Sweep Smart Final Report

BCOT Team: Yi Gai, Zhi Li, Anna Waldo, Tobey Yang, Jessie Lyu

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1. Executive Summary

The sweep smart project was initiated with a serious problem being realized -- more than 50% of all the parking violation tickets issued in the city of Oakland are attributed to parking during street sweeping hours in the past several years. More precisely, this translates to around 180,000 parking tickets being issued solely to street sweeping related violations and more than 10 million dollars almost every year in the past years. While street sweeping is essential to keep the city clean, we wanted to understand how the city can minimize the interruption to the community activities while maintaining adequate street sweeping. To answer this question, we first conducted extensive user researches with the Department of Transportation officials, the street sweeping planning team, and the residents of the city of Oakland to understand different perspectives of the street sweeping activity, from planning, to execution and impact. We also did a holistic data analysis using the historical parking ticket data and the street sweeping schedule data to identify the hot spots. Based on the hot spots identified, we conducted a field study and case analysis to understand the key reasons behind the high ticketing volume in these areas.

Based on the insightful research findings through several iterations of hypothesis, design, and feedback, we were able to uncover the primary reasons behind the scene:

- Street sweeping schedules have not been changed for years. While the local community and their activities have evolved over the past years, the obsolete street sweeping schedule does not suit the local communities' needs anymore.
- The street sweeping planning and execution team has been managing the schedule and personnel planning manually on paper. This resulted in the situations where some changes in the execution cannot be efficiently managed and analysed. The changes in schedule often lead to unnecessary ticketing or continuing with obsolete schedules.

- Street sweeping is not an awareness issue. Although the residents are very aware of the street sweeping schedules in their neighborhood, they are not aware of the channels to raise their concerns about the unreasonable schedules.

With these challenges in mind, we conducted a few design iterations by employing design thinking methodologies and developed the below solutions:

- Route Optimization - based on hot spots identified through a comprehensive analysis of the historical ticket and schedule data, we conducted detailed case analysis of the hot spots and presented a detailed and actionable street sweeping optimization plan to the Department of Transportation and the Street Sweeping Management team. Further details on the optimization plan can be found in section 3 of this report.
- Sweep Smart Application - to help digitize and optimize the street sweeping planning activities, we developed a web application for the street sweeping team of the city of Oakland. The design and interactions were finalised after 3 design iterations with the real users. We employed technologies including MariaDB, Flask and React to build the tool. Further details on the application can be found in section 4.
- Public Website sweepsmart.github.io - to help raise the public awareness of the issue, and also to establish more channels for the residents to feedback concerns around street sweeping, we launched the https://sweepsmart.github.io/ website with street sweeping ticket and schedule data visualization and communications to solicit feedback. Details on the design considerations and the technologies used behind the visualization can be found in section 5 of this report.

1.1 Background and Goals

The Sweep Smart project was initiated by five graduate students of the School of Information at UC Berkeley. As a team with skills and interests in data science, software design and development, and a big heart for social justice and good, we wanted to

contribute our capstone project effort to serve people and society by creating technologies that promote social equity and transparency. While we were exploring project ideas, we were connected with the city of Oakland, whose mission was to promote community engagement, mitigate harm and revert historical equity. With this alignment in our missions, we quickly identified the problem space where the team's expertise can be leveraged and practiced.

Although the parking ticket violations have generated millions of dollars of revenue to the Department of Transportation of the city of Oakland, the city officials were genuinely concerned about the situation where a considerable amount of street sweeping cannot be completed properly due to the violating cars. The city was also at the time considering implementing GIS based technologies to track locations and completion rate of the brooms. Therefore, we agreed on the project goal to really understand the key pain points behind such high street sweeping ticket volume, so that we could facilitate the city activities to minimize interruptions to the city communities and at the same time improve the city's operational efficiency to better serve the residents.

1.2 Roles And Responsibilities

The team consists of five team members: Yi Gai, Zhi Li, Jessie Lyu, Anna Waldo and Tobey Yang (ordered alphabetically by last name).

Yi Gai is the initiator and the product manager of the project. Yi oversees the project strategy, direction, communications with the clients, planning, project deliverables, prioritization and timeline. Yi leads the team scrum meetings and the team collaborative efforts. Yi was a major contributor in user research and feature design. Yi contributed extensively to the system design and database schema design. Yi implemented part of the front-end development of the sweep smart tool (performance page, part of daily schedule view). Yi authored the content and storyline of the public website and implemented the animation in section 2.

Zhi Li is the co-initiator, primary data scientist and full stack engineer of the project. Zhi contributed significant data analysis, ideas and development throughout the research, design and development phases. Zhi was a primary contributor to the route optimization effort with constructive data cleaning, analysis and visualization. Zhi contributed tremendously to the web server and API development, database design and engineering and front-end development of the sweep smart tool (vehicle page and daily schedule view). Zhi helped resolve several major technical roadblocks of the project.

Jessie Lyu is the lead of user research and chief product designer of the project. Jessie oversees the user research activities, including planning, execution and retrospective review. Jessie led the multiple iterations of product design and usability testings. Jessie was also the chief designer of the brand theme, images, and design system. Jessie also initialized the API design and contributed to the front-end development by implementing the weekly schedule page of the sweep smart tool. Jessie was the primary author of the visualization website (page setup, section 1 and connection sections).

Anna Waldo is the tech lead, primary data scientist, backend engineer and database architect of the project. Anna led the data science team for the route optimization analysis and recommendations. Anna oversees the database architecture and engineering to build the database and webserver with the required API capabilities. Anna was the primary data engineer who gathered data requirements and imported the necessary data into the database. Anna was also responsible for implementing the ticket and schedule frequency maps in the visualization website (section 4).

Tobey Yang is the primary data scientist, and full stack engineer of the project. Tobey was a primary contributor to the data analysis, hot spot identification and case study in the route optimization effort. Tobey actively participated in user research and ideation activities to contribute technical perspectives. Tobey contributed extensively to the API

design and implementation. Tobey was also a major contributor to the front-end development who established the app framework and implemented the operator page. Tobey was also the author of section 3 of the visualization website.

2. Research & Design

The research and design processes of this project were composed of three major stages: defining problems, narrowing the scope, and iterating the design. Additionally, we also recruited a group of three students from User Experience Research class (INFO 214) to help us do some more research throughout the whole project development period.

2.1. Define Problems

2.1.1 Meetings with Oakland Department of Transportation (DOT)

To kick off the project, we conducted 3 rounds of needfinding meetings with our client, the Oakland Department of Transportation, to understand their demands for improving public wellbeing by reducing parking violation tickets. DOT has started the project of helping people get fewer tickets since late 2019, and the department has partnered with a few design agencies and consulting firms to research the reasons behind the high number of parking violations, and also to come up with solutions.

During those meetings, we found that DOT already got some qualitative data on the major pain points of parking in the City of Oakland from those agencies and groups, and was considering doing further research to narrow down the solution scope. At the time of the meetings, DOT was partnering with Civil Design Lab (CDL) on doing user research on parking violations in the city and was planning to leverage software technologies to streamline the parking process in the future. The detailed meeting notes and meeting agenda (interview guide) with DOT are attached in the appendix.

We identified the following most high-prioritized demands from our client:

- Build trust between residents and the government.
- Make the work done by the government more transparent to the public.
- Increase residents' awareness of street sweeping parking violation enforcement hours in their neighborhood.
- Reduce the number of tickets for street sweeping parking violations.
- Streamline the street sweeping planning process, make both sweeping and ticketing processes more efficient.
- Propose reasonable recommendations on ticket policy change or street sweeping schedule change.

We were able to summarize four key findings from needfinding meetings with DOT:

- Street sweeping is the main pain point of street parking in Oakland, and it accounts for the most tickets issued annually.
- Even though parking ticket violations contribute the most income to the government, the government believes the wellbeing of the residents is more important than money. So DOT still wants to reduce the number of parking tickets even though it might compromise the government's profit.
- Currently, DOT and Street Sweeping Unit is using an old-style paper-based method to manually plan for street sweeping and ticket issuing, and there is no efficient way for DOT and SSU to communicate about ad-hoc changes or updates with each other.
- DOT is aware that the street sweeping time might not align with residents' activities, and schedule changes might be needed.

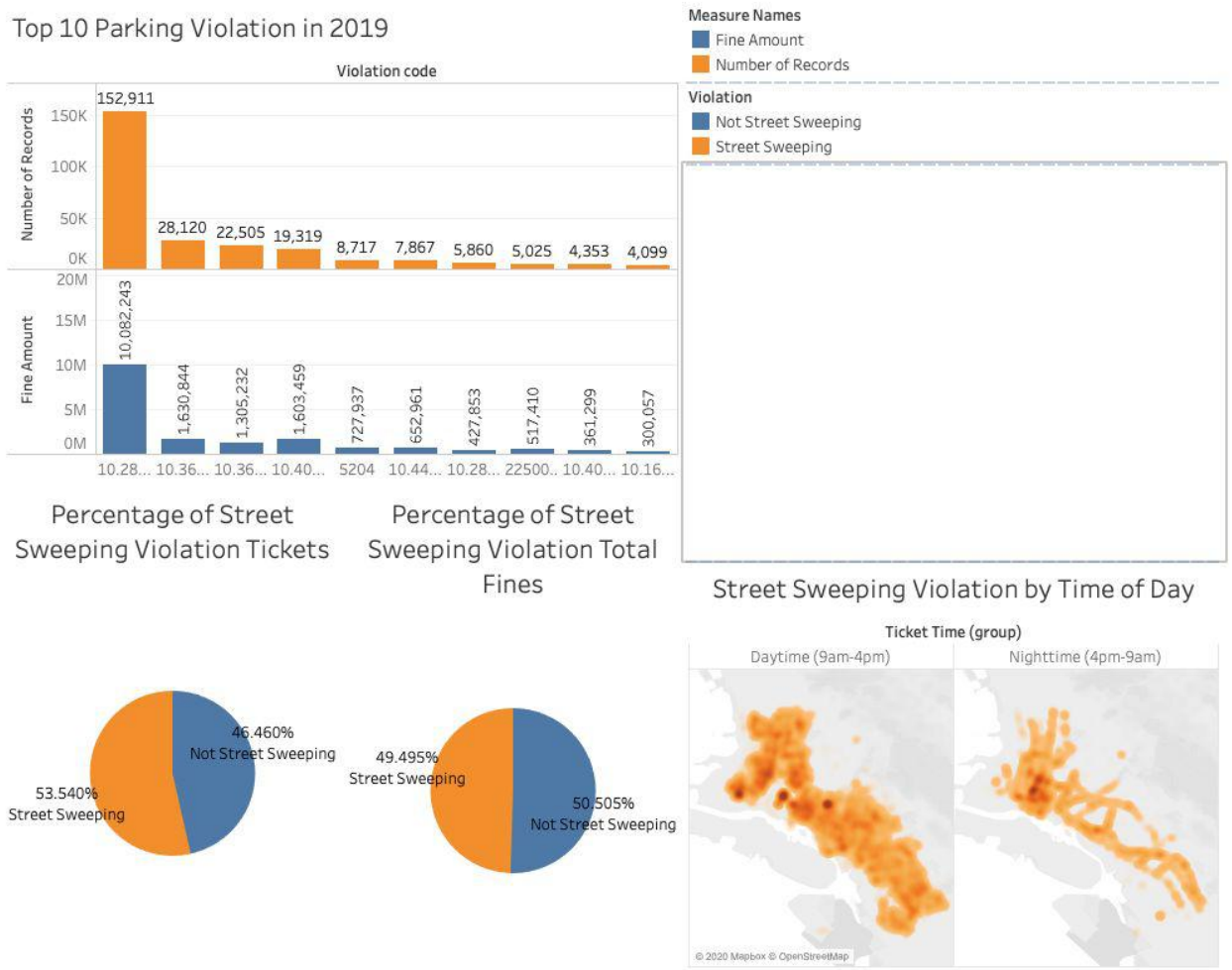
2.1.2. Quantitative Research on Violation Tickets

From needfinding meetings, we learned that the government does have a large amount of data about parking violations, but lacked the technology to analyze them. To better

understand the problems, we performed data analysis on parking violation tickets data for the past few years to observe the parking tickets distribution and trends for Oakland.

From EDA using ticket data for the past few years, we got a more solid understanding of the problems supported by quantitative analysis results:

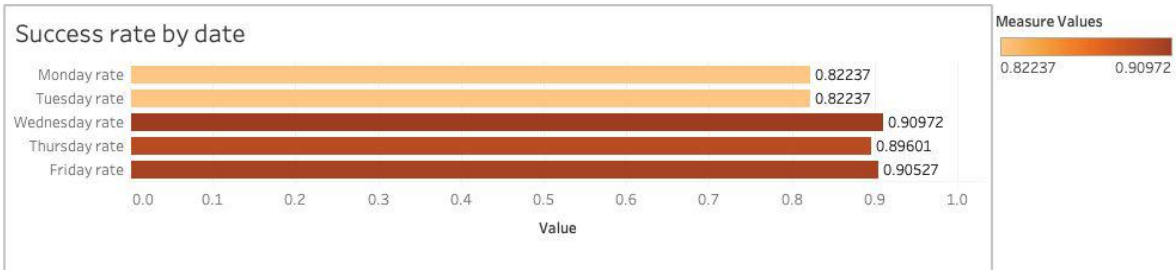
- Street sweeping accounted for 57% of all parking violations in 2019, contributed >$10M in revenue (confirmed the finding from meetings with DOT).
- Parking violation enforcement could occur anytime during street sweeping hours, and ticketing officers don't work side-by-side with broom vehicles.
- Some locations receive more tickets than other areas.

