

Task 6 Curbside Data Assessment

final report

prepared for

Seattle DOT

prepared by

Cambridge Systematics, Inc.

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Cambridge Systematics, Inc.
505 East Huntland Drive, Suite 550
Austin, TX 78752

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1.0 Introduction

Seattle Department of Transportation (SDOT) is currently undertaking initiatives to enhance their digital management of curb signs, spaces, and regulations. One of SDOT's goals is to streamline internal processes to improve workflows and prepare for future transportation challenges. This effort is driven by the increasing need for accurate, accessible, and actionable curb data to support city planning, curb space management, coordination with external stakeholders, and public communication. This report summarizes key findings from an analysis of existing workflows related to digital curb sign and curb space data.

1.1 Project Scope

This project focused on analyzing digital curb sign and curb space data. It involved examining how curb data is created, updated, and maintained, as well as identifying technical and system-level constraints. The aim was to help define specific goals for managing curb signs and curb space assets, assess the current state of related datasets and processes, and develop actionable recommendations for improving data quality, consistency, and operational alignment as part of a broader enterprise asset management system.

Curb Signs: Data table of city wide SDOT maintained street signs in the public right-of-way. Contains information such as sign location, type, MUTCD category, and regulation text. Data is publicly accessible to the public via Street Signs on Seattle's Open Data Portal. This project primarily focuses on the parking-related (paid parking, time limited, load zones, etc.) subset of all street signs.

Curb Spaces: Digital representation of SDOT maintained curb spaces. Curb space data is limited to Seattle's paid parking areas only. Contains information such as space location, length, and space type. Data is publicly accessible via Curb Space Categories in Seattle's Open Data Portal.

1.2 Methodology

To support this work, Cambridge Systematics (CS) primarily leveraged three sources of information:

- **Existing technical documentation:** SDOT provided documentation outlining existing processes, including:
 - SDOT Asset Onboarding and Data Maintenance report, which outlined existing workflows for managing digital sign assets and SDOT's asset management challenges in general.
 - Previous internal interviews that SDOT held to develop the SDOT Asset Onboarding and Data Maintenance report.
 - SMART grant funded analyses of curb space and curb sign data (performed by CurbiQ).
 - Screenshots from SDOT's asset management software showing main windows used by curbside management.
- **Interviews and working sessions:** CS held multiple interviews with various departments within SDOT, which are listed in the Subsection 1.3 Groups and Software Applications Involved. In each of these interviews, the project team identified existing processes, challenges, and visions for an ideal system.

These discussions provided valuable insights into the existing workflows, system dependencies, pain points, and opportunities for improvement across departments involved in digital curb asset processes.

- **Continuous engagement with Curbside Management Team:** Throughout the project, there was constant communication with the Curbside Management Policy team, including hosting working sessions and receiving feedback on the findings observed.

1.3 Groups and Software Applications Involved

The SDOT groups interviewed for this project are listed below:

- The Curbside Operations team,
- The Asset Management team,
- The Curbside Management Policy team,
- The Traffic Data and Records team, and
- The IT GIS team.

The software applications that are used by these teams (and referenced throughout this document) are listed below:

- **INFOR:** This is the enterprise asset management software selected by SDOT to manage the inventory of curb signs, curb spaces, and other infrastructure assets in the city. This software is also referred within SDOT as Hansen and Hexagon.
- **ArcGIS (by ESRI):** This software is widely utilized by curbside engineers to perform calculations related to curb spaces.
- **Accela:** This is the enterprise right-of-way permit management software used to manage curb space reservations. (among other permits) This reservation data is used in conjunction with curb space and transaction data to calculate paid parking occupancy models.

1.4 Content of this Report

This Technical Memorandum summarizes the findings from the document review and working sessions with SDOT teams and outlines recommended strategies to enhance the digital curb asset data ecosystem. The subsequent sections of the Technical Memorandum include the following information:

- **Section 2.0: Digital Curbside Data Management Vision** - Describes the long-term goals and strategic direction for curb asset data at SDOT
- **Section 3.0: Current Practice of Data Management for Curb Signs and Curb Spaces** – Summarizes existing workflows and systems, highlights strengths of the processes, and identifies challenges and operational barriers

- Section 4.0: Recommendations for Asset Management Plan – Provides actionable strategies for improving data structure, systems integration, workflow optimization
- Section 5.0: Conclusions – Summarizes key takeaways and outlines the path forward

2.0 Digital Curbside Data Management Vision

This section describes the long-term goals for the digital curb asset data at SDOT. Understanding the Curbside Management team's vision is important for two purposes:

- Identify the ideal state desired by the Curbside Management team
- Identify gaps that may not be considered existing issues but are still barriers to achieving the team's goal

As part of this effort to define a long-term vision for curb asset data management, the consultant team facilitated a collaborative visioning exercise with members of the Curbside Management team. The vision was expected to be aspirational, feasible and strategic, describing ideal conditions in the context of SDOT's long-term goals. This session was designed to co-create a shared vision for how digital curb asset data, particularly curb signs and curb spaces, should be managed in the future. The exercise included five rounds of questions, beginning with two warm up prompts that asked how SDOT's curbside management might be recognized in the future for its digital curb asset data management.

Overall, participants envisioned a future where SDOT provides publicly accessible Application Programming Interfaces (APIs) along with interactive and intuitive web maps that allow non-technical users to understand curb right of way rules based on time of day and location. They also emphasized the importance of curb data being consistently accurate and easily updated by staff. Other ideas included real-time curb availability displayed through interactive maps, and an integration with a curb space reservation permitting system that is seamless and efficient. Participants imagined SDOT continuing to lead in curb data management best practices by maintaining a comprehensive, publicly accessible, and user-friendly digital inventory of all curb space regulations. Together, these ideas reflect a strong desire for a transparent, open, and integrated curbside management system that is adaptable, future-ready, and accessible to both internal users and the public. The remaining three rounds focused on key functional areas: the overall process, inventory, usage of the curb spaces, and planning.

2.1 Overall Process

For the overall process, six responses were received. The themes that emerged from this discussion included:

- **Simpler Process:** Streamlined workflows across teams, easy to be followed by different staff
- **Standardized Processes:** Clear, consistent procedures across the organization
- **Documentation of procedures:** Reliable references and guides for consistent practices
- **Data is Open, Accessible, and Integrated:** Data can be shared in large volumes in a consistent way, supporting internal and external users
- **Easy to Scale:** A flexible system that can grow with organizational needs, and a system that is not a constraint to continuous improvement
- **Alignment with SDOT Data Governance:** Ensuring consistency with broader data management principles

- **Easy reporting:** Ability to quickly generate and share insights
- **Open access:** Compatibility with external tools and public sharing
- **Up-to-date inventory:** Developing and sustaining an up-to-date inventory

These themes were summarized in the following vision:

A unified, open, and fully integrated digital curb management system that empowers SDOT and its stakeholders to seamlessly track, analyze, and respond to curb space changes. Through standardized workflows and strong data governance, the system will provide up-to-date data, with visualization tools that support planning, operations, communication, and collaboration across internal teams and external partners.

2.2 Vision for Inventory

Inventory forms the foundation of all asset management work. It begins with answering a fundamental question: “What do you manage?” For curb asset management, this means defining and quantifying physical sign assets in the public right-of-way, identifying key attributes such as type, location, and regulation, and establishing a reliable system to digitally manage this information. During the visioning exercise with the DOT team, several themes emerged that reflect aspirations for an improved inventory process and system. It is worth noting that some of the themes may overlap with previous themes identified:

- **Simpler Process:** A simpler process for updating and maintaining the inventory
- **Backlog Reduction:** Reduction of the current backlog of unrecorded or outdated asset information
- **Accurate Digital Information:** Accurate records that reflect real-world curb conditions
- **System Data Standardization:** Data is standardized and streamlined for data entry, update, and analysis
- **Integration:** Flexibility to integrate with other digital tools and services
- **Usefulness:** An inventory that supports cross-functional teams, enabling shared use and input
- **Shareable:** System facilitates machine readable digital communication

These themes were summarized in the following vision:

A reliable, up-to-date digital inventory system for curb assets that accurately reflects the physical environment, supports efficient updates, and supports cross-functional teams with standardized, connected, and transparent data for planning and operations.

2.3 Vision for Curb Usage Data

Understanding how curb spaces are being used is essential for maintaining safe, effective, and well-managed public space. This component captures relevant attributes like whether a curb space is occupied, available, or used without authorization. Establishing a shared framework for curb usage helps inform maintenance priorities, supports timely interventions, and ensures that planning and operations are based on accurate, up-to-date information. Although outside the project scope, understanding the vision for curb usage is important to identify gaps and challenges of current processes. During the visioning exercise with the SDOT team, participants identified several key themes:

- **Link Between Physical World and Digital World:** A system that allows monitoring the condition of curb assets, verifying that digital curb asset records are accurate
- **Integration:** Connection with the curb space reservation permitting system
- **Comprehensive:** Relevant attributes are capturing the possible uses of curb spaces

These themes were summarized in the following vision:

A real-time system for monitoring curb assets and conditions and supporting continuous field validation of sign status.

2.4 Vision for Planning

The planning component of curb asset management focuses on using data to inform strategic decisions. It involves leveraging inventory and usage data to support policy development, long-term planning, and effective allocation of resources. Planning ensures that curbside data informs not only operational choices but also broader city goals, helping staff anticipate needs, test scenarios, and communicate across teams and to the public. During the visioning exercise, SDOT participants identified the following priorities to guide future planning efforts:

- **Occupancy Models:** Accurate parking occupancy models and curb utilization
- **Data-driven Policy Decisions:** Decisions are made based on reliable data and analysis
- **Enhanced Planning:** A system that supports scenario and neighborhood-level planning based on data
- **Improved Communication:** Communication of curbside data to other SDOT teams beyond curb management
- **Sharing Curb Space Location, Regulations, and Availability:** Communicating parking space information to the public and city stakeholders

These themes were summarized in the following vision:

A curb data management system that supports data-driven policy, scenario planning, and provides clear, searchable curb data to inform decisions and improves communication and coordination within internal teams and the city.

