measure Target
Were partnerships formed with entities that use curb spaces? Does the system improve communication of information to curb users and partners, and increase customer service?	Digital twin is implemented and communicating curb data	3-5 stakeholders pilot APIs and digital communication tool during Stage 1 Stakeholders report positive experience and results using the digital tool Stakeholders report tool supports positive outcomes for them, and they wish to continue to use the digital communication tool
Does this system reduce curb violations?	Citations and 311 complaints related to inappropriate use of curbspace and double parking.	Reductions in citations and 311 complaints
Does the system reduce traffic congestion?	Traffic counts for the area Air quality readings	Changes in specific air quality and traffic measurements, as determined by air quality sensors and traffic volume measurement devices
Does the system improve safety?	Traffic accident data	Reduction in relative traffic accident frequency
Does the system improve data collection to inform city planning and policies and	City is satisfied with data collection and determines a process	Improves and informs city processes

city-based monitoring and performance management of curb space?	for ongoing data collection City can leverage system data to make meaningful policy changes % or proportion of curb space reallocation via learnings from deployment of digital tool	Improved reallocation of curb space for optimization
Does this system improve the efficiency of curb space and promote enhanced use of the curb space (curb productivity)?	Increased space turnover, decreased curb violations, occupancy rate	Dwell time and turnover increases over time Utilization between 70% and 80%
Does this system improve curb access and reliability?	Increased space turnover, decreased curb violations, occupancy rate optimization	Turnover increases over time Utilization between 70% and 80% during peak curb demand Violations are reduced over time

Proof-of-Concept Performance Findings

Limitation: Data Accuracy Challenges

Reliable curb policy and event data were critical for evaluation. Accurate curb inventory and event readings were foundational for making data-informed decisions, implementing physical changes to the curb, and testing with various users. Significant time was spent on the foundational components of the project- validating and improving data collection methods and technologies. Ultimately, delays in finalizing the baseline inventory, curb policies, and event data prevented some of the anticipated curb changes during Stage 1. However, because we invested the necessary time in evaluating data collection technologies, we have high readiness for Stage 2 and using data for private-sector partnerships.

The following represent current data and findings, which represent a 'before' state, while the Stage 2 implementation will represent an 'after' state.

Digital twin is implemented and communicating curb data

The project team did not achieve our KPIs in this category. We were unable to conduct testing of the digital tool with stakeholders.

However, we have identified freight and logistics stakeholders who would be interested in testing the tool once it is ready for pilot deployment. We conducted several engagement sessions to understand how private companies use digital tools, so that we are better prepared to respond to operator needs when testing the digital tool.

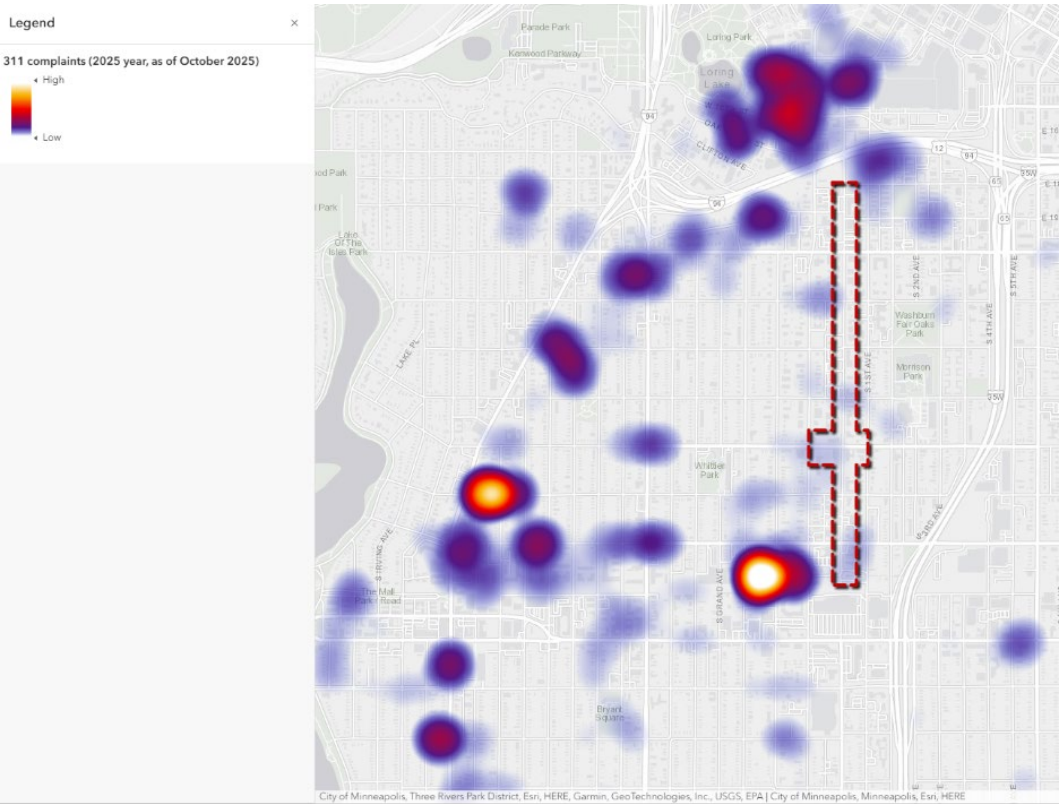
Reducing curb violations

Our Evaluation Plan called for measuring reductions in curb violations through 311 complaint data. The city records 311 complaints and maintains its repository on the OpenData portal. This is useful for informing the city about which neighborhoods and streets have violations, as shown in Figure 7.

311 data was evaluated; however, there are some downsides to using 311 data alone. For one, 311 relies on complaints being called in, which may differ depending on each neighborhood. Additionally, 311 does not record key details. That is, we do not know how long the vehicles are in violation, what type of violation is occurring (such as double parking, blocking a driveway, parking in a restricted area, or overstaying time limits), the type of vehicle, or the exact location (311 complaints are recorded per block face).

The Nicollet Avenue study corridor has far fewer vehicle-related complaints than nearby Pleasant Avenue and 29th Street, which are part of a Critical Parking Area, a permit program designed to prevent spillover parking demand from the Karmel Mall. Areas with the highest parking violation complaints in Minneapolis are often part of a Critical Parking Area. No section of the Nicollet Avenue South focus area is a Critical Parking Area.

Figure 7: Parking-related 311 complaints in South Minneapolis, 2025



Source: City of Minneapolis

Nicollet Avenue is in the Whittier and Stevens Square neighborhoods. Between 2024 and 2025 (up to October 22, 2025), the highest-reported case type in the two neighborhoods was vehicle-related. Whittier, the largest neighborhood in Minneapolis (3.3% of the population), also has the most vehicle and commuting-related 311 complaints in the city (6.2% of complaints). As Figure 7 shows, most complaints within the Whittier neighborhood occur to the southwest of the focus area.

While we initially thought that 311 complaints and traffic accident reports would provide a more detailed understanding of where safety 'hotspots' are along the corridor, we realized that this data is not targeted to specific locations and times when unsafe behaviors occur (such as double-parking, parking in the bike lane, or parking in a "no-parking" zone). However, by installing and reviewing computer vision camera inventory and event data, we have gained a deeper understanding of safety violations on a more micro, block-by-block level.

Reducing traffic congestion and improving air quality

Our Evaluation Plan called for measuring traffic volumes and air quality readings to evaluate whether the project would reduce traffic congestion. The team had two hypotheses to test with the goal of improving air quality and traffic congestion through implementing changes to the curb.

1) There is a correlation between air pollution (specifically nitrogen dioxide (NO_2) and total volatile organic compounds (TVOCs), which are emitted from vehicle tailpipes), and traffic volumes and congestion.
2) Curb management efforts can reduce traffic congestion, therefore improving air quality. Curb management includes changes in policy and reallocation of curb space.

In summary, the data is inconclusive for both hypotheses. First, in the effort to establish a baseline correlation and measure the impacts of traffic volumes and congestion on air quality, we discovered several limitations in determining the strength of the relationship. Ongoing construction on the corridor itself and in surrounding areas was a major limitation - construction projects changed typical traffic patterns, added large construction vehicles, and added non-transportation-related air pollutants to the study area.

The largest construction project, dubbed 'New Nicollet', at the southern end of the corridor, began on September 15, 2025. New Nicollet aims to reconnect the north and south portions of Nicollet Avenue, which was split in the 1970s to build a retail box store. In preparation for reconnecting the missing two blocks of Nicollet, First Avenue South, which runs parallel to Nicollet Avenue one block east, has been closed for reconstruction since 2024. Construction has also been ongoing on 26th Street at its intersection with First Avenue and Nicollet, involving the use of construction vehicles and reducing the traffic lane from two lanes to one.

Similarly, air quality metrics from Stage 1 are likely to have been affected by construction activities associated with New Nicollet and the 1st Avenue reconstruction. Project air quality sensors are also likely to pick up higher levels of pollutants from nearby Interstate 35W, which is located just two blocks away in the southern portion of the study area.

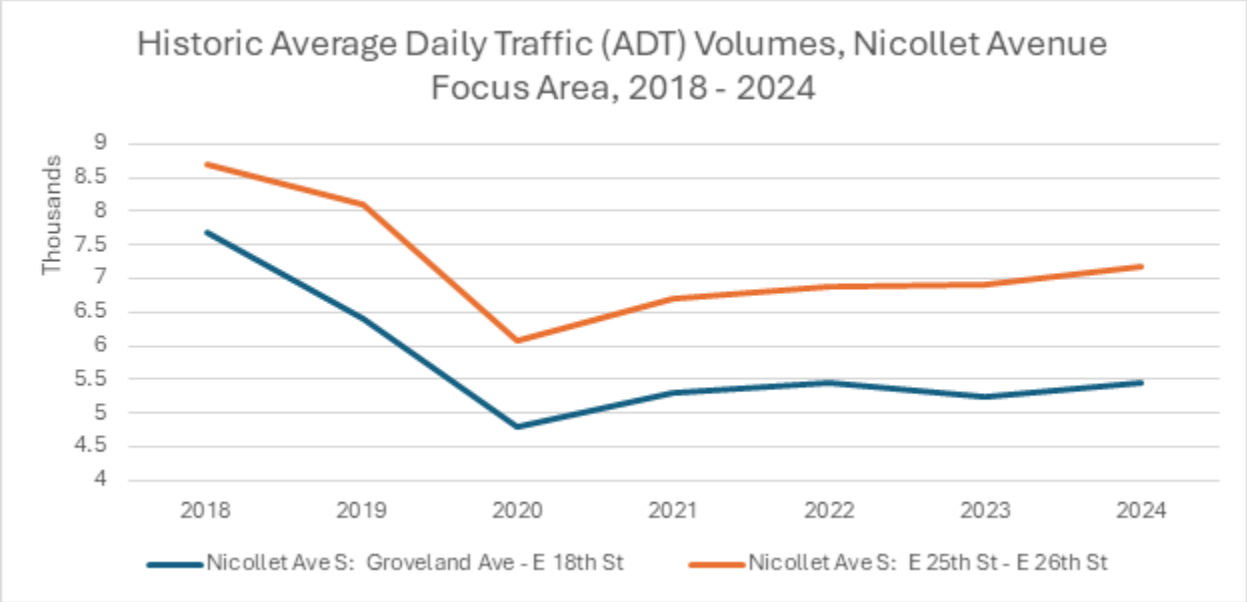
Evidence suggests a strong relationship between traffic volumes and air pollution. In a 2013 NIH study evaluating the relationship between air pollution and health risks due to vehicle traffic, health researchers found a strong linear relationship between traffic volumes and nitrogen dioxide (NO_2) concentrations on an 8.5 km five-lane arterial in Detroit, MI. However, because of longer exposure to pollutants during periods of peak traffic congestion, incremental health risks become exponentially higher as traffic volumes increase. Because health concerns are heightened when there is both high traffic volume and low vehicle speeds due to traffic congestion, the project team initially decided to use air quality monitors rather than relying solely on traffic count data.