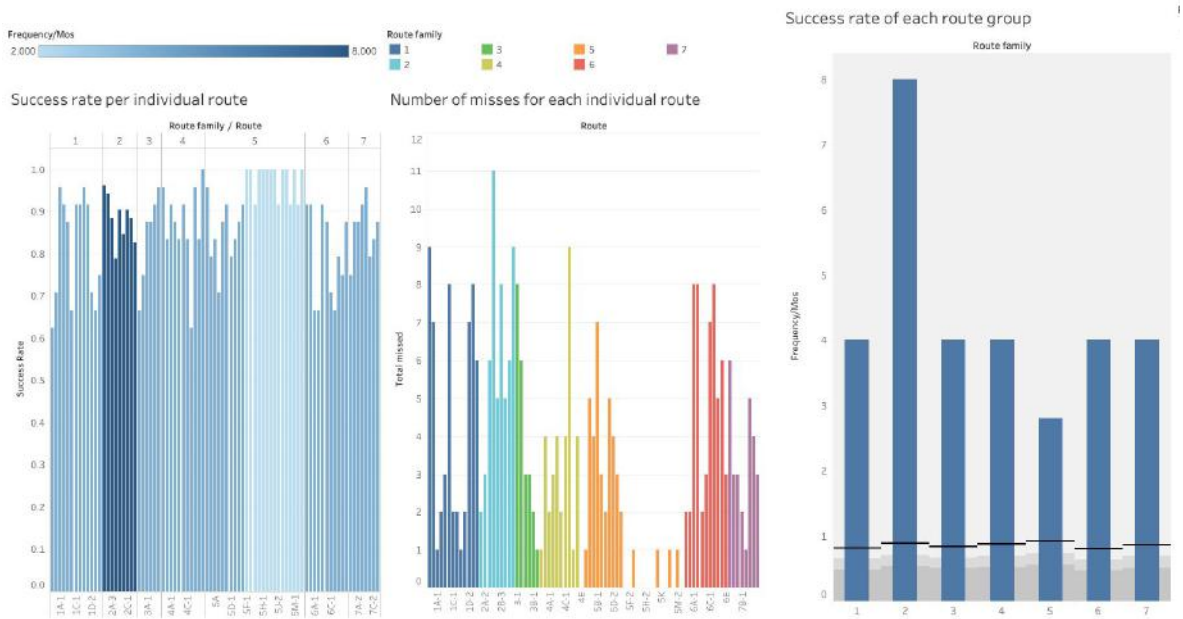


Dashboard created using Tableau

2.1.3. Quantitative Research on Route Completion

We also did quantitative research on route completion status for the first half of the year in 2019. For detailed charts please refer to the appendix.





Route completion analysis

We found that:

- In general, the route completion rates are very high, mostly around 80-90%. However, a few routes have lower completion rates around 60-80%.
- Monday and Tuesday routes have lower completion rates.

Connecting the result of route completion rate and ticket distribution, we found that the results coincide: routes with the most misses have more tickets than other routes, and many of those routes contain streets that are swept more frequently.

2.2 Narrow Project Scope

2.2.1. Quantitative Survey Analysis

The CDL has distributed a survey asking residents' parking experience and parking violation fine paying experience prior to our research, and sourced 435 responses from Oakland residents. The quantitative survey results indicated that:

- More than half of the respondents received at least one parking ticket in the past year.
- The cost of tickets and street sweeping are the two key pain points according to the responded residents (cost of tickets had been mentioned in 19% of the responses, and street sweeping had been mentioned in 16% of the responses[1]).

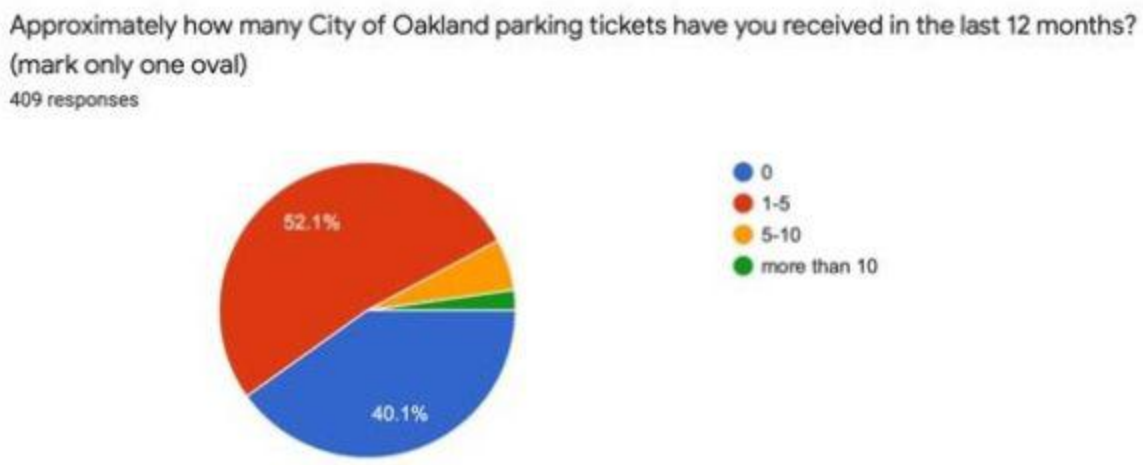


Image resource: CDL

[1] Data source from CDL

The quantitative survey results confirmed our assumption that street sweeping parking violation is one of the major concerns for residents. And the percentage of residents getting parking tickets is very high from the sample.

2.2.2. 1-1 Qualitative Interviews with Consented Respondents

From the quantitative survey, the number of people getting parking violation tickets was higher than we expected. Related to one of the demands from our client that the government wants to make the public better informed about street sweeping hours, we assumed that one of the reasons for getting parking tickets might be that the residents are not aware of the street sweeping enforcement hours. We thought it might be helpful to build a mechanism to notify the residents about upcoming street sweeping schedules.

To better understand the residents' pain points and concerns, we conducted a few 1-1 qualitative interviews with consented respondents from the quantitative survey. The interview guide and scripts are attached in the appendix. The interviews were semi-structured, with open-ended questions. The interview was divided into 5 sections:

- Get the resident's basic demographic and parking information.
- Understand the resident's pain points and difficulties in parking.
- Ask about the resident's feedback about the current street sweeping plan in his/her neighborhood.
- Ask about their opinions in improving parking in the neighborhood.
- Test design ideas and assumptions with the resident.

The interview results were very insightful to us, and some feedback from the interviewees was opposite to our assumptions. Following are some selected feedback and pain points from our interviewees:

- Residents are familiar with the street sweeping schedules in their neighborhood, they park cars during sweeping enforcement hours for inevitable reasons such as falling sick.

- A lot of parking violations come from people not living in the neighborhood. For example, an interviewee living near a hospital area said that there is “never a day the street got swept since there are always cars blocked.” Additionally, for people visiting the neighborhood, they might park their car because there are other cars on the street, which leads to more violation tickets.
- Another reason for getting parking violations is due to limited parking space. According to an interviewee, in her neighborhood there are “27 apartment units with just 5 parking spaces, so people always need to park on the street.”
- Finding alternative parking might also be a major pain point for residents. An interviewee needs to “get up at 6 am to find an alternative spot”. Sometimes people have to make working schedule changes to accommodate for street sweeping, from an interviewee, she needs to “work from home during the two sweeping days of the week to move cars.”
- All of the interviewees complained about unreasonable street sweeping hours, such as sweeping very busy streets during the daytime or sweeping the neighborhood too often.
- Interviewees were also skeptical about parking violation enforcement. They mentioned that abandoned vehicles never get ticketed, while cars with valid license plates always get ticketed, and they think it is unfair.
- The street sweeping signs on the street might be blocked or faded, so visitors might not easily notice the hours.
- Opposite to our assumption, people don’t think a notification mechanism via app or text message will be helpful to them since the sweeping schedules are very stable and rarely changed.

Summarize the key findings from the interviews:

- Street sweeping is not an awareness issue since the schedule always stays the same. So a notification system is less helpful since people are familiar with street sweeping hours in their neighborhood.

- Unreasonable sweeping hours might lead to most of the violation tickets. Schedules might need to be updated to better accommodate people's parking needs.
- It's important to inform the public about the purpose of street sweeping, and the reasons for street sweeping parking violations, to build trust with the residents.

2.2.3. Interviews and Observation Studies with SS Unit

To narrow down the design scope for the Sweep Smart Management Tool, we conducted 3 rounds of interviews and observations with the Street Sweeping Unit (SSU) to understand the current planning and tracking processes. The detailed interview guide, notes, and recording could be found in the appendix. In summary, the working flow for street sweeping are:

- The street sweeping schedule has been the same for many years. The supervisor plans routes to sweep for each day based on a "master" schedule table.
- There are about 20 operators and 15 sweeping vehicles, responsible for sweeping every street in Oakland. Operators are either assigned to the day shift or night shift. For each shift, there are two 4-hour time blocks. Each operator sweeps one map during a time block. The night shift is mostly sweeping commercial districts while the day shift is mostly sweeping residential areas.
- All the maps are paper-based. Operators need to manually read the map to follow the sweeping routes.
- The supervisors make a daily schedule everyday morning on a piece of paper. The daily planning includes: assigning operators and vehicles to the scheduled route, logging weather information.
- At the end of each day, operators need to report working status to the supervisors, such as sweeping completion status, blockers, etc.

Day Shift

Month | Year | % Done

Calculate "# Done" divided by "To Do"

Calculation of percent serviced on schedule this month:

364 Routes MINUS Routes on Holidays EQUALS To Do MINUS # Missed EQUALS # Done

		Routes	1	2	3	4	5	6	7	8	9	10	11
1st Mon	AM	10	7	7A-1	7A-2	7B-1	7B-2	7C-1	7C-2	7D	7E-1	7E-2	
	PM	11	6-1	6-2	6A-1	6A-2	6B-1	6B-2	6C-1	6C-2	6D-1	6D-2	6E
1st Tues	AM	10	7	7A-1	7A-2	7B-1	7B-2	7C-1	7C-2	7D	7E-1	7E-2	
	PM	11	6-1	6-2	6A-1	6A-2	6B-1	6B-2	6C-1	6C-2	6D-1	6D-2	6E
1st Wed	AM	10	5-1	5-2	5A	5B-1	5B-2	5C	5D-1	5D-2	5E-1	5E-2	
	PM	11	4-1	4-2	4A-1	4A-2	4B-1	4B-2	4C-1	4C-2	4D-1	4D-2	4E
1st Thu	AM	10	5-1	5-2	5A	5B-1	5B-2	5C	5D-1	5D-2	5E-1	5E-2	
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
1st Fri	AM	11	4-1	4-2	4A-1	4A-2	4B-1	4B-2	4C-1	4C-2	4D-1	4D-2	4E
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
2nd Mon	AM	10	1-1	1-2	1A-1	1A-2	3-1	3-2	3A-1	3A-2	3B-1	3B-2	
	PM	9	1B-1	1B-2	1C-1	1C-2	1C-3	1D-1	1D-2	1E-1	1E-2		
2nd Tues	AM	10	1-1	1-2	1A-1	1A-2	3-1	3-2	3A-1	3A-2	3B-1	3B-2	
	PM	9	1B-1	1B-2	1C-1	1C-2	1C-3	1D-1	1D-2	1E-1	1E-2		
2nd Wed	AM	8	5J-1	5J-2	5K	5L-1	5L-2	5M-1	5M-2	5N			
	PM	7	5F-1	5F-2	5G-1	5G-2	5H-1	5H-2	5I				
2nd Thu	AM	8	5J-1	5J-2	5K	5L-1	5L-2	5M-1	5M-2	5N			
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
2nd Fri	AM	7	5F-1	5F-2	5G-1	5G-2	5H-1	5H-2	5I				
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
3rd Mon	AM	10	7	7A-1	7A-2	7B-1	7B-2	7C-1	7C-2	7D	7E-1	7E-2	
	PM	11	6-1	6-2	6A-1	6A-2	6B-1	6B-2	6C-1	6C-2	6D-1	6D-2	6E
3rd Tues	AM	10	7	7A-1	7A-2	7B-1	7B-2	7C-1	7C-2	7D	7E-1	7E-2	
	PM	11	6-1	6-2	6A-1	6A-2	6B-1	6B-2	6C-1	6C-2	6D-1	6D-2	6E
3rd Wed	AM	10	5-1	5-2	5A	5B-1	5B-2	5C	5D-1	5D-2	5E-1	5E-2	
	PM	11	4-1	4-2	4A-1	4A-2	4B-1	4B-2	4C-1	4C-2	4D-1	4D-2	4E
3rd Thu	AM	10	5-1	5-2	5A	5B-1	5B-2	5C	5D-1	5D-2	5E-1	5E-2	
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
3rd Fri	AM	11	4-1	4-2	4A-1	4A-2	4B-1	4B-2	4C-1	4C-2	4D-1	4D-2	4E
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
4th Mon	AM	10	1-1	1-2	1A-1	1A-2	3-1	3-2	3A-1	3A-2	3B-1	3B-2	
	PM	9	1B-1	1B-2	1C-1	1C-2	1C-3	1D-1	1D-2	1E-1	1E-2		
4th Tues	AM	10	1-1	1-2	1A-1	1A-2	3-1	3-2	3A-1	3A-2	3B-1	3B-2	
	PM	9	1B-1	1B-2	1C-1	1C-2	1C-3	1D-1	1D-2	1E-1	1E-2		
4th Wed	AM	0											
	PM	0											
4th Thu	AM	0											
	PM	9	2A-1	2A-2	2A-3	2B-1	2B-2	2B-3	2C-1	2C-2	2C-3		
4th Fri	AM	0											

Master schedule for street sweeping

We found the following design opportunities for Sweep Smart Tool:

- Transfer paper-based schedule information to software for easier information reading and retrieval.
- Streamline the planning process by unifying different resources such as operators and vehicles into a single storage location.
- Make the sweeping tracking more efficient by using software to monitor the completion rate, staff absence, equipment breakages, etc. Using data visualization techniques to track route sweeping status and staff working performance.

