



LADOT

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Code the Curb

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1. Executive Summary

Downtown is the birthplace of Los Angeles and the primary center of urban activity in the region. It remains the commercial, entertainment, cultural, and civic heart of Los Angeles. Downtown is home to a diverse range of industries and distinct neighborhoods at the center of an expanding regional transportation network. The Downtown core experiences over 700,000 vehicle trips daily, creating competition for limited curb space among freight, transit, passenger vehicles, micromobility, active transportation, and outdoor dining. This competition for the curb space leads to congestion, related pollution, confusion, and less safe environments for walking and biking, disproportionately affecting vulnerable communities. The Code the Curb project, led by the Los Angeles Department of Transportation (LADOT), addressed this challenge by establishing new tools to manage curb space in one of the city's densest neighborhoods, Downtown Los Angeles.

Project Location

The project area for Code the Curb was the Downtown Los Angeles (DTLA) Neighborhood, which spans **5.9 square miles** and contains over **200 miles of curbs**. The DTLA neighborhood serves as the heart of Los Angeles and was selected due to its density, high traffic volumes, and the diverse set of curb typologies.

Goals and Objectives

Code the Curb sought to organize and increase access to limited curb space in DTLA by developing data-driven curb management policies to increase transportation safety, transparency, and scalability. In Stage 1 the project team created digital twins of existing curbside assets while developing a platform to host and visualize curb policy regulations in DTLA. The vision for a future Stage 2 would aim to apply this exercise across the entire City of Los Angeles, and to use curb data to inform curb management policies.

Results and Learnings

The successful implementation of Stage 1 established a robust and functional proof of concept for a comprehensive citywide curb management system. LADOT implemented phased data collection and focused on dense DTLA areas. LADOT and its partners successfully digitized over 200 curb miles, cataloged 22,726 curb zones, 11,778 curb objects, and created 315 unique curb policies in the Curb Data Specification (CDS) format.

The resulting products include:

- A **public-facing platform** for users to query collected data on curb policies, time of day restrictions, and objects in the public right-of-way.
- An **internal-facing platform** offering additional functionality like policy review, scenario planning, and curbside metrics.

- An **Application Programming Interface (API)** for programmatic querying of data with over 25 API tokens provided to a variety of users.

The evaluation also established critical baseline metrics, such as quantifying that over 60% of paid parking sessions are under 30 minutes, which will inform future at-scale dynamic pricing models aimed at reducing cruising and Vehicle Miles Traveled (VMT). Finally, the project used data-driven methods to identify corridors with high non-compliance and unsafe curb activity focusing on instances of red curb, loading zone, and bike lane violations. Although this process made use of enforcement data to identify corridors, enforcement activity was not changed as a result of this pilot. This data-driven approach informed LADOT in the development of a policy framework to guide future scaling and ensure fair access for all communities.

Scaling Up - A Stage 2 Implementation

Building on the lessons learned from Stage 1, LADOT intends to scale up beyond DTLA and deliver a digital twin of curbside assets across the city in a Stage 2 implementation. This scaled approach, which will include deploying 200 cameras in key corridors and citywide digitization of curb policies, is designed to increase safety, reduce pedestrian/vehicle conflicts, and enhance parking policy transparency, serving as a model for cities nationwide.

2. Introduction and Project Overview

Demands for the curb lane are increasing due to the proliferation of freight, transit, and passenger vehicles, shared mobility, active transportation, outdoor dining, and more. Uncertainty around the availability of on-street curbside parking or loading spaces exacerbates driver confusion, congestion, and vehicle pollutants, and can create less safe walking and bicycling environments. These impacts often disproportionately affect communities that are already overburdened by historical disinvestment. With more reliable and real time information on curb availability, City staff can more precisely and nimbly manage this high-demand public space and reduce related negative externalities.

2.1 Project Description

The Code the Curb (Project) aims to address the growing challenges of managing curb space in dense urban spaces like Downtown Los Angeles (DTLA). The DTLA neighborhood was selected for this pilot project for several reasons. DTLA is the heart of Los Angeles and is a densely populated center for urban activity in the region having diverse activities such as commercial, entertainment, cultural, and civic activities all occurring within the neighborhood. As shown in **Figure 1**, the Stage 1 grant area is located between three major highways and covers an area of **5.9 square miles** and encompasses over 200 miles of curb line miles. Approximately 70,000 people live in DTLA and 258,000 trips end in DTLA each day for work. DTLA was chosen for all these reasons, as well as to support greater investment in historically disadvantaged areas, with over 90 percent of the project area located in a Historically Disadvantaged Community.

With increasing demands from delivery services, passenger vehicles, shared mobility, outdoor dining, and other uses, the current state of curb space contributes to congestion, higher vehicle related pollutants, and potentially unsafe conditions for pedestrians and cyclists through improper use of curbs and public right of way. The project's goal is to document how curb policies and how the curb space is being utilized, in order to improve management of the curb lane by monitoring and managing curb availability through the use of digital tools in real-time which will streamline the use of this critical public space.

This was achieved by leveraging existing parking management systems, digitizing existing assets in the public right of way, and use of new technologies such as smart camera technology,

the project collected real-time curb event data that allowed City staff to monitor, predict, and understand curb space occupancy in real-time. This pilot gives the City the tools that it can use to adopt a more data driven approach and enable curb management strategies dynamically, reducing cruising for parking, improving traffic flow, and minimizing the environmental impact of urban transportation addressing key program benefits such as safety, resiliency, integration, access, and reliability.

2.2 Prototype Overview

The Stage 1 prototype focuses on digitally transforming curbside management by creating a digital twin of existing curbside assets. By digitizing physical assets such as parking meters, street signs, and curb paints, the City established a comprehensive digital inventory built on the open-source Curb Data Specification (CDS) standard.

The digital inventory supports a centralized hub known as the Curb Viewer visualization map which was developed alongside our partners at CurbIQ. The platform features a:

- Public-facing interface that allows for users to query collected data on curb policies, time of day restrictions, and objects in the public right-of-way.
- Internal-facing interfaces enable City staff to review policies, conduct scenario planning, and reveal insights based on historical curb demand.

To build this prototype platform, a multi-tiered data collection approach was used.



1. **Open Data Automation:** ingesting and standardizing existing georeferenced City datasets (e.g. parking meters, bikeshare stations, sidewalks) into CDS format.
2. **Curb Level Surveying:** Deployed field staff with mobile applications to capture photos and attributes of physical assets.
3. **High-Resolution Imagery:** Utilized aerial and street-view imagery to extract curb paint and policies in areas challenging to survey on foot.

2.3 Technology Deployed

The success of the Project prototype relied on the integration of specialized technologies, open data standards, advanced camera sensors and strategic partnerships.

Open Mobility Foundation

A critical foundational component to this project was the development of the Curb Data Specification, architected by the Open Mobility Foundation (OMF), in collaboration with public City agencies and private partners who carried out implementation of CDS. By adopting CDS, the project established a common, machine-readable format that streamlined data sharing across vendors and departments. This open data standard is what allows the system to effectively join the static, physical curbside inventory with dynamic, real-time demand metrics.