While we have access to annual traffic volume counts at two points in the corridor, we do not have a reliable source of data on average vehicle speeds and traffic congestion at different times of the day.

The following chart, Figure 8, measures traffic volumes in two locations along the Nicollet Avenue corridor: one in the northern section (Groveland Avenue – E 18th Street) and one in the middle of the corridor (E 25th Street – E 26th Street). As Figure 8 shows below, traffic volumes

on the corridor decreased significantly in 2020, and remained low even after the pandemic. This may be attributed to the persistence of remote work among downtown office workers, who may not be commuting on Nicollet Avenue as frequently. The northern segment of the route (Groveland/18th Street), closer to Downtown, has consistently lower traffic volumes than the center of the corridor (between 25th and 26th Streets).

Figure 7: Historic Average Daily Traffic in Focus Area

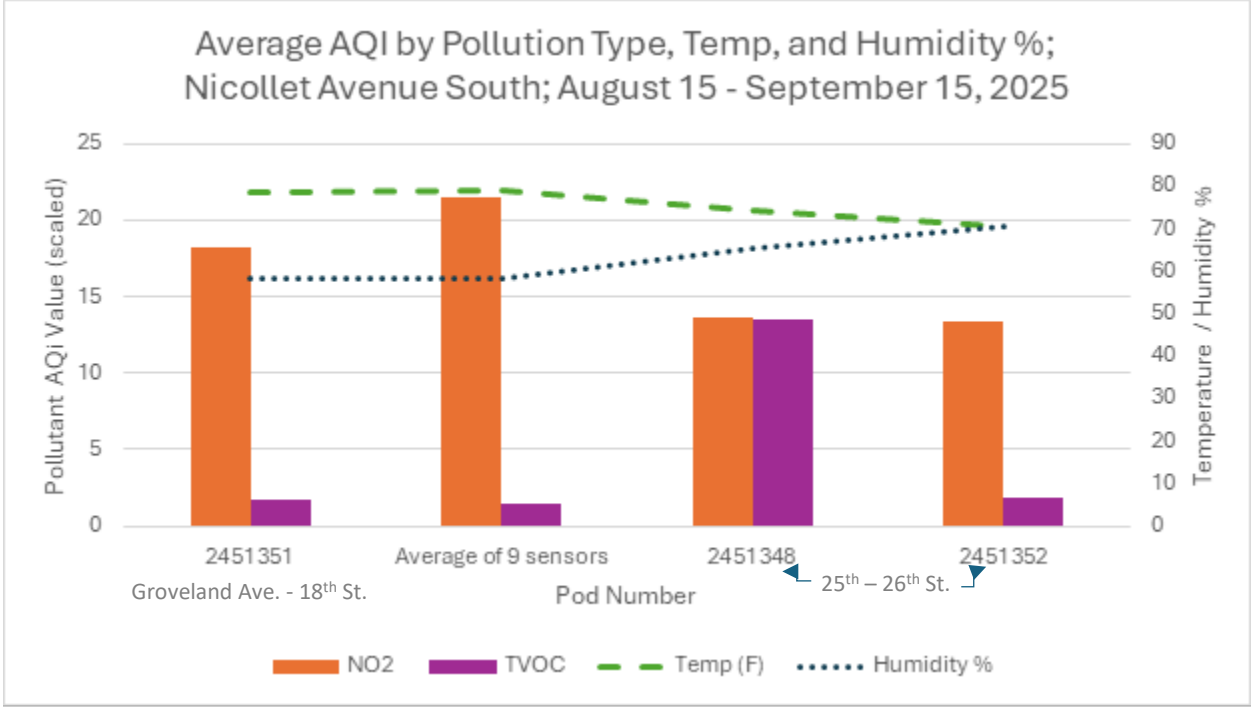


Source: Minnesota DOT

To test the hypothesis that air pollution is strongly correlated with higher traffic volumes, we reviewed air quality sensor data from the sensors closest to the traffic count locations. Sensor #2451351 is located at the northernmost point of the corridor, where traffic is less concentrated, while sensors #2451348 and #2451352 are situated in the center of the corridor, where the most traffic is typically found. Therefore, if traffic volume and air quality are highly correlated, we would expect sensor #2451351 to record lower levels of air pollution. Air quality data is from August 15 – September 15, 2025.

The chart below, Figure 9, shows the two air pollutants most closely associated with motorized vehicles: nitrogen dioxide (NO2) and total volatile organic compounds (TVOC), which collectively represent various organic chemicals that serve as a general indicator of outdoor chemical contamination. The chart is scaled in accordance with the Environmental Protection Agency's Air Quality Index (AQI), where values between 0 and 50 are considered good, values between 50 and 100 are of moderate concern, and values greater than 100 are increasingly unhealthy.

Figure 8: Average AQI by Pollutant Type



Source: Ambilabs, data collected from nine (9) air quality sensors located along the Nicollet Avenue South corridor.

The selected data in this analysis fails to support our hypothesis, indicating that there is no observable relationship between traffic volumes and air quality in the selected study areas. NO_2 levels are higher in the section of the corridor with less traffic, and TVOC levels are generally low, except for one sensor. Temperature and humidity varied slightly across the corridor, but the variation does not explain differences in air pollutant levels. Instead, as mentioned previously, differences in ambient air quality are most likely associated with construction activities within and surrounding the corridor, exposure to the nearby interstate freeway, and prevailing wind patterns. During the August 15 – September 15, 2025 timeframe, the maximum scaled NO2 reading reached only 38, indicating that NO2 pollutant levels were within satisfactory levels according to the EPA's AQI index.

We were unable to validate the first question in our two-part hypothesis, therefore we were unable to test the second part (whether curb management can improve air quality).

In Stage 2, we plan to reimagine traffic congestion as a performance measure. For the Nicollet Avenue corridor, there was too much noise in the air pollution data such that we did not determine a clear relationship. The noise includes other ambient air pollution, air pollution from the nearby I-35 W, pollution from construction activities, and pollution from the prevailing wind direction.

However, we believe that air quality monitoring can still be a source of data in Stage 2, albeit not a primary source of data collection. While it may be difficult to pin air quality changes on a particular corridor, we aim to shift our monitoring to broader, neighborhood-level impacts of curb management. For example, when we make neighborhood-level changes in Dinkytown to reduce vehicle circling, we plan to deploy air quality monitors around the neighborhood to compare with the baseline. While we wouldn't expect to see significant variation on a given street, we hypothesize that changes can be determined at a larger-scale neighborhood level. We also plan to pair sensor data with more granular vehicle count data to analyze the relationship on a day-to-day basis. This way, we can visualize and compare air quality on high-traffic and low-traffic days and times.

Safety improvements

Based on our observations around the study corridor, we no longer believe that traffic accident data is a meaningful performance indicator for measuring the results of our project. Results from a 2019 Vision Zero Crash Study found that the five behaviors that lead to the most severe and fatal crashes on Minneapolis streets are:

1. Red light running,
2. Speeding,
3. Driving under the influence of drugs or alcohol,
4. Unsafe turning (failure to yield the right-of-way when turning), and
5. Distracted driving.

None of the top five criteria that lead to crashes necessarily relates to the curb, so even if curb availability increases and double-parking decreases, it would likely not have a significant impact on overall crashes. As the corridor-specific crash data shows, most crashes do not involve collisions with fixed objects (such as vehicles in the roadway). Nicollet Avenue is a 3-lane street with a center turn lane, which is likely a much higher crash contributor than curb activity. Because Nicollet is not a through street, there is a significant volume of turning activity, and many of the trips using Nicollet originate or end along the corridor; therefore, vehicles may be more attentive to looking for parking spaces than they are on other corridors in Minneapolis.

VEHICLE CRASH DATA

Between October 1, 2023, and September 30, 2024, there were 26 recorded crashes involving motor vehicles on the Nicollet corridor. Sixteen (16) did not result in injuries, six (6) resulted in possible injuries, and four (4) resulted in suspected minor injuries. Only one of the collisions involved a fixed object. Two (2) of the incidents involved a pedestrian or cyclist- the pedestrian incident occurred at Nicollet and 24th, and the bicyclist incident occurred at Nicollet and 28th.

Crash data over the same period in 2024/2025 shows consistent findings. Between October 1, 2024, and September 30, 2025, there were 25 recorded motor vehicle crashes. Fifteen (15) did not result in injuries, six (6) resulted in possible injuries, and four (4) resulted in suspected minor injuries. All but one involved collisions with a non-fixed object- the remaining incident is unknown. Six (6) of the incidents involved a pedestrian, cyclist, or person rolling. Two (2) of the pedestrian crashes occurred at intersections- Nicollet and Franklin, and Nicollet and 26th Street. The other two (2) pedestrian crashes occurred on Nicollet between 26th and 27th Streets, and between 22nd and 24th Streets. One crash with a bicyclist occurred at Nicollet and 19th Street. A collision involving a person using a personal conveyance device (wheelchair, skates) occurred at Nicollet and Groveland Ave, although it is unknown whether this involved a vehicle or a fixed object.

Since traffic crashes are not a highly representative performance indicator for this project, it would be more useful to review actual double-parking event data collected during this project. Because curb monitoring devices were being calibrated during the first phase of the project, we do not have reliable data on the volume of double-parking events that occurred before the implementation of additional loading zones on the corridor. The following represent current typical double-parking events. We will compare these as a baseline for Stage 2 for this corridor and other corridors.

DOUBLE-PARKING EVENT BEHAVIOR

Between August 15th and September 15th, over 10,000 double-parking sessions were recorded, averaging 331 per day. The mean duration of double-parking events was 1 hour 10 minutes, and the mode (the most common duration increment) was between 30 minutes and 1 hour. 1,140 double-parking sessions lasted longer than 2 hours, averaging 35 per day, which is 11% of the total daily double-parking sessions. Double-parking sessions are prevalent between 11 a.m. and 5 p.m., although the peak is at 4 p.m. (Note that this data is incomplete due to a lack of data after 6:59 p.m.).