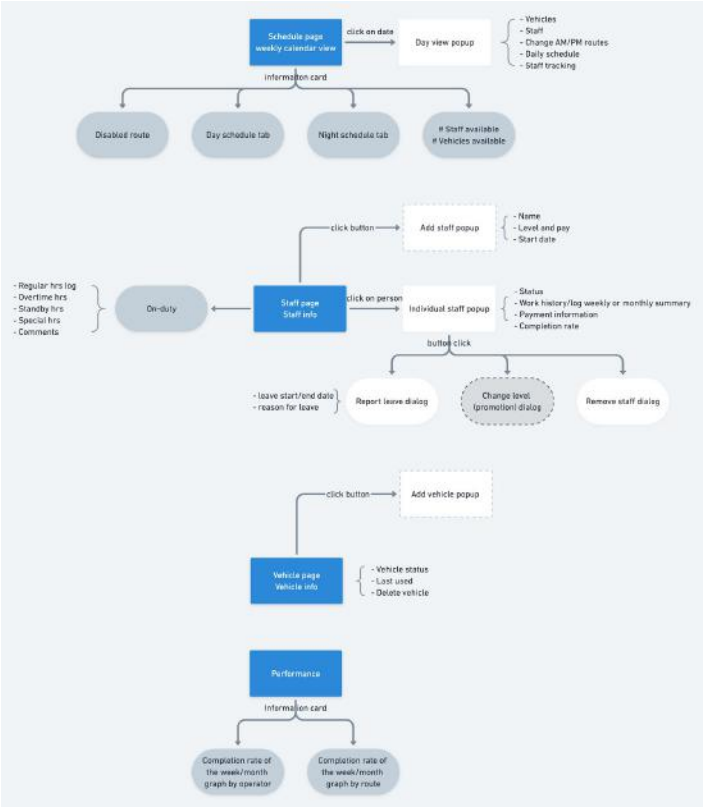
2.3 Iterate The Designs

From earlier research we identified three improvement opportunities for DOT, and two of them are application development:

- Since we found that DOT and SSU are still using paper-based planning methods, we think it will be helpful to build a digital street sweeping management tool (Sweep Smart Tool).
- We also believed that the public needed to be informed about street sweeping and its purposes, to bridge the communication gap, increase transparency, and build trust between the government and the residents.

2.3.1. Design of Sweep Smart App

User Flow Chart



User Flow Chart

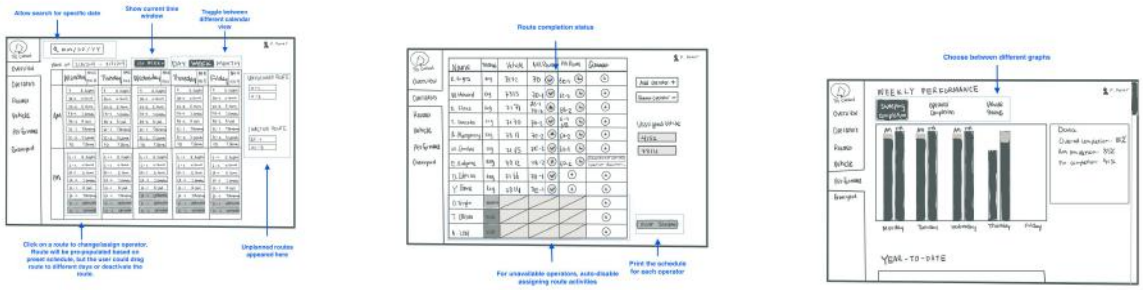
Based on results from interviews and observation studies, we decided to have four major pages for the tool:

- Schedule: manipulate route planning, assign operators and vehicles to routes
- Operators: staff management, working time tracking
- Vehicles: equipment management, working status tracking
- Performance: charts about completion rate, absence etc.

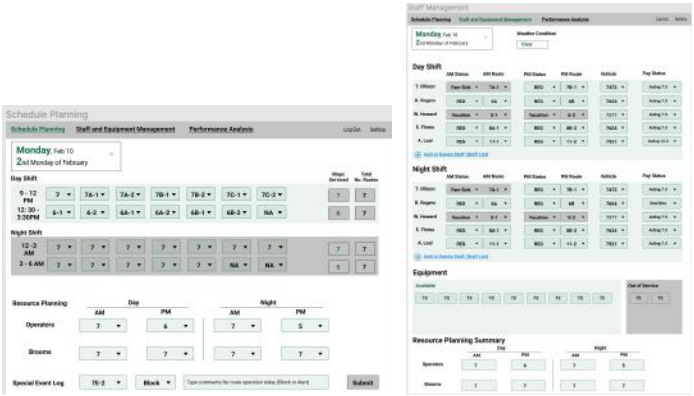
To view the detailed user flow chart, please refer to the appendix.

Low-fidelity sketches

We have two versions of low-fidelity designs. We roughly sketched out the page layout and features, and denoted possible interactions on the side. For low-fidelity design, please refer to the appendix.



Version 1

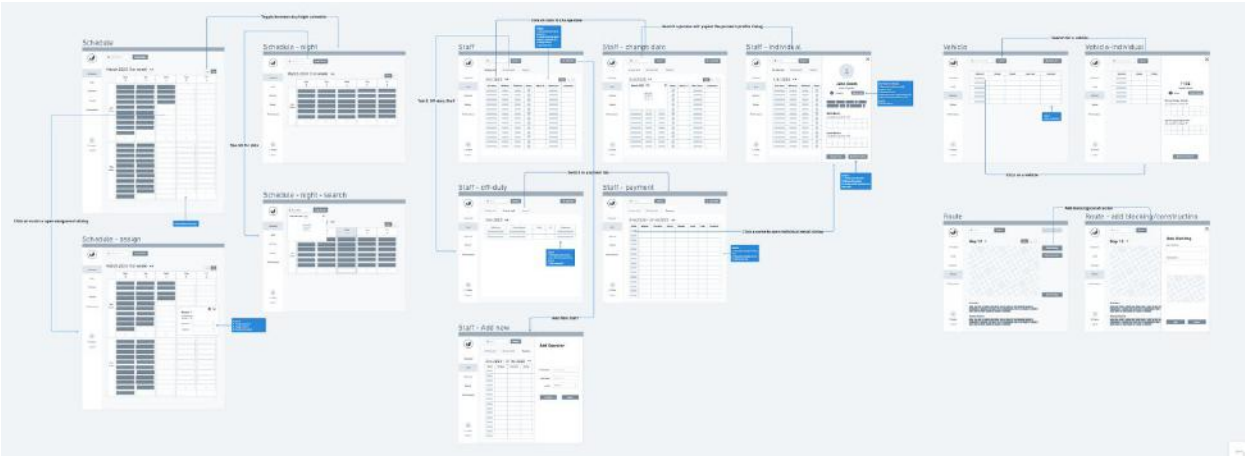


Version 2

We reviewed the initial designs with SSU, and received positive feedback from them. Some key takeaways from the reviews were:

- The interfaces are understandable to the supervisors.
- Making routes as blocks aligning under a calendar is understandable to street sweeping supervisors.
- Supervisors like the performance tab we designed.

Wireframe

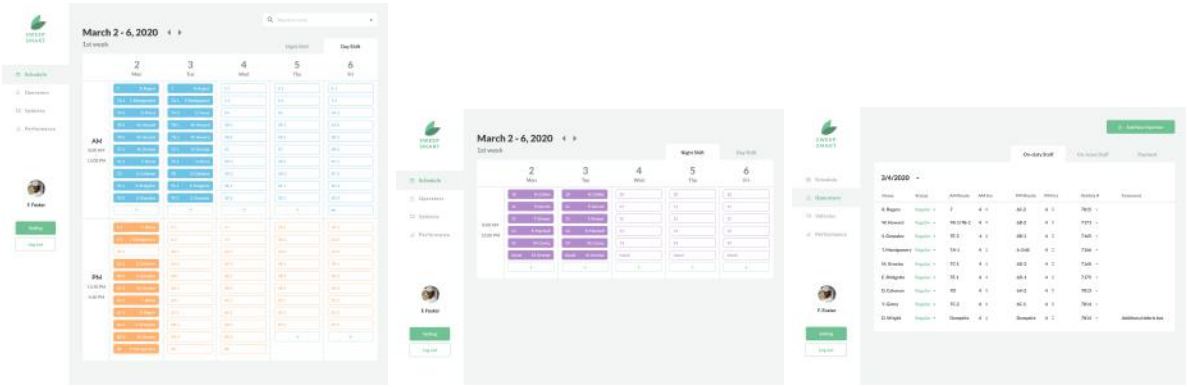


Wireframe Made by Whimsical

We then drew the wireframe graph of the applications with more detailed page layout and interactions. To view the detailed wireframe graph, please refer to the appendix.

Iteration 1

For the first iteration we created three high-fidelity main tab pages using Figma. To see detailed design mockups, please refer to the appendix.



Iteration 1

The color palette we chose was inspired by the mission statement of Street Sweeping Unit: make Oakland clean and healthy. So we chose green as the primary color.

Color palette

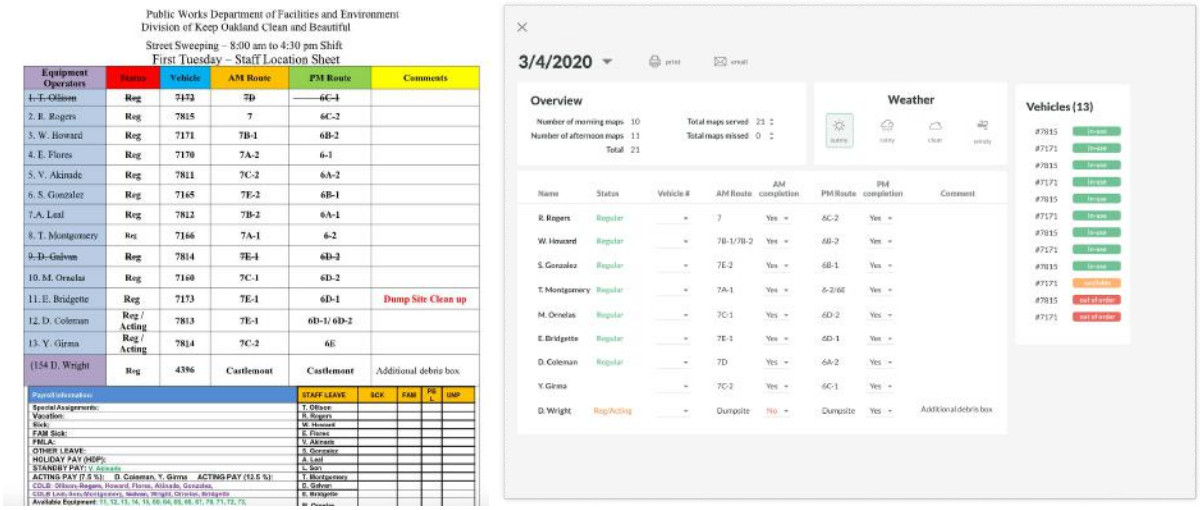
We did an expert review of this design within the team. Some feedback we received among the peers were:

- A daily schedule table with detailed assignment information was needed to simulate the working flow with SSU's current working flow.
- It could be helpful to list resources (on-duty staff and available vehicles) on the schedule page to help supervisors make assignments.
- The route had more status than assigned and unassigned, such as disabled, incompleted, etc. So we need to include more route states.
- This design used too many colors, and some of them didn't match the overall color palette.

Iteration 2

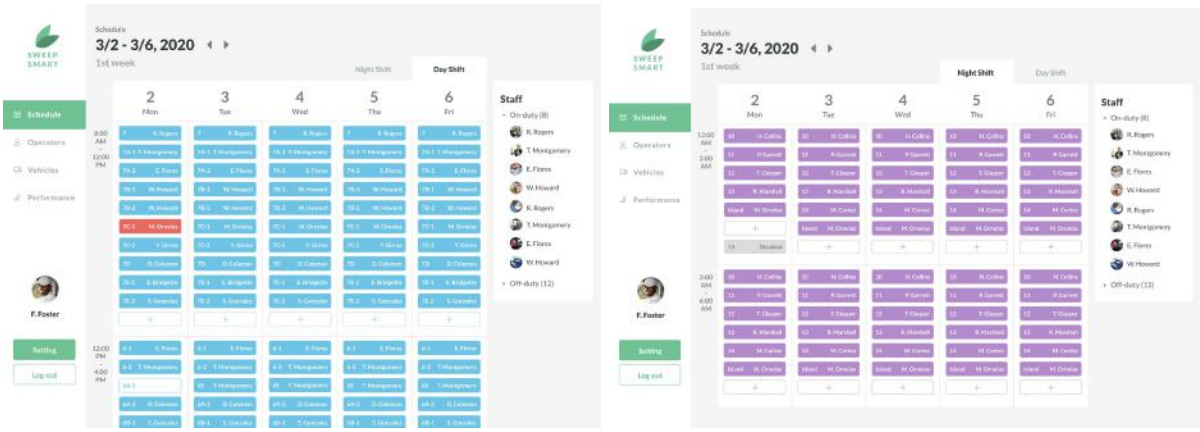
For iteration 2, we mainly addressed the feedback from the team. Some key changes to the design were:

- Designed a daily view page.



Left: Word-based daily schedule table SSU is currently using, right: Digitized design of daily schedule

- Added available staff panel on the schedule page
- Reduce the number of colors used.
- Added more route status, including incompleted, disabled, unassigned, and assigned routes.