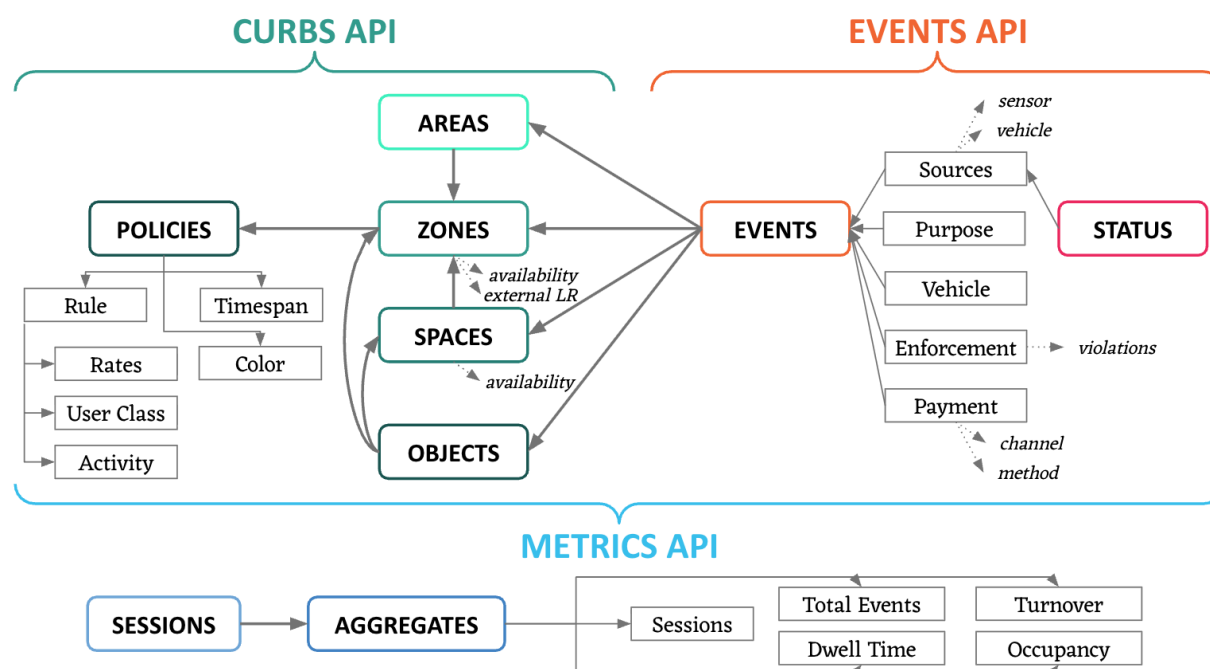


Figure 2: CDS Architecture

CurblQ

This partnership served as the data collection and aggregation hub for this CDS data. The CurblQ *Curb Viewer* platform hosts the City's digital twin and offers several modules to manage and interpret the data. It serves as the primary visualization map as shown in **Figure 3**, allowing users to navigate and understand parking options, restrictions, and mobility infrastructure. Because it displays real-time demand data, it can be deployed publicly via embedded web pages to inform the public.

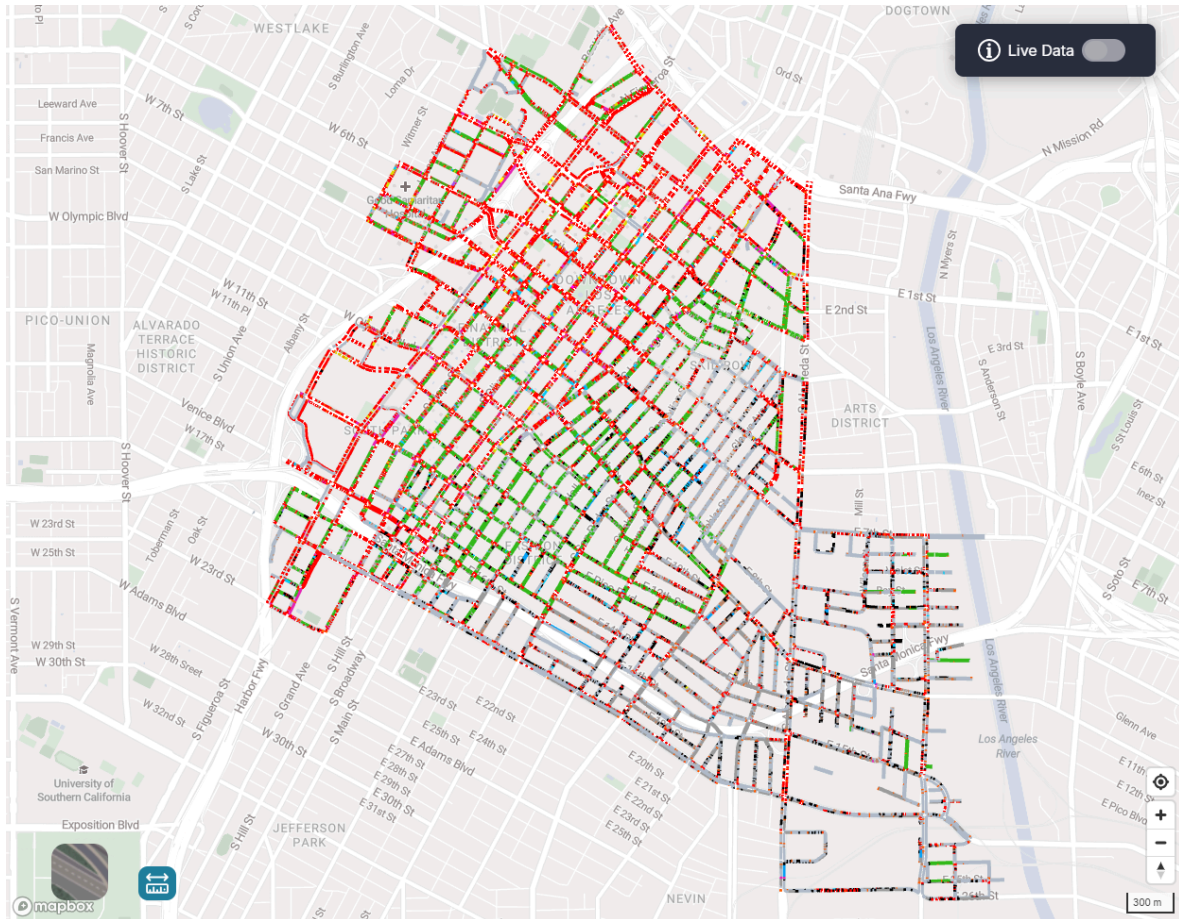


Figure 3: Curb Viewer Curb Designations

To make sense of the data being collected, the platform utilizes the Curb Analyzer, an analytics tool that assesses curb regulations (supply) against utilization (demand). By digesting third-party sensor data, LADOT is able to gain detailed breakdowns of occupancy rates, dwell times, and potential revenue. Lastly, the system also provides API endpoints that are built directly on the CDS standard. These APIs facilitate real-time access to the curbside inventory, allowing third-party users such as FedEx, UPS, Amazon, DHL, and others to run queries and locate relevant curb regulations and nearest loading zones for delivery drivers.

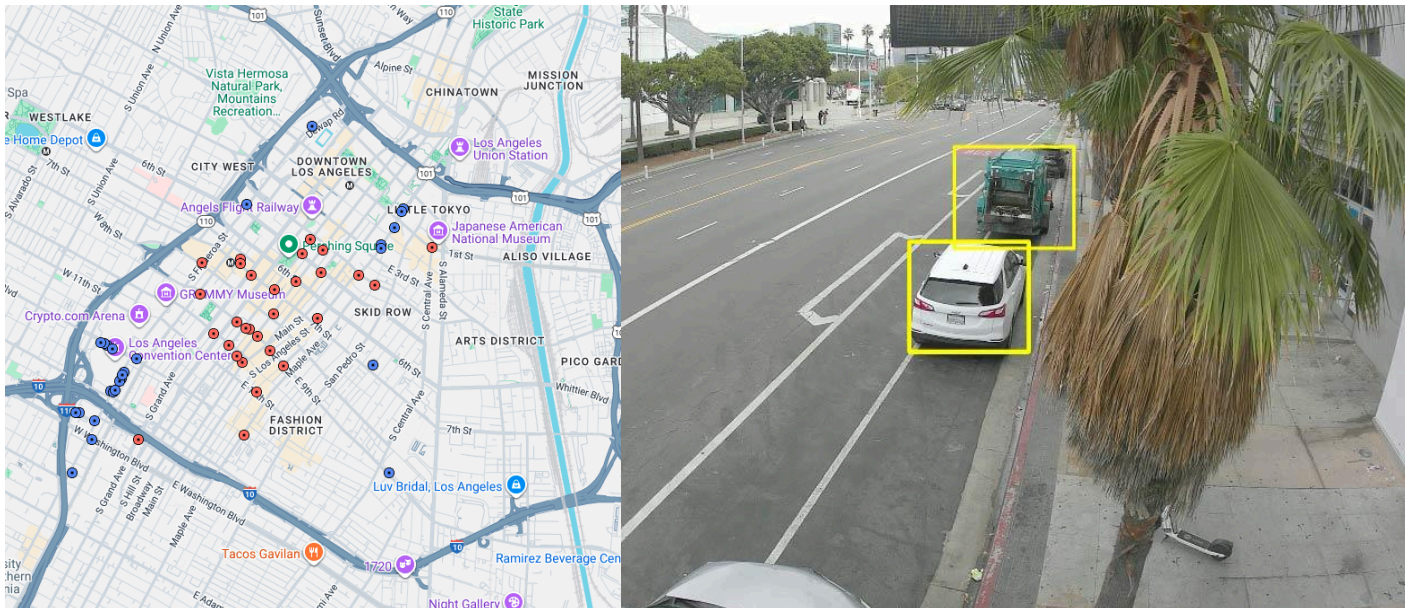


Figure 4: Curb Supply Sample of Automotus Data

Automotus

Feeding the digital ecosystem is a network of advanced camera sensors deployed on City street lights. LADOT partnered with the consulting firm Automotus to deploy smart cameras across high-priority corridors to collect data in a CDS compliant format. An existing 30 installed cameras were activated and an additional 26 new camera locations were deployed across high-priority areas in the project region. **Figure 5** shows the locations of where cameras were installed throughout the project area.