Data collection and data-driven curb management

The project team found accurate and reliable data collection to be the most valuable and foundational component. Without an accurate representation of curb rules, regulations, and inventory, as well as event metrics, data cannot be relied upon for sharing or making decisions.

Through this project, Minneapolis was able to compare:

- Three methods of inventory collection (manual, LiDAR, asset management platform integration)
- Two methods of collecting parking event data (in-ground sensors, camera vision edge computing)
- Four methods of collecting parking occupancy and availability metrics (manual, camera vision edge computing, predictive analytics (INRIX), mounted vehicle sensors (ParkMobile)

Below are the data comparisons for each metric, including the ease or difficulty of using the data collection tool, its integration with other data systems, and the accuracy of the data.

INVENTORY DATA COLLECTION

The following table compares inventory space counts for the Nicollet Avenue South study area. The counts include all curb uses except for ‘No Parking’ zones, which encompass free and metered parking, loading zones, ADA and disability transfer zones, and EV charging zones. Since most of the corridor is free parking without delineated parking spaces, there is likely to be some variation in the inventory depending on how it was calculated (i.e., what was the average space length, and how much space at the edge of driveways was assumed to be no parking). This is

why computer- and GIS-backed inventory was found to be more accurate than manual counting, especially in corridors without delineated spaces.

Data Collection Method	Unit Count	Accuracy	Ease of Collection (at scale)	System Integration
Manual inventory collection	300 (260 on Nicollet, 40 on 26th Street)	Medium	Low	Low
Umojo's LiDAR scan	317 (275 on Nicollet, 42 on 26th Street)	High	Low	Medium
INRIX's OpenGov integration (using sign policies and locations)	325 (281 on Nicollet, 44 on 26th Street)	High	Medium	Medium

PARKING EVENT DATA COLLECTION AND DURATION

Two (2) data sources provide real-time data about parking sessions (events): in-ground sensors and solar-powered cameras with edge computing. In-ground sensors capture curb activity every 5 seconds, while computer vision cameras capture activity every minute.

While not funded by SMART Stage 1, Minneapolis strategically located 134 in-ground sensors along the corridor, as shown in Figure 10, leading up to the project, providing the project team with a separate technology with which to verify and test others against. These in-ground sensors, provided by Risetek, have been found to be especially reliable but are best suited to delineated parking environments where the precise location of vehicles can be controlled, ensuring proper positioning of the vehicle relative to the sensor.

Figure 9: Map of Risetek sensor locations and occupancy around the Nicollet and 26th Street intersection.



Source: Risetek

The following table assesses the number of parking sessions recorded that began between 12:00 a.m. on Thursday, August 14th, and 11:59 p.m. on Friday, August 15th. Only sensors directly on Nicollet Avenue were included, as ongoing construction on 26th Street prevented the use of sensors on that street.

Data Collection Method	# of parking sessions	Average/ median duration	Overstay Violations	Accuracy	Ease of Collection (at scale)	System Integration
In-ground sensors	1,752	Average: 57 mins Median: 5 mins	83 overstay violations	Medium	Medium	Medium
Solar-powered computer-vision cameras	2,632	Average: 1 hour 27 mins	444 overstay violations	Low (especially in winter months)	Medium	High

The results show a significant difference in both the number of observed parking sessions and the number of reported overstay violations from each collection type. We are hopeful that

NEMA-powered cameras will increase the reliability of the computer-vision cameras. Because undelimited parking spaces are not the ideal testing locations for in-ground sensors, the project team is wary about over-reliance on their accuracy. Additional ground-truthing will be required in the early stages of Stage 2 following the installation of NEMA mounts on Nicollet and other focus areas.

OCCUPANCY AND AVAILABILITY METRICS

Minneapolis tested four different ways of collecting data about curb occupancy and availability:

- Manual occupancy data collected at 10 time periods on 5/1/2024, 5/3/2024, and 5/4/2024
- Umojo's solar-powered computer-vision cameras with edge computing
- INRIX's predictive curb availability using floating vehicle data (gathered anonymously from connected cars, fleets, and mobile devices)
- ParkMobile's mounted vehicle sensors attached to city fleet vehicles

The following table shows curb parking utilization and predicted availability on a typical Friday at 2:00 p.m. Because INRIX and ParkMobile only show occupancy and availability by block, the table shows results for the 2600 block of Nicollet Ave, located between 26th and 27th Streets.

Data Collection Method	Parking utilization %	Predictive analytics	Accuracy	Ease of Collection (at scale)	System Integration
Manual occupancy collection	74%	N/A	High	Low	Low
Umojo's solar-powered computer-vision cameras	47%	N/A	Low	Low	High
INRIX's predictive occupancy	N/A	99% likelihood of parking availability	Medium	High	High
ParkMobile's vehicle-mounted sensors	82%	9 – 11 available spaces on the block	Medium	High	High

The results show a significant difference in results between the solar-powered cameras and the other three data sources. Only the cameras are capable of showing parking utilization in real-time (the ground sensors are less reliable in an undelimited environment, and do not capture parking outside of a valid space). However, without the ability to tap into the electrical grid,

solar-powered cameras are not reliable 24/7/365. For a city aiming to initiate parking utilization data capture, it is recommended to use more reliable, although potentially not real-time predictive analytics sources, such as vehicle-mounted sensors or floating-car data (FCD) models that predict parking occupancy/availability at a given time of day. Cameras are most useful when working with private operator stakeholders who want to know precisely how many spaces are available and where they are located on the block.

In conclusion, each data collection method has its pros and cons. While manual data collection can be performed cheaply and easily for a small corridor, it is not easily scalable and lacks connection to the digital ecosystem. On the other end of the spectrum, camera installation is highly integrated with the digital ecosystem, but is also not easily scalable due to the high costs of installing and maintaining each camera. We also found that cameras must be connected to the electrical grid, since solar-powered camera batteries do not survive Minnesota winters or have enough power to record continuously or in short time increments. Considering how to scale citywide during Stage 2, we anticipate continuing to rely on multiple data collection resources and to test them for accuracy and cost efficiency. For cities without SMART funding, predictive analytics and vehicle-mounted sensors may be the most reliable methods of data collection. They enable cities to begin to understand their curb space activities, even if the data is not real-time.

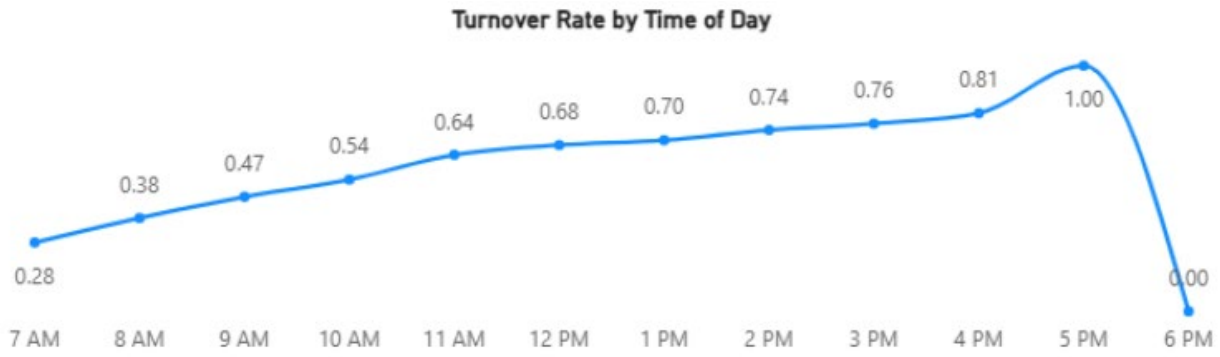
Efficiency and reliability of curb space

The final two evaluation criteria are whether the digital tool increased curb space turnover, reduced curb violations, and maintained utilization between 70% and 80% during peak curb demand. Since there were minimal project-related physical changes to the curb (besides adding a loading zone on the 2700 block of Nicollet), and the digital tool was not tested, we do not anticipate that the project caused significant changes in curb activity. However, the city now has a good understanding of baseline conditions to compare against after changes are made in Stage 2. In addition to the data reported in the previous section (*3.1.5 Data collection and data-driven curb management*), the following represents the 'before' conditions describing existing turnover, violations, and utilization.

PARKING TURNOVER

Based on Umojo camera data, depicted in Figure 11, the average turnover rate in the Nicollet Avenue focus area was 0.60 vehicles/hour (August 15th – September 15th, 2025). This means that for a 12-hour day, the average space hosted approximately 7 vehicles. On an hourly basis, vehicles turn over more frequently in the late afternoon, peaking at the 5:00 p.m. hour, with a turnover rate of 1.00 vehicles/hour. This is likely due to utilization peaking in the afternoon compared to earlier in the day, along with potentially more frequent food order pickups.

Figure 10: Parking Turnover Rate by Time



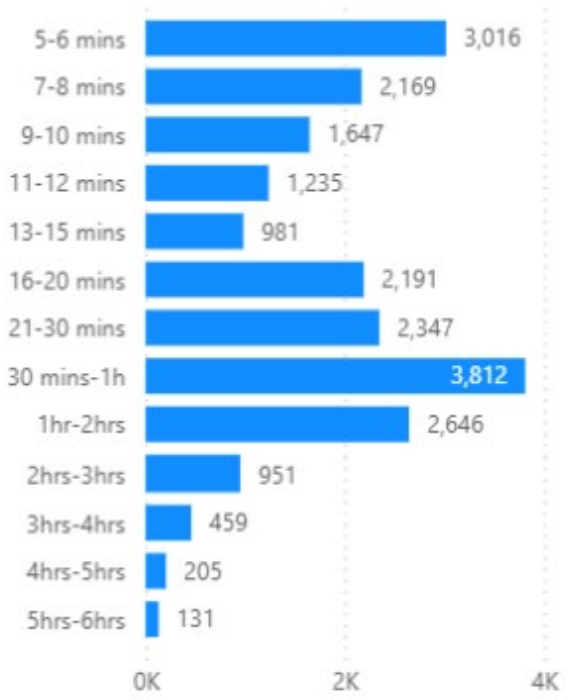
Source: Umojo NexCity

PARKING VIOLATIONS (INVALID-PARKING)

Invalid parking includes double parking, parking in the center turn lane, right turn lane, or any other prohibited parking space. Umojo cameras recorded an average of 697 invalid-parking violations per day between August 15 and September 15, 2025. There is low deviance from the average, with a max daily double-parking violation of 843 on Friday, August 15th, and a minimum of 591 on Monday, September 1st (See Figure 12)

A surprising find was that the average invalid-parking dwell time was 57 minutes, approximately 66% of the average dwell time in permissible spaces. This suggests that there is infrequent parking enforcement along Nicollet Avenue, allowing people to park in violation of traffic laws for an extended period.

Figure 11: Double Parking by Duration Band



Source: Umojo NexCity

We plan to conduct additional ground-truthing in Stage 2 to ensure that cameras accurately detect double-parking and do not falsely associate vehicles idling at traffic lights as double-parked. We are evaluating whether we can integrate traffic signals with the curb digital twin to eliminate any potential false positives. Note that the Umojo cameras do not currently include any double-parking sessions under five minutes to reduce this possibility.