Left: day shift view, right: night shift view

We did another round of expert review within the team to solicit feedback from members. Overall we are all very comfortable with the design at the point, however some minor edge cases were missed:

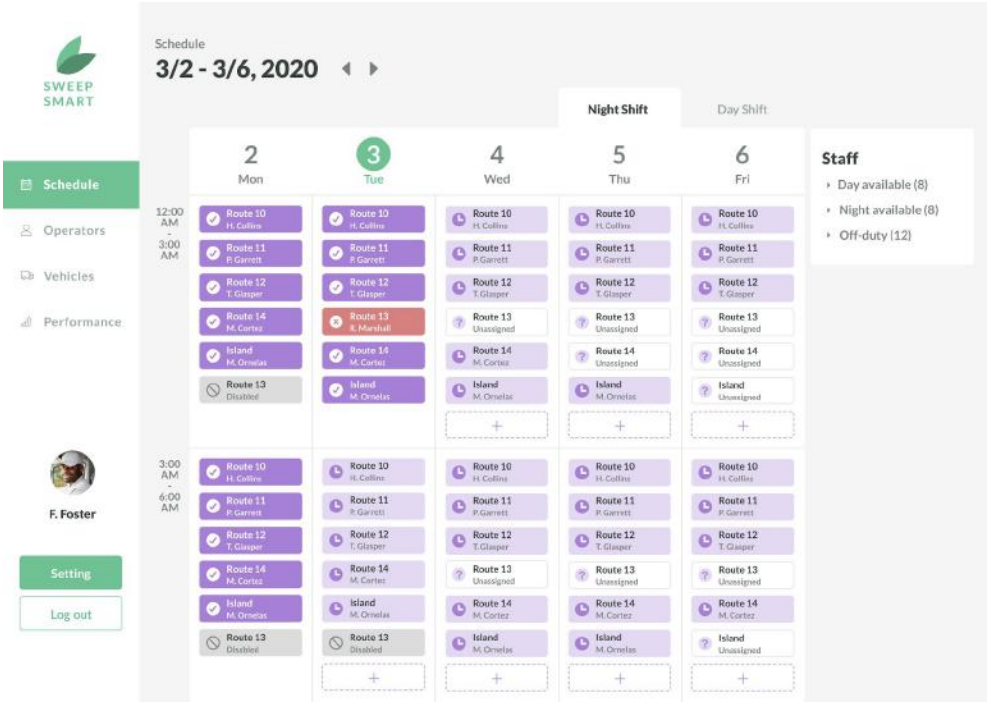
- There were still missing route status, such as scheduled but not completed, scheduled but missed, etc.

- We didn't consider the situation that the operator's name was too long to fit in the block.
- We need to simplify the flow of logging daily completion information, ie. all route completion status logging should happen in one place, while there should be another place to track staff day-offs and absences.

Iteration 3

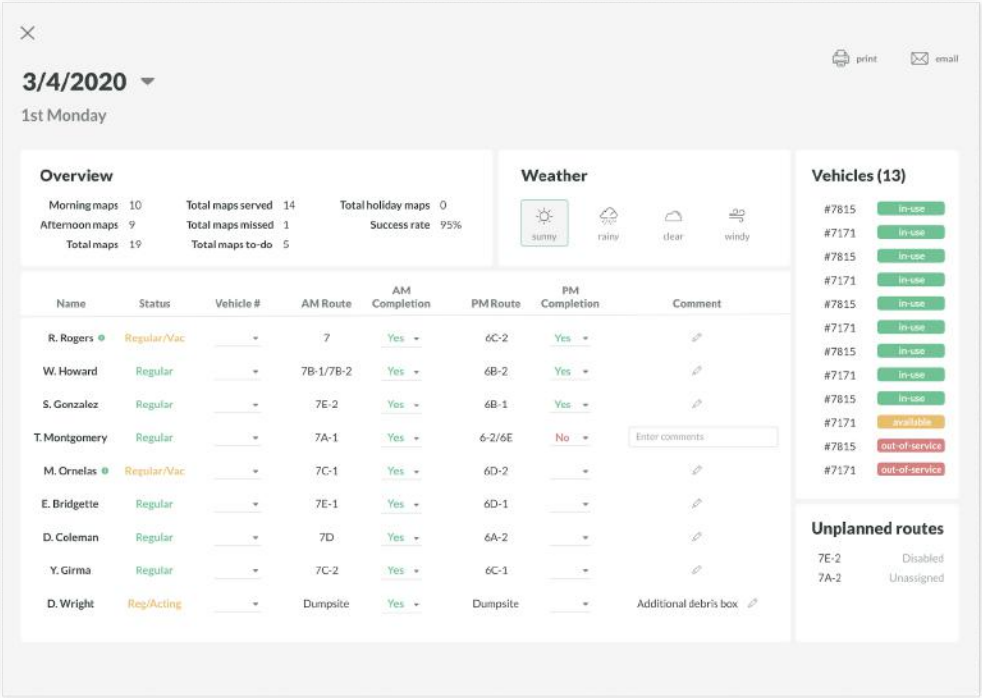
In this version we incorporated all of the edge cases emerged from previous iterations into the design. Major changes were:

- Change the design and layout of each route block to include all possible status.
    - Use color and icon as markers for two status layers.
    - Moved operator name to a new line to address long last names.



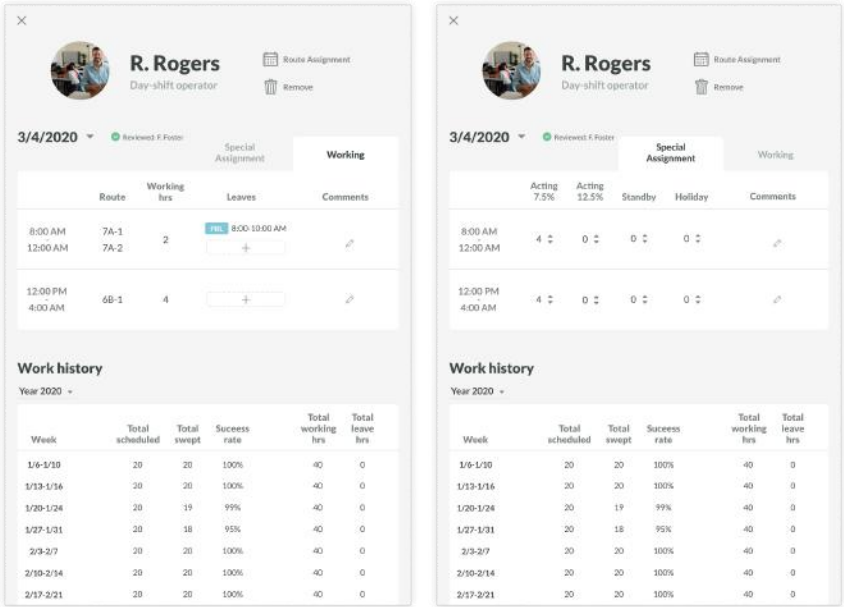
Night shift weekly schedule

- Added route tracking interactions inside the daily schedule page.



Daily schedule page

- Added staff tracking interactions inside individual staff's page.
    - Daily completion status.
    - Absences log.



Individual operator view

For a detailed prototype, please refer to the Figma link in appendix.

Usability testing with SSU

We had our final prototype tested with supervisors in the Street Sweeping Unit. The testing was very successful, and two tested supervisors gave positive feedback to the design.

From the testing, supervisors had minimal troubles understanding the UI, navigating between pages, and figuring out interactive elements. The learning curve for them was lower than we expected. All of them were able to complete tasks and find the information they wanted.

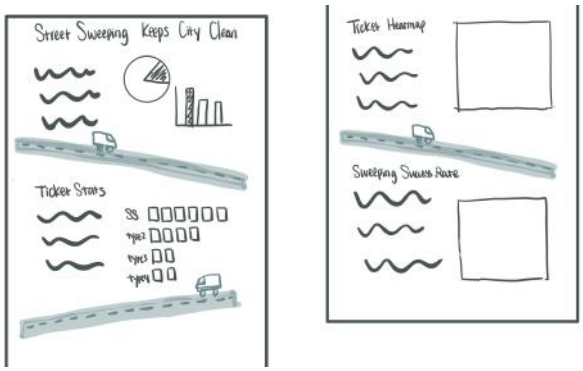
One major design suggestion we received from the testing participants was that the application might be overly complicated. Since we tried to include as many edge cases as possible in the design, we overthought some functions, such as staff absence logging and special assignment assignments. The actual use case is way simpler than we thought. In the final implementation, we took out some redundant features to make a comprehensive yet still simple application for SSU.

2.3.2. Design of Public Website

For the public website, the main goal is to help residents build trust in the government. Breaking down the main goal, here are some sub-goals:

- Inform the public about the work done by the Street Sweeping Unit.
- Explain the reason for the high number of street sweeping parking violations.
- Make street sweeping schedule information across different areas of the city more transparent to residents.
- Let people know the channels for them to communicate with the government.

Sketches

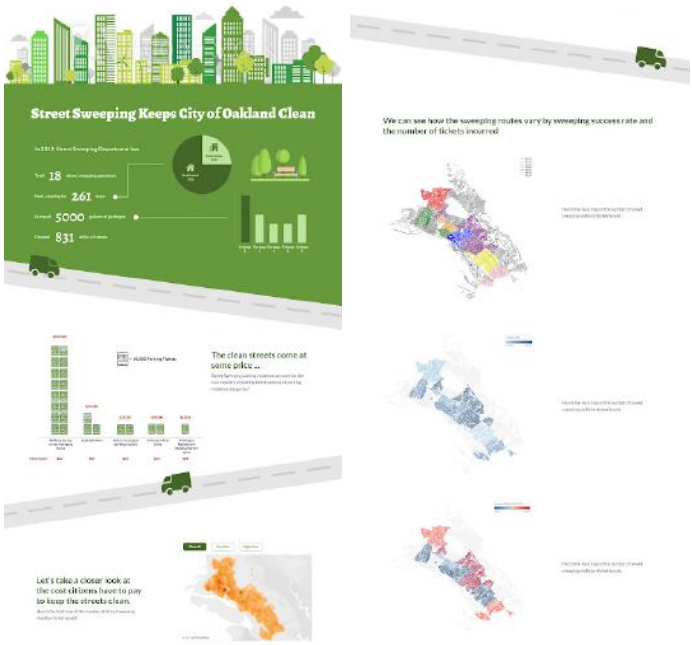


Low-fi sketches

We divided the page into four major sections:

- Overview about street sweeping
- Overview about violation tickets
- Ticket heatmap
- Street sweeping completion rate in relation to ticket density

Iteration 1



Iteration 1 design

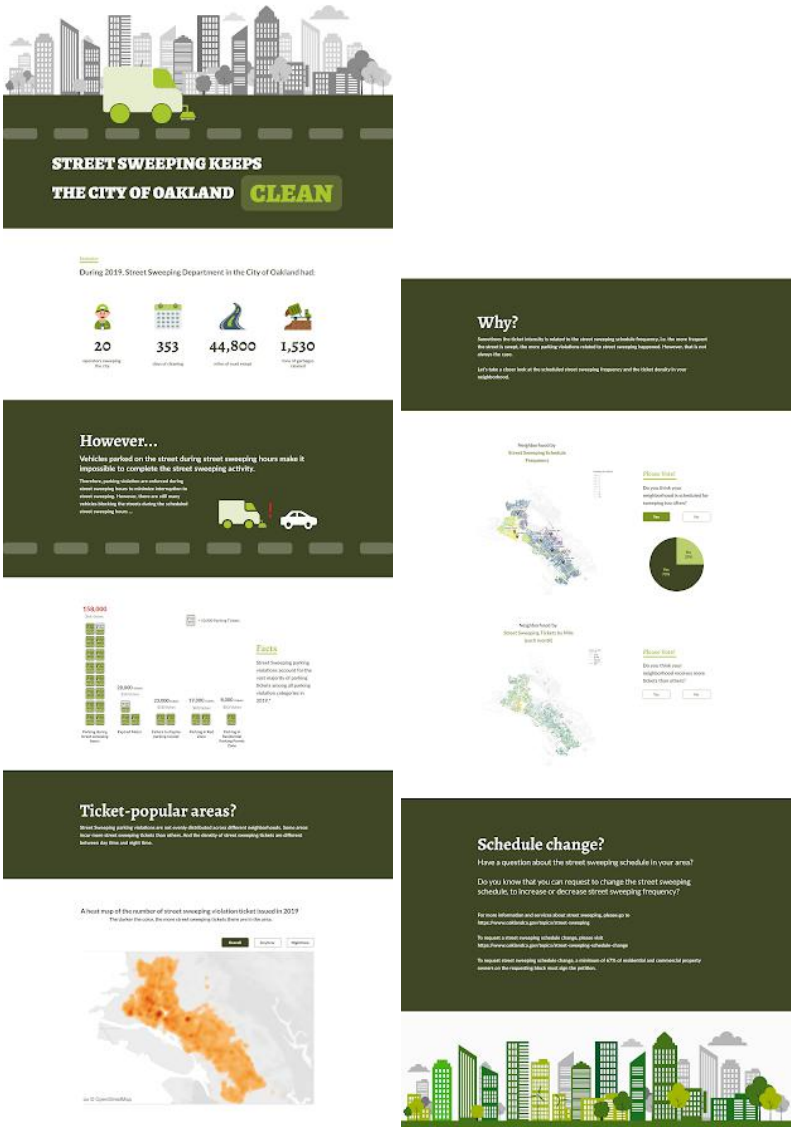
We got the initial version of design reviewed with both Professor Marti Hearst and SSU supervisors. The feedback we collected from them was:

- Some of the data in the first section were not obtainable.
- We lacked transitions between visualizations. The whole page looked like a stack of images without explanation.
- We didn't communicate certain information effectively to the viewers.
- The page was not interactive enough to engage people.

Iteration 2

We made major modifications to address feedback from the previous design:

- Added transition text to connect visualizations, to improve the storytelling of the whole page.
- Changed the design of the first section based on the data we collected.
- Add poll questions to ask for user input.



Iteration 2 design

Usability testing & critiques

We formally conducted usability testing with our stakeholders for this prototype. For the usability testing, we recruited 4 Oakland residents with cars and 3 government officials from DOT and SSU. The key feedback we got from them were:

- Numbers in the first section didn't make sense to many participants since they are not familiar with street sweeping.

- The color palette should match the theme colors of Oakland government website.

We also had this prototype reviewed with Professor Hearst, and the critiques we got from her were:

- The storytelling still needed to be improved, ie. adding a brief introduction at the top about street sweeping work purposes before showing the numbers.
- Some information layout needed to be changed to guide the users' view direction.
- The CTA links in the last section are not obvious.