2.5 Key Takeaways

The vision exercise provided an opportunity to the Curbside Management team to indicate the ideal state for the management of digital curb assets. In general, it was observed that:

- Most of the themes expressed in the visioning exercise are related to the inventory component. Based on observations of existing data management processes, inventory is also the area with the most immediate opportunity for improvement (this is explained in more detail in Section 3.0 Current Management of Digital Curb Sign and Curb Space Data). Improving this foundational step (inventory management) will enable the Curbside Management team to make progress towards achieving the vision in other areas.
- Some themes were emphasized multiple times, such as simpler and streamlined processes, up-to-date inventories, and a desire for data-driven decisions. Recurring themes are key to understanding potential gaps in existing processes.

3.0 Current Management of Digital Curb Sign and Curb Space Data

This section presents a summary and takeaways of the current management of digital curb space and curb sign data within SDOT. These findings are based on existing documentation shared by the Curbside Management team, and staff interviews from multiple departments. This chapter summarizes the current workflows, the strengths observed, and the challenges identified.

3.1 Overview of the Current Processes

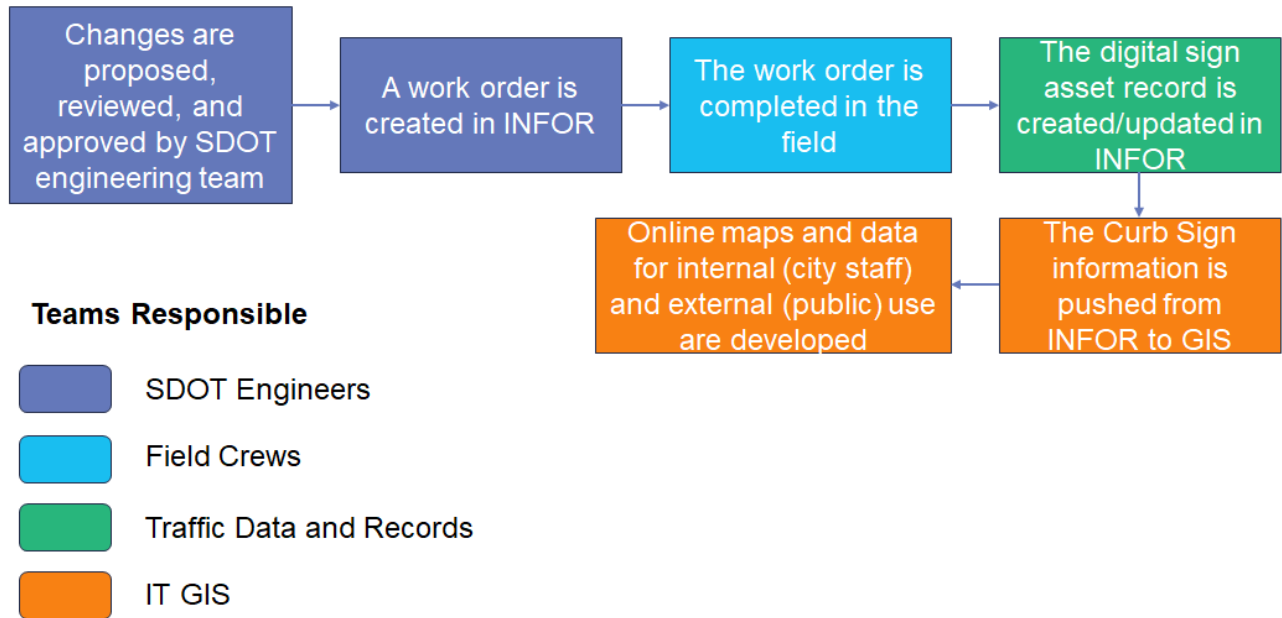
Although interrelated, there are variations in the workflows for creating and/or updating digital curb sign records and curb space data. These workflows are summarized below.

3.1.1 Curb Signs

There are two primary workflows for managing digital curb sign records. These workflows depend on if either SDOT or an external contractor will perform the work order of installing the physical curb sign. Projects installed by SDOT crews are often smaller in scale. Major capital projects performed by an external contractor refer to awarded contracts for large roadway construction projects, such as the construction of a major corridor. Both processes are described below.

Management of Digital Curb Signs for Projects Installed by SDOT

The process can be summarized in six steps, as shown in Figure 3-1 and described in the subsequent list. Four teams participate in this process: the SDOT Engineers, the field crews, the Traffic and Data Records Team, and the IT GIS team. While Curbside Team is primarily the staff that create or update a curb sign via work order – other SDOT Divisions also complete this work, namely in Transportation Operations and Project Delivery divisions.

Figure 3-1. Workflow for the Management of Digital Curb Sign Assets (SDOT)

1. **Changes are proposed, reviewed, and approved by SDOT engineering team:** There are multiple triggers for a curbside engineer to review a roadway segment's digitized curb sign inventory. For example, changes in parking regulations, new paid parking areas, ongoing capital projects, speed limit changes, or requests for other new curbside zones. The general public can also request a sign replacement (e.g., a sign is knocked down) through the "Find It, Fix It" app. An SDOT engineer will look at the context of the roadway segment, usually through online maps connected with the current inventory, or by possibly going to the field, to understand the current conditions versus the proposed use of the curb sign and space. Based on this information, the SDOT engineer will make a decision about replacing, removing, or adding curb signs according to the expected use of the curb space.
2. **A work order is created in INFOR:** SDOT engineers will create a work order in INFOR containing the information for the field crews to perform the work, including a depiction of the sign and associated maps.
3. **The work order is completed in the field:** Once the work order is submitted, a field crew will be assigned to go out and complete the work order. In general, the crews can complete the work order with no issue, but in some cases, they will reach out to an SDOT engineer when adjustments are needed to the work order.
4. **The digital sign asset record is created/updated in INFOR:** After completing the work order, the field crew will mark the associated work order as completed in INFOR. For signs in paid parking areas, once the sign installation is done, the Paid Parking shop office staff mark that the work order is complete and transfer the work order to Traffic Data and Records for them to update or create the curb sign asset and location in INFOR. Outside of paid parking areas, the SDOT Signs and Markings Crew Chiefs or administrative staff mark the record as complete and transfer to Traffic Data and Records. It is important to highlight that the digital curb sign asset has a unique ID that is linked to a support (also with a unique ID), and the support is linked to a segment. Currently, there is a backlog at the Traffic and Records team

with an estimated lag between three months and a year to create/update curb signs in INFOR after the crews perform the change in the physical world.

5. **The curb sign information is pushed from INFOR to GIS:** There is a nightly script that pushes curb sign inventory information from INFOR to SDOT's GIS environment. If there are errors in the process, the IT GIS team will investigate and work to address them. It was reported that issues in the process are usually resolved within a day and while not frequent, they do occur.
6. **Online maps and data for internal (City Staff) and external (public) use are developed:** The IT GIS team coordinates with the Curbside Management team to develop maps that can be useful for internal and external use. An example of internal use are the maps that the Curbside Management team can use for analysis and planning purposes. Examples of external use maps and data is the SDOT Street Signs dataset, displaying sign types and regulations¹, and SDOT staff using the street sign inventory to create parking regulation maps such as the Seattle Parking Map.

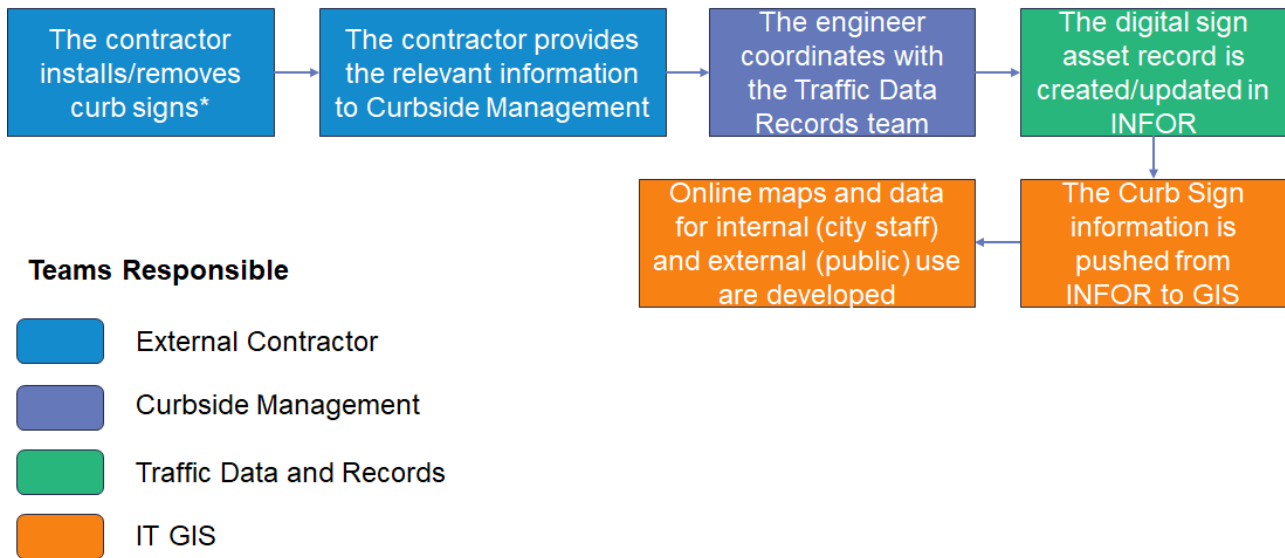
Overall, the steps to update the digital curb signs require multiple manual inputs. Moreover, there is a bottleneck when creating the curb sign records in INFOR by the Traffic and Data Records team. These challenges are explained in more detailed in the Section 3.3 Overview of Current Challenges.

Management of Digital Curb Signs for Projects Performed by a Contractor

There is a slight, but important, variation for updating curb signs when the installation, removal, or update is performed by a contractor. In theory, at the end of a roadway project, the contractor will provide the as-built designs (drawings and specifications) to the Traffic Data and Records team. The team reviews the as-builts and creates the digital records for curb signs in INFOR.

However, in practice, the workflow is different because there is currently a backlog from the Traffic and Data Records team to review the as-builts (in some cases, reported to be years). If a contractor is making changes in a paid parking area, they will communicate directly with the Curbside Management team. Then, the Curbside Management team will coordinate with the Traffic Data and Records team to create and update the records in INFOR to expedite the process. This process is summarized in Figure 3-2. The remaining workflow steps are the identical to when SDOT completes the work.