Both manual data collection and ParkMobile Insights indicate that peak parking utilization in the Nicollet Avenue focus area occurs on weekend afternoons (2:00 p.m. – 7:30 p.m.). Umojo camera data indicate that, on average, parking utilization is approximately 46.6% at 5:00 p.m. on Saturdays between August 15 and September 15, 2025.

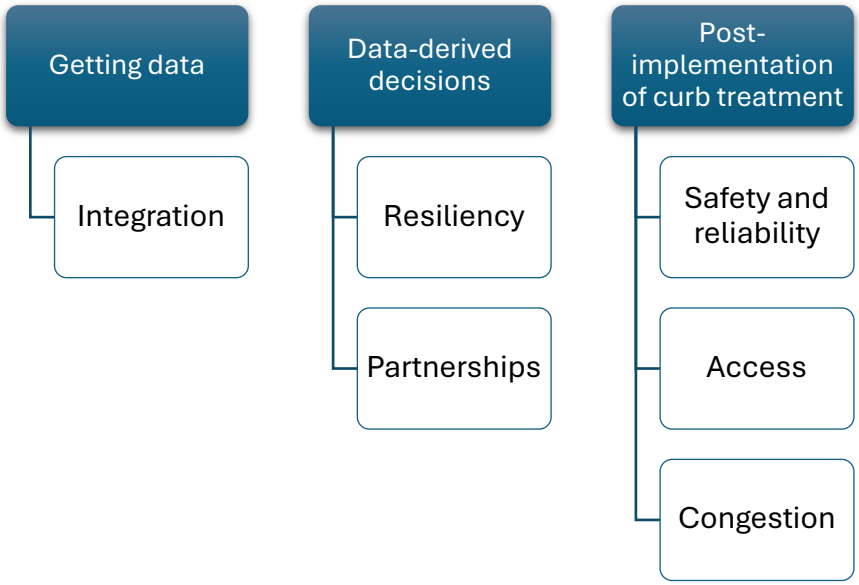
How Proof-of-Concept met the Original Project Expectations

The original project goals described in the grant proposal were as follows:

- **Integration:** Development of a digital curb inventory and a system for accurate and useful curb data collection.
- **Resiliency**: Enabling the city to understand localized curb use and make decisions, such as changing curb space allocations.
- **Partnerships:** Develop partnerships with the USDOT, OMF, cohort communities, private businesses, and freight, goods, and passenger delivery operators.
- **Safety and reliability**: Increased safety for vulnerable users of the corridor, as well as reducing vehicles circling the corridor.
- **Access**: Support increasing access to jobs and essential services.
- **Congestion:** Decreasing vehicle circling.

We were more successful in completing some goals than others. Additionally, as we worked on the project, we realized that achieving some goals was foundational for others. Figure 13 groups goal areas into whether they are foundational or higher-level. To make data-driven decisions, city leadership requires accurate data and a digital curb inventory. Then, to achieve congestion, safety, and access goals, the city must utilize data to inform physical, operational, or policy changes at the curb.

Figure 12: Stage 1 Goal Area Prioritization



Source: SMART Project team

Minneapolis has met its goal of developing a digital curb inventory and ecosystem for collecting, updating, and analyzing data, satisfying the Integration goal. Data derived from the SMART Grant also assisted Minneapolis in the development of its Curbside Access Policy, a framework for implementing changes to curb space following adaptation. With the City Council reviewing the *Curbside Access Policy* for anticipated adoption in 2026, the city's curb space is becoming more resilient. Minneapolis engaged with a variety of local individual and business stakeholders, as well as local and regional freight operators, to understand workflows and data needs. Although we were unable to test the digital tool with operators, we have found that they are energized to continue working together in Stage 2 to undergo testing of the digital tool.

Finally, due to challenges in refining data, testing, and accuracy, we were unable to make substantial data-driven changes to improve space management or user allocation. Therefore, Stage 1 of this project would not have substantially impacted the project's safety and reliability, access, or congestion goals. We anticipate Stage 2 at-scale implementation and beyond will bring positive impacts.

Stage 1 Project Demonstrated Improvement in the Relevant Statutory Areas

Statutory areas of the IIJA Act include:

- Reduce congestion and delays for commerce and the traveling public;
- Improve the safety and integration of transportation facilities and systems for pedestrians, bicyclists, and the travelling public;
- Improve access to jobs, education, and essential services;
- Connect or expand access for underserved or disadvantaged populations and reduce transportation costs;
- Contribute to economic competitiveness;
- Improve reliability of existing transportation facilities and systems;
- Promote connectivity between connected vehicles, roadway infrastructure, pedestrians, bicyclists, the public, and transportation systems;
- Incentivize private sector investments or partnerships;
- Improve energy efficiency or reduce pollution;
- Increase the resiliency of the transportation system;
- Improve emergency response

Minimal physical changes were made to the study area, and the digital tool was not tested with stakeholders, resulting in a limited ability to influence statutory areas. The most meaningful strength we had in Stage 1 was the ability to compare different data collection methods, which sets us up to go into Stage 2. Since potential digital tool users told us that they needed accurate data to utilize the tool, this was our key focus area in Stage 1. Now that we have more reliable data, we anticipate leaning into making improvements in statutory areas in Stage 2.

4. Anticipated Costs and Benefits of At-Scale Implementation

Anticipated/Estimated Impacts of At-Scale Implementation for each Goal Area

The project, when implemented at scale, will have numerous impacts on data sharing, refinement of CDS standards, and coordination and technology transfer across cities, governments, and private sector curb users (including freight/delivery, ride-hailing, etc.). Currently, there is limited coordination between cities and private sector curb users, resulting in non-compliant parking without a legal alternative. Cities need to create the technological, policy, and operational frameworks that encourage curb users to behave in a way that benefits all parties, including those related to city safety, accessibility, and congestion. When scaled, this project will operationalize curb data tools in collaboration with private sector partners, demonstrating the benefits and communicating with and engaging a national audience to facilitate widespread nationwide adoption. There has been a significant unmet need in this area, and our project will address that need, leading to long-term partnerships between the public and private sectors around curb access, with mutual benefits.

Building from the Stage 1 proof-of-concept work, we anticipate the impacts of at-scale implementation, organized below in the various SMART program goal areas.

Safety & Reliability

Two of the most prolific safety issues derived from improper curb use on Nicollet are double parking and parking near intersections. Both of these cause potential conflicts with pedestrians and bicyclists, since they reduce visibility and sightlines. Community members cited safety as the most significant concern when using Nicollet Avenue's curb space.

At scale, we anticipate reducing the number of violations occurring in the designated focus areas. This will be feasible through a combination of policy, technology, improved signage, and operations strategies. By increasing the availability of parking spaces throughout the day (especially during peak times), we aim to reduce parking violations. This will be aided by improved dynamic e-ink signage to share regulations and direct users to available parking.

Resiliency

Through the Stage 1 work, we have come to understand that the long-term resiliency of curb management in Minneapolis and beyond depends on strong internal capacity and commitment, technological solutions, and data management, as well as partnerships with vendors, community stakeholders, other cities, and curb users. The at-scale implementation of our

project will fortify our capability and commitment to each of these areas. At-scale work will include the following:

- Increasing use of CDS to improve communication with and between the city, curb vendors, and curb users;
- Implementation of permanent curb monitoring technology and the adoption of an ongoing data-driven curb management policymaking and operations process;
- Hiring of new staff and increasing digital literacy to maintain data quality, security, and integrity;
- Promulgation of data standards and supportive policies and practices across the Public Works' asset management and procurement life cycle; and
- Cultivation and maintenance of lasting commitments across the local and national curb management space, including with curb policy partners, the general public, and private curb users.

Through these efforts, the City of Minneapolis will establish a foundation and initiate an ongoing policy-based, dynamic, and data-driven curb management initiative citywide, supporting the local economy and quality of life.

Access

We aim to expand access by focusing across communities and small, locally-owned businesses. Minneapolis will cultivate economic benefits for local businesses through more efficient deliveries and a reliable flow of goods.

Implementing data-driven curb management at scale will lead to more cohesive use of curb space for all users. Curb changes based on real-time data will lead to reduced congestion, improved safety of truck-related activities, and better access for all. The at-scale Stage 2 intention is to prioritize areas that curb turnover by 30% and achieve utilization rates of 70-80% during peak hours.

Additionally, by reducing double parking and bus stop violations, we anticipate that bus speeds will increase within the focus areas. We are aiming to increase average speeds by 15% within the focus areas.

Congestion

Interviews with businesses and curb users in Stage 1 consistently pointed to ongoing concerns about vehicle cruising. At scale, reduced congestion, violations, and conflicts, along with increased clarity of curb regulations, availability, and road closures, will lead to substantial time and cost savings for delivery drivers and businesses, as well as improved safety outcomes. While we will continue to use air quality monitors to measure ambient air quality and any changes associated with the implementation, we have found that air quality monitors often pick up air quality readings that are unrelated to the project changes.

Additionally, we anticipate that as some parking spaces are reallocated toward other uses (such as loading, bus stops, transit priority lanes, bike lanes, and EV charging), there will be a greater share of trips made by walking, biking, transit, or ridesharing. While the percentage of users who switch depends on the corridor, surrounding land uses, transit and bike networks, and existing modes, we anticipate that there will be fewer single-occupant vehicles in all focus areas following implementation of the curb digital tool and curb space re-allocation.

Partnerships

In Stage 1, we engaged with stakeholders from the freight, logistics, delivery, ride-hailing, and small business sectors. Through one-on-one interviews or focus groups, we developed trust and buy-in. Explaining the program and its benefits naturally builds consensus and support. At scale, partnerships and stakeholder engagement will continue to foster these conversations and will be a centerpiece of the work.

In Stage 2, we aim to partner with two (2) to three (3) private freight operator companies to test and refine the APIs created in Stage 1. Additionally, we will work with those interested in integrating digital curb information tools that inform route planning and lead to beneficial outcomes in the private sector. We learned that local and national freight companies are updating their delivery routing systems, including reducing customer delivery windows. They want to collaborate with us to use API data for route planning. However, some stakeholders are regional but not national decision-makers. Some use a contractor model for conducting deliveries, further dispersing responsibility for making deliveries and determining the types of in-vehicle tools and systems used for dispatch and delivery (referred to as “delivery information acquisition devices” or DIADs). In Stage 2, we will leverage our partnerships with the City of Seattle, the Open Mobility Foundation, and other industry stakeholders to engage with these decision-makers and develop usable tools that work for drivers.

At scale, the project will demonstrate the merits of CDS adoption and enhanced digital resources, ensuring long-term benefits that extend beyond the grant period. We will provide technical assistance on CDS adoption and compliance, and develop a step-by-step guidebook and digital curb roadmap for other cities to develop systems for operationalizing curb management and CDS at scale. Stage 2 will build a transformative and first-of-its-kind roadmap for other cities to replicate this effort.