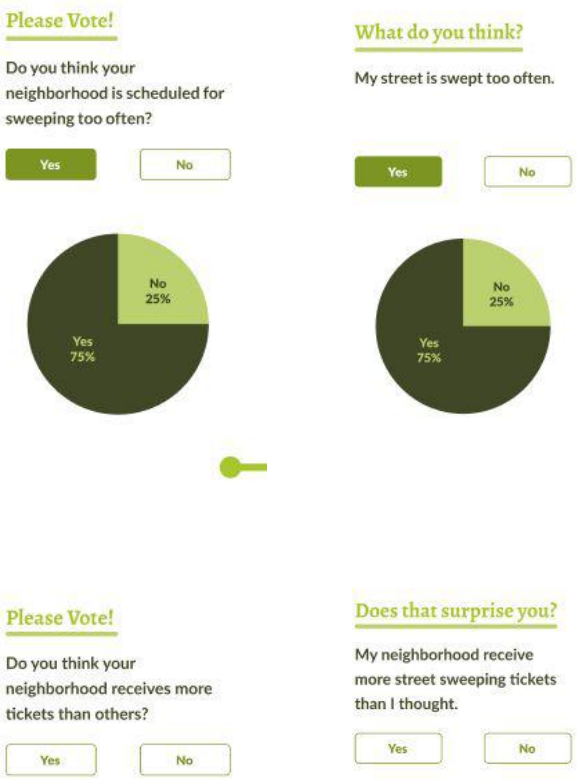
Iteration 3

We made some design changes based on usability testing results and critiques received from Professor Hearst:

- Change the visualization of section 1 (numbers) to make it more understandable to users.

Left: before, right: after

- Make the font size larger.
- Changed some wordings, ie. the question for asking residents to poll.



Left: before, right: after

2.4. Input from Research Team in UXR Class

We recruited a group of three students[2] from User Experience Research Class (INFO 214) to help us conduct more research. The UXR team contributed a lot to our research findings throughout the whole research and design process.

2.4.1. Remote Field Study about SS Signs

Using Google Map Street View and other similar tools, the UXR team helped us identified the issues of street sweeping signages:

- Many signs across the city are faded and completely illegible.
- Some signs are vandalized, blocking street sweeping info from view.
- Some signs are placed at inconvenient positions on the street

[2] Lenor Alcaraz, Everette Woolsoncroft, Sophia Sharif

- Too few signs
- Put at the far end
- Mixed with meter signs, which is confusing

Some signages with unclear information

For a detailed signage report, please refer to the appendix.

2.4.2. Market Research

The UXR team also helped us by doing market research about existing to-government location based management products:

- FleetRoute
- ServiceMax
- Eagle Eye

For a detailed report of market research, please refer to the appendix.

2.4.3. Heuristic Evaluation

The UXR team performed heuristic evaluation to our interactive Sweep Smart Tool prototype, and the major flaw they found was the accessibility issue. They pointed out that some background and text failed the WCAG guideline. However, since we are

designing for very specific target users, we worried less about accessibility. For details, please refer to the appendix.

3. Route Optimization

The goal of our route optimization was to highlight specific areas of Oakland that have a disproportionately high amount of street sweeping violations, and make recommendations for changes that could be implemented by the sweeping department to reduce the number of tickets incurred. This is helpful not only to those who rely on street parking, but also helps the street sweepers complete their routes, as cars parked on streets during the sweeping hours get in the way of the sweepers from cleaning the roads completely. We did not want to make major structural changes to the current sweeping schedules, but rather offer adjustments that should be relatively easy to implement, as to disrupt the current system as little as possible and ensure ease of use.

3.1 Data

Our data was provided to us by the Department of Transportation and Street Sweeping Unit. For our analysis, we focused on the data for the sweeping route schedules and the ticketing history.

Our primary source of data for route information was a csv file containing entries for each section of a street, denoted by an id number, its address range, the street name, the coordinates of the street section, and the route that the section belongs to, along with several other attributes (Fig. 1). The columns ending in _ADD refer to the numerical address that the route spans, with L_ referring to the left side of the street and R_ referring to the right side (the data isn't consistent to whether this refers to the odd or even addresses). The DAY_ and TIME_ columns refer to the days of the week and time of the day the entry is scheduled to be swept. For example, 'T13' in the DAY_ columns refers

to the first and third Tuesday of the month, and M3 in the TIME_ column refers to the 9am-12pm Morning shift. Note that DAY_ODD and DAY_EVEN will refer to different days of the week - this is so that on these days during sweeping hours, people are still able to park on the side of the street that's not being swept.

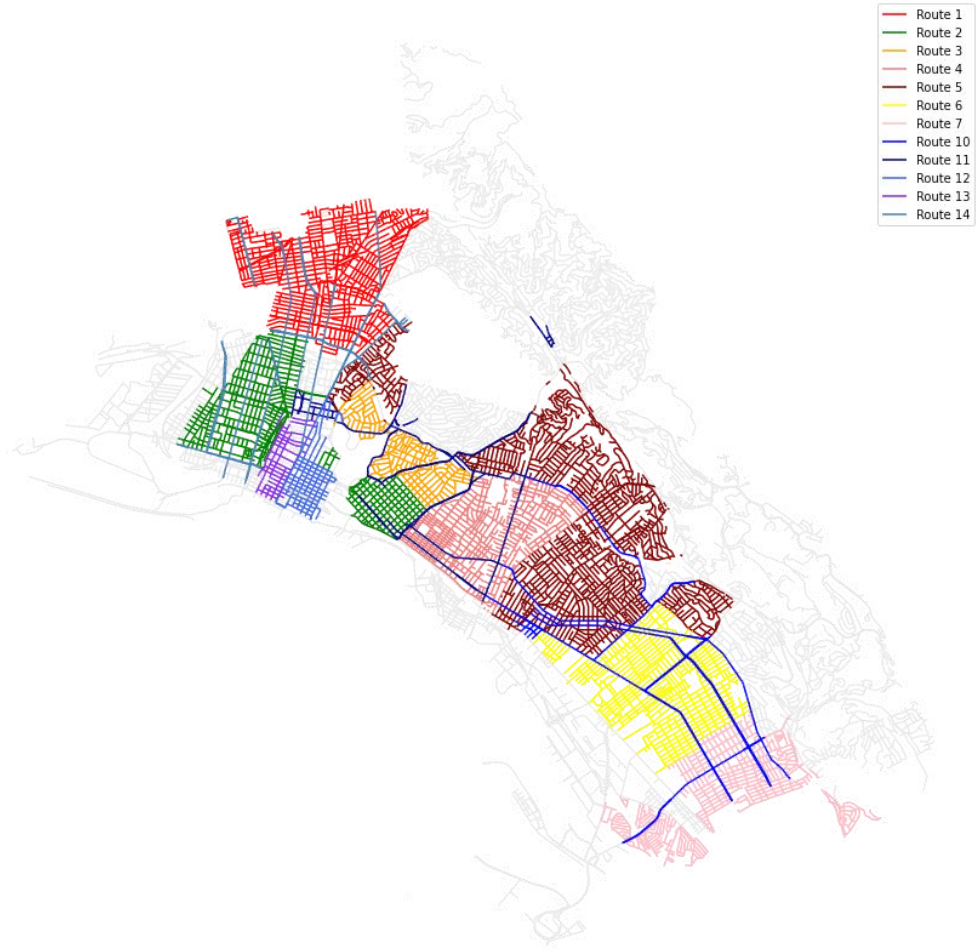
Each entry in this dataset is the most granular level available of our route data, in that each entry is a small section of a street (so that multiple entries may refer to the same street), and furthermore each entry is a smaller section of a route.

We had a separate version of the routes data that contained solely the routes and their scheduled sweeping days and shifts, which we used for the backend database for our website (see section 4).

DYNAMAP_ID	ROUTE	L_F_ADD	L_T_ADD	R_F_ADD	R_T_ADD	DAY_ODD	TIME_ODD	DAY_EVEN	TIME_EVEN	NAME	TYPE
416195184.0	10	9700.0	9798.0	9701.0	9799.0	TTHS	M1	MWF	M1	MacArthur	Blvd
416195215.0	7D	2741.0	2899.0	2740.0	2898.0	T13	M3	M13	M3	Frazier	Ave
416195218.0	7D	10300.0	10498.0	10301.0	10499.0	T13	M3	M13	M3	Shaw	St
416195221.0	7D	2701.0	2739.0	2700.0	2738.0	T13	M3	M13	M3	Frazier	Ave
416195223.0	7E	10200.0	10298.0	10201.0	10299.0	T13	M3	M13	M3	Shaw	St

A sample of the routes data. Note the three middle entries all have a Route of 7D, while the second and fourth entries are both on Frazier Ave. Meanwhile, the third and fifth entries are both on Shaw St, but belong to different routes, as streets can be covered by multiple routes.

In total, there are 91 separate routes being swept in the current schedule. Routes are denoted by a numerical value followed by a string of characters, such as '3A-1' or '7D'. Routes can be grouped in the same categories of routes beginning with the same number. Routes that begin with a number of a single digit are routes swept during the day time, while routes beginning with a two-digit number are night shifts. Figure 2 shows how the routes are organized throughout the city. Note that certain route categories cover a much greater area than others. Downtown Oakland for example is made up of mostly smaller routes.



Distribution of routes, grouped by their numeric category.

For our sweeping citation data, we obtained ticketing data from January 2012 to October 2019. Citation data includes the unique ticket id, the date and time the ticket was issued, the address where the citation was issued, and other attributes. For our preliminary analysis, we primarily focused on data from 2018 and 2019, as we wanted to focus on the most recent trends in ticketing data. Additionally, the file formats were not consistent between each year or month, and for convenience we mainly wanted to use files that were of approximately the same format and contained similar data. We also had to take care to properly clean the data; street names from the addresses attribute for example tended to switch between notations, such as specifying 'Blvd' versus 'Boulevard' within the same

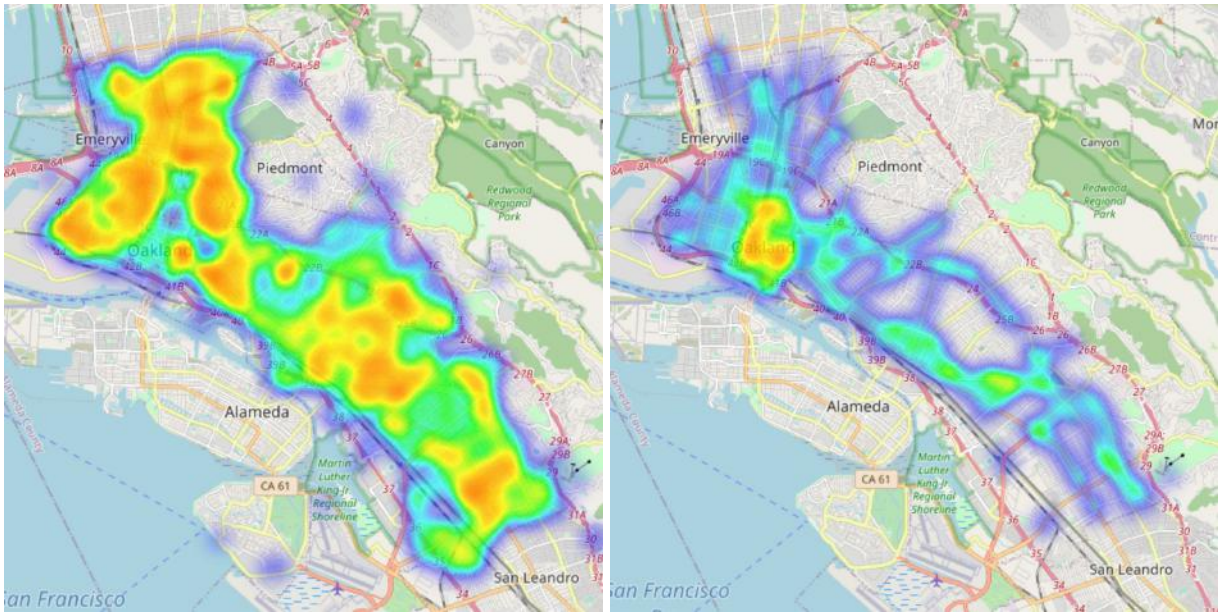
file. We had more than enough data to work with (October 2019's data for example had 17218 street sweeping ticket entries alone), and so we did not have a strong need to use seven years worth of ticketing data.

3.2 Analysis of ticket distributions

3.2.1 EDA and Focus

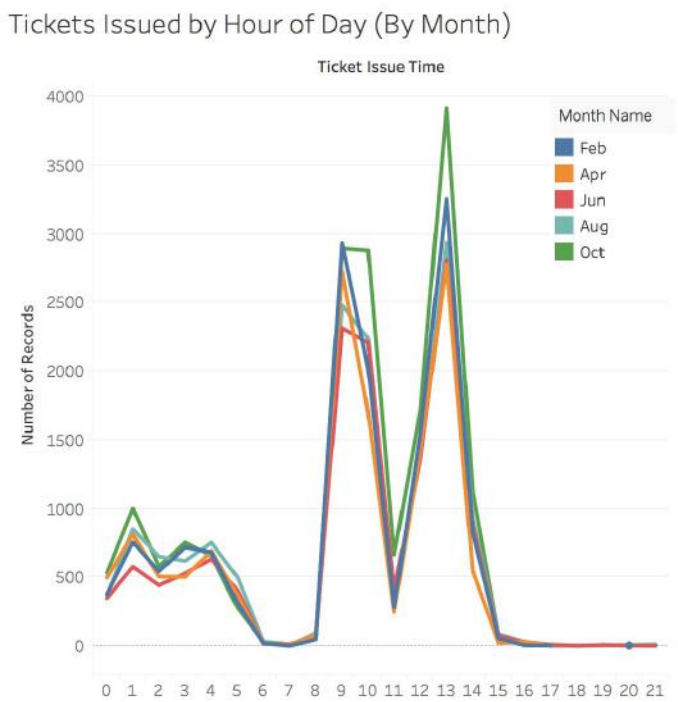
For our exploratory data analysis, we wanted to gain insight into the nature of ticket distributions. The results of our initial quantitative research were covered in section 2.1.2., and we will review some of those here.

A visualization using a heatmap (Fig 3) depicting the location of each street sweeping ticket issued in 2018 provides a rough estimation of the distribution of tickets. While this doesn't provide much in terms of granularity or exact quantitative analysis, it is clear from these images that some areas are more ticketed than others, and that the downtown Oakland area seems to be ticketed more at nighttime, while this area is less ticketed during the day.