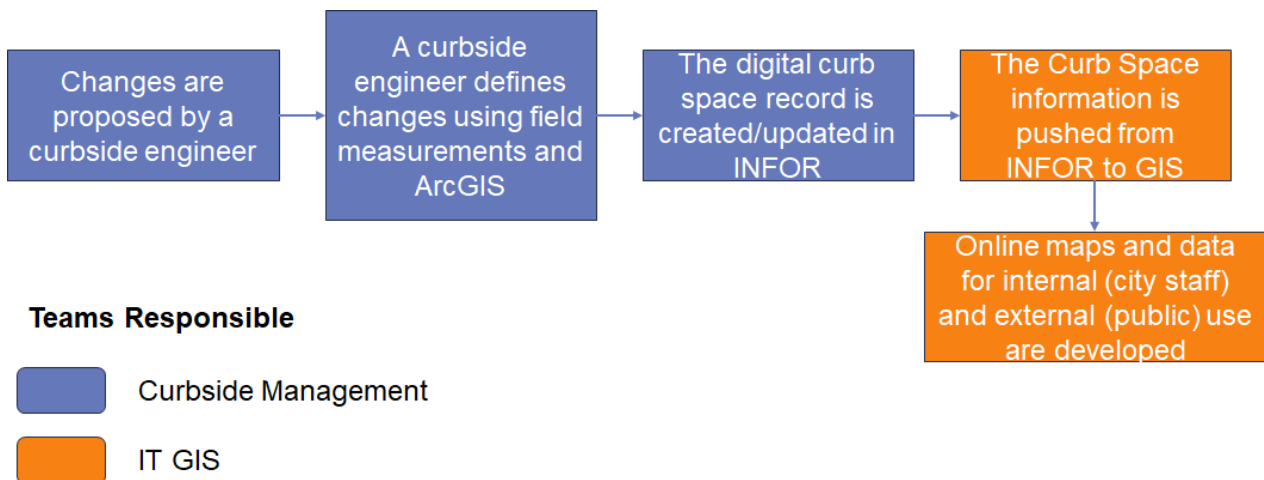
¹ Seattle Department of Transportation. (2025). SDOT Street Signs. *Seattle Open Data Portal*. Retrieved from https://data-seattlecitygis.opendata.arcgis.com/datasets/f4ba1c9fd5ac43edadf6565835269b51_1/explore

Figure 3-2. Workflow for the Management of Digital Curb Sign Assets (Contractor)

* In coordination with SDOT engineering team.

3.1.2 Curb Spaces

The process to update curb spaces can be summarized in five steps, as shown in Figure 3-3. The process is similar to curb signs, though primarily involves the Curbside Management team and IT GIS team. It is critical to note that curb spaces are only identified in paid parking areas (separately maintained polygons).

Figure 3-3. Workflow for the Management of Digital Curb Space Assets

The description of each step is presented below:

1. **Changes are proposed by a curbside engineer:** There are multiple triggers for a curbside engineer to review a roadway segment's digitized curb space inventory. For example, changes in parking regulations, new paid parking areas, ongoing capital projects, or requests for other new curbside zones.

The curbside engineer will look at the context of the roadway segment, usually through online maps connected with the current inventory. Based on this information, the curbside engineer will make a decision about the geometric distribution of the curb spaces.

2. **A curbside engineer defines the changes using field measurements and ArcGIS (From ESRI):** a curbside engineer will typically go into the field and measure the curb to verify the proposed changes. ArcGIS is also often used to help engineers define the geometric boundaries of the curb spaces and quantify measures such as offsets and distances.
3. **The digital curb space record is created/updated in INFOR:** The curbside engineer will update the records for the curb spaces in INFOR. INFOR is the enterprise asset management software used by SDOT to manage the inventory of curb spaces, along with other SDOT assets. Some of the parameters identified in ArcGIS (previous step) are manually added as attributes in INFOR (e.g., curb space ID, space length, pay station kiosk).
4. **The curb space information is pushed from INFOR to GIS:** There is a nightly script that pushes curb space inventory information from INFOR to SDOT's GIS environment. If there are errors in the process, the IT GIS team will investigate and work to address them. It was reported that issues in the process are usually resolved within a day and while not frequent, they do occur.
5. **Online maps and data for internal (city staff) and external (public) use are developed:** The IT GIS team coordinates with the Curbside Management team to develop maps and data that can be useful for internal and external use. An example of internal use are the maps and data that city staff use for analysis, planning, and curb space permit reservations. Examples of external use maps and data are the Curb Space Categories dataset, displaying the types of curb space categories², and SDOT vendors using the curb space inventory to create curb space occupancy data models used to set paid parking rates.

3.2 Overview of Current Strengths

Based on a review of existing documentation and team interviews, four strengths were identified in the management of digital curb sign and curb space data. These strengths are presented below, ordered according to how strongly the Curbside Management team perceives each one as currently contributing to the team's vision.

- **Proficient and knowledgeable staff:** Within the Curbside Management team, there are technical staff, both from a planning and engineering perspective, with the capability of understanding complex workflows and adapting to evolving needs.
- **Strong motivation to improve processes:** Starting with the Curbside Management team and continuing with other interviewed teams, SDOT staff demonstrates a strong motivation to continuously improve data management, processes, and systems.
- **High-level support:** SDOT has leadership that are aligned with a data-driven approach for managing assets, supporting modernization and evidence-based decision-making.

² Seattle Department of Transportation. (2025). Curb Space Categories. *Seattle Open Data Portal*. Retrieved from <https://data-seattlecitygis.opendata.arcgis.com/datasets/SeattleCityGIS::curb-space-categories/about>

- **Technological support:** SDOT has third-party systems for different processes that can analyze large volumes of data, providing a foundation for analytics and process improvement.

3.3 Overview of Current Challenges

This section outlines the key challenges currently affecting the digital management of curb sign and curb space data. The challenges span technical limitations, manual processes, data structure constraints, and organizational capacity gaps. The section also identifies the team(s) exposed to each challenge and the potential implications for policy, planning, operations, and long-term system improvement. The challenges are divided into three categories:

- **General Challenges:** These challenges span both curb signs and curb spaces and typically impact multiple teams. Addressing these broader issues is likely to reduce the number of challenges in the other two categories.
- **Specific Challenges:** These are specific technical and operational challenges that, while narrower in scope, continue to hinder the Curbside Management Team's progress toward its desired vision.
- **Potential Challenges:** These are challenges not currently affecting SDOT but could become critical as the system scales and expands to achieve future goals and vision.

3.3.1 General Challenges

The general challenges refer to challenges that cover issues across both curb signs and curb spaces, and usually affect more than one team. This includes foundational issues such as system flexibility, integration between datasets, or the number of manual inputs on the overall process. Table 3-1 presents the summary of the general challenges identified, followed by a detailed description. The challenges are ordered according to how strongly the Curbside Management team perceives each one as currently impacting the team's vision.

Table 3-1. Summary of General Challenges Identified

Challenge	Impact (1-Minor, 5-Critical)	Impacting Curb Signs	Impacting Curb Spaces	Teams Exposed to this Challenge
GC-1: Lack of direct data connection between curb regulations and curb spaces	5.0	Signs contain regulation data but are not directly linked to the associated curb spaces	Curb spaces lack a direct connection to regulatory data (curb signs)	Curbside Engineering, GIS, Curbside Planning
GC-2: Digital curb spaces unable to display all associated regulations	4.5	Signs often contain multiple regulations in an unstructured field, making it hard to differentiate	Digital curb spaces are defined as if they have few associated regulations, limiting accuracy	Curbside Planning, Curbside Engineering, GIS
GC-3: Lack of a holistic view when building the current processes	4.0	The current processes are fragmented and rely heavily on manual interventions, resulting in inefficiencies and a lack of seamless workflow integration	The current processes are fragmented and rely heavily on manual interventions, resulting in inefficiencies and a lack of seamless workflow integration	Curbside Planning, Curbside Operations, GIS, Traffic Data and Records, Asset Management, Accela
GC-4: High effort required to edit the current structure of the information	4.0	Limited opportunities for continuous improvement of data structure	Limited opportunities for continuous improvement of data structure	Curbside Planning, Asset Management
GC-5: Resource constraints	3.5	The Traffic Data and Records team's and Crew Chiefs/Parking Shop limited resources and capacity are bottlenecks in the curb sign asset creation or updating process	The Asset Management team expressed limited staff capacity to develop their vision; the GIS team has limited bandwidth for updates	Curbside Planning, Asset Management, Traffic Data and Records, Curbside Engineering, GIS
GC-6: Difficulty to Share Curbside Data in a Systematic Way	3.0	Difficult to share sign regulations and policies in a systematic way internally and externally	Difficult to share curb space data in a systematic way internally and externally	GIS, Asset Management, External Partners, Curbside Planning
GC-7: Manual processes and workflows	3.0	Specific steps require manual inputs into INFOR, which are time-consuming and could result in errors	Creating curb space records involves multiple manual inputs, which are time-consuming and could result in errors	Curbside Engineering, Traffic Data and Records
GC-8: Limited accessibility to historical records of curb spaces and regulations	3.0	Lack of historical records for regulations limit long-term analysis and knowledge retention	Lack of historical records for curb space delimitation limit long-term analysis, knowledge retention, and vendor accountability	Curbside Planning, Curbside Engineering, Asset Management, Curbside Planning

Source: Analysis by Cambridge Systematics.

General Challenge 1: Lack of Direct Connection between Curb Regulations and Curb Spaces

A key challenge is the lack of direct connection between curb sign regulations and rules and their associated digital curb spaces. Currently, the digital curb signs and curb spaces operate as separated assets without a formal relationship. A transportation technology company the Curbside Management team has been working with (CurbIQ) to develop a data processing method to match signs to curb spaces, with higher accuracy compared to SDOT's original method. However, a main challenge with this approach is that SDOT stores the unique curb space number intended to match a sign to a curb space in an unstructured data field. (FIELDNOTES) This means that a connection between the sign and space cannot always be made.