We will work closely with stakeholders during the data and gap analysis to develop appropriate curb changes. New maps of proposed changes, including the addition and removal of commercial vehicle loading zones, passenger pickup and drop-off zones, and other curb and parking regulations, will be shared with stakeholders to solicit input and gain support before finalizing the plans. This focus on improving curb access through digital curb data representations fosters long-term, collaborative relationships that have historically been difficult to develop and maintain with the freight and business communities.

Integration

Data and systems integration have been central to the proof-of-concept work and will remain so for the project at scale. We anticipate that, at scale, the digital curb inventory and CDS-based curb architecture will be embedded into city processes for evaluation and data-driven, policy-based decision-making. Powered by digital literacy and technical ability within the Public Works Department, the effort will support private sector API curb data business integrations and data sharing between the public and private sectors. Using the CDS standard, the digital twin and open API communication tools will integrate curb, event, and metric data from multiple sources to provide easily accessible information to all curb users and private sector partners.

By leveraging the city's APIs, the private sector can enhance last-mile logistics and efficiency through public-sector data, gain insight into curb regulations, road closures, and availability, reduce parking violations, and deliver more on-time deliveries to residents and businesses safely, supporting their economic bottom line. This is especially important as the demand for food and package delivery grows. Developing a toolkit detailing how to operationalize CDS will lead to wider adoption by other cities. This project will serve as the foundation for normalizing and standardizing the use of CDS in curb management planning and operations nationwide.

The SMART grant work is also deeply integrated with the City's 10-year Transportation Action Plan (TAP), adopted in December 2020. The TAP is intended to guide the future planning, design, and implementation of transportation projects for all people in the city, regardless of their mode of choice. The SMART grant is most closely related to the following actions identified in the TAP:

- Technology 7.1: Develop a City multi-disciplinary team and funding mechanisms to facilitate advancing transportation technology and pilots in Minneapolis.
- Freight 3.5: Support regional and statewide agencies in their freight planning efforts to install intelligent transportation systems (ITS) and other wayfinding or real-time signage information.
- Freight 5.1: Investigate freight loading zone demand and supply.
- Freight 5.2: Identify high-intensity delivery zones in the city.
- Freight 5.5: Pilot multiple locations to implement dynamic curb pricing for on-street deliveries and other curbside needs.
- Freight 6.4: Engage with independent freight owners/operators and the union to better plan for freight movement and solve potential freight-related issues.
- Freight 7.3: Develop City standards to ensure that technology-related guidance impacting freight movement, including autonomous vehicles, drones, and delivery bots, integrates into city streets and aligns with City goals; work with agency partners to ensure compatibility across jurisdictions.

- Street Operations 5.12: Continue the process of digitizing the activities on the curb (parking, loading, etc.), and plan for digital communication between the curb and vehicles.

Minneapolis's Curb Management Division has been simultaneously developing a *Curbside Access Policy* and a corresponding Curbside Action Workplan, outlining strategies to implement the policy. The policy, when adopted by the City Council, will serve as a guide for making policies, programs, and space allocations. Because it was developed alongside Stage 1 progress, with the knowledge that Minneapolis was awarded Stage 2 funding, several strategies are related to data collection, digital tool development, and management. Strategies relate to:

- Maintaining a digital curb inventory and backend management ecosystem, including hiring staff needed to maintain the inventory.
- Sharing curb regulation and real-time curb use information with public and private curb users.
- Engagement around delivery types, including around micro-delivery adaptability.
- Piloting geofencing of some curb space using the digital curb inventory and open-source mapping standards.
- Evaluating meter compliance rates across city neighborhoods.
- Clearing the way for faster and more reliable transit services.

Anticipated Costs of At-Scale Implementation

The following describes the anticipated costs of at-scale implementation, broken down by Stage 2 budget categories, along with a budget summary table (See Figure 14). Where relevant, we discuss the at-scale implementation costs of our partner city, the City of Seattle, but this section mostly focuses on City of Minneapolis at-scale implementation costs.

Figure 13: Minneapolis SMART Grant Stage 2 Budget Summary

Minneapolis								
Title	Total Hours	Hourly Rate	Fringe	Health	Total Rate	Labor Total	Fringe Total	Total
Mobility and Curbside Manager	936	$60.00	15.6%	$ 4.60	$ 73.96	$ 56,160.00	$ 13,066.56	$ 69,226.56
Mobility Planner	936	$55.00	15.6%	$ 4.60	$ 68.18	$ 51,480.00	$ 12,336.48	$ 63,816.48
Operations Analyst	3,120	$45.00	15.6%	$ 4.60	$ 56.62	$ 140,400.00	$ 36,254.40	$ 176,654.40
Assistant Parking Systems Manager	936	$55.00	15.6%	$ 4.60	$ 68.18	$ 51,480.00	$ 12,336.48	$ 63,816.48
Intern	960	$25.00	15.6%	$ 4.60	$ 33.50	$ 24,000.00	$ 8,160.00	$ 32,160.00
Intern	960	$25.00	15.6%	$ 4.60	$ 33.50	$ 24,000.00	$ 8,160.00	$ 32,160.00
Minneapolis In-kind Personnel Total						**$ 347,520.00**	**$ 90,313.92**	**$ 437,833.92**
Data Systems Project Manager	6,240	$73.00	15.6%	$ 4.60	$ 88.99	$ 455,520.00	$ 99,765.12	$ 555,285.12
Data Systems Deputy Project Manager	6,240	$63.00	15.6%	$ 4.60	$ 77.43	$ 393,120.00	$ 90,030.72	$ 483,150.72
GIS Technician	6,240	$63.00	15.6%	$ 4.60	$ 77.43	$ 393,120.00	$ 90,030.72	$ 483,150.72
Electrician	360	$63.00	15.6%	$ 4.60	$ 77.43	$ 22,680.00	$ 5,194.08	$ 27,874.08
Minneapolis Personnel Total						**$1,264,440.00**	**$285,020.64**	**$1,549,460.64**

Source: Minneapolis Project Team

Personnel

These positions are intended to be full-time permanent positions, and the city is committed to funding them on a long-term basis. Time for an electrician has also been included to support installation and ongoing maintenance efforts for the camera and sensor network. The fringe benefits rate for the Minneapolis personnel is 15.6%.

Travel

We are allocating a total of $256,500 for the three-year travel budget between the Cities of Minneapolis and Seattle. Travel will comprise four (4) staff traveling to an annual USDOT SMART Summit, either in Cambridge, MA, or Washington, D.C., as well as four (4) staff traveling to the opposite city once per year for an in-person working session/collaborative meeting. We assume one such meeting in Minneapolis and one in Seattle each year, for a total of six (6) meetings. Additionally, two (2) staff will travel to three (3) industry conferences annually to share learnings and help broaden the national discourse. This would include conferences such as the International Parking and Mobility Institute (IPMI), National Association of City Transportation Officials (NACTO), or Curbivore, as well as conferences reaching the freight and logistics industries (e.g., FreightWaves and Home Delivery). Our budget also includes two (2) staff personnel making three (3) additional site visits across North America annually to support project objectives.

Equipment

Minneapolis is allocating $405,920 for equipment to purchase fifty (50) fixed air quality sensors (with a per unit cost of $9,440) to be installed across the city's six (6) project focus areas.

Supplies

The city is allocating $84,581 for solar power hardware for the air quality sensors.

Contractual

Minneapolis is allocating $4,015,187 for contractual expenses, including a core expenditure of $2,265,937 for cameras, sensors, and other data collection services throughout the six (6) project focus areas. The total also includes $579,250 for Project Management and Reporting, $100,000 for additional Data Collection purchases, and $495,000 for Community Engagement. Lastly, we've included $450,000 for Workforce Development initiatives and engagement with external entities, such as MCTC, in curriculum development and internal city staff digital literacy training activities.

Joint costs with the City of Seattle - Coordination between Minneapolis and Seattle will be crucial as we work to identify shared lessons and contribute to the project's broader objectives. These objectives include refining the implementation of CDS, building a roadmap and guidebook to help other cities build digital literacy and operationalize new digital curb management tools. We have allocated $661,000 to harmonize project management and systems development across both cities, ensuring alignment in the project and the final data systems architecture. We have also included $450,000 for the Open Mobility Foundation to continue providing technical assistance as we implement CDS, and $375,000 to develop resources and a toolkit for other cities based on the shared learnings of our project. Lastly, we have included $600,000 to support private sector curb users (e.g., ride-hailing and commercial delivery companies) in integrating and ingesting digital curb information through the CDS APIs for delivery and route optimization.

Other

$32,400 for conference registrations and $51,335 for air quality sensor software and cellular access.

The proposed budget contains no construction costs nor indirect charges.

Comparison of Expected Deployment & Operational Costs of At-Scale Implementation and Benefits/Savings of the Project

Personnel & Contractual

Increasing the internal capacity of staff will cost approximately $1.98M over the grant period. A critical finding from Stage 1 is that our IT departments struggle with bandwidth; therefore, building the IT capacity within DOT and Public Works will ensure the permanence of these project components. The grant will directly support hiring three (3) new interns from local community colleges/universities to work with new digital transportation tools. Supporting local students at this early stage in their careers serves as a valuable investment in the future practitioners in this field. Staff at various levels will have educational opportunities to learn about digital technology for transportation, curb, and asset management. This will increase our institutional capacity to sustain digital tools for the long term. Staff will have the capacity to build and maintain a robust infrastructure that will reap benefits for all curb users across the city far beyond the grant period.

Meeting community needs is the primary purpose of effective curb management. Costs associated with community engagement will support the city's continued efforts to understand the needs of community members to make curb changes that are wanted and supported by the people who use the curb every day. Feedback from users and stakeholders will continue to directly shape physical and regulatory changes throughout the six (6) study areas that will lead to lasting benefits across those communities.

Travel

The travel budget of $256k will give the city the opportunity to attend multiple conferences and better coordinate with Seattle. The city will prioritize conferences with secured speaking and panel opportunities to share insights from the work to date and contribute to expanding the national conversation on curb management and data analytics.

Equipment & Supplies

The fifty (50) fixed air quality sensors to be purchased will track air quality data in focus areas. Having detailed air quality data will help track the effectiveness of strategies used and support the city's goal of reducing air pollution within the six (6) study areas.

In Stage 2, air quality sensors will be more effectively used to understand neighborhood-level air pollution, rather than corridor-level. This will enable us to detect air quality changes associated with broader trends in citywide curb management and street operation efforts. We also plan to deploy traffic count monitors alongside air pollution monitors to better evaluate the impacts of curb management on reduced circling for parking.

Other

Overall, project costs serve as an investment in the continued development of a more effective and efficient process for managing the curb. The automatic collection of occupancy and demand data is vastly more capable, reliable, and useful than manual data collection. Large-scale data collection also makes the data itself more useful for shaping curb regulation changes that can have significant impacts on curb usage and compliance. Curb management would take a significant amount of time while being much more unreliable and, ultimately, not possible on a large scale, if not for this initial investment.