Figure 5: Automotus Smart Camera Installation Locations



Camera deployment focused on key corridors in DTLA that demonstrated a high need for data collection due to high volumes, collisions, parking availability, existing infrastructure, and more. These corridors have been selected to serve as the proof-of-concept areas for the new technologies, helping to gather essential data on curb space usage and parking patterns.

These cameras capture data to track curbside uses, generating detailed real-time insights into legal loading sessions as well as violations in red curb zones. **Figure 5** shows the CurbSight cameras used by Automotus to collect curb activity. These cameras detect vehicles and analyze parking usage. They capture comprehensive metrics including parking turnover, average dwell times, occupancy rate, traffic counts, and violations such as double parking or overstays in loading zones. These cameras work in tandem with the existing City infrastructure, IPS parking meter sensors. This allowed for real-time data capture of valid parking sessions and illegal red curb or commercial loading zone violations. The violations observed as a result of this pilot were not related to, or created, as a result of the SMART grant. These cameras were deployed solely to gather data on existing curbside activity.

Table 1: CurbSight Camera Detection Metrics

Category	Example
Modality	Vehicles, bike, and pedestrians
Propulsion type	Internal combustion, hybrid, or electric
Vehicle Type	Passenger vehicles, delivery vans, freight, and bus



Figure 6: LADOT Curb Monitoring Camera

2.4 Stage 2 At-Scale Deployment

An at-scale deployment for Stage 2 would build on the foundation of Stage 1 technologies and implement different data collection in place of larger scales. A curb level survey method was employed in Stage 1 in order to ensure higher quality assurance and was achievable due to the smaller project area. Building a digital twin for the curbside assets across the entire City of Los Angeles would be a difficult task and maintaining over 7,500 miles of streets. Thus a scaled approach would focus on key corridors throughout the City and implement data collection methodologies that lend itself to larger scale.

Table 2: Stage 1 and Stage 2 Deployment Overview

Feature	Stage 1 Deployment	Stage 2 Deployment
Coverage Area	DTLA Neighborhood (5.9 SqMi; 200 curb miles)	Expansion to neighboring cities and digitization of high density neighborhoods
Data collection	Open Data automation, curb level surveying, and aerial imagery	Augmented mobile mapping and automated change management
Real-time Data sensors	56 Smart cameras (30 existing, and 26 newly deployed) 5,198 Parking meters	200 cameras across key citywide corridors 34,156 parking meters Citywide

To prepare for this citywide expansion, LADOT executed several key milestones, including intensive outreach efforts. LADOT engaged major stakeholders, including the Downtown Neighborhood Council and the Central City Association, to gather insights and build community support. These meetings have been vital in understanding local concerns and identifying curb management priorities. They also provided insights into specific curb areas of interest, as well as locations that need improvements, helping to shape the next steps of the project and ensuring that the at-scale deployment addresses real-world needs.

Another important activity paving the way for Stage 2 has been the development of key project deliverables, including best practices based on successful curb management models in other cities. Central to this effort is a policy assessment designed to ensure that the project addresses the needs of historically disadvantaged communities and supports fair access to curbside space. Building on this, a curb policy framework has been developed to guide the implementation of real-time curb management. This policy framework guides how to support differing curb functions by land use to promote fairness and accessibility through the establishment of paratransit zones, ADA prioritization, and clear signage for all users.

3. Proof-of-Concept or Prototype Evaluation Findings

This section examines the findings of the Stage 1 evaluation. For Stage 1, LADOT focused on digitization curbside supply and understanding demand dynamics to assess the viability of a citywide digital curb management system. Performance metrics were established to evaluate utilization, compliance, and safety across the project area.

3.1 Evaluation Metrics and Data Collection

During the performance period of the project, LADOT and its partners successfully digitized over 200 curb miles, cataloged **22,726 curb zones**, **11,778 curb objects**, and created **315 unique curb policies** in the CDS format. To evaluate the performance of the project four primary demand data sources were integrated:

Table 3: Demand Data Sources

Data Capture device	Metrics collected	Description
Smart Camera Sensors	Session volumes, occupancy rates, and dwell time	These cameras monitored activity at specific loading zones and no stopping areas to capture real-time commercial and passenger behavior.
IPS Parking Meters	Real-time occupancy and turnover rate	Tracked the utilization of paid parking spaces to inform parking availability and evaluate turnover efficiency.
Citations	Location and time of illegal parking activities (e.g. red curb parking, overstays, etc.)	Analyzed historical data to identify hotspots for unsafe, unauthorized, or non-compliant curbside behavior.
MDS Data	Passenger loading events	Evaluated taxi and ride hailing demand to identify hotspots of passenger loading and unloading areas.

These sources were used to develop key findings for the project. These provided a robust foundation for how users were using the curb, however the data also had several limitations that were noted during the evaluation. Smart camera sensors proved to be an effective device and monitoring the curb consistently. Field audits however demonstrated that despite having been strategically placed to capture a wide field of view and create CDS events it could not capture all instances of events. Several instances showed where users were parked just out of the field of view of the cameras and thus were not captured. Additionally, IPS meter sensors generally stop recording new events after paid parking hours end (e.g. 8:00PM), meaning nighttime occupancy data relied only on sessions that began prior to the cutoff. Finally, citation data maps violations to the nearest curb segment, which serves as a proximity indicator rather than an exact location of where these instances occurred. The citation datasets also only indicate instances that coincide with our parking enforcement teams, whereas the Smart Cameras could continuously collect violation instances.

3.2 Findings of the Proof-of-concept

The integration of supply and demand data into the CurblQ platform yielded several key insights into how the DTLA curbside operates in real time.

Paid Parking Utilization and Turnover

Analysis of data collected from IPS meter sensors indicates that paid parking remains the primary curbside use, though overall vacancy can be observed in the project area. Curbside parking events are most concentrated in proximity to high-intensity trip attractors. Throughout the project area, weekday parking occupancy peaks at 30% midday (between 11:00 AM and 12:00PM). The data suggests that these spaces are highly effective at promoting turnover. Also, approximately 63% of all parking sessions in the project area have a dwell time of under 30 minutes. This is significant, as a significant portion of the meters in the project area permit max session lengths greater than 30 minutes as detailed in **Table 4**.

Table 4: Parking Meters within Project Area

Meter Interval	Number of Metered Parking Spaces	Percent of Metered Parking Spaces
15 minutes	43	0.8%
30 minutes	29	0.6%
1 hour	109	2.1%
2 hours	2,813	54.1%
4 hours	1,868	35.9%
4 hours and 30 minutes	22	0.4%
6 hours	32	0.6%
7 hours	11	0.2%
10 hours	271	5.2%
Total	5,198	100%

Camera Event Data

The following data focuses on events captured by Automotus' smart cameras. Taking a look at the Financial District, a district in the northwestern side of the project area we can see a number of insights that helped inform policies and can be used to inform future policies as well. Analysis of the data, specifically, weekend occupancy data indicates a drop to around 5%, highlighting a stark contrast in land-use demand. This is due to the surrounding land use zone for office spaces which generally operate during weekdays. Taking into consideration these land uses, they can inform an at-scale future dynamic pricing models for the entire City to promote additional uses during off peak times. We can see that nearly 40% of the zone has on-street metered parking as indicated in Figure 7.