General Challenge 2: Digital Curb Spaces are Unable to Display all Associated Regulations

The digital curb space attributes are currently set up to allow the assignment of minimal amount of regulations per curb space via SPACETYPEDESC. In reality, a curb space can have multiple curb regulations over time and week (24 – 7) (e.g., commercial loading in the morning, restricted parking during peak hours, and paid parking any other time). For policy and operational analyses, this can lead to approximations of the real-world data but does not describe the full picture given regulations can change by time of day or day of the week. A workaround for this challenge is staff manually read the separate digital curb sign record to interpret the applicable regulation for the curb space. SDOT cannot do this work automatically which is why manual interpretation is required to ensure accuracy. Curb sign regulations are represented as a single row in unstructured text strings containing multiple regulations and details in the data. However, unstructured data limits the ability to efficiently query curb space regulation data.

General Challenge 3: Lack of a Holistic View when Building the Current Processes

When curbside asset data was initially collected and managed at SDOT, there was not a unified vision or structure, with underlying purposes and approaches developed in isolation and in different phases by the varying departments and teams. This is not uncommon among DOTs, with varying planning, system design, and coordination processes across the agency. However, it can lead to suboptimal workflows and database structures for storing and consuming data effectively.

General Challenge 4: High Effort Required to Edit the Current Structure of the Information

The Asset Management group shared that there are some limitations within INFOR to implement changes in the data structure, specifically how the system lacks features allowing SDOT to perform changes directly. This means updates and improvements to the data structure depend on external vendor support, and would potentially have costs. To circumvent this challenge, sometimes fields are reused for other purposes, although that could lead to size or field type limitations (e.g., integer versus text). This challenge also hinders continuous improvement, as it can be difficult to anticipate all data needs during development. However, as the system is implemented, new data requirements may emerge.

General Challenge 5: Resource Constraints

Limited staffing and resources make it difficult to enter new data, maintain timely and up-to-date records, upgrade systems, and onboard new staff effectively, resulting in delays and backlog. This affects multiple operational and support teams across the curbside management process. The Asset Management group expressed limited resources to keep asset data current and reliable, and to fully develop an asset

management plan that goes beyond inventory. The field crew chiefs and paid parking shop have limited resources to always ensure timely work order closeouts which can create bottlenecks getting data to the Traffic Data and Records group. The Traffic Data and Records group has limited resources and capacity to create digital curb signs in a timely manner, causing delays for the Curbside Engineering Team when work order updates are not created quickly into the system. The IT GIS group also expressed limitations on implementing system upgrades. Across all the groups, it was mentioned that limited bandwidth hinders the implementation of new projects.

General Challenge 6: Difficulty to Share Curbside Data in a Systematic Way

The current system has limitations to share data in a consistent, systematic way. While there is an open data program in place, it is a limited version where people can request data that is typically delivered in a small-scale format like a spreadsheet. Therefore, the current data sharing system is not suited to meet the needs of vendors or external partners that would consume large volumes of data in a structured way, such as transportation technology companies, autonomous vehicles, or logistics services. This challenge limits the department's ability to effectively support modern, data-driven applications and integration efforts.

General Challenge 7: Manual Processes and Workflows

Across different processes, it was observed there is a high reliance on individual expertise and manual inputs. For example, creating curb space records requires multiple manual steps, such as assigning curb space numbers or writing sign text information. These manual processes make the overall workflow slow, labor-intensive, and prone to human error, risking data consistency. These steps could be contributing to the growing backlog of work orders. Moreover, this challenge makes SDOT vulnerable in the case of sudden staff turnover.

General Challenge 8: Limited Accessibility to Historical Records of Curb Spaces and Regulations

The system is capturing robust datasets; however, the database structure within SDOT is not maintaining historical records of regulations for curb spaces. Only parking transaction records and paid parking spaces are available historically, although transactions are available via payment vendors. Paid parking space records (and only the paid space not a nearby load zone on a blockface in a paid area) are available via a Seattle data set on Open Data. This challenge limits SDOT's data retention and system design. For policy and planning purposes, it could restrict the ability to conduct multi-year analyses where SDOT may want to evaluate trends, policy changes, and curb usage over time.

3.3.2 Specific Challenges

Specific challenges focus on detailed operational processes, such as manual data entry, regulation parsing, and database limitations. These highlight inefficiencies or inconsistencies in how curb data is currently handled. Table 3-2 summarizes the specific challenges identified.

Table 3-2. Summary of Specific Challenges Identified

Challenge	Impact (1-Minor, 5-Critical)	Impacting Curb Signs	Impacting Curb Spaces	Teams Exposed to this Challenge
SC-1: Unstructured curb sign information Stored in the FIELDNOTES and TEXT Fields	5.0	Sign descriptions vary in format and clarity, often with multiple regulations and truncated text	Difficulty connecting curb spaces to curb regulations	Curbside Planning, Curbside Engineering, Traffic Data and Records, GIS
SC-2: Manual generation of the Curb Space Number	4.0	N/A	Space numbers are manually calculated and assigned, leading to potential inconsistencies	Curbside Engineering
SC-3: Multiple SIGNTYPE categories and sign iterations	3.5	SIGNTYPE categories are complex, difficult to aggregate for data analysis, including missing metadata explaining the codes	N/A	Curbside Engineering, Traffic Data and Records, Curbside Planning
SC-4: Linear Referencing System (LRS) Challenges	3.0	LRS is complex and hinder the management of curb sign inventories	LRS is complex and hinder the management of curb space inventories	Curbside Planning, Curbside Engineering, GIS, Asset Management
SC-5: Difficult post-processing of clearance segments	2.0	N/A	Difficult to manage and visualize clearance spaces	Curbside Engineering, GIS

Source: Analysis by Cambridge Systematics.

Specific Challenge 1: Unstructured Curb Sign Information Stored in the FIELDNOTES and TEXT Fields

Unstructured fields, such as FIELDNOTES, often contain inconsistent formatting or are truncated due to character limits, making it difficult to extract accurate or complete information. This challenge affects data integrity. The field FIELDNOTES entries often include informal, inconsistent notations (e.g., “40'-02/04T, Sup-28/30T, -03/05T”) that lack standard syntax. These fragments are difficult to interpret, vary widely in style, and often include typographical inconsistencies that make them unsuitable for automated processing or querying. Similarly, the TEXT field contains variations of regulatory language for signage (e.g., 30 M CLZ 7A-8P EXC SUN-HOL, USE PS EXC WITH PERMIT, TAZ). This variability combined with character limits, truncation, and the inclusion of redundant details limits their usefulness in system integration and GIS analysis. Moreover, unstructured fields cause a lack of an automated query builder, meaning that queries need to be case specific, multiple versions of the same word, and spelling errors.

Specific Challenge 2: Manual Generation of the Curb Space Number

The curb space numbering system depends on manual calculations and estimations of segment lengths, clearances, and block IDs. Field staff must manually assign space numbers in increments (e.g., every 20 feet) and ensure they align with clearances and regulations. The Curbside Engineering team is responsible for manually counting, dividing, and assigning space numbers and block IDs. The Traffic Data and Records team relies on these numbers to write or update work orders, and any errors in numbering can cause confusion during sign implementation and must match physical signs to the correct space numbers. The IT

GIS team receives curb segments that may not align with the digital map if the space numbers are off. These manual and error-prone processes reduce efficiency and increase data integrity risks.

Specific Challenge 3: Multiple SIGNTYPE Categories and Sign Iterations

The number of unique SIGNTYPE values in the system has increased significantly over time, with now hundreds of unique SIGNTYPE codes inconsistently utilized and documented. For example, there are many SIGNTYPE codes ending in X which were initially designed to be used sparingly and only if there were less than 20 signs being produced. However, now SDOT has X SIGNTYPE codes with [#] qualifiers on the TEXT field that indicates how many iterations of that sign there are. This is typically well beyond the intended 20. (example: SIGNTYPE = R8-DISABLX TEXT = (31)[WHEELCHAIR] STATE DISABLEDPARKING PERMIT REQUIRED4 HOUR LIMIT9A-3P MON-FRI 8A-8P NO PAYMENT REQUIRED[TOWED CAR]) This shows that the initial coding design was not flexible enough to evolve with changing data tracking needs. This level of fragmentation introduces inconsistencies in how similar signage is classified, making it difficult to organize, analyze, or interpret the data in a reliable way. In some cases, different SIGNTYPE values are used to describe signs with similar messages, resulting in redundant classifications. Moreover, some of the SIGNTYPES are composed of multiple regulations, and there is a lack of a complete metadata describing the SIGNTYPES. This lack of standardization complicates data maintenance, increases the potential for input errors, and reduces the overall efficiency of systems that rely on this data for operations, reporting, and visualization.

Specific Challenge 4: Linear Referencing System (LRS) Challenges

The digital curbside asset management process depends on a linear referencing system (LRS). Across the different teams, it was expressed that managing curb sign and curb space inventories using the LRS was challenging. The IT GIS team spends time troubleshooting mismatches when street network changes break the LRS. The Curbside Engineering team must manually re-check measurements for updates of the assets. The Traffic Data and Records team's sign placements can appear misaligned in maps if referencing does not match real-world conditions, and field crews could spend additional time referencing curb assets in the physical world. Also, within Seattle DOT, different teams use different start points as reference. This means that measuring and locating signs is challenging for a curb sign. For example, a curb sign and a traffic sign like a stop sign might have different starting points.

Specific Challenge 5: Difficult Post-processing of Clearance Segments

Clearance areas between parking spaces must be entered as separate curb space segments in the system, which results in numerous small segments that are hard to translate into clean GIS analysis. For a definition, clearance space is created virtually to allow for separation of vehicles within the real parking world, but the clearance distance is entirely invented distance, historically tying back to when there were single space meters in paid areas instead of multi-space kiosks. The Curbside Engineering team must enter each clearance manually and often recalculate space lengths if a clearance causes a segment to fall below the minimum required length. This challenge makes spatial analysis and post-processing of curb space data more difficult.

3.3.3 Potential Challenges

The potential challenges are issues that could emerge in the future, even though SDOT is not currently experiencing these challenges. Table 3-3 summarizes the potential challenges identified.