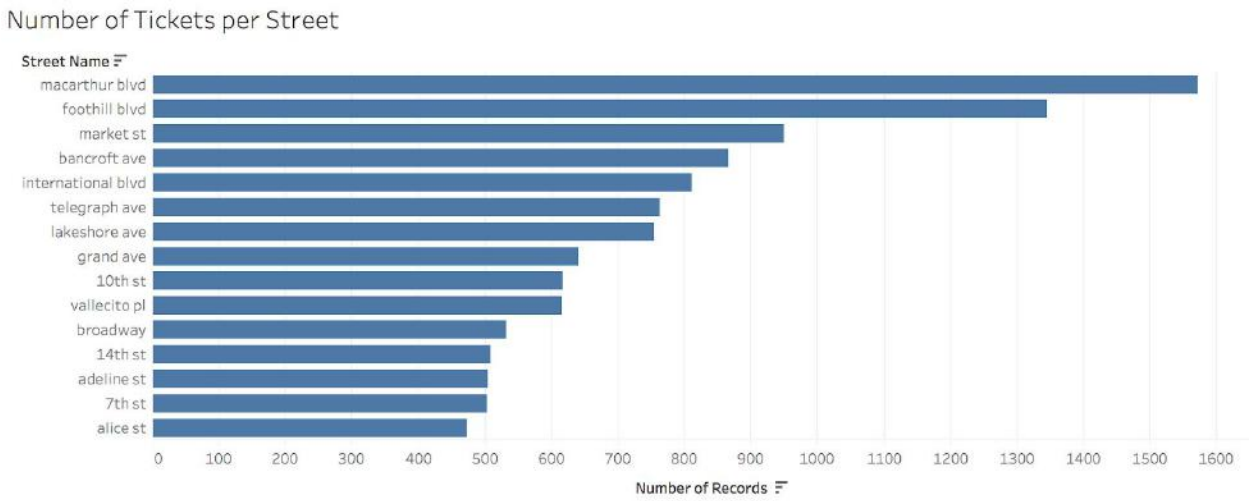
Heatmap of sweeping tickets issued during the daytime (left) and night (right) during 2018.

We can also get a sense for what times tickets tend to be issued (Fig. 4). Aggregating the tickets issued by hour of the day shows spikes in the morning and early afternoon, and a more consistent amount issued during the nighttime shift. Separating this data by month also reveals that this trend is constant throughout the year.



Number of tickets by hour of the day. Each color denotes a separate month.

From grouping together street names from the addresses within the citation data, we can also see which streets have incurred the most tickets. Figure 5 shows the tickets accumulated per street during select months of the 2019 data. What this lacks, however, is any indication of how often the street was swept, or how long the street is. For example, MacArthur Blvd, the first street in the list, is one of the longest streets in Oakland, spanning both commercial and residential areas.



Streets with the highest number of tickets in 2019.

With this in mind, we needed to determine a method of focusing our analysis and really defining what exactly we were looking for when we were trying to find ticketing hot spots. We can't simply say, "most tickets are issued at 1 in the afternoon, so try to avoid scheduling sweeping during that time," as this would not only completely disrupt the entire sweeping schedule, but also simply spread out the times when tickets are issued. Similarly, claiming certain streets need to be rescheduled by streets with the highest ticket counts would not be sufficient, as it lacks granularity and doesn't consider sweeping frequency. Additionally, we didn't want to make the claim that entire routes were more problematic than others, as we knew that the sweeping department would not benefit from the need to completely change an entire route's schedule. Fortunately, we have data for a higher level of granularity than the streets; our route data. Referring back to Figure 1, each entry of our route data corresponds to a small section of the street, and contains address and scheduling information. For our hotspot analysis, we join the route data and ticketing data in order to create a granular view of which street sections are the more disproportionately ticketed in relation to their scheduling.

3.2.2. Finding Hotspots and Case Studies

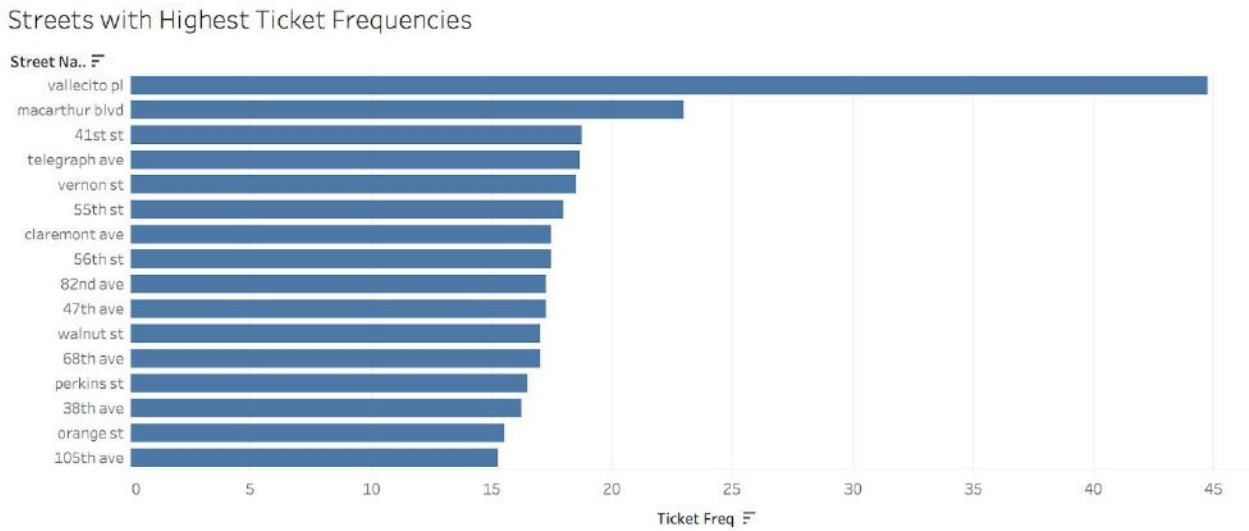
Because both our route and ticketing data has address information, we can join these two tables based on the address. A ticket entry will correspond to a route entry if the ticket address has the same street name, and its address number falls between the range of addresses as listed in the route entry. This is also where it became very important that our data was properly cleaned and consistent, as we relied on the fact that streets were spelled the same way when we were joining the two tables (e.g. 'st' versus 'street'). For each ticket entry, we can then assign it its corresponding route entry, denoted by the value in the column DYNAMAP_ID, which is a unique identifier for each of the route entries.

With each ticket labeled with a dynamap_id, we can simply group these values together to determine which street sections are the most ticketed. At this point though, we're still missing that information about schedule - a street that's scheduled to be swept 10 times a month is more likely to incur more tickets than a place scheduled to be swept only once a month. Fortunately, from our routes table we know which days of the week the given street section is scheduled to be swept. For the DAY_ODD and DAY_EVEN columns, we determine how many times a month that route is scheduled. For example, an entry with DAY_ODD = T13 and DAY_EVEN = M13 is scheduled to be swept the first and third Tuesday of the month on the odd side of the street, as well as the first and third Monday on the even side of the street; this section of the street is therefore scheduled to be swept four times a month. We run this calculation on every entry in the table, and thus we know how many times every street section is scheduled to be swept a month.

Now that we know the monthly sweeping frequency, we can determine which dynamap_id street sections have the most number of tickets relative to how often they're swept. Our reasoning is that if two streets both receive 100 tickets in a month, but one is only swept four times a month while the other is swept ten times a month, the one that's swept four times is a bigger problem.

We'd also like to point out here that we're not considering physical distance in our relative ticketing frequency calculation. The first reason for this is that for each dynamap_id street section, all of the physical distances are going to be relatively small compared to a normal street, perhaps in the range of a single city block. Additionally, we don't have information about no-parking zones within these street sections, which means that even if we do count for distance, we're still missing a significant portion of the street. Thus, we are going to work under the assumption that all dynamap_id street sections are close enough to the same distance and we will not worry about how far the distance is from one end of the section to the other.

Having completed the ticketing count in relation to monthly sweeping frequency, we now have a more granular and accurate depiction of our hotspots, or street sections that have a disproportionately high number of tickets issued. In Figure 6, we show some of the highest ticketed areas (referred to by street name for recognizability). Now that we know which streets have higher ticketing rates, we move on to a case by case analysis of these streets sections.



Streets that have the highest number of tickets in relation to their monthly sweeping frequency. Note that these streets mentioned are actually referring to the section of the street as defined by the dynamap_id identification, and not the whole street (address ranges left out of this graph for readability).

3.2.3 Case by Case Analysis

Given the street names and addresses, as well as the tickets incurred relative to the monthly sweeping frequency, we don't really know what it is about certain areas might be more prone to being ticketed than others. Thus we need to perform a case by case analysis for each street section to determine if there might be problems with the current sweeping schedule that is causing a particular place to yield more tickets.

In total we identified 65 street sections that were of interest by having high ticketing frequencies. After reviewing those, we narrowed down the list to 25 streets that our group would review with virtual fieldwork, namely employing Google Maps to get a sense for the surroundings (Fig. 7). We narrowed down the list to less than half partially due to time and personnel constraints, but also we did not want to focus too much on streets that seemed to be genuinely busy but not particularly problematic in their schedules. Thus we picked the 25 streets that had a chance to be improved upon with their schedules.

With our case by case studies, we focused on the following aspects:

- How frequent is the street swept?
    - Does the traffic of the street warrant the sweeping frequency?
- Are there inconsistencies with the current sweeping schedule?
- Is the street section residential, commercial, or both?
    - Are the residential streets being swept during the day time? (At night, residents can't move their cars.)
    - Are the commercial streets being swept during the night time? (During peak business hours, more people need to park on the street.)
- Are there particular public areas nearby, such as schools, parks, or hospitals, that may result in extra traffic and increase demand for street parking?

Google Maps satellite (left) and street view (right) of Vallecito Pl, the street with the highest ticketing rate. On one side of the street is Highland Hospital, a busy hospital which has many visitors and a small parking lot. The other side of the street is made up of apartments and small houses.

3.3 Issues Found and Recommendations

3.3.1 Too Frequent Sweeping

We determined that certain streets are being swept too many times a month. Although these streets may have had a lower ticketing rate in relation to their monthly frequency, we noticed these streets seemed to have too high a monthly sweeping frequency for the type of streets they were. For example, residential streets that aren't near highways or large industrial areas don't need to be swept as frequently as streets near commercial areas. We identified 24th St, 18th St, and Pleasant Valley Ave as residential streets that are swept multiple times a week, every week of the month. These residential streets do not experience enough traffic, nor are they near any major pollution-emitting sources, to warrant such frequent sweeping. We thus recommend that the frequency of sweeping for these streets be reduced.

3.3.2 Residential Sweeping Times

Ideally, residential area streets should be swept during the morning shift. This is ideal for the sweeping department because people are awake and available to move their cars

during the scheduled sweeping times, plus many people drive their cars to work and therefore the cars aren't on the streets, which furthermore leaves more room for other people to park their cars if they need to move their cars from one side of the street to the other. The morning shift is generally preferable over the afternoon shift, as in many cases people own cars but commute to work through other means of transportation, and thus by sweeping the street in the morning, people can move their cars before they leave for work. Most residential areas are scheduled correctly, but we identified four residential areas that are being swept during the night shift or afternoon.

The streets 64th Ave, 24th St, 18th St, and Pleasant Valley Ave are all residential streets that are currently scheduled for the night shift (after midnight). This is inconvenient for residents who need street parking but can't move their cars, and thus they should be removed from the night shift route and added to a day shift route.

3.3.3 Commercial Sweeping Times

Commercial areas and busy streets should be swept during the night shift. Sweepers are large and slow vehicles, and the sweeping department does not want them to disrupt traffic. Additionally, during peak business hours, many customers rely on street sweeping, and having limited parking options is detrimental not only to those trying to park, but businesses as well, as they rely on their customers. Most busy streets are already scheduled correctly, but we have identified streets that need to be updated.

Claremont Ave, Telegraph Ave, Stuart St, and 23rd St are all commercial areas that are currently scheduled for the day shift. These should be removed from their current routes and added to a night shift route, during which the sweepers will encounter much less traffic and fewer cars from customers during peak business hours.

3.3.4 Inconsistent Schedules

In some cases, we see that schedules change part way through a street on one side, but not in the same place as the other side of the street (Fig. 8). Even for residents who are familiar with street sweeping schedules, this can be confusing, as there may not be a clear indication where the schedule change border is, and may accidentally park in the wrong area.

Grand Ave, which has an uneven schedule border.

Grand Ave, 47th Ave, and Bartlett St were identified as areas having this issue, and thus we recommend updating the borders to be consistent on both sides of the street.

3.3.5 Avoiding Specific Times

In the case of certain streets, specific days or times are undesirable for sweeping as they may interfere with community activities.

Lakeside Dr runs near an event center, which is often busy Fridays and weekends. This street is also scheduled to be swept the night shift on Monday, Wednesday, and Friday, as well as Friday afternoons. For this case, we would recommend removing the Friday afternoon shift, as Fridays tend to be busy days, and the street is already swept 3 days a week in the evenings.

Vallecito Pl is a particularly difficult case, as it experiences a high amount of traffic being located right next to Highland Hospital and is used as a source of street parking for when

the hospital parking lot fills up, but is also a residential street that houses several apartments. It is a relatively short street and is scheduled to be swept four times a month (the second and fourth Mondays and Tuesdays of the month), yet despite this it had a history of acquiring over 100 tickets per month in 2019. It is currently scheduled for the morning 9am-12pm shift. We hypothesize that this street in particular has so many tickets largely due to the high volume of incoming patients who are either unaware of the street sweeping schedule, or are under too much medical related stress to prioritize legal parking. From our user interviews, however, we also know that residents in the area struggle with street parking here, as often there isn't enough space on the street for them to move their cars out of the way. With Vallecito Pl, we therefore recommend:

- Further reducing the street sweeping hours from a 3 hour window to a 1 hour window. This narrows down the window of time when parking is reduced. (Another hotspot area, Stuart St, also intersects the same hospital, and would similarly benefit from this recommendation.)
- Increase signage. Street sweeping schedules may not be obvious to hospital visitors, and more signs clearly expressing the no parking hours can reduce confusion and uncertainty.