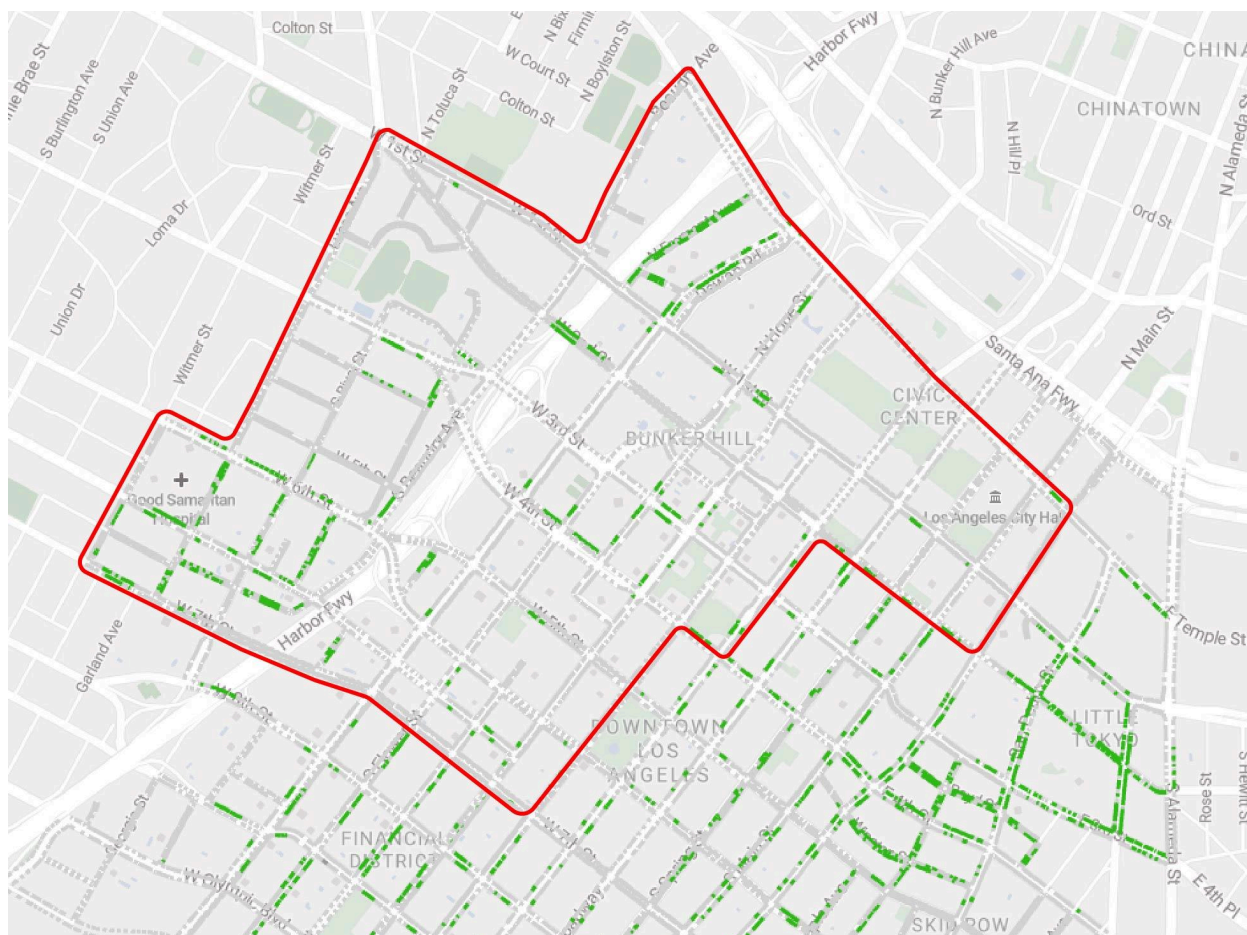


Figure 7: Financial District Boundaries

Loading Zone Dynamics

Analysis of curbside event data from Zero Emission Delivery Zones (ZEDZ) and standard commercial loading zones indicates that occupancy levels increase progressively throughout the day, with all ZEDZ loading spaces reaching a peak of 50% occupancy between 5:00 PM and 10:00 PM. The standard commercial loading zones were most occupied during business hours between 5:00PM and 7:00PM and peaked with an occupancy of 23%.

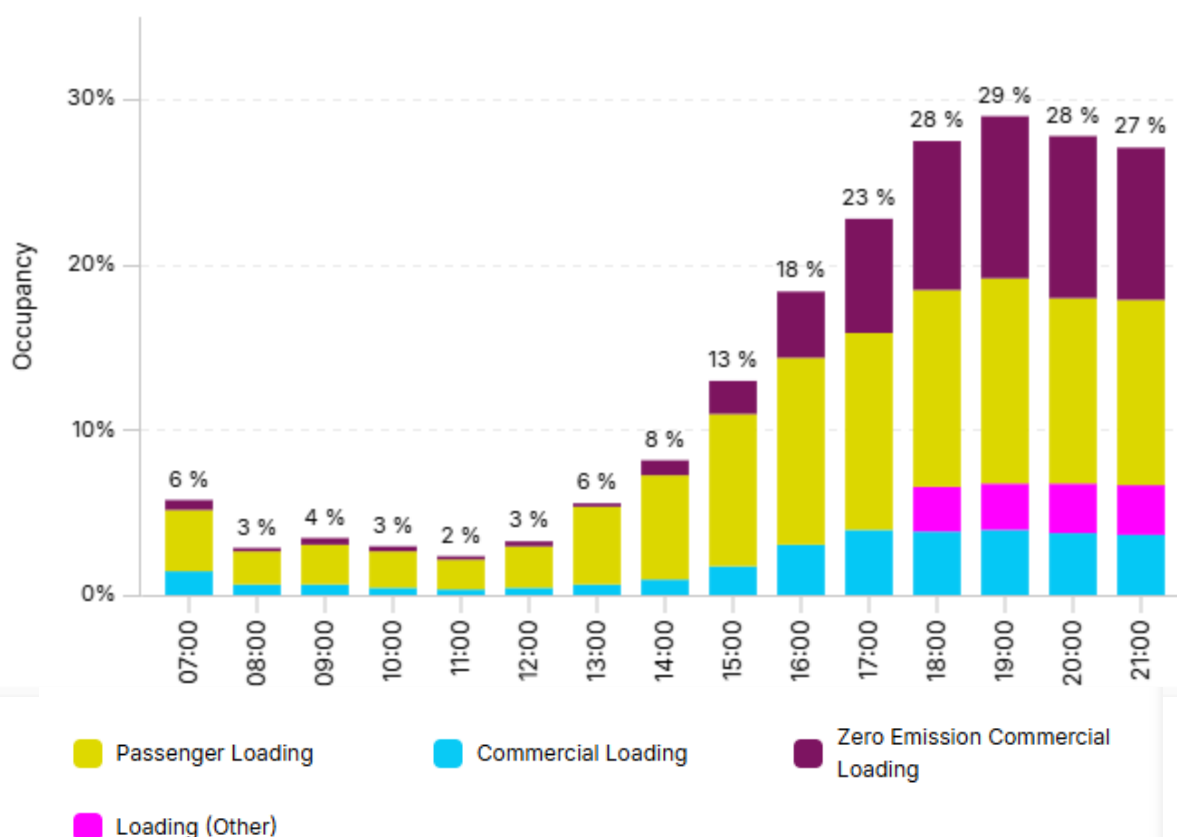


Figure 8: Total Loading Zone Occupancies by Zone Type

Notably, while the afternoon window exhibits higher session volumes, the longest average dwell times occur during the 9:00 AM morning period as demonstrated below in Figure 9. Commercial delivery vans (shown in yellow) occupy spaces for up to 123 minutes, followed by trucks (cyan), motorcycles (green), and freight (purple). This divergence identifies a mismatch in curbside behavior, where morning logistics are defined by time-intensive unloading activities carried out by smaller sized delivery vehicles, whereas afternoon utilization centers on high-frequency, short-duration sessions.