Table 3-3. Summary of Potential Challenges Identified

Challenge	Impact (1-Minor, 5-Critical)	Impacting Curb Signs	Impacting Curb Spaces	Teams Exposed to this Challenge
PC-1: New APIs needed if current processes change	4.0	Changes to current data structure or processes could lead to breakdown of existing APIs	Changes to current data structure or processes could lead to breakdown of existing APIs	Curbside Planning, Curbside Engineering, GIS, Accela
PC-2: High impact if there is a sudden departure of staff	4.0	High reliance on individual expertise and manual processes makes the system vulnerable when key staff depart	High reliance on individual expertise and manual processes makes the system vulnerable when key staff depart	Curbside Engineering, Traffic Data and Records

Source: Analysis by Cambridge Systematics.

Potential Challenge 1: New APIs Needed if Current Processes Change

The current management of digital curb sign and curb space data involves APIs (scripts, interfaces, etc.). For example, there is a nightly script (also called “refresher”), which pushes curb sign and curb space data from INFOR to GIS. Likewise, there is a script that allows Accela to consume curbside data and identify changes of the space geometry in the city. Addressing some of the previous challenges could potentially involve restructuring the data and data structure of the system, which could impact existing scripts. In this case, the scripts would need to be revised accordingly. For example, if there is a new field for curb signs, the nightly script that refreshes GIS needs to be updated to capture this new field.

Potential Challenge 2: Sudden Departure of Staff

A sudden departure of key staff presents a risk due to the high dependency on manual inputs, calculations, and individual expertise in the current processes. Some steps, such as curb space numbering, or SIGNTYPE coding, are not fully documented or automated. Moreover, it is difficult to follow the steps based on existing system workflows (e.g., when the curbside engineer adds an ID1 and ID2 they refer to StreetID and SegmentID respectively). If there is a sudden departure of key staff, it would be difficult for others to understand or continue the work without extensive corrections, leading to delays, errors, and knowledge gaps. This could affect the continuity and reliability of curbside management operations and increases the risk of data inconsistency or loss of process efficiency.

4.0 Recommendations to Improve the Management of Digital Curb Sign and Curb Space Data

This section summarizes the recommendations proposed to the Curbside Management team and SDOT overall. The recommendations were based on three aspects:

- Observed challenges,
- The team's vision, and
- Observed strengths.

The recommendations were grouped into four categories:

- **Organizational Recommendations:** recommendations at the organizational level, which can typically be implemented independently of the software system.
- **System Recommendations:** recommendations that are specific and directly related to the existing asset management software system. These recommendations include potential alternatives and ideal features of this system that could meet SDOT's needs.
- **Recommendations to Reduce Digital Curb Sign Backlog:** recommendations specifically aimed at reducing the existing backlog in the creation of digital curb sign records.
- **Recommendations Related to GIS:** recommendations that are specific and related to the overall management of GIS data.

Table 4-1 summarizes the recommendations proposed. The "Interdependencies" column highlights the recommendations that are interdependent on other recommendations, meaning that implementation should be looked at together.

Table 4-1. Summary of Recommendations

Category	No	Recommendation	Challenges Addressed*	Interdependencies*
Organizational Recommendations	R1	Continue Internal (SDOT) Stakeholder Involvement	GC-3, GC-4, GC-7, PC-1	None
	R2	Document Existing Processes and Standard Operating Procedures	GC-3, GC-5, SP-2, SP-3, PC-2	None
	R3	Build a System Responding to SDOT's Needs while also Ensuring Compatibility with Curb Data Specification (CDS)	GC-1, GC-2, GC-3, GC-6, GC-8, SC-1, SC-2	None
System Recommendations	R4	Build a Formal Relationship between Curb Regulations and Curb Spaces	GC-1, GC-2, GC-3, GC-6, GC-7, SC-1, SC-3, SC-5	R5, R8, R14, R15
	R5	Standardizing and Structuring Curb Policy Information	GC-1, GC-2, SP-1, SP3	R4
	R6	Batch Changes	GC-3, GC-4, GC-5	None
	R7	Aim for a Flexible Asset Management System	GC-3, GC-4, GC-7, SC-1, SC-2, SC-3	None
	R8	Store Curb Spaces as a Stand-Alone Table in the Asset Management Software	GC-1, GC-2, SC-2	R4, R5, R14
Recommendations to Reduce Digital Curb Sign Backlog	R9	Assign Priorities to the Backlog	GC-5, GC-7, SC-3	None
	R10	Reduce Steps for the Update/Creation of Curb Sign Records	GC-5, GC-7, SC-3	R5
	R11	Assign Curb Sign Creation Responsibilities to Curbside Management	GC-5, GC-7, SC-3	R10
	R12	Implement Mobile Sign Creation by Field Crews	GC-5, GC-7, SC-3, SC-4	None
Recommendations Related to GIS	R13	Aim for an Adaptive Database for LRS Data Management	SC-2, SC-3, SC4	R8,
	R14	Standardize Curb Space Numbering System	GC-1, GC-2, GC-7, SC-2,	R4, R8
	R15	Integrate Clearance Segments	SC-5	R4, R8, R14
	R16	Consider Alternatives to the LRS System	G-7, SC-4	R8

*GC means General Challenge, SC means Specific Challenge, PC means Potential Challenge, and R means Recommendation.

Source: Analysis by Cambridge Systematics.

4.1 Organizational Recommendations

4.1.1 *Recommendation 1: Continue Internal (SDOT) Stakeholder Involvement*

During various interviews and working sessions, it was expressed that the existing system was built without a holistic view of the different workflows (including the most efficient ways to perform some of these workflows). It was also expressed that the current system (in particular, the asset management system) requires significant resources for small modifications. Third, over time what had been an internal asset system is now seen as valuable data for external purposes – providing data to push certain City transportation and curb management goals. This is not a challenge that is unique to SDOT, as multiple agencies have seen their systems and procedures being built by varying initiatives from different departments, often in isolation. Although this recommendation does not address the current situation, it looks into the future by recommending to strengthen SDOT's current practice: continue internal stakeholder involvement when changes are implemented. This can provide different perspectives and workflows to avoid blind spots where certain procedures could be omitted in future implementations. Moreover, this can reduce additional changes once a system is implemented, avoiding significant resources spent on system modifications. Therefore, it is recommended that SDOT continues implementing and sustaining involvement of multiple departments when making changes to current systems and procedures.

4.1.2 *Recommendation 2: Document Existing Processes and Standard Operating Procedures*

The existing processes to manage the digital curb sign and curb space data require multiple steps that rely on individual knowledge. It is recommended that the Curbside Management team formalizes a process to document the procedures in a systematic way. In the long term, this effort can be aligned with SDOT's data governance efforts to define roles, outline responsibilities, and document processes.

This recommendation can have different levels. This recommendation includes identifying common steps of the processes that are not documented but are still critical. For example, identify the different common scenarios where curb space numbering is created. Then, annually or biannually, SDOT can establish a process to document (or update existing documentation). Examples of this could include: asking the Curbside Engineering team to record videos outlining the process and creating a library, creating a formal role and responsibility definition that is integrated with other SDOT departments, or the Curbside Management team developing guides that formalize workflows.

This recommendation could help to capture individual staff knowledge on different day-to-day activities (e.g., curved curbs, odd clearance rules, etc.) and prevent institutional knowledge loss in case of sudden departures. It can also help when implementing new systems, as documented procedures can be handed over to other departments and to showcase the Curbside Management team's need. This recommendation is also aligned with SDOT's broader data governance plan.

4.1.3 *Recommendation 3: Build a System Responding to SDOT's Needs while also Ensuring Compatibility with Curb Data Specification (CDS)*

Across the US, multiple cities are participating in the Curb Data Specification (CDS) initiative, which entails the development of an open-source data structure for sharing curb space data. There are many aspects of CDS that could be useful for SDOT, such as the principle of moving from analog, static management of curb

spaces to dynamic digital management. There are additional principles such as inventory APIs, a structure for recording parking events, and a unified platform for data exchange, that could progress the maturity of the curbside management program.

It is recommended that SDOT continues participating in the development of CDS, and incorporate data structures that can ease SDOT's ability to translate curbside data into a CDS format processes. It is also recommended that SDOT build a crosswalk that allows SDOT to share data in CDS format for use by external parties. In that way, SDOT will retain flexibility of developing data structure changes that respond and are specific to SDOT's needs while at the same time maintaining the ability to translate data into CDS when needed.

4.2 System Recommendations

4.2.1 Recommendation 4: Build a Formal Relationship between Curbside Regulations and Curbside Spaces

This recommendation addresses challenges that the Curbside Management team identified as critical. Although these challenges have different perspectives, the overall challenge can be summarized as a lack of a formal, established link between curbside signs, curbside spaces, and curbside regulations, which limits the Curbside Management team's capability to perform advanced analysis. Previous efforts to establish a link have involved multiple steps, are inefficient, difficult to implement in the long term, and have a high margin of error.

This recommendation consists of changing the data structure to establish a direct data relationship between curbside spaces and curbside regulations. The following subsections provide additional details regarding this challenge and the proposed recommendations.

Existing Data Structure Description

The current data structure has two areas that can be improved: Entity mixing and the presence of unstructured relationships.

Entity Mixing

One of the challenges identified in the current schema is the presence of multiple dimensions of information within a single table. Specifically, the Street Signs table from Seattle's Data Open Portal contains attributes that are applicable to signs *and* to curbside regulations, resulting in a structure that blends distinct conceptual entities. This design may introduce ambiguity in data interpretation, hinder normalization, and create challenges in querying, maintaining, and scaling the database. Ideally, attributes belonging to different logical classes should be separated into distinct tables, with appropriate relationships defined to preserve data integrity and clarity. For example, fields such as FACING indicate the direction the sign is facing, while fields such as TEXT, which are in an unstructured format, usually contain information about the type of curbside regulation is associated with the sign. Therefore, it is necessary to identify which fields should be defined at the sign level and which fields could be defined at the regulation level. A preliminary identification of such fields is summarized in Table 4-2. Moreover, the current structure does not allow the database to properly store and manage situations where a sign includes more than one curbside regulation. Currently, this additional information overloads fields, such as TEXT, by including sizable information within a single field.