After Stage 2

After Stage 2 funding concludes, Minneapolis will likely not be able to offer the same level of funding without the addition of grant financing. Therefore, Minneapolis will continue to evaluate different technologies throughout Stage 2 to determine which ones are the most efficient and scalable.

Additionally, Minneapolis anticipates using curb technologies as potential revenue sources following Stage 2, which will aid in the continued monitoring of curb activity. Potential revenue sources may include paid loading zones (such as reservations, permits, or meters) and dynamic curb pricing.

Stage 1 Preliminary Baseline Data Collection – Evaluation of At-Scale Implementation

We collected data using a variety of data collection tools throughout Stage 1. to represent a baseline to compare against after physical changes are implemented and the digital tool is tested in Stage 2. Stage 1 focus area will also be used as a comparison point once we begin collecting data in the five (5) other Stage 2 focus areas.

In addition to the data presented in Part 3 of this report, the following provides further baseline data relevant to Stage 2.

Invalid Parking

Current invalid-parking rates & locations will be used as a baseline for invalid-parking behavior in the Nicollet study area. Currently, there are an average of 697 invalid-parking violations per day along the focus corridor, or 2.2 invalid-parking events per valid space per day. Invalid parking occurred most frequently during the 4:00 p.m. hour.

Average Length of Stay

Based on Umojo camera data, the average parking duration is 1 hour and 27 minutes. In-ground sensor data indicates that approximately 50% of parking sessions last 5 minutes or less.

Curb Inventory Digital Twin

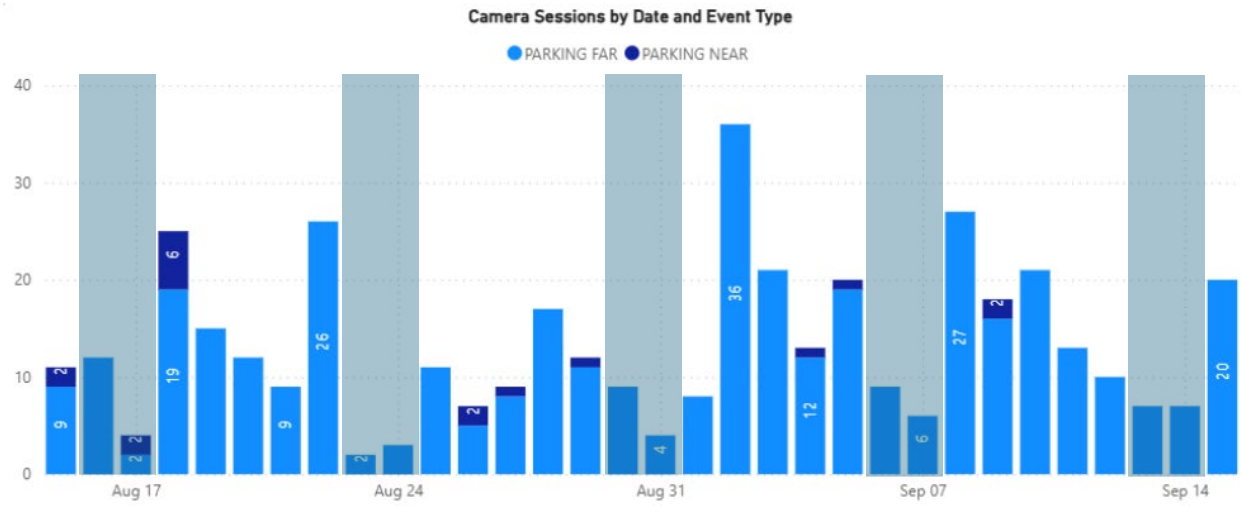
The Evergreen curb map was created as an integration between the city's digital asset management platform, OpenGov, and the digital curb inventory. This allows faster development of curb metrics, as the underlying curb inventory has been established citywide.

Daily Freight Curb Sessions

Approximately 93.6% of parking events in the focus areas were cars, and 4.4% were pickups, meaning that only 2% of parking sessions were by commercial vehicles or buses. Between August 15th and September 15th, 2025, an average of 14 commercial vehicles were parked per day, according to Umojo's AI-powered vehicle type detection. Among company fleet vehicles, USPS had by far the largest presence (83 USPS vehicles detected during the timespan), followed by Amazon (16), FedEx (12), and UPS (6).

In the chart below, boxes are used to signify weekend days. While there isn't a discernible trend for which weekday is the most popular for commercial parking sessions, it is clear that there are more commercial vehicle parking/loading sessions on weekdays than on weekends.

Figure 14: Daily Freight Curb Events



Source: Umojo

Umojo is continuing to work on training the AI, which has had difficulty differentiating between delivery vehicles and construction vehicles. There was a higher-than-usual amount of construction vehicles in the focus area during this period due to construction work on 26th Street and preparation for the New Nicollet construction project. This means that a portion of the vehicles identified as commercial vehicles in Figure 15 are actually construction vehicles.

Freight Uses by Land Use

The following locations experience the highest frequency of commercial vehicle parking sessions between August 15 and September 15th, 2025:

- E 26th Street had the highest frequency of 'commercial' vehicles, as detected by Umojo's AI, however, these are almost all construction vehicles, given the active construction occurring on this block during the timespan.
- In front of Cajun Boiling and Family Tree Clinic on the 1900 block of Nicollet (12 sessions)
- In front of (former) Old School thrift store on the 1900 block of Nicollet (15 sessions)
- W 26th Street (00 block) immediately abuts a parking lot, but is located near residential apartments (20 sessions)
- In front of Good Dwelling (apartment & grocery store) and Christo's Greek Restaurant on the 2600 block of Nicollet (14 sessions)
- In front of the Tobacco y Mas bodega on the 2600 block of Nicollet (11 sessions)
- In front of Eat Street Dental on the 2700 block of Nicollet (25 sessions)
- In front of HCMC Whittier clinic on 2800 block of Nicollet (21 sessions)

The data are inconclusive about which land use types generate the most commercial vehicle parking and loading demand. In a dense corridor, it is possible that the above locations are simply where there is more frequent availability for commercial vehicle parking, while they make deliveries to other locations within a block away that may be more constrained. We will seek to further review land use and freight loading patterns with the additional focus areas included in Stage 2 to better understand demand generators.

5. Challenges and Lessons Learned

Stage 1 Project Challenges, Lessons Learned, and Recommendations

There were several challenges throughout Stage 1 that provided valuable lessons learned as we scale in Stage 2, and for others on their digital data-driven curbside management journey. These are summarized below by category:

Vendor Procurement and Management

Our team faced challenges with procurement and vendors, including process-related procurement challenges that added time and complexity to the project, as well as challenges with vendor work items, schedule, quality, and completeness. In some cases, vendors overpromised, and deadlines had to shift, and in other cases, deployed technology solutions did not perform as intended. Of our available procurement options, we found the Informal Request for Proposals (IRFP) mechanism to be the most suitable. The Formal Request for Proposals (RFP) process applies to all procurements exceeding $175,000 and typically requires 4-8 months to complete. The small scale of the chosen project corridor allowed us to estimate a total cost for individual data collection processes below $175,000 for the project's duration, moving us into the IRFP category, which only required 3-4 weeks from posting to vendor selection. We overcame vendor issues as discussed in the document and are ready for Stage 2.

LESSONS LEARNED INCLUDE:

- Procurement timelines and mechanisms are best defined and identified before submitting a project proposal.
- A collaborative and supportive relationship with your procurement teams, as well as "best fit" procurement policies, can dramatically shorten procurement timelines.
- Constant vendor collaboration and feedback are required for the best results when operating in the arena of emerging technologies.
- Evaluation criteria should place a high value on previous experience with similar types of work. During interviews, ask about vendor experience, lessons learned, and ask to see and test any previously created dashboards. Take the time needed to ask previous/existing clients about their experiences working with the vendor, especially regarding the communication methods that work best, how they deploy personnel, and how they operate in a fast-paced environment.
- Dedicate specific project staff to serve as the primary contract compliance and quality control agent for vendors.
- Structure requests for proposals and contracts in such a way as to ensure you have a mechanism to hold vendors accountable for quality, completeness, and timeliness, and drive solutions to unforeseen problems.

- Weekly or more frequent planning calls were useful to ensure continued progress between the city and vendor(s). This was critical, given the numerous integration issues that needed to be addressed during the early stages of CDS adaptation.

Equipment Deployment and Data Quality

Data collection was a primary objective of our project, and, as with all other data objectives, the goal was to collect a comprehensive dataset, meaning total geographic coverage of the curb space for Stage 1. Our team had a strong awareness of available technologies at the outset of the project, while also being keenly aware of the limited time we had to procure such technology.

We encountered several challenges related to the use, deployment, and quality of data from the sensors and cameras deployed in Stage 1 for the purposes of curb inventory and usage data collection. Umojo Inc. was selected as our primary data collection vendor, which scoped a LiDAR scan as well as complete sensor coverage, utilizing a lightweight solar/cellular solution that allowed for rapid installation. Their camera-based sensors relied on a GPS-calibrated camera view, with each mapped zone tied to specific portions of each camera's frame data. Event detection and categorization were handled by Umojo's proprietary systems.

Given our team's position within the Traffic and Parking Services Division, we found easy and ready collaboration with relevant teams for hardware installation, such as Lane Use (which facilitated obstruction permits for the necessary lift vehicles) and Street Lighting (which provided the host poles for each sensor).

Installation of the solar-powered computer-vision cameras was swift, with promising data being produced by the camera sensors in short order. The solar power solution was initially suitable for our starting data collection window of 7 a.m. to 7 p.m., but it limited our ability to collect data beyond that time window and restricted the frequency of camera image capture. The most significant limitation of the solar solution was found in the winter months. Lower temperatures and reduced sunlight (along with snow covering solar panels mounted on each camera) rendered our camera fleet inoperable, compelling a solution from Umojo. With further analysis of the camera sensor data set, we have found that it can become actionable and reliable with a significantly increased capture frequency and a full 24-hour capture window, but its usefulness is limited without these enhancements.

As a solution, Umojo developed a customized power adapter that would allow us to tap directly into the existing power in our city-owned light poles. In early 2025, once the power tap specifications were finalized, we consulted with our local electricity utility, Xcel Energy, for guidance on how to deploy these adapters.

We learned that, under Minnesota utility regulations at the time, the rate we were being charged for street lighting could not be applied to any pole that hosted devices beyond the scope of the lighting. This resulted in an extensive negotiation period with Xcel, lasting late into

2025, to find a solution for converting the electrical rates for affected light poles to the standard rate, allowing the powering of devices other than lights. The primary challenge was the specificity with which the devices and their adapters were deployed, requiring a framework to identify poles, related electrical meters, and their host cabinets so that just the necessary poles could be placed into their own billing category. This effort was ultimately a success, setting us up to directly power our existing Stage 1 devices and all future technologies to be deployed in Stage 2.