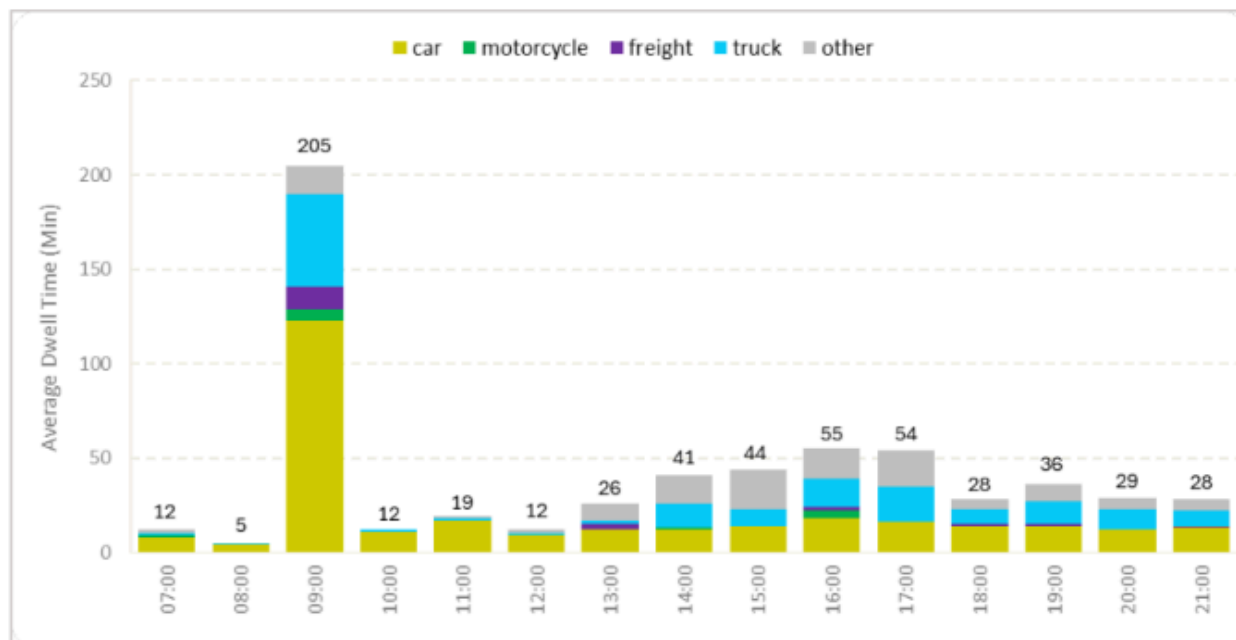


Figure 9: Average Dwell Times by Vehicle Type

Safety and Illegal Curbside Activity

Citation and MDS Pick-Up/drop-off (PUDO) data highlight persistent challenges regarding non-compliant and potentially unsafe curbside behavior. Between January and March 2025, enforcement issued 9,199 Red Curb (no stopping) violations, 3,225 loading zone violations, and 157 bike lane violations within the project area. This analysis timeframe was driven by the availability of information across the various datasets. Further analysis reveals that citation activity peaks during the weekday midday window, specifically between 9:00AM and 1:00PM. These are existing City functions and were only used to inform activity occurring at the curbsides and intended to highlight challenges. Enforcement activities were not changed, either enhanced or reduced, as a result of this project.

Furthermore, taxi PUDO data shows a surge in activity between 5:00 PM and 8:00 PM, with a significant number of these events occurring in prohibited spaces such as No Stopping zones, driveways, and near fire hydrants. The high concentration of PUDO activity in prohibited zones suggests a shortfall in regulated passenger loading capacity along high-demand corridors, creating localized safety risks for pedestrians and cyclists. These activities near prohibited zones create visibility obstructions further creating risks for all users of the curb.

3.3 Meeting Stage 1 Goals

The completion of the Stage 1 prototype successfully met the original expectations that LADOT set out to achieve from the theoretical planning phase to an active, data-driven management approach.

Demonstrated improvements include:

1. **Improving Safety and Integration:** Using a data-driven approach staff were able to focus on citation hotspots and PUDO data to successfully identify specific corridors where illegal parking was most prevalent and where they create hazardous conditions for all users. These illegal parking events cause a range of hazards from blocking bike lane infrastructure for active transportation users, to blocking travel lanes for other bus and car travel.
2. **Increasing Transparency:** The project successfully launched the public-facing Curb Viewer and standardized API endpoints. The Curb Viewer web application allowed users to access real-time curb policy information in an intuitive platform.

LADOT worked directly with logistics companies such as FedEx, DHL, Amazon, UPS, and others to provide API tokens. The API endpoints provided logistics companies the ability to integrate directly with the data allowing them to make custom queries to meet their high volume delivery needs. Over 25 total API tokens as demonstrated in table 5 were issued during the project duration. Citywide implementation would likely result in substantially more users requesting an API token. These APIs were used to support a variety of use cases such as real-time curb regulation lookups, regulatory and asset inventory queries, and specific block-by-block searches.

Table 5: Sectors and Organizations Provided API Tokens

Sector	Organization	Number of API Tokens Issued
City of LA	LADOT Staff, City of LA	4+
Public & Mobility Partners	Shared Use Mobility Center, Bicycle Transit Systems, Appyway, Hack for LA	4
Logistics & Delivery	FedEx, DHL, Amazon, UPS, VAMO Delivery, Coco Delivery, Circle Lockers, Harbor Lockers	8+
Tech & Data Providers	SWIFT Navigation, HERE Technologies, Compiler, XRoadz	4
Micromobility & EV	Bike Culver City, It's Electric	2
Other	The Alfam (Creative Design Agency)	1

3. **Reducing Vehicle Congestion and Vehicle Related Pollutants:** The project established baseline metrics required to reduce the need to cruise for parking. By quantifying that over 60% of current parking sessions are under 30 minutes, LADOT can design dynamic pricing models in an at-scale Stage 2 implementation. This approach

ensures high demand blocks maintain parking availability, thus reducing vehicle miles traveled (VMT) and vehicle related pollutants associated with searching for available parking.

4. **Improving Access:** The evaluation findings underscore that flat parking rates do not serve all neighborhoods evenly. The establishment of the digital inventory allows the City to seamlessly integrate the newly developed policy framework, ensuring that future dynamic pricing models and digital payment platforms do not create barriers for unbanked individuals or historically disadvantaged communities. The need to balance curb space can present challenges, however as part of the project LADOT developed a curb prioritization framework to serve as a guide for determining precedence at the curb (Figure 10). The framework highlights the importance of mobility and access, especially near commercial areas where curbside demand is high, and residential areas where access is vital for local residents.



Figure 10: Prioritization of Curb Functions by Land Use

While Stage 1 goals have been met successfully, LADOT recognizes that further improvements are still needed for future success of an at-scale implementation. The City of Los Angeles has over 14,260 miles of curbs and the task of implementing the successes seen at this smaller scale have yet to be realized on a large scale.

4. Anticipated Costs and Benefits of At-Scale Implementation

4.1 Estimated Impacts of At-Scale Implementation

The at-scale implementation of the Code the Curb project will have significant impacts across multiple critical areas, including integration, access, safety, and resiliency. These impacts will help transform how Los Angeles manages its curb space, leading to a more efficient, sustainable, and accessible transportation system.

Environmental Impact Reduction: One of the primary benefits of the at-scale implementation is the reduction of VMT and vehicle related pollutants. Currently, drivers searching for parking contribute to congestion and pollution as they circle for available spots. By deploying dynamic pricing and real-time curb management technologies citywide, the system will optimize parking availability, reducing the time vehicles spend cruising for spaces. This, in turn, will lead to a significant reduction in vehicle related pollutants. The project aligns with the City's Green New Deal goals, which aim to reduce vehicle related pollutants and vehicle dependency, contributing to a healthier, more sustainable urban environment.

Integration: The at-scale deployment of the CDS will also improve the integration of curb management systems across Los Angeles. The CDS format will serve as a universal language for curb data, allowing it to be seamlessly integrated into existing systems used by LADOT and other city agencies. Additionally, as curb data feeds into the city's broader asset management platform, it will improve the city's ability to plan, maintain, and optimize curbside infrastructure, ensuring resources are allocated effectively. This level of integration will enhance both day-to-day operations and long-term strategic planning for the city's transportation needs.

This integrated system will provide a single source of truth for all curbside data, which city staff can use to monitor curb space availability, occupancy, and turnover in real time. This integration will not only streamline curb management but will also provide open data through Application Programming Interfaces (APIs) that can be used by third-party developers to create public-facing applications. Furthermore, the work with the OMF and other cities will continue to help establish CDS as a national standard, enabling wider adoption and interoperability across jurisdictions.

Access: The project places a strong emphasis on ensuring fair access to curb space, particularly in historically disadvantaged communities. The Project highlighted a need for access to parking payment for those who are unbanked or underbanked and have considered several historically disadvantaged community issues and how best to integrate them.