Table 4-2. Breakdown of SDOT Street Signs Table Columns by Functionality

Role of the Fields	Field
Primary and Foreign Keys	OBJECTID, COMPKEY, COMPTYPE, SEGKEY, INTKEY, ELMNTKEY, SUPPORTKEY, SUPPORTID
Location Information	DISTANCE, WIDTH
Sign Attributes	UNITID, UNITTYPE, , UNITDESC, FACING, SUPPORT, SUPPORTDESCR, COLOR1, SIGNSZ, REFLECTIVEYN, CUSTOM, SIDE, OWNERSHIP, CURRENT_STATUS, CONDITION, ADDDTM, MODDTM, INSTDATE, EXPDATE, PRIMARYDISTRICTCD, SECONDARYDISTRICTCD, OVERRIDEYN, OVERRIDECOMMENT
Regulation Attributes	SIGNTYPE, CATEGORY, CATEGORYDESCR, FIELDNOTES, STARTDAY, ENDDAY, STARTTIME, ENDTIME, TEXT
GIS Shape Attributes	SHAPE_LNG, SHAPE_LAT, Shape

Note: Based on the ArcGIS Metadata Form. Names of the columns could be different in INFOR.

Source: Analysis by Cambridge Systematics.

It is important to note the entity mixing issue does not seem to be present for other sign types in the SDOT Street Signs table. For example, street name signs do not tend to use the fields identified as “Regulation Attributes” (Table 4-2) avoiding blending distinct entities within the table. This finding suggests that the current structure of the SDOT Street Signs table may be working for signs that do not have additional curb regulations.

The entity mixing issue is present on the SDOT Curb Space Categories table as well but to a smaller degree. Only one field was identified that could be defined at the regulation level: TIME_LIMIT.

Presence of Unstructured Relationships

As curb signs and curb regulations blend in the Street Sign table, the only way to connect the curb spaces to curb regulations is through the curb signs. The existing process creates that crosswalk link using the FIELDNOTES field. For the Curbside Management team, the FIELDNOTES field has become almost as a foreign key that contains the curb space numbers that are related to the curb signs. It can also include information such as length of the segments and similar attributes of the spaces. However, based on the ArcGIS Metadata Form document, the FIELDNOTES had a different original purpose: *“Additional information about sign location or configuration.”* Moreover, the data contained in the FIELDNOTES is unstructured, meaning that although a user could use educated assumptions to understand the content, it is very difficult to query due to inconsistencies in how data are entered. Table 4-3 presents some examples of how the FIELDNOTES field is being used.

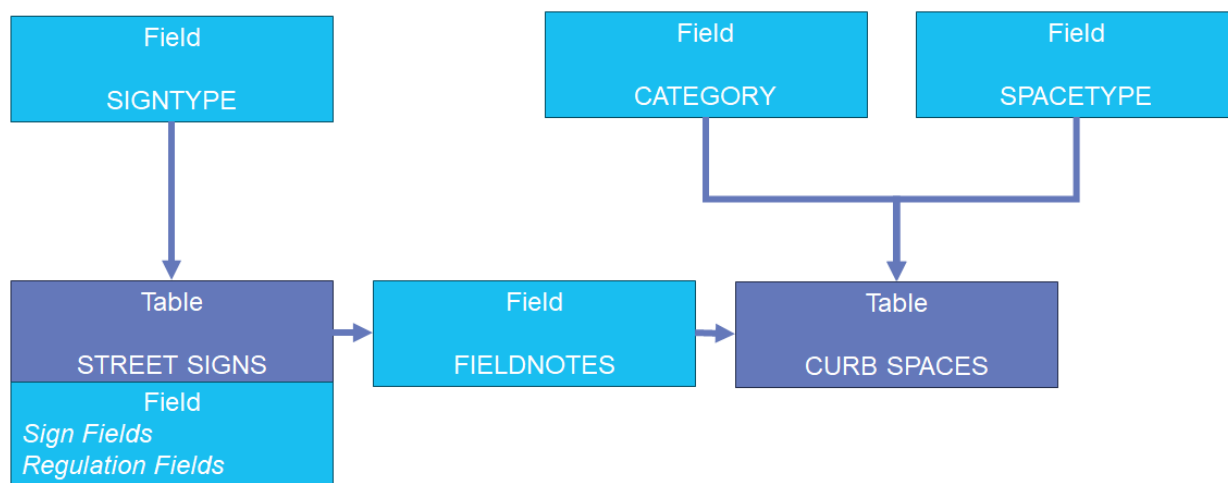
Table 4-3. Data Examples of FIELDNOTES

FIELDNOTES Data Examples	Interpretation
18'-04	18 feet of length, curb space number 4
-22/24	Curb space numbers 22 and 24
-13 #2311	Curb space number 13, "#2311" meaning is unknown
22' -30	22 feet of length, curb space number 30 (note the text space difference compared with the first example in this table)

Source: Analysis by Cambridge Systematics.

Summary of Existing Data Structure Challenges

Figure 4-1 summarizes the key components of existing data structure for the purpose of this analysis. In summary, the existing data structure increases the complexity to establish a link between curb spaces and curb regulations.

Figure 4-1. Diagram of Existing Data Structure

Source: Analysis by Cambridge Systematics.

Recommendations

Ideally, curb regulations should be defined in their own table and not be defined at the sign level. This is because the data needs for curb regulations and curb signs, differ. Completely new regulations aren't frequently introduced although there are numerous slightly different versions of a common regulation (time or days in effect) and could be listed in a small database. On the other hand, multiple signs could have the same regulations, multiple regulations, and must reflect changes to said regulations in addition to other sign features.

Creating a curb regulation table allows the data structure to create a relationship between curb regulations-curb spaces and curb regulations-curb signs. This will allow a smoother flow of data and could help to reference fields/information from regulations that maybe are not present or relevant for curb signs but can be used for analyzing curb spaces.

Curb Regulation Table Definition

This subsection presents a preliminary visualization of what a new curb regulation table could look like. This table would have fields from both the existing curb sign and curb space tables that were identified as potential regulation fields. Moreover, the table should follow the principles of database normalization³.

One critical field that needs to be defined for the curb regulation table is the attribute that defines the type of regulation (for example, no parking, paid parking, commercial vehicle load zone, etc.). Based on the existing fields in the database, this field can be collected from CATEGORY or SPACETYPE. However, these fields seem to have different definitions and are not completely compatible. It is recommended that the Curbside Management team define the differences between the two fields mentioned and assess whether the table needs a new field or may use one of the existing fields.

It is acknowledged that curb signs and curb spaces could have more than one regulation. This is addressed through the type of join defined (explained in the next subsection). For the purposes of the new curb regulation table, it is important to define only one type of category per record and avoid defining multiple variations in regulations. For example, if the only difference between two regulations is the start and end time, they still need to be reflected as two separate entries.

Table 4-4 presents the potential columns that could be included in the new curb regulation table.

³ Microsoft (2025). *Description of the database normalization basics*. Retrieved from <https://learn.microsoft.com/en-us/troubleshoot/microsoft-365-apps/access/database-normalization-description>

Table 4-4. Preliminary Curb Regulation Table

Field	Description	Format	Existing or New Field?	Example
REGULATION_ID	Unique identifier for each regulation row (primary key for the regulation row)	Long, 6	New	000100
Type of regulation (CATEGORY or SPACETYPE or new field)	ID that links to the definition of regulation type	Text, 10	Existing or new	PPL
Description of type of regulation	Describes the ID that links the regulation with the type of regulation	Text, 255	Existing or new	3 Minute Passenger Load Zone
STARTDAY	Start day of regulation	Text, 1	Existing	Sunday – 1, Saturday -7
ENDDAY	End day of regulation	Text, 1	Existing	Sunday – 1, Saturday -7
STARTTIME	Start time for regulation	Text, 4	Existing, consider to change to Time format	700
ENDTIME	End time for regulation	Text,4	Existing, consider to change to Time format	1800
HOLIDAY_EXCEPTION	Indicates if the regulation has an exception for holidays (including Sundays)	Boolean (True/False)	New	TRUE
TIME_LIMIT	Parking time limit value	Text, 10	Existing, consider to change to number	3
Phone No	Contact number appearing on the sign	Text,20	New	206-684-5444

Source: Analysis by Cambridge Systematics.

There are multiple advantages to creating a new regulation table:

- Easier relationship building between curb spaces and curb signs
- Regulations could be standardized and normalized without the need of altering the street sign table, isolating changes to curb regulations from changes to sign-related information
- Allows the possibility of adding new columns in the future without altering the existing signs table
- The process of creating curb signs could be simplified as some of the fields (such as FIELDNOTES and TEXT) could be left empty and/or used for their original, intended purpose
- This proposal is more aligned with the principles of CDS.

The downside of implementation of this alternative is the significant modifications needed to the existing data structure, and confirmation whether within INFOR this is even possible.

Linking Curb Regulations, Curb Spaces, and Curb Signs

It is recommended that both relationships (curb regulations-curb signs, and curb regulations-curb spaces) be established as a many-to-many relationship. A many-to-many relationship in a database occurs when multiple records in one table are associated with multiple records in another table. In this case, one regulation can be applied to multiple signs and multiple spaces and, at the same time, a sign or a space can be associated to multiple regulations. This type of relationship cannot be directly implemented in relational databases, so it is typically managed using a junction table that holds foreign keys referencing the primary keys of the related tables.

A junction table is a table used to manage a many-to-many relationship between two other tables. It contains foreign keys that reference the primary keys of the related tables. This allows multiple records in one table to be associated with multiple records in another table. Table 4-5 presents an example of a junction table for curb regulations and curb spaces. This table shows two cases. The first two rows are the case where one curb regulation ("1") is related to multiple curb spaces ("100-12" and "100-14"). The last two rows represent the case where one curb space ("100-16") is related to two curb regulations ("2" and "3"). A similar table can be built to represent the relationship between curb regulations and curb signs.