3.3.5 Inconsistent Ticketing Data

We noticed several streets seemed to be incurring street sweeping tickets on days that the street was not scheduled to be swept, say for example a street section scheduled to be swept only on Mondays and Tuesdays would have tickets issued on other days of the week. If this were an occasional one off occurrence, we could have possibly written it off as a documentation error, but the prevalence of the issue indicates a problem with either the ticket enforcement or the data itself. For example, Vallecito Pl, our highest ticketed street section by monthly frequency, is scheduled to be swept four days a month (the entire street operates on the same schedule). However, during the month of October in 2019, street sweeping tickets were issued on that street on 21 separate days, over five times the number of days scheduled.

Because the ticketing enforcers operate in a different department from the street sweeping department, we don't know for sure why we see data such as this. Possible explanations are that tickets are being filed incorrectly as sweeping violations when they're actually other violation types, or routes may be rescheduled due to incomplete sweeping in a previous attempt and streets are being swept on additional days. Without clear answers, the best we could do with this issue is simply point out the discrepancies in the data to the street sweeping department for their reference, as they do not monitor the ticketing themselves and thus are not immediately made aware of issues such as this. We hope that by providing this data to them, that they can make any adjustments needed, or may be incentivized to work in closer contact with the ticketing department.

3.3.6 Recommendations

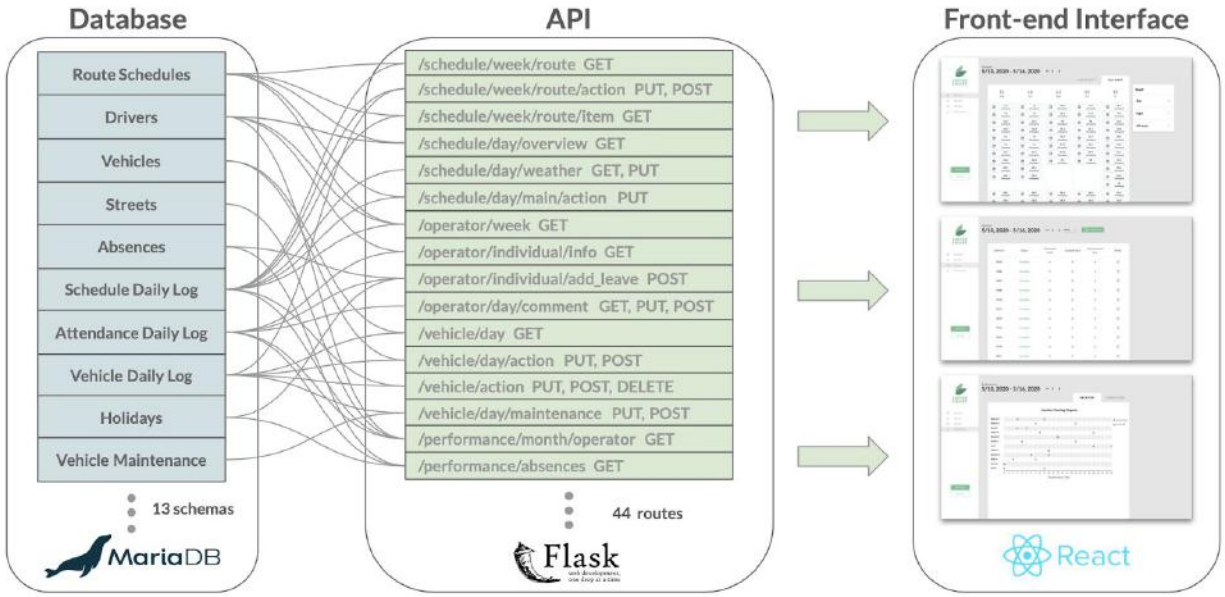
In general, we wanted to avoid recommending signficant schedule changes to the street sweeping department, as we knew our clients did not want to completely restructure their route schedules and operations. We compiled a document with all of the hotspot street areas and our corresponding recommendations and provided them to the street sweeping department for their reference. We recognize that not all changes can be implemented easily due to scheduling challenges (hopefully this will be alleviated by our tool as discussed in section 4), but we believe that by drawing attention to these issues, we can help bring awareness to the department of which areas are in more need of adjustment. By focusing our attention on a relatively small portion of Oakland streets that have a disproportionately high impact on the number of tickets issued, we hope that the street sweeping unit can easily transition to more efficient street sweeping with minimum disruption to their current schedule.

4. Sweep Smart Application

In order to improve the operational efficiency of the street sweeping planning team so that they could better respond to the future schedule changes, we designed and implemented an operational digitization and intelligence tool for the street sweeping planning team.

4.1 System Overview

The system of the tool consists of three components: backend database, API, and frontend interface. They each run on a separate container with its own server, and connect with each other by API calls.



System structure

4.2 Backend

We implemented the backend database in MariaDB. The database consists of 13 schemas: absences, citations, day_log, drivers, dynamaps, holiday, overtime, route_log, routes,

streets, vehicle_day_log, vehicle_maintenance, and vehicles. These schemas include all the data about schedules, drivers, vehicles, and all logs relating to the actions taken by users.

Schema Name	Description
Absences	All absences of employees
Citations	Citation data issued in last few years
Day_log	Information about each day including weather
Drivers	All operators with the route fixed assignment
Dynamaps	Geospatial information about street sections, the finest-grained level of streets
Holiday	Information about holidays
Overtime	The overtime working records for employees
Route_log	Actual daily assignment and completion of routes
Routes	Fixed assignment of route schedules
Streets	Street information, higher level than dynamaps
Vehicle_day_log	Daily assignment of vehicles
Vehicle_maintenance	Maintenance data of vehicles
Vehicles	Basic vehicle information

4.3 API

APIs are written in Flask. They have access to all database schemas, and by combining actions on some of the schemas to achieve a single purpose and hiding the implementation details from the frontend, they provide the frontend interface with cleaner and more logical API calls to interact with the backend.

API routes	Description
/schedule/week/route GET	Get weekly route schedule data
/schedule/week/route/available GET	Get routes available to be cleaned
/schedule/week/route/action POST PUT DELETE	Make changes on route schedules
/schedule/week/route/item GET	Get detailed information about one route

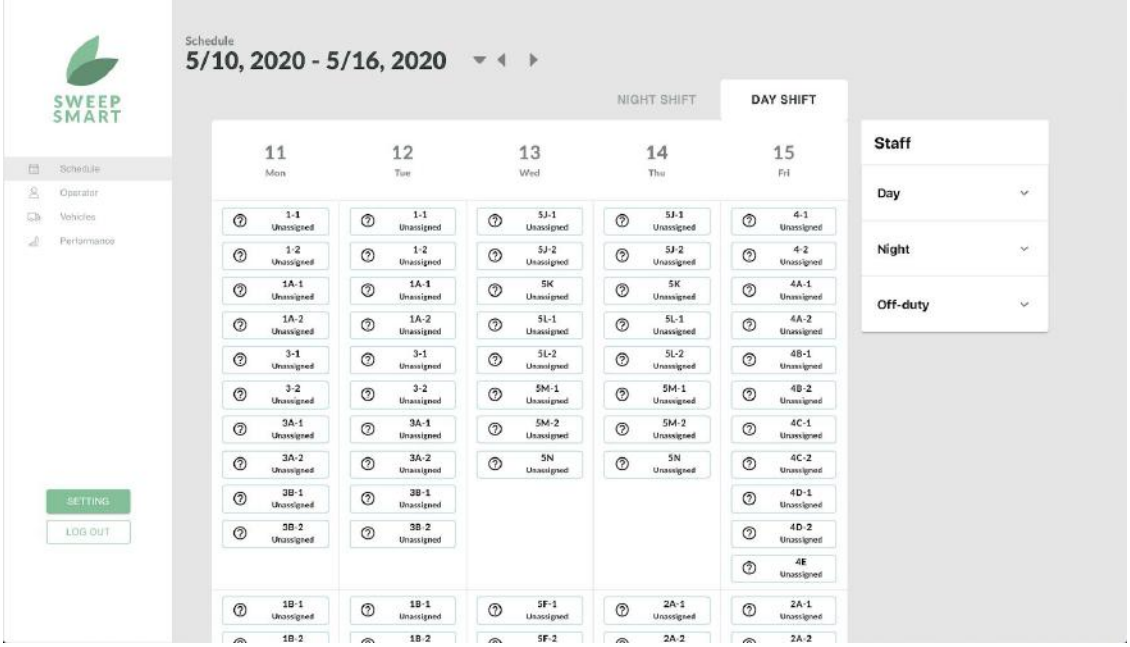
/schedule/week/staff GET	Get the staff available to be assigned a route
/schedule/day/overview GET	Get the overview of routes scheduled and cleaned of a day
/schedule/day/weather GET PUT	Get and change weather
/schedule/day/main GET	Get the main operator list on daily schedule view
/schedule/day/main/action PUT	Make changes on the operator route assignment
/schedule/day/vehicle GET	Get the vehicles on daily schedule view
/schedule/day/unplanned GET	Get unplanned routes for a day
/operator/week GET	Get the weekly operator data
/operator/day/onduty GET	Get the operators on duty
/operator/day/offduty GET	Get the operators off duty
/operator/individual/info GET	Get the individual information of operator
/operator/individual/add_leave POST	Add a leave for an operator
/operator/day/comment GET POST	Get and add comments on an operator
/vehicle/day GET	Get daily vehicle data
/vehicle/day/maintenance GET	Get vehicle maintenance information
/vehicle/day/action PUT	Update vehicle maintenance and out-of-service days
/vehicle/day/comment GET POST PUT	Get and add comments on a vehicle
/vehicle/week GET	Get weekly vehicle data
/vehicle/action POST DELETE	Add and delete vehicles
/performance/month GET	Get monthly performance by route
/performance/month/operator GET	Get monthly performance by operator
/performance/absences GET	Get absences of operators

4.4 Frontend

The frontend is developed in React. The interface consists of four main pages: schedule, operators, vehicles, and performance, which are the top needs of the street sweeping team. The pages are fully functional, connected with the backend via API calls.

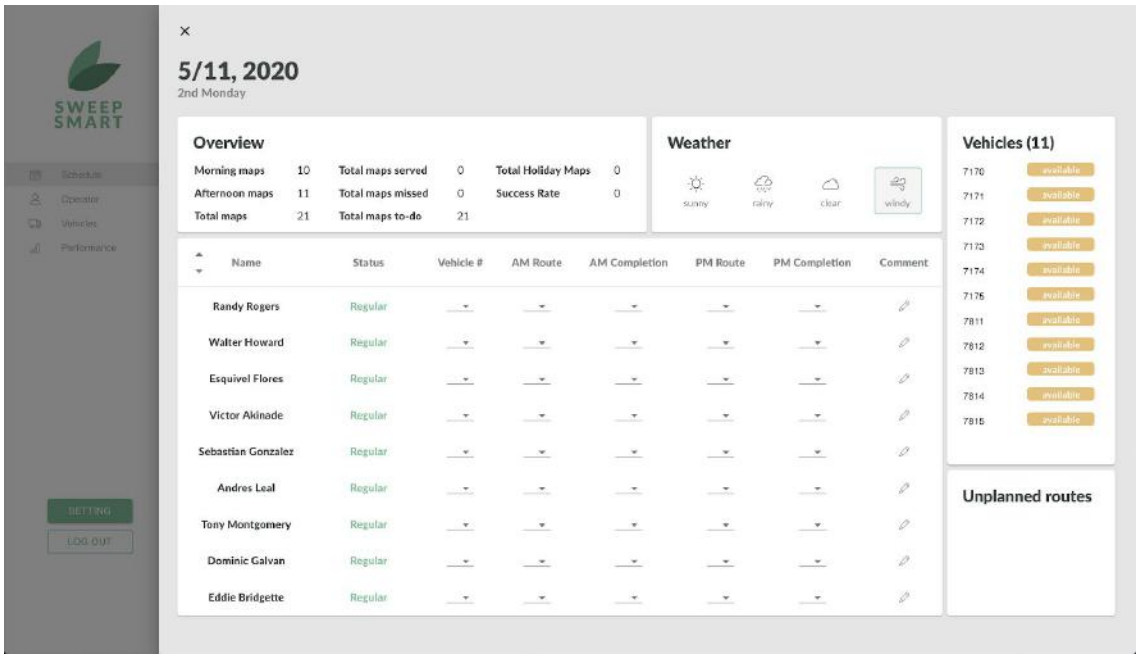
4.4.1 Schedule

Schedule page has weekly view and daily view. In the weekly view, all fixed route assignments get automatically displayed based on the number of the week in a month and the day of week. The color of the block indicates the status of the route, including assigned, unassigned, completed, missed, and disabled.



Schedule page

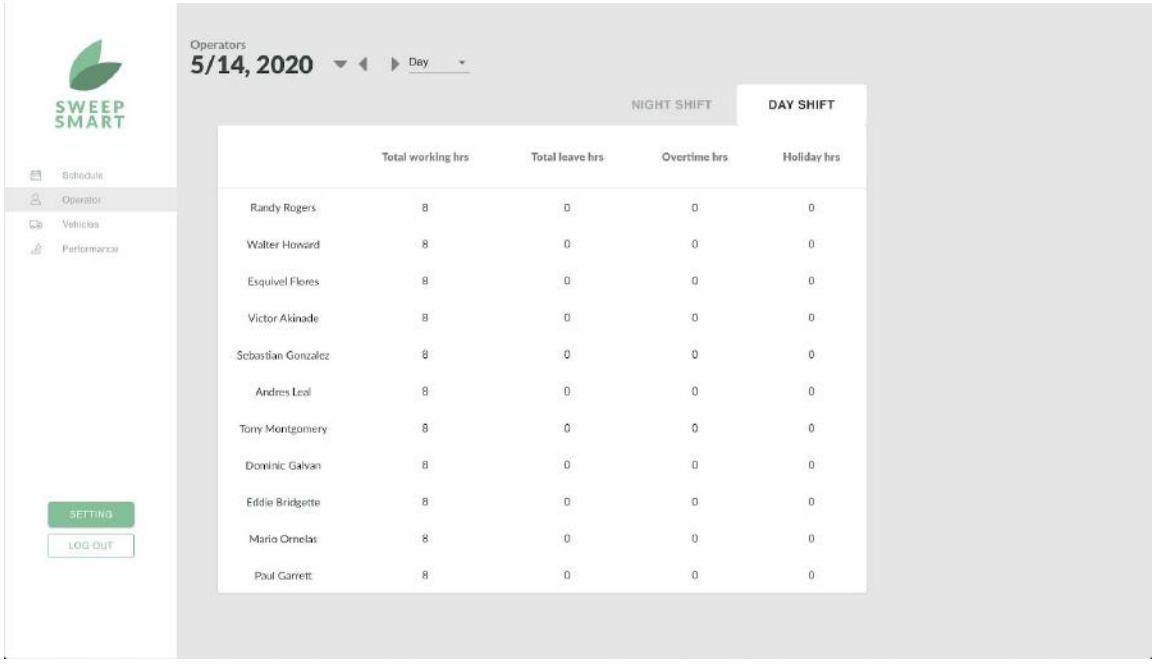
In the daily view, the overview, weather, vehicles, operators, and unplanned routes are shown to help understand the current status and assign routes and vehicles to operators.