At scale, the dynamic pricing model will be informed by these policy metrics to ensure that curb management policies do not disproportionately impact low-income communities or small businesses. This will improve access to essential services such as loading zones, parking, and public transportation, providing greater mobility options for residents and local businesses. By

tailoring curb management policies to meet the specific needs of different neighborhoods, the project will help bridge gaps in transportation across the city.

Safety: At-scale implementation will lead to safer streets by reducing instances of illegal parking and improving pedestrian and cyclist safety. There are currently observed instances of double parking and vehicles blocking bike lanes within the project area, creating hazardous conditions for drivers, cyclists, and pedestrians alike.

The integration of real-time curb monitoring and dynamic regulations will allow LADOT to better manage traffic flow, reducing double parking, loading zone conflicts, and other safety hazards. Additionally, the improved data on curb usage will enable more informed decision-making on where to allocate resources for pedestrian and bicycle infrastructure, further enhancing safety in high-traffic areas.

Resiliency: Finally, the project will improve the resiliency of Los Angeles's transportation system, particularly in response to large-scale events such as the 2028 Olympic and Paralympic Games as demonstrated in **Figure 11**. The dynamic curb management system will allow LADOT to quickly adapt curb regulations to meet the changing needs of high-demand areas, ensuring that the city's transportation infrastructure can efficiently handle surges of people, goods, and vehicles. This flexibility will also prove essential during emergencies or unexpected disruptions, allowing the city to respond in real-time to changing circumstances.



Figure 11: Example of Resilient Transportation System for 2028 Olympics

By digitizing curb assets and using real-time data, the project allows for dynamic adjustments to curb use, ensuring that space can be allocated efficiently based on demand. This adaptability is demonstrated in **Figure 12**, which shows how a curb can be made flexible through the use of digital signage. The signage conveys current policies—such as loading zones, parking restrictions, or bus lanes—in real time, responding to the needs of different users throughout the day. While digital signage was not part of the Stage 1 pilot, it is envisioned for Stage 2 of the

project. This future at-scale implementation would further strengthen the city's ability to manage curb space in real time, enhancing the overall resiliency of the transportation system by making it responsive to fluctuations in demand and contributing to reduced environmental impacts and improved mobility outcomes.

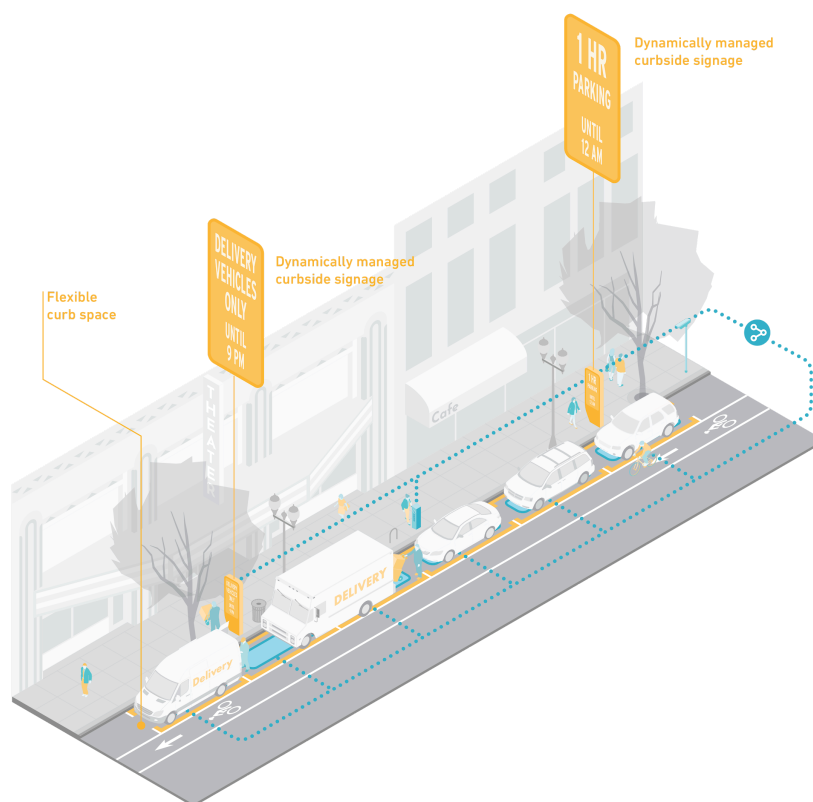


Figure 12: Example of Dynamically Managed Curb with Dynamic Signage

In summary, the at-scale implementation of Code the Curb will bring transformative benefits that can reduce pollutants and improve integration, access, safety, and resiliency. It will modernize curbside management, enhance urban mobility, and contribute to a more sustainable and safe Los Angeles.

Table 6: Stage 1 Impacts

Project Goal	Evaluation Question	Performance Measure	Findings
Overall project Objective	Can a digital twin be created for Los Angeles' curbside assets in CDS?	Percentage of curbs digitized and integrated into the system	The digitization was effective and yielded highly accurate results, although it is time intensive. For future scaled approaches a more automated solution would be more cost effective.
Safety and Reliability	How can curb monitoring improve pedestrian, cyclist, and vehicle safety and parking reliability?	During the pilot period a total of 44,944 violations were observed.	The high number of violations indicates a need for proper compliance with City regulations.
Access	How can curb management ensure access for all users, including historically disadvantaged communities?	Assess access improvements for businesses, residents, and underserved communities.	Most residents prioritized access to transit and active transportation uses, whereas business owners prioritized more loading zones and short term metered parking availability.
Environmental Impact Reduction	Can optimized curb management reduce VMT vehicle related pollutants?	Review baseline data collection of volumes and compare with traffic volumes at the pilot conclusion	Further research is needed to determine the benefit of curb management strategies of mitigating vehicle related pollutants & VMT.
Partnerships	Are partnerships with key stakeholders helping to advance the project?	Partnerships with local stakeholders Downtown LA Neighborhood Council and with large freight operators (e.g. Amazon, FedEx, UPS, DHL).	Collaboration with existing stakeholders highlighted the need for monitoring on additional corridors in the future. Existing data and real-time information was still a bit too limited to be as useful as intended.
Integration	Can LADOT successfully implement and scale the Curb Data Specification	Create a workflow to integrate open data sources along with collected data for use across systems.	A data workflow was created, however it was difficult and time intensive. LADOT has not yet implemented its Department wide asset management system to

	across existing systems?		determine integration with that system.
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4.2 Anticipated Costs of At-Scale Implementation

In order to continue the project from Stage 1 to a Stage 2 at-scale implementation we must expand the area to encompass additional neighborhoods. Additional costs, outlined in **Table 7**, will be incurred for staff training, system upgrades, additional digitization of assets to ensure the project meets the growing demands of curbside management across Los Angeles.

The anticipated costs of the at-scale implementation will include increased contractual services to support the expanded digitization of curbside assets and ongoing platform management over the 36-month Stage 2 period. These services will be essential for scaling the digital inventory across the city's 7,500 miles of street segments and ensuring that the CDS platform operates effectively. Additionally, the budget will account for the salaries of additional staff who will be responsible for monitoring curbside data, ensuring policy compliance, and developing new curb management strategies based on real-time insights. This investment in both technology and personnel will be critical to the success of the project at scale, enabling Los Angeles to meet the growing demands for efficient curbspace management. Costs Include:

- Salary: For onboarding new staff (e.g., data analysts, GIS specialists, field technicians, project managers) to manage the expanded data upkeep, policy creation, and system monitoring for the city-wide implementation (36-month period).
- Standard benefits package (e.g., healthcare, retirement contributions) calculated as a percentage of the total salary for new personnel
- Supplies
 - Upgraded meters - For modernizing existing parking meters or procuring new meters in expansion areas to support real-time data transmission and dynamic pricing capabilities
 - Digital signage - Purchase and installation of dynamic digital signs (as envisioned in Stage 2) to convey real-time curb policies and regulations to the public
 - Smart Cameras - Procurement and deployment of additional smart camera technology and associated hardware across new high-priority corridors in expansion neighborhoods for real-time curb activity monitoring and data collection.
- Contractual
 - Project Management - Contractual services for external project management and specialized consulting (e.g., legal, technical) to oversee the complex, multi-phase at-scale implementation and ensure timely delivery.
 - Platform Upkeep - Ongoing licensing fees, cloud hosting, software updates, and maintenance for the CurblQ platform and integrated CDS system over the 36-month Stage 2 period.
 - Data Collection - Contractual services for comprehensive, city-wide curbside

- asset digitization, including specialized mobile mapping and field surveying in new neighborhoods, and semi-annual data validation efforts.
- Public Engagement - Budget for expanded community outreach, public awareness campaigns, development of educational materials, and organizing stakeholder workshops across new neighborhoods to secure buy-in and address privacy concerns.
- OMF Collaborative - Membership fees, participation costs, and dedicated staff time to actively engage with the Open Mobility Foundation (OMF) to contribute to and align with the Curb Data Specification (CDS) standard's evolution.