LESSONS LEARNED INCLUDE:

- No single sensor technology can provide all the data required for actionable curb management strategies; layering and combining sensor results dramatically increases data usefulness.
- Consider the larger strategic questions that sensors will help you answer and procure technology as a best fit for the mission. Many data needs can be collected with less time and at a lower expense than installing cameras along the corridor. Cameras are most useful when real-time space availability/occupancy/duration data is required.
- Direct powering of sensor technology is highly recommended over solar and/or battery power, unless the vendor can show evidence of desired performance in a similar climate. Constant power and "up-time" are critical for capturing the full picture of what is happening at the curb.
- Begin necessary discussions with utility companies as early as possible, as their decision-making processes are opaque and challenging to predict. Timespan for securing approval and AC power from a utility may span 9 to 12+ months, based on reporting from Umojo's client contacts.
- Traditional curb imaging techniques, such as LiDAR, require significant post-processing and can only capture a single moment in time.
- A specific issue with LiDAR scanning that Minneapolis confronted was that, because Minneapolis maintains a pay-by-space meter environment, each space can potentially have its own curb zone and associated regulations. Some areas of the city had conflicting signage and meter regulations, so the city had to work with Umojo to determine a schema for addressing such conflicts. In general, any conflict was resolved by pointing to the Flowbird policy information as the source of truth. About 1,000 metered spaces had to be manually reviewed due to conflicting policies between Flowbird and on-street signage detected in the LiDAR scan.

- While LiDAR technology is emerging in the curb management space, vendors generally have limited experience with Smart Curb applications related to the services they offer. As such, the initial subcontractor chosen to complete the work produced unusable output. This required the selection of another vendor. The subsequent development of a Data Dictionary and Street-Sign Image Data Set artifact enabled improved data quality,

but intensive, manual quality assurance is still required at each step of the extraction, import, and curb build process.

- The accuracy of curb inventory mapping techniques increases as you layer data sets from multiple sources and/or vendors for cross-validation.
- We will still need to be cognizant of the size of data collected. Instead of limitations from battery storage capacity, we may have limitations from cellular network availability. This will be further evaluated in Stage 2.

Staff Capacity and Professional Development

Our team benefited from existing knowledge and comfort with curbside technologies, having the capacity to manage the procurement, implementation, and evaluation of those technologies within the limited project corridor for the duration of the Stage 1 project. However, we have also learned that to operationalize the use of these technologies in day-to-day curbside operations and management, as well as to maintain the digital tools we built over Stage 1, additional staff bandwidth will be required. Additionally, it is necessary to establish a means to ensure the specific technical competencies of new hires while maintaining a constant awareness of the ever-changing curbside technology market.

In collaboration with Minneapolis Community & Technical College (MCTC), a continuing education plan was developed, featuring a bespoke offering of online training modules on topics such as software engineering, data analytics, and AI business implementations. These courses will be attended by current members of our Curbside Management Team, as well as any potential new hires in 2026, to evaluate their content and inform the development of a fully customized curriculum to be adopted in 2027. This will ensure our team maintains a constant awareness of emerging technologies and the ability to utilize them most effectively.

Minneapolis Public Works was already heavily invested in technological innovation and utilization, but the learnings from SMART Stage 1 have shown us that building and maintaining internalized technological competencies and knowledge is an operational necessity to successfully procure, utilize, and manage the ever-expanding suite of systems proliferating in the curbside management marketplace.

LESSONS LEARNED INCLUDE:

- Internal technical expertise is necessary to most effectively manage, maintain, and extract true operational value from curbside technologies.
- Building redundancy in your team's knowledge base is highly recommended to avoid single points of failure.
- The presence of technology in curbside management is increasing year over year. Effective technology vendor management is only possible when your team can directly validate the technical aspects of a vendor's proposal.

Building and Maintaining Digital Curbside Records

The City of Minneapolis identified the creation of a digital curb inventory as one of its primary objectives for SMART Stage 1 and planned several potential mechanisms to achieve this goal. Through our data collection RFP, we were exposed to a variety of curb mapping options, with the selected vendor, Umojo, offering to perform a LiDAR scan of the project corridor as well as an additional allotment of mileage that we allocated to our Downtown core, as well as the highest volume commercial areas that surround it.

Before the scan was completed, the study corridor was walked, measured, and inventoried as a control for all future digitization efforts. As minimal changes occurred on the corridor over the life of the project, this control inventory served as a reliable baseline, with the only corridor alterations coming from project-initiated actions (such as the installation of a new loading zone on the eastern block face of Nicollet Avenue between 27th and 28th Streets).

The Umojo LiDAR scan presented numerous challenges, which are summarized elsewhere in this section. However, those challenges drove us to strategize alternative methods for curb digitization. Through the Curb Collaborative hosted by the OMF, we were exposed to a variety of curb digitization methods, as well as fundamental differences in how Cities mark for curb regulations, which led us to analyze all our available curb data sets for useful data points that would serve our goal of large-scale curb digitization. Learnings from the collaborative led us to engage INRIX for a secondary curb digitization effort through the cooperative purchasing system, Sourcewell.

We found that, given our average annual snowfall, Minneapolis formats its street signage with very thorough and consistent bracketed arrows. Additionally, our asset management system, provided by OpenGov, has been richly populated with our entire inventory of regulatory signage, including geocoordinates. The city maintains a tariff package on OpenGov, which outlines all the regulations affecting curb use and parking within the city. The tariff package key defines 196 potential combinations of hourly parking rates, time limits, enforcement hours, and event schedules. This data set was easily enhanced to specify curb zone relevant data points, providing us with a strong foundation from which to generate delineated zones with applicable regulations described in each sign record.

After working extensively with OpenGov to open potential integrations and automations in their software, we were then able to ideate a workflow that would collect changes made in the asset management system each night, aggregating them into actions that would modify, remove, or generate curb zones automatically. The final integration work was performed by INRIX, which also utilized the APIs of our parking payment system vendor, Flowbird, to ensure that all paid parking zone regulations and rates were included in the new Evergreen Curb Map Engine.

The result is an automated system, with daily reconciliation and authentication performed by an administrator, that maintains our curb map indefinitely. It will be crucial to ensure that the integrations built out during Stage 1 can become agnostic of any individual vendor and instead rely on our own internal data integrity, as well as the Curb Data Specification, as a source of continuity.

An ongoing city-wide LiDAR scan is being performed by Flowbird/Arrive to serve as a final data set for validation and geospatial accuracy, allowing us to refine the true regulatory signage positions and verify the presence of any potentially anomalous signs in the asset management database.

We now have the digital architecture in place to maintain an updated, CDS-compliant, digital curb inventory map in perpetuity. This forms the basis for more robust data collection and evaluation, as well as data sharing with the public and outside curb users.

LESSONS LEARNED INCLUDE:

- Consider your existing sources of truth for curb regulations and how they may be used to form, or update, your curb map.
- Reliable data cannot be shared with outside parties without a complete, standardized, updated digital curb inventory as a foundation. This curb inventory must be kept up to date when changes are made in the field. We highly recommend a strategy for maintaining an updated curb inventory, including a change management process.
- It will be crucial to ensure the integrations built out during Stage 1 can become agnostic of any individual vendor, and instead rely upon our own internal data integrity, as well as the Curb Data Specification as a source of continuity.

In-House Versus Outsourcing Digital Solutions

A central element of our Stage 1 work, as outlined in the Stage 1 grant application, was for our City Information Technology staff to build the digital architecture to store and view curb inventory, utilize data, and communicate the data to external users for ingestion. The backbone of this digital architecture platform was to be the Curb Data Specification, with the Curbs API, Metrics API, and Events API serving as the vehicles for data tracking and sharing related to curb inventory and regulations, real-time and historical use data, and aggregated curb key performance indicators, respectively. Minneapolis found that the two most challenging aspects of building the digital architecture in-house were staff training and implementing new API development tools, which were introduced during the course of this project. The project team faced a challenge in learning to use the new API development tools on a project of this scale, as explained in greater detail below.

The City of Minneapolis and the State of Minnesota have several policies, ordinances, and laws that provide the framework and guidelines for sharing data with the public. As a result, the city has an existing open data portal built on the ESRI platform that allows for the sharing of its

public datasets (https://opendata.minneapolismn.gov/), making it an ideal solution for not only hosting the data but also publishing the CDS API endpoints. Prior to undertaking this grant project, the city's IT department was also in the process of procuring an Enterprise Service Bus ("ESB") that would ideally allow for flexibility in integration and standardization of API development/publishing.

Since the city already has a robust open data platform that is built on the ESRI-supported Open Data platform (which was an early front-runner to host this data set), by nature of the grant requirements, would need to not only be available to the public for consumption and review, but also available in perpetuity for the Federal Department of Transportation ("DOT"). In addition, the ESRI Open Data platform would automatically publish APIs for the datasets published to the software, which was attractive due to the potential agility challenges arising from needing to transcribe the data and map APIs in another solution.

The IT department's familiarity with city enterprise software made the City's Open Data portal the preferred option for both hosting and publishing the CDS APIs from the camera data vendor. With the choice of the hosting platform decided, we were presented with two early challenges:

1. Creating the API endpoints so they adhere to OMF's CDS API specification, and
2. Closing the gap on publishing CDS events data in real-time.

To better understand the constraints of both, the city project team met with ESRI technical contacts to see if the gap between the two could be narrowed within the existing ESRI platform and tooling the city currently uses. It was determined from that conversation that the Open Data platform the city uses would not be conducive to modifying the automatically generated APIs.

The city project team had a demo with ESRI regarding the Curb Management solution, a structure that would be more aligned with the OMF Curb Data Specification. However, the City project team had determined that, because the management of curb space is currently handled through separate software systems, implementing a new solution within the short timeframe would require additional time and training for existing project staff, which would jeopardize the completion of Stage 1.

City project team also met with the City of Omaha to better understand the ESRI-based CDS solution they had implemented, which was aligned to the goals and outcomes we were seeking as part of Phase 1. While the City of Omaha utilizes several similar ESRI platforms/software that Minneapolis is using, we ultimately determined that it would require custom modifications and additional software to fully realize the publication of the CDS API. This would greatly hamper the agility and speed needed in order to attain the goals and outcomes of Stage 1, we decided to proceed forward as-is, knowing the foundation would be set for future development of this solution.

It was also at this point that it was noted that the ESB the City had procured required additional system configurations, which would lay the foundation for enhancing the City's IT security posture. Additionally, this necessitated the upskilling of current staff to assume administration, development, and ongoing support of the platform. On a longer time horizon, the ESB would likely have satisfied the flexibility required to develop the API endpoints according to the OMF CDS API specification, as well as provided a platform for real-time data ingestion, assuming the camera data vendor would allow direct connection to the underlying data from the ESB.

There were multiple ESRI solutions explored in hopes of finding a CDS-friendly solution, such as the ESRI Curb Regulation Management, but that proved to have too much overhead in terms of capabilities, as well as the additional time needed to train city staff up on this solution. In addition, the capabilities offered with this solution were technically covered as part of the engagement with the curb camera data collection and analytics solutions vendor, Umojo.