Daily schedule page

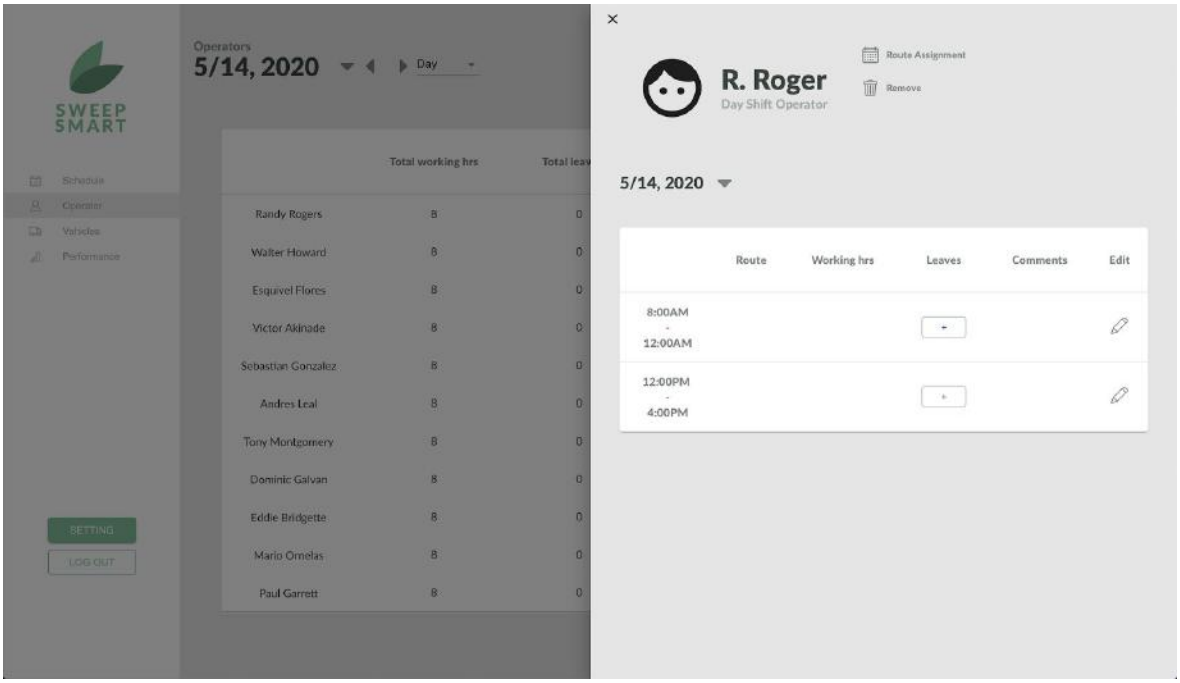
4.4.2 Operators

Operator page also has a daily view and a weekly view, where the working hours, vacation hours, etc are shown.



Operator page

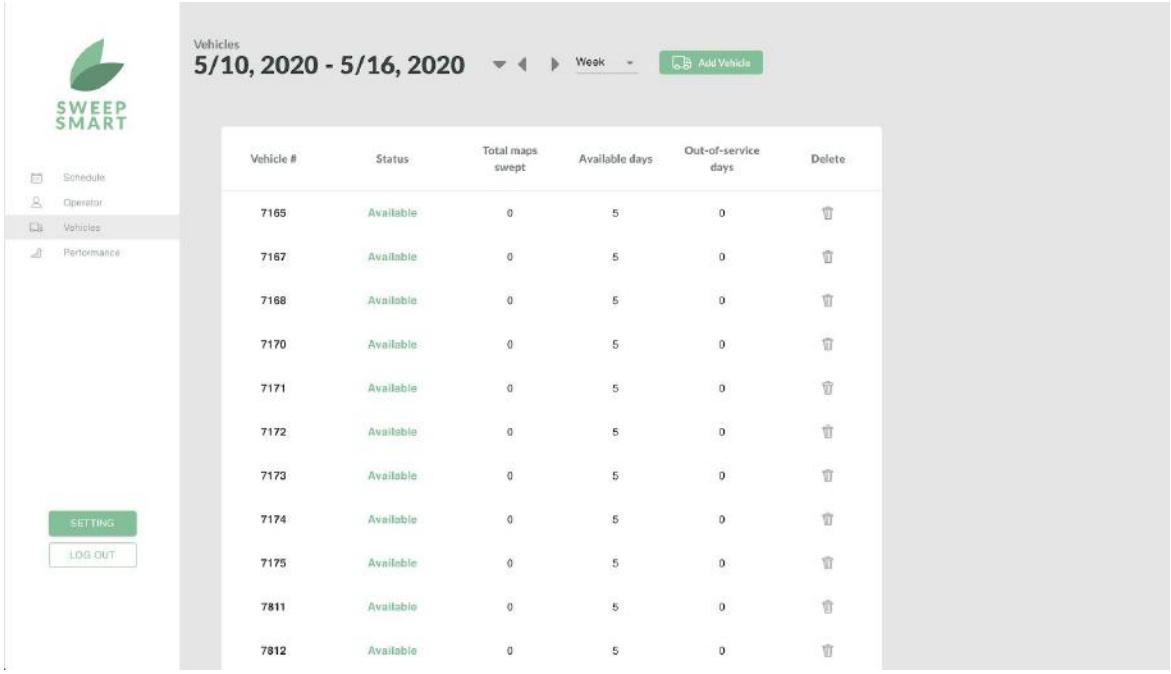
There is an individual page of the operator page, where one can see more details about a single operator, including the route assignment, working hours, leaves taken, etc, and one can change the operator's assignments and leaves too.



Individual operator page

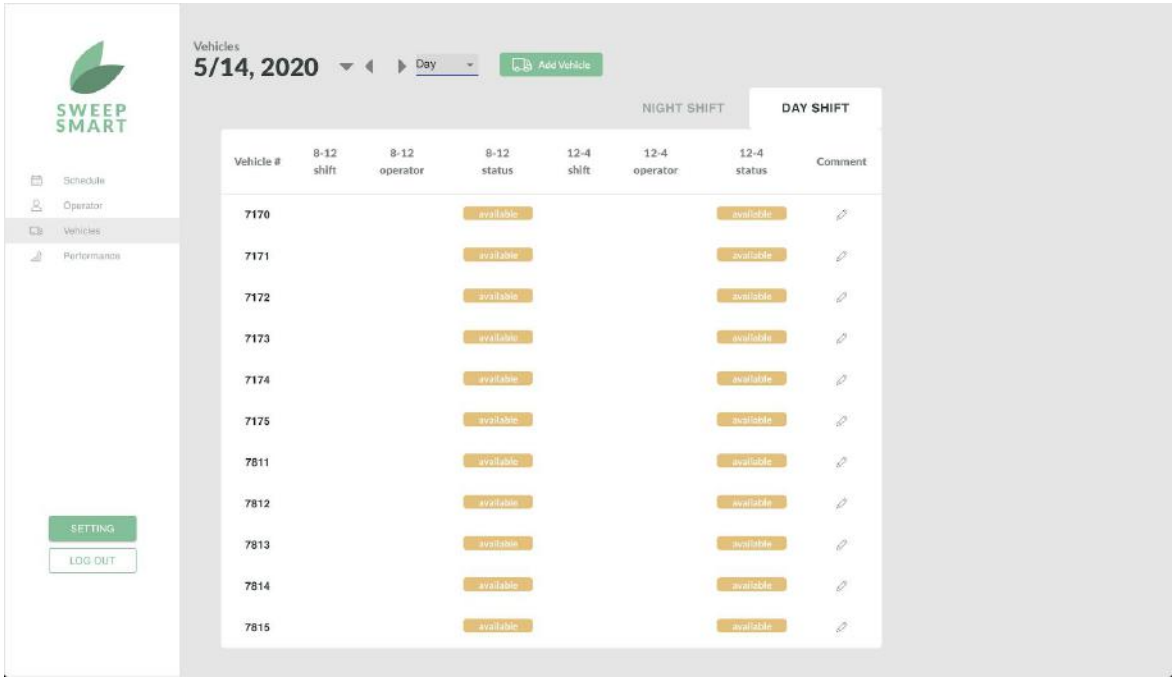
4.4.3 Vehicles

Vehicle page lists all vehicles currently tracked in the database, with the status, available days, out-of-service days, in the weekly view.



Vehicle page weekly view

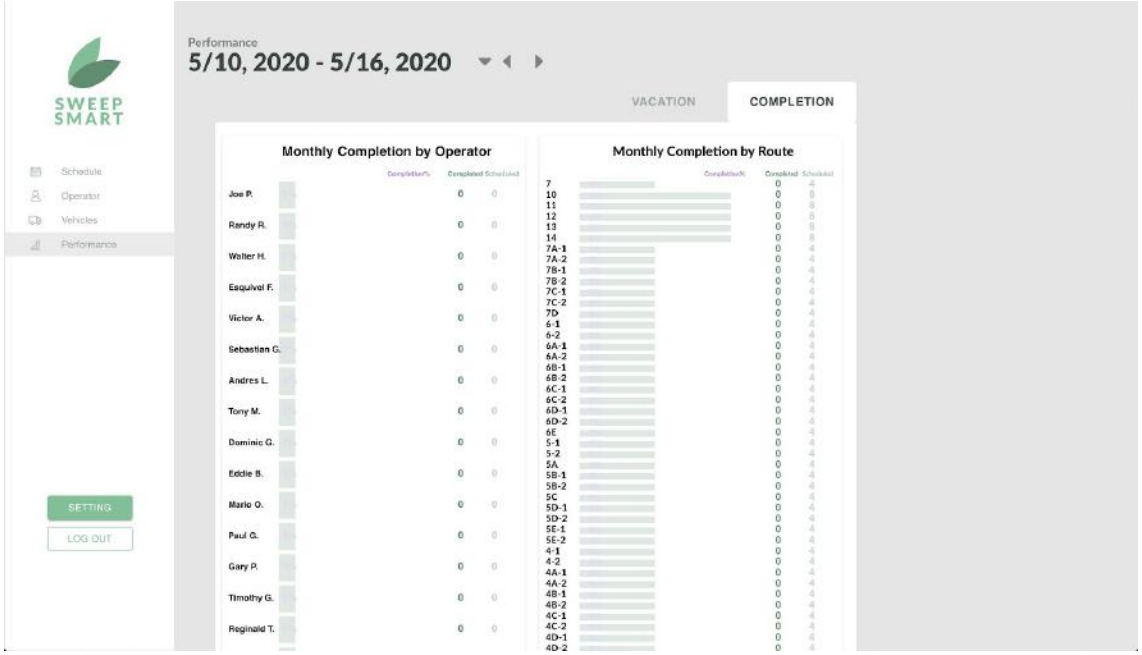
In the daily view, the page shows the assigned route and operator for each vehicle, and whether they are available, in-use, or out-of-service. One can leave comments for each vehicle.



Vehicle page daily view

4.4.4 Performance

In the performance page, we track the completion rate and the vacation hours taken, which are the most important factors for the street sweeping team to consider now. In the completion panel, the monthly completion rate by operator and by route are automatically calculated based on the data logs, and shown to the users.



Performance page completion rate

In the vacation panel, a table of the vacation hours taken so far by operators is shown based on the vacation data.

Performance page vacation tracking

5. Information Visualization Site (Tobey)

The main goal of the information visualization website is to inform the public about the current street sweeping situation so that drivers in Oakland can take measures to avoid street sweeping parking violations. The information we hope to present includes what has been done by the city to keep the environment clean, the proportion street sweeping violations have taken up in all the parking citations, and the distribution of street sweeping parking citations in terms of sweeping frequency, time and location. Also, in our user interviews, we realized that residents are not aware of the channels available to them to make suggestions regarding street sweeping schedules. In our website, we included the feedback channel information in the end so readers can make recommendations if they believe a current street sweeping schedule is unreasonable.

5.1 Data

- **Statistical data on street sweeping activity**

The data was provided by the street sweeping operation team who are responsible for collecting debris and garbage on the street. The data includes the number of days they worked, miles of road they have cleaned and tons of garbage they have collected in 2019.

- **Parking citation data in Oakland in 2019**

  Parking citation data is publicly available on the City of Oakland Open Data Platform for download. We mainly used the parking citation data in 2019. The citation data includes the date, time, location, fine amount, and violation type of all the tickets.

- **Current street sweeping schedule in Oakland**

  We also incorporated the current street sweeping schedule data into our visualization. Although the current schedule is available on the Internet, the format is an interactive map that does not allow downloading. Thus, we acquired the data from the City of Oakland government officials. The data includes route names, linestring objects (geographic coordinates) of all the routes, sweeping frequency, sweeping time, street name, and so on.

5.2 Website

The website is live and accessible at: http://sweepsmart.github.io/

5.2.1. Page Header

This section is the design users would see first when they visit the website. The title and the image convey the idea that street sweeping is essential in keeping the environment clean. The overall green design is used to align with the city's image.

Website header