Table 7: Anticipated At-Scale Cost

Category	Estimated Cost
Personnel	
Salary	\$2,500,000
Fringe Benefits	\$650,000
Supplies	
Upgraded Meters	\$500,000
Digital Signage	\$400,000
Smart Cameras	\$2,500,000
Contractual	
Project Management	\$2,000,000
Platform Upkeep	\$2,000,000
Data Collection	\$1,500,000
Public Engagement	\$450,000
Other	
OMF Collaborative	\$500,000
Total	\$13,000,000

4.3 Cost Benefit Comparison

While the initial capital expenditure for a citywide digital twin is substantial, the anticipated long-term benefits and operational efficiencies are projected to far outweigh the deployment costs. Benefits will be primarily realized through the reduction of traffic delays, lowered fuel consumption from reduced cruising, and the recovery of lost time for commercial operators.

Internally, the transition from manual, on-foot, curb surveying to automated change management and augmented mobility mapping will significantly reduce LADOT's operational cost for maintaining curb inventory. Furthermore, a dynamic curb management enables more efficient, data-driven pricing models. This ensures financial sustainability capable of generating operational efficiencies to offset long-term software maintenance and hardware lifecycle replacements.

4.4 Baseline Data and Future Evaluation

Significant time and effort were dedicated to establishing a comprehensive baselining of the Stage 1 assets using various data collection methods. To measure the success of Stage 2, LADOT will employ similar methodologies to baseline citywide assets. As the system scales, LADOT will continuously monitor these performance indicators via the Metrics API. This iterative evaluation loop will ensure the at-scale deployment meets established targets for reducing environmental impacts, safety improvements, and access, while also allowing for policy adjustments as real-world trends evolve.

Additionally, work would be expanded on the existing methodology on determining priority corridors and implementing this methodology Citywide with up to date data. Several key corridors were identified using existing datasets, and an index was created to prioritize these areas. The index uses weighted variables and incorporates several variables which can be found in **Table 8**. This comprehensive analysis ensures that the most critical and high-traffic areas are addressed first, allowing for more targeted and effective implementation of the monitoring technologies in future stages of the project.

Table 8: Corridor Prioritization Weighting Table

Variable	Variable Weight
Annual Average Daily Traffic (AADT) Volume	25%
Number of Collisions on Segment	20%
Within a Disadvantaged Community	15%
Parking Meters Available	10%
Along Bike Infrastructure	10%
Number of Bus stops on Segment	10%
Total Citations	10%
Total Score	100%

5. Challenges and Lessons Learned

5.1 Challenges

The Code the Curb project encountered several significant challenges that affected its progress, particularly in terms of procurement, engagement, change management, and data limitations. The most pressing challenge was the delay in procuring the necessary services to begin the crucial digitization efforts, which formed the core work of the project.

Procurement

One of the most significant administrative challenges involved navigating the City's competitive procurement process. The typical method for procuring services through the Request for Proposal (RFP) process proved to be impractical for the project timeline, as the RFP process typically takes up to 12 to 18 months to develop, release, and execute a contract. Since the SMART Grant was designed to be completed in 18 months, this lengthy procurement timeline severely impacted the ability to move forward with the digitization work in a timely manner. Secondly, the scope of work was outside of existing established operators in the curb management space.

LADOT staff explored alternative methods such as Sourcwell, a cooperative purchasing program, as well as LADOT's On-Call Professional services bench. Ultimately Sourcwell was not selected, however an RFP was posted by the OMF SMART Collaborative, and a contract list was created for Curb Management Solutions. The On-Call Professional services bench was selected for two of the three vendors used for this project. While it was expected to provide a faster solution for contracting, this service bench expired in January 2024. The expiration of this option created additional delays in the procurement process until it was finally renewed in August 2024. This setback delayed the initiation of many key project activities and pushed back timelines, including the digitization of curb assets, which was essential for converting these assets into CDS compliant structure. Furthermore, the project also faced difficulties in entering into a collaborative membership agreement with the OMF, which was critical for sharing insights and developing standards with other cities working on similar curb management projects. As a result of these delays, an extension was required in order to continue to deliver on the project and achieve its goals.

Engagement

Community engagement was also a challenge, initially failing to generate the expected level of participation from residents and stakeholders. The initial outreach efforts did not reach a wide enough audience, limiting the project's ability to gather meaningful input from the community. In response, the team shifted its approach to engage a broader range of individuals in the neighborhood, aiming to increase participation and ensure that the project meets the diverse needs of the community. This pivot was successful, but highlights the initial difficulty of garnering representative engagement.

Initial community and logistics partner engagement proved challenging during the project's development, highlighting a critical need for greater stakeholder buy-in. An at-scale deployment will require greater engagement efforts to ensure the public remains fully informed about data collection and processing methodologies throughout the project lifecycle.

Baseline data

The project was constrained by the limited availability of data on existing curb assets. Without a comprehensive and detailed dataset, the team was restricted to creating only a preliminary framework for the CDS standard until further assistance could be procured for full data translation. The lack of complete and accurate data hindered efforts to fully digitize and manage

curb spaces dynamically. Although these datasets were gradually collected and digitized, the incomplete information slowed down progress, making it challenging to implement the full scope on the original project timeline.

Compliance

Lastly, one of the anticipated challenges for the Project is ensuring curb user compliance with new digital curb management tools. While there are great benefits through real-time curb management and dynamic pricing, maintaining compliance from drivers and users is critical to its success. Experience from similar projects has shown lack of compliance can undermine the effectiveness of such systems. Although these digital tools offer better curb space management, the current grant restrictions prevent LADOT from utilizing enforcement mechanisms to ensure adherence to the new policies. This limitation may present hurdles in the future, especially as the technology expands and non-compliance persists. Without the ability to enforce curb regulations, achieving the full potential of the system might be challenging, and this issue will likely need to be addressed in subsequent project phases.

These combined challenges have emphasized the importance of flexibility and adaptability in meeting the project's ambitious timeline and objectives.

6. Deployment Readiness

6.1 Project Readiness

Successful implementation requires addressing several key issues, ranging from building a comprehensive citywide curb inventory to securing stakeholder buy-in and overcoming procurement challenges. At the same time, integrating the new system with existing infrastructure and expanding workforce capacity will be essential to ensuring that the project can scale effectively and achieve its intended goals.

Successful Implementation Requirements

A fundamental requirement for the project's success at scale is the development of a comprehensive and accurate inventory of curbside assets throughout Los Angeles. While the Stage 1 deployment in DTLA focused on a limited area, scaling up will require data collection across the city's 7,500 miles of streets. This will not only involve digitizing existing assets like parking meters, loading zones, and EV charging stations, but also integrating this data into LADOT's asset management system to ensure seamless functionality. Given the dynamic nature of curb management, maintaining the accuracy of this data is crucial, which is why semi-annual or annual data collection efforts will be necessary. High-quality, regularly updated data will form the backbone of the project, enabling the city to make informed decisions and manage the curb in real time.

Another critical requirement is securing buy-in from stakeholders across a wider geographic and demographic range. DTLA, as a densely populated and commercially active area, has a well-established network of stakeholders who are already engaged with the project. However, expanding citywide will require reaching out to neighborhoods with diverse needs and challenges. Ensuring that community groups, local businesses, and residents are not only aware of the project but also supportive of its goals will be key to the long-term success of the implementation. This means that greater efforts in stakeholder engagement will be necessary during Stage 2, including more focused outreach and demonstrations of the project's efficacy in improving mobility, safety, and access.