Due to the software development and maintenance work required, as well as Umojo having the user interface established along with API connections to their own proprietary devices and other parking and curbside monitoring devices and systems on the market, we elected to rely on Umojo and their NexCity platform as our digital curbside management platform and ecosystem. Minneapolis' endpoint APIs allow for pulling of data from the Umojo cameras into the OpenData portal, which can then be shared with end users.

LESSONS LEARNED INCLUDE:

- The development and maintenance of a digital platform requires significant investment of staff time, and technical knowledge for both set-up and maintenance.
- ESRI's Open Data platform is robust but lacks the flexibility needed to publish CDS API endpoints that are configured to match the CDS API endpoints specification or supply the real-time data needed for the CDS Events API endpoint.
- Partnering with a private-sector vendor(s) allows for the use of turn-key solutions offered by said vendor(s), given that many of the vendors in this space are already serving on CDS specification workshops and steering committees with OMF. They also have a head-start on the capabilities that would need to be home-grown or internally developed with public-sector entities.
- Stage 2 presents an opportunity to more effectively tap into the ESB API-development capabilities, and compare to vendor capabilities in API and integration development.
- For most other cities that have the same or less experience with CDS API development, the most prudent path to developing a digital curb environment may be to partner with a proven private-sector vendor(s) in order to utilize turn-key solutions offered by said vendor(s). Given many of the vendors in this space are already serving on CDS specification workshops and steering committees with OMF, they are uniquely positioned to not only stay abreast of updates to the technologies and specifications surround curb data management (CDS in particular), but also have a head-start on the

capabilities that would need to be home-grown or internally developed with public-sector entities. Cities should weigh the benefits and considerations of partnering with a vendor (i.e., data ownership, costs, personnel, long-term benefits and ownership, and transferring to city control).

Internal and External Use of Data

A critical component of our Stage 1 work from the beginning has been, once a foundational curbside inventory and curbside use data sets have been established, presenting and sharing the data to curb users (via the CDS open API framework), including the public, freight operators, and others. Although we have not yet tested API endpoints, our IT group has successfully hosted and published the CDS Curbs API on the City of Minneapolis Open Data portal. This represents an important step in creating open-source, publicly available curb data, and informs our team of what is required to host and maintain CDS APIs in the long term. Stage 1 has made it increasingly clear that the ability and willingness of external entities to ingest our curb data through open APIs depends on us keeping our curb data as reliable and robust as possible.

Next steps in Stage 2 include ensuring the Curbs API data remains up to date, making it accessible to the public and curb users in meaningful ways, and integrating the Events API and Metrics API for sharing.

Hosting and sharing the API data is just one side of the equation. The other side is securing willing partners to ingest and utilize data. Our engagement with freight entities informed us that maintaining and publishing an accurate data set for a corridor as limited as Nicollet Avenue would not provide sufficient incentive or benefit for the necessary technical integration.

Additionally, data sharing and ingestion are complicated by the sheer number of freight operators, the disparate and freelance nature of some of the company driver networks, and the number of different transportation management systems and software used across the industry (these transportation management systems comprise in-vehicle telematics devices and mobile terminals to track location, and conduct dispatching, routing, and delivery functions). Stage 2 will involve getting Curbs API, Events API, and Metrics API data out for freight operators to ingest and begin to incorporate into the workflows. We aim to establish a bi-directional data feed between freight operators and our digital ecosystem, where we share data with them and they, in turn, share data back to our system, resulting in a richer curb-use data set.

As work continued, it became increasingly clear that the ability and willingness of external entities to ingest our curb data through open APIs were crucial to making our curb data as reliable and robust as possible. Our own operational needs also called for a curb map that would represent the city as a whole, as effective curb management requires a holistic approach.

LESSONS LEARNED INCLUDE:

- CDS APIs require a robust and reliable digital curb inventory map (Curbs API) foundation for Events and Metrics to be recorded upon.
- Even a “free” product (such as CDS APIs) requires a high level of quality and reliability to be desirable by external stakeholders.
- External integration partners have an incentive to hold the architecture and development of data integrations internally, which can run counter to an open data project. Consider incorporating open data requirements into such procurements to ensure the final products are shareable with other cities and maintainable by internal staff.
- The most important determinant of the ongoing success of open data sharing with curb users is the comprehensiveness and usefulness of data being shared, and how valuable that data is for freight and other curb users to optimize their routing, deliveries, and performance outcomes.

Engaging the Public, Freight Operators, and Other Curb Users

Much of our engagement in Stage 1 focused on having stakeholders (neighborhood residents and business owners) share their current struggles with the curb and what their priorities are if things were to change. Although we received valuable feedback and insights during our outreach efforts, a disconnect seemed to exist between stakeholders and their understanding of the project's goals. The abstract concepts of a digital curb inventory and data-driven curbside management presented a challenge during outreach, as stakeholders did not readily understand how these topics might impact them.

We achieved success in engaging with curb users, including passenger and goods gig drivers, as well as freight companies, by learning their motivations and barriers to curb use, how these parties utilize curb space, and how they might benefit from more data and information on curb regulations and availability.

LESSONS LEARNED INCLUDE:

- Outreach efforts must begin with developing a marketing strategy that clearly explains the *why* of the project and how the final product will impact stakeholders. The engagement timeline must include allotting time for sharing progress reports throughout the project and preliminary results at the end of the project period with community partners and key stakeholders.
- Issues related to engagement fatigue and the role of government agencies and technology being perceived as “surveillance” technology can come up in engagement efforts, and need to be addressed with a clear communication and marketing strategy.
- Technology, data security, data ownership, and policy barriers exist to data ingestion by outside curb users, and data sharing by these curb users back to the city. Engaging with

these entities on an ongoing basis and seeking incentives and policy-based solutions that enable an open data environment is critical.

6. Deployment Readiness

Requirements for Successful Implementation

Obstacles to scaling include challenges with technology procurement and deployment, internal capacity and expertise, and establishing effective partnerships. Leading up to the submission of our SMART Stage 2 application, and especially after the notice of award, our work plan for Stage 1 was increasingly geared towards setting us up for Stage 2 success.

With the creation of the Evergreen Curb Map enabling backend integrations of curb inventory data, the implementation of our first sensor stack (combining a diverse array of in-ground, camera, and mobile LiDAR technologies), approval of direct-power workflows through our local utility, creation of a continuing education package, and strong partnerships formed with other cities and vendors, we are poised to scale our project across the full area of Minneapolis.

The dramatically increased scope and scale of Stage 2 will necessitate the expansion of our team, which is made possible through grant funding. However, it will take time to ramp up internal staffing, and we anticipate a high level of workload until those positions can be posted and filled, necessitating our use of vendor assistance. Continuing education, which we will implement in Stage 2, will work to develop digital literacy among the current and future generations of our city's workforce.

It is also vital not to underestimate the infrastructure maintenance requirements involved when scaling a sensor fleet of a few hundred by a full order of magnitude. The relatively limited exposure of our Stage 1 sensor inventory to damage or loss will not hold true in Stage 2, and we will need to plan for frequent inspections, maintenance, and corrections as our use of technological infrastructure in the field expands. A diverse array of sensors and devices in Stage 2 at-scale deployment will mitigate potential risks. This need also applies to digital infrastructure, as we take our alpha APIs from Stage 1 and seek to ensure their continued reliability for both internal and external use.

Necessary Learnings to Better Understand Maintenance & Operating Requirements (after At-Scale Implementation)

With outside support from vendors and plans to expand the personnel and expertise of our internal team, we have established a solid foundation for ongoing maintenance of our hardware and software systems. We are confident we will have the capacity and expertise for at-scale implementation and ongoing maintenance. That said, we acknowledge that there are aspects we need to learn, including the cadence and type of recurring sensor and camera maintenance required, as well as how to integrate that into city staff workflows. Additionally,

we will need to learn the equipment's lifespan, cadence, and process for decommissioning and replacing equipment.

On the software side, we have created the integrations for ongoing maintenance of the city's curb inventory map, but we acknowledge that we must navigate unknowns during at-scale implementation as to how much of the digital data-driven curbside management ecosystem beyond the curb inventory will rely on vendor-created software solutions versus being built and hosted within the city's cloud infrastructure.

New workflows will need to be created within Public Works to conduct all of this work. To scale the work beyond Stage 2, new funding sources and ongoing commitments must be established among leadership and operations staff. We intend to prioritize these aspects on an ongoing basis, ensuring the work receives the attention it deserves for the long term.

Harnessing Technology and Mitigating Job Impacts on the Availability of Good-Paying Jobs

We expect at-scale implementation to have a significant positive impact on good-paying jobs with a free and fair choice to join a union. First and foremost, we will be adding personnel to our city's workforce, introducing new workflows, and implementing a long-term digital training and workforce development program to invest in both current and future generations of city staff. Field maintenance and backend software maintenance at scale require human creativity and attention, and personnel must be highly skilled and specialized.

Additionally, efficiencies gained through at-scale implementation mean we are reducing busy work in data collection and daily curb operations. In addition to reducing busy work, we can redeploy staff to roles that better suit and maximize their unique talents.

7. Stage 1 Project Reflections

Advice we would give others embarking on their digital, data-driven curbside management journey includes:

- Carefully define your curbside operations and management challenges and procure proven vendors that understand your challenges and develop customized solutions to specific use cases.
- Form your partnerships early: with local utilities, with freight and other curb users, with local and neighborhood groups, with other city departments, divisions, and services interacting with the curb, and with businesses.
- Work with curb users to determine what curb data is useful, and how it should be shared.
- Determine your procurement method before starting so that procurement and deployment can be timely.
- Establish the backend integrations and processes for your digital curb inventory to keep itself maintained even when policies are modified and/or changes are made in the field.
- Lean on CDS to standardize your data for ease of digital communication.
- Establish your data-driven curbside management plan to ensure that you have meaningful workflows to put curbside data to use.
- Ensure you have the internal capacity to maintain software and hardware systems for the long term.
- Consider the use cases for your data. Many use cases can be achieved without the need for real-time data, allowing cities to advance curb management at a lower cost and with less expensive equipment.
- Contacts with peer cities are incredibly useful to compare other cities' experiences with different vendors and curb technologies. Take the time to set up calls with peer cities to learn from their experience, and don't be afraid to ask for their thoughts before endeavoring to try something new. Perhaps they might want to join!

Our proposed Stage 1 solution largely met our expectations, with two primary exceptions. First, given the new technology, we underestimated the time needed to quickly develop and deploy an in-house open digital ecosystem to host, view, analyze, and publish/share CDS data. Second, we learned that the ease, ability, and, in some cases, willingness of outside entities to ingest CDS API data for their own use can vary. Given the timeframe, these factors contributed to a delay in fully collecting, hosting, sharing, and leveraging data for our pilot corridor. However, the digital curb map we have created, with backend integrations, along with our strong partnerships and ability to scale data collection technology, sets us up for success in Stage 2 and beyond, with data-driven and dynamic management of curb space across Minneapolis and Seattle.