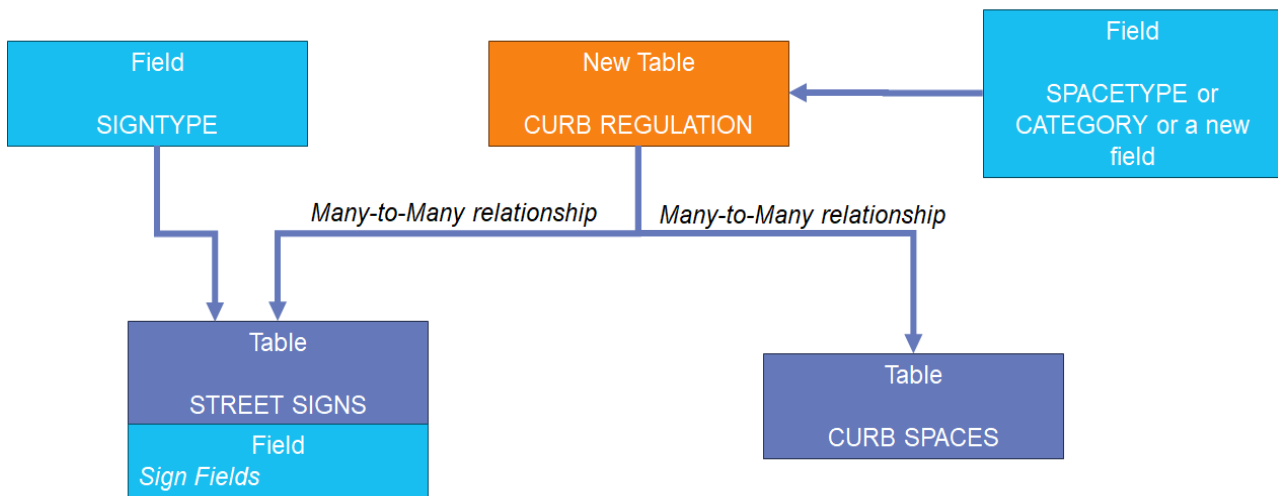
Table 4-5. Example of a Junction Table for Curb Regulations and Curb Spaces

CURB_REGULATION_ID	CURBSPACE_ID (segment + curb space number)	Explanation
1	100-12	This is the case where the same regulation is related to multiple curb spaces
1	100-14	
2	100-16	This is the case where the same curb space is related to multiple curb regulations
3	100-16	

Source: Analysis by Cambridge Systematics.

The final structure of the window for the users will depend on the capabilities of the asset management software. In general, a junction table looks like an additional table (input table) where each record of one of the tables (for example, curb spaces) can link to one or multiple curb regulations.

Figure 4-2 presents the diagram with the overall structure being proposed in this recommendation.

Figure 4-2. Diagram of the Proposed Data Structure

Source: Analysis by Cambridge Systematics.

4.2.2 Recommendation 5: Standardizing and Structuring Curb Policy Information

This recommendation addresses challenges that the Curbside Management team identified as critical. The overall challenge can be summarized as the presence of non-structured regulation information captured by various fields in the curb sign asset data. It is recommended to transition from free-text regulatory entries (e.g., “No Parking 8–10 AM Mon–Fri”) to a structured, normalized data format. Regulation attributes such as restriction type, time window, day of week, duration, and applicability should be stored as discrete fields within the database. This structured approach will enable more accurate translation of complex curb regulations into GIS layers and support automated queries for planning and enforcement.

This recommendation will require updating the data schema by creating dedicated fields for frequently stored elements. However, when implementing this recommendation, it is necessary to coordinate the actions resulting from **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**, because the final structure may affect attributes that should be defined at the curb sign level. For example, if there is a new asset class that captures the regulations, some information such as STARTDAY and ENDDAY can be captured by the regulation and would not need to be part of the curb sign.

As a short-term action, it is suggested to conduct a pilot test in a sample area using normalized regulatory fields, comparing the effectiveness and accuracy of this approach against the current text-based storage method. Table 4-6 summarizes the changes proposed to the Street Sign table, showing the new fields that would allow a better relationship to curb spaces and the process to include more than one regulation for the same sign. It is important to highlight that Table 4-6 assumes the regulation information is kept at the curb sign level, meaning that **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces** is not implemented. Another assumption is that each curb sign contains at most four regulations.

Table 4-6. Changes Proposed to the Street Sign table

Field	Description	Existing or New?	Format	Example
STARTING_CURBSPACE	Starting curb space number where the sign is applicable	New	Long, 3	20
ENDING_CURBSPACE	Ending curb space number where the sign is applicable	New	Long, 3	22
REGULATION_LENGTH	Length of the segment where the sign is applicable	New	Long, 4	81
STARTDAY_1 through 4	Start day of the week when the regulation is active	Existing but adding additional fields (for example, STARTDAY_1, STARTDAY_2, etc.)	Text, 1	Sunday – 1, Saturday -7
ENDDAY_1 through 4	End day of the week when the regulation is active	Existing but adding additional fields (for example, ENDDAY_1, ENDDAY_2, etc.)	Text, 1	Sunday – 1, Saturday -7
STARTTIME_1 through 4	Start time of regulation	Existing but adding additional fields (for example, STARTTIME_1, STARTTIME_2, etc.)	Text, 4 (consider using hourly format)	0800
ENDTIME_1 through 4	Start time of regulation	Existing but adding additional fields (for example, ENDTIME_1, ENDTIME_2, etc.)	Text, 4 (consider using hourly format)	1700
TEXT_1 through 4	Text displayed on the sign	Existing but adding additional fields (for example, TEXT_1, TEXT_2, etc.)	Text, 255	NO PARKING ANYTIME
TIME_LIMIT_1 through 4	Parking time limit value	Existing in Curb Space table. Adding additional fields (for example, TIME_LIMIT_1, TIME_LIMIT_2, etc.)	Text, 10 (consider changing to Long, 3)	3
HOLIDAY_EXCEPTION 1 through 4	Indicates if the regulation has an exception for holidays (includes Sundays)	New	Boolean (True/False)	TRUE

Source: Analysis by Cambridge Systematics.

The advantage of this recommendation is that it is modifying one table and preserving the overall existing structure. In theory, implementing this recommendation will require a lower level of effort compared to implementing **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**. This recommendation could be a temporary solution (for example, if there is a new asset management software solution in 2-4 years, and this alternative is implemented as an intermediate step).

However, this alternative is not recommended in the long term because it fundamentally does not solve the challenges of entity mixing (curb signs and curb regulations will continue in the same table). Moreover, the digital curb sign creation process will increase in complexity as there will be additional fields to be completed. Another disadvantage is that this alternative is changing the data structure of the Street Sign, affecting the table that also has records for other street signs besides the curb signs.

4.2.3 Recommendation 6: Batch Changes

It is recommended that the Curbside Management team institutionalize a process where proposed changes to the existing asset management system are batched to reduce the cost of implementing those changes. This recommendation is aimed to mitigate the challenges associated with an asset management software that is costly to customize/change over time. The main challenge is that, at the time of deployment, it is difficult to identify all the workflows needed or the most efficient way to perform them. Moreover, even if all the present needs are attended at implementation, it is difficult to anticipate future needs, especially in the context of new, disruptive transportation technologies that could alter the use of curb spaces.

This recommendation involves making sure that the Curbside Management team has an active role with the annual or biannual assessment of new needs/improvements to the asset system, and account for a budget for such implementations. This also involves defining a time frame for receiving recommendations, assessing the recommendations and prioritize according to the team's goal, and coordinating with SDOT's Asset Management team to implement changes.

4.2.4 Recommendation 7: Aim for a Flexible Asset Management System

It is recommended that, in the long term, the Curbside Management team advocates for a flexible system to store and manage a curbside asset inventory. This recommendation is aimed at mitigating the challenges associated with an enterprise asset management software that is costly to customize/change over time and not necessarily designed for curb management specifically. Although the decision to select a specific software will not depend exclusively on the Curbside Management team, advocating for a flexible system would enable other teams at SDOT to visualize the dynamic nature of managing curb assets and the need for an adaptable system.

This recommendation has two levels that are explained in detail below:

- **Flexibility to customize fields, tables and windows:** In general, there are software applications that allow you general customizations to the systems without the need of the vendor's intervention. For example:
 - New fields: including defining format, validation rules, and length.
 - New tables: where you can add or remove different fields
 - New windows: customize how the windows look, and which tables and fields could be included
- **Flexibility to push and pull data:** Ideally, a flexible system will be capable of pushing data (export and share data) and pulling data (import and incorporate data) from external systems. This is particularly important as it will allow the team to maximize the best capabilities of different systems. For example, an asset management system could have the best capabilities for budget planning, while an external platform could have the best capabilities for managing the inventory. In this scenario, an ideal system

would allow the team to manage the inventory externally and push the data to the asset management system for subsequent analysis at a relative low effort.

4.2.5 *Recommendation 8: Store Curb Spaces as a Stand-Alone Table in the Asset Management Software*

It is recommended that, in the long term, the Curbside Management team consider storing the digital curb space data independently from street segment assets and in a separate table. This could provide many advantages such as:

- Increased flexibility: To add or edit data structure of the curb spaces without altering segment attributes
- Decreased complexity to establish relationships: Related to **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**, managing curb spaces as a stand-alone asset will make the development of relationships easier
- Easier to query: Curb space data could be foundationally structured making it easier for analysis, visualization, and data translation (including CDS) if it is its own asset class
- Increased trackability: Data updates will be tracked at the curb space level instead of the segment

The development of a new asset class for curb spaces will require some key considerations which are presented below. Although this list is not exhaustive, it provides details that will guide the conversations regarding this recommendation:

- Establish a primary key (ID): It is recommended that all the curb spaces have an ID. This includes curb spaces that typically will not have a curb space number such as paid parking clearance. This way all the curb spaces can be clearly identified and linked to other attributes. The final format and data structure of such ID will depend on **Recommendation 14: Standardize Curb Space Numbering**.
- Relationships: Define relationships with other tables. In the ideal scenario, the key relationship to be established is the regulation-curb space relationship. This will depend on the final structure resulting from **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**. Other important relationships are blocks and streets.
- Location attributes: Define location information such as LRS references (beginning point, offsets, etc.).
- Attributes and formats: Define the attributes of the spaces like curb space type (SPACETYPE), length (SPACELENGTH), etc. This also involves defining formats (data type, length).
- Automated fields (calculated): Assess the feasibility to automate or calculate some of the fields.
- Validation rules: Assess the feasibility of applying validation rules to data inputs. This will avoid wrong data entries that could affect data integrity. Some examples include dropdown menus and error messages when the values are not appropriate.
- Windows: Identify the most common fields being updated and/or reviewed and create a window that will help the user navigate through the process of update/creation of records.