Strategies and Demonstrated Progress

One strategy that has emerged from the lessons learned in Stage 1 is the use of mobile mapping solutions for data validation. Mobile mapping is a cost-effective and efficient way to gather and validate data on curbside assets, particularly in less densely populated areas where traditional methods may be slower. By leveraging this technology, the project team can speed up the process of building a comprehensive inventory and reduce costs. However, it has also become clear that in more densely populated neighborhoods, mobile mapping alone may not be sufficient due to obstructions like parked vehicles or street furniture that block views of the curb. In such areas, a more granular, field-based approach will be required to ensure the accuracy of the data.

Another key strategy for Stage 2 is to build partnerships that will support the project during critical periods of high demand, such as large-scale events. Partnerships with organizations like LA28, which is leading the Olympic planning efforts for the 2028 Games, and the Los Angeles County Metro Transportation Authority (Metro) will be vital in coordinating and optimizing the use of curb management technologies. These partnerships will not only provide a testbed for the technologies during high-traffic events but will also demonstrate the scalability and adaptability of the system.

Key Obstacles to Scaling the Project

One of the primary obstacles to scaling the project is procurement. The delayed renewal of LADOT's On-Call Professional Services bench in January 2024 caused significant delays in procuring services and initiating key digitization efforts. The RFP process, which can take up to 12 months, is too slow for an 18-month program, making it critical to explore alternative procurement mechanisms to avoid bottlenecks in Stage 2. Addressing procurement inefficiencies will be crucial to ensuring that the project can move forward on schedule.

Another challenge lies in public acceptance, particularly regarding the use of camera technology to monitor curbside activities. Privacy concerns around the use of cameras could lead to resistance from the public if not managed properly. Strategic messaging, along with transparent communication about how the data will be used and safeguarded, will be necessary to garner public support. Public outreach campaigns, partnerships with local advocacy groups, and clear communication on the project's benefits—such as improved safety, reduced environmental impact, and better access to curb space—will help ease concerns and ensure smoother implementation.

Integration with Existing Systems and Workforce Capacity

The integration of the new curb management system with LADOT's existing infrastructure, particularly its asset management system, is another key component of project readiness. While there has been progress in developing workflows for asset management, ensuring full integration with other city systems, such as parking enforcement and public transit, will be essential. The success of the project hinges on its ability to operate as part of a larger ecosystem of urban management tools, rather than as a standalone system. This will require robust coordination between different city agencies and departments to ensure that data flows smoothly and that real-time curb management is possible.

Workforce capacity also presents a challenge for scaling the project. As the system expands citywide, more staff will be needed to monitor curbside data, ensure policies are being adhered to, and manage the dynamic pricing and other real-time adjustments. This will likely involve hiring additional personnel or retraining existing staff to work with the new system. Ensuring that LADOT has the internal capacity to manage these changes will be critical to the success of the project's at-scale implementation. Staff will need to be trained not only on how to use the new technologies but also on how to interpret the data to make effective policy decisions. Lastly, a need to develop further training information for third-party developers will be essential for ensuring that they have the tools necessary to leverage CDS into their projects.

The Code the Curb project is positioned for successful at-scale implementation, but several critical factors must be addressed to ensure its readiness. A citywide curb inventory, frequent data collection, and strong stakeholder engagement are essential for building the foundation of the project. Strategies like mobile mapping solutions and partnerships with organizations such as LA28 and Metro will help the project scale effectively, especially during large events. However, obstacles related to procurement, public acceptance, and workforce capacity must be

overcome to ensure smooth scaling. By addressing these challenges and building on the lessons learned from Stage 1, the project can achieve its goals of creating a more efficient, safe, and accessible curbside management system for Los Angeles.

6.2 Project Gaps and Maintenance Requirements

LADOT along with the consultant team, Cambridge Systematics, have identified gaps in existing data sets and some gaps in maintaining the operating requirements for the project. One major gap is the lack of existing baseline data for many curbside assets, which complicates the development of a comprehensive management system. Furthermore, current schemas have not yet been able to capture temporary changes such as construction or emergency road closures. A need for more frequent automated updates will be necessary to maintain consistent curb data.

Additionally, long-term maintenance, especially for camera sensors, is expected to be a gap that has not been addressed. The pilot saw procurement related delays, and as such Smart Cameras were only operational for a brief four-month window during this pilot project. While LADOT has assessed long-term maintenance plans, it remains uncertain if additional maintenance resources will be necessary to maintain this infrastructure for a multi-year implementation. Throughout the pilot, these devices experienced only temporary downtime during their initial installation. To ensure consistent operation, contingency plans and departmental partnerships have been established to address any potential future service interruptions. Addressing these gaps will be crucial for ensuring the smooth operation of the system and preventing disruptions in curb management, particularly for an at-scale implementation.

6.3 Assessment of Project Benefit and Negative Impact

The implementation of the project seeks to harness the benefits of new technologies, such as camera sensors and cashless payment systems, while carefully mitigating their potential negative impacts. The use of camera sensors will help provide real-time insights into curb usage, reducing vehicle pollutants and improving transportation access in high-demand areas. Additionally, the use of dynamic pricing enabled by these technologies will optimize curb space usage, benefiting both businesses and the public by reducing cruising time and vehicle related pollutants. These are all clear benefits that can be obtained by implementing these technologies.

However, to mitigate the negative impacts of these technologies, especially on vulnerable populations, it is important to address potential barriers. For instance, cashless payment systems can disproportionately affect unbanked or underbanked individuals, as well as those without smartphones or reliable internet access. LADOT suggests providing alternative payment options such as prepaid debit cards or SMS payments, to ensure accessibility to the curb for all users. Furthermore, privacy concerns related to the use of camera technologies must be carefully managed through clear communication about data usage and robust security measures. By implementing strategies like maintaining cash payment options and ensuring inclusivity in technology deployment, the Code the Curb project can balance innovation with

accessibility, ensuring that the benefits of the new technologies are widely distributed and do not expand the digital divide. It is in LADOT's assessment that these negative impacts can be mitigated with proper planning and has taken steps to actively mitigate these impacts on Stage 1 and shall extend to Stage 2 of the program.

7. Conclusion

The Stage 1 prototype of the Code the Curb project successfully achieved its initial objectives, establishing a robust and functional proof of concept for a citywide curb management system. The project met several key goals, including the creation of a comprehensive digital inventory of curbside assets in DTLA, the deployment of accessible curb management tools for both public and internal stakeholders, and the promotion of fair curb access. Specifically, the team developed the CDS as an open-source API, launched a functional platform to serve diverse stakeholder needs, and successfully digitized over 200 miles of curbside assets through active engagement and feedback loops.

As an open-source standard, the CDS API is increasingly adopted by both public and private partners within the OMF. The OMF continues to develop the specification along with these partners. These partnerships, supported by work completed under the SMART grant, have driven the evolution of a specification that effectively serves a broad range of mobility stakeholders.

This foundational work has formalized LADOT's understanding of the curb into a data specification that is gaining traction across sectors, providing the essential groundwork for a future at-scale implementation.

Following the conclusion of Stage 1, LADOT is now focused on scaling these successes citywide. While the initial 5.9-square-mile pilot allowed for testing various methods, the challenge of digitizing Los Angeles's massive 7,500-mile street network requires more efficient methodologies. Consequently, the City will pivot from manual, on-foot surveying and aerial imagery toward automated data collection methods, such as augmented mobile mapping and LiDAR.

Public and stakeholder engagement remains a cornerstone of the project's success. While communication in DTLA was positive, a citywide expansion will necessitate more targeted outreach to address the unique concerns of various residents and businesses. Building public buy-in, particularly regarding the use of camera technology, requires robust communication strategies centered on data privacy and the concrete benefits of dynamic curb management for safety and access.

For cities seeking to implement a similar technology, early and thorough stakeholder engagement is the most critical lesson learned. Building trust early ensures project goals align with the needs of the community. Additionally, maintaining flexibility within the project plan and prioritizing all curb users are essential for long-term success. Technologies like cashless

payments and camera-based monitoring can disproportionately impact disadvantaged communities, unbanked populations, or those without smartphones. Providing alternative payment methods and structuring penalties fairly are vital steps toward an inclusive system.

Ultimately, the Code the Curb project has demonstrated that integrating accessibility, flexibility, and transparency into every stage creates a fairer, more effective project. By applying the lessons of Stage 1, Los Angeles is better prepared to navigate the complexities of advanced curbside technology to the benefit of all its residents.