- Scalability: Avoid hard coding values.

4.3 Recommendations to Reduce Digital Curb Sign Backlog

4.3.1 Recommendation 9: Assign Priorities to the Backlog

It is recommended that the Curbside Management team coordinates with the Traffic Data and Records team to define priorities for the creation of digital curb sign records. This recommendation is to mitigate the challenges associated with a long backlog between curb sign installation and the creation of curb sign records in the asset management system.

There are two objectives for this recommendation. First, a clear, agreed priority list for curb signs could increase efficiency of limited resources, attending the needs that are more critical. For example, curb signs related to ADA compliance or paid parking could have a higher priority than unrestricted parking signs. Although there is currently an informal priority process where a curbside engineer reaches directly to the Traffic Data and Records team for priority signs, a clear priority list will reduce these ad hoc requests. Second, a priority list will enable the team to document reasonable times to create/update curb sign records, and if some categories are taking additional time, this could serve as evidence for potentially asking for more resources.

4.3.2 Recommendation 10: Reduce Steps for the Update/Creation of Curb Sign Records

It is recommended that the Curbside Management team, in coordination with the Traffic Data and Records team and the Asset Management team, considers an in-depth review of the process for update/creation of curb sign records. The objective is to identify areas where the process can be simplified (for example, define required fields, optional fields, fields that could be automated, etc.) in order to reduce the time needed to update/create a curb sign record. This recommendation needs to be considered along with **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces** and **Recommendation 5: Standardizing and Structuring Curb Policy** Information, as the final data structure could alter the fields that can be simplified. For example, if there is a new asset class storing the regulations, there would be less fields required in the curb sign (such as STARTDAY and ENDDAY), simplifying the curb sign update process.

4.3.3 Recommendation 11: Assign Curb Sign Creation Responsibilities to Curbside Management

It is recommended that, in the long term, the Curbside Management team and other SDOT departments assess the feasibility of shifting the responsibility of curb sign creation/update from the Traffic Data and Records team to the Curbside Management team. This recommendation involves coordination to ensure that proper definition of responsibilities is performed (to avoid overlaps) and that enough resources are provided to perform the new function.

It is acknowledged that the Traffic Data and Records team is managing, creating, and updating the sign records for SDOT, and that curb sign records are a subset of all the sign records. Therefore, any shift in responsibility needs to be clearly defined to include curb signs only. The reasoning behind this recommendation is that, currently, curb signs are the link connecting curb regulations and curb spaces.

Moreover, the Curbside Management team is already owning the process to update curb spaces, creating an opportunity for an integration of curb sign and curb space updates.

An important aspect of this recommendation is that it needs to be aligned with **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces** and **Recommendation 5: Standardizing and Structuring Curb Policy** Information, as the curb sign backlog could be less impactful depending on the final data structure implemented. For example, if as a result of other recommendations, the data structure is changed to enable curb spaces a direct connection with curb regulations, further analysis of curb space designation could be done without the need of reducing the curb sign backlog.

4.3.4 Recommendation 12: Implement Mobile Sign Creation by Field Crews

It is recommended that, in the long term, the Curbside Management team and other SDOT departments assess the feasibility of shifting the responsibility of curb sign creation/update from the Traffic Data and Records team to field crews that install the signs. This will be applicable only to curb signs that are installed by SDOT field crews, as curb signs that are part of larger construction projects performed by external contractors would still need to be created/updated by SDOT separately.

The goal of this recommendation is to reduce the backlog of curb sign creation/update by allowing field crews to create/update the records as curb signs are installed. This recommendation depends on the final database structure from **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces** and **Recommendation 5: Standardizing and Structuring Curb Policy** Information as it could impact how many fields would need to be added by the field crews. For example, if there is a new asset class that contains the curb space regulations, the curb sign fields could be reduced and focus on attributes related to the sign (for example, location, pole ID, facing direction, etc.). In this scenario, it will be easier to shift the responsibility of curb sign record update/creation to crew fields.

Some key considerations include:

- Feasibility of the asset management system (or the system that has the curb sign inventory) to have mobile compatibility
- Build a crosswalk from a latitude and longitude system to the LRS, to allow crews use the device location information for georeferencing
- Devices to be purchased, who will be the users, training of staff
- Data protocols and validations to avoid systematic errors for data inputs

4.4 Recommendations Related to GIS

4.4.1 Recommendation 13: Aim for an Adaptive Database for LRS Data Management

It is recommended to implement an adaptive, intelligent database architecture for LRS (Linear Referencing System) data management. This would allow dynamic boundary adjustment capabilities, enabling the system to automatically recalibrate LRS start/end point in response to user edits, thereby maintaining spatial and attribute data integrity. The main objective behind this recommendation is to reduce the number of manual editing that occurs any time there are changes to the curb space geometry. For example, if the user is editing

the length of a curb space, it would automatically adjust the boundary of the contiguous curb space segments, or alert the user if an edit would violate a rule (e.g., a space length is smaller than the minimum requirements).

An ideal system should also support in-system data editing to streamline workflows and reduce dependency on external tools. This means that all the calculations can be completed within the same software (e.g., the asset management software) without the need of external platforms to visualize the data.

As a short-term action, it is suggested to evaluate existing practices within SDOT's pavement management group, particularly their methodologies for handling LRS boundary modifications. It may be possible to mimic their approaches for implementing LRS and is an opportunity to identify applicable strategies and design requirements of an adaptive database.

4.4.2 Recommendation 14: Standardize Curb Space Numbering

It is recommended to establish a standardized, automated, unique identification system for numbering curb spaces. Each curb space should be assigned a consistent, unique identifier that is applied across field surveys, regulatory records, asset inventories, and GIS layers. A standardized numbering convention will ensure that curb assets can be reliably referenced, updated, and integrated with LRS workflows while also being useful for analyses, reserving spaces, and API uses. This recommendation also includes investigating different alternatives for number curb spaces, from existing rules (consecutive odd or even numbers, starting at 1 or 2, respectively), random ID generation, references 'fixed' characteristics (e.g., roadway ID, direction, etc), or something in between (human-readable IDs for SDOT staff and public-facing uses such as space reservation, and more complex IDs for the database).

This recommendation is related to **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**, and **Recommendation 8: Store Curb Spaces as a Stand-Alone Table in the Asset Management Software**. If either of these recommendations are implemented, the final data structure needs to consider the best strategy to automatically generate curb space numbering.

As a short-term action, it is suggested to define the existing criteria for when to assign curb space numbering. For example, what does not get assigned curb space numbers, is there a specific threshold, how many segments do not have curb space numbers, how often do un-numbered spaces receive numbering and vice versa? This documentation can provide guidance on curb space numbering rules and processes.

4.4.3 Recommendation 15: Integrate Clearance Segments

While clearance segments are useful for the engineers to define safe curb space distances, they are not relevant for planning purposes and require post-processing cleanup for subsequent analyses. It is recommended, instead of creating separate records / segments for clearances, segments should be directly incorporated into curb space records.

This recommendation depends on the final data structure being implemented for **Recommendation 4: Build a Formal Relationship between Curb Regulations and Curb Spaces**, **Recommendation 8: Store Curb Spaces as a Stand-Alone Table in the Asset Management Software**, and **Recommendation 14: Standardize Curb Space Numbering**. However, a possible general approach is to link / blend clearance segments to the same regulation(s) as the adjacent curb space (assuming the curb space has regulation(s)). For example, if a clearance segment is defined between two paid parking spaces, the curb space type can

be defined as “Clearance” and, at the same time, link the segment with the same regulation(s) of the contiguous paid parking spaces. This alternative will still enable the engineers to visualize the clearance segment while also enabling analysis of the clearance space as part of the segments related to the regulation.

4.4.4 Recommendation 16: Consider Alternatives to LRS

The current process for managing curb space and sign data utilizes an LRS process, indicating when a space starts and ends along a roadway. However, it is recommended to consider alternatives to LRS with the goal of easier data management, analysis, and helping address the listed challenges.

One option is to generate pre-split, segmented curb space geometry, such as a segment every one foot or five feet. Then, the database managers only need to edit the attribute table of the small segments to indicate the space type, regulations, and other key information. There would be no need to further measure/edit the polylines. However, this would likely result in a very large dataset and would take effort to set up. Additionally, any analysis would need to conduct pre-processing by merging ‘like’ adjacent segments. There is also a possibility that the split, one-foot increments may not satisfy all use-cases.

Another alternative to LRS is using absolute locations / geographic coordinates by having the curb spaces and signs be spatial features with latitude and longitude information. This would result in a dataset ready and easy to visualize and analyze. It would also have the benefit of housing both the spatial information and associated asset data in one location. However, care and attention are needed on how to edit the dataset when a curb space is expanded / compressed. It runs the risk of generating overlapping segments or gaps and editing polyline vertices is prone to human error. Because of the precise nature of this dataset, additional care is needed to ensure the correct projection is used when updating and utilizing the dataset.

5.0 Conclusions

This project looked at the workflows and processes for the management of digital curb sign and curb space data. The main takeaways of this study are the following:

- The Curbside Management team has multiple strengths, particularly those related to existing staff. As described in previous sections, strong motivation and proficient staff have been key to sustaining the current operations.
- The overall data process has challenges, especially in the early steps. Data record creation and updates of curb signs and curb spaces face operational and system challenges that are interconnected.
- The recommendations outlined in the current report can provide a general path to the Curbside Management team to make progress toward their desired goals. It is important to note that SDOT should understand the interdependencies among the recommendations in order to prioritize their actions.
- One of the key recommendation for SDOT is to consider scalability and flexibility in its curb data management systems to ensure they can adapt to emerging mobility trends, technologies, and policy changes. In general, in the long term, it is more beneficial to have a flexible system that can adapt than a robust, rigid system that satisfies current requirements but is difficult to adjust to future changes.

Overall, SDOT is facing challenges with its existing processes but is also a front-runner in curb asset management. SDOT is at a crucial moment where it can adapt and enhance the management of digital curb data and serve as a model for other cities across the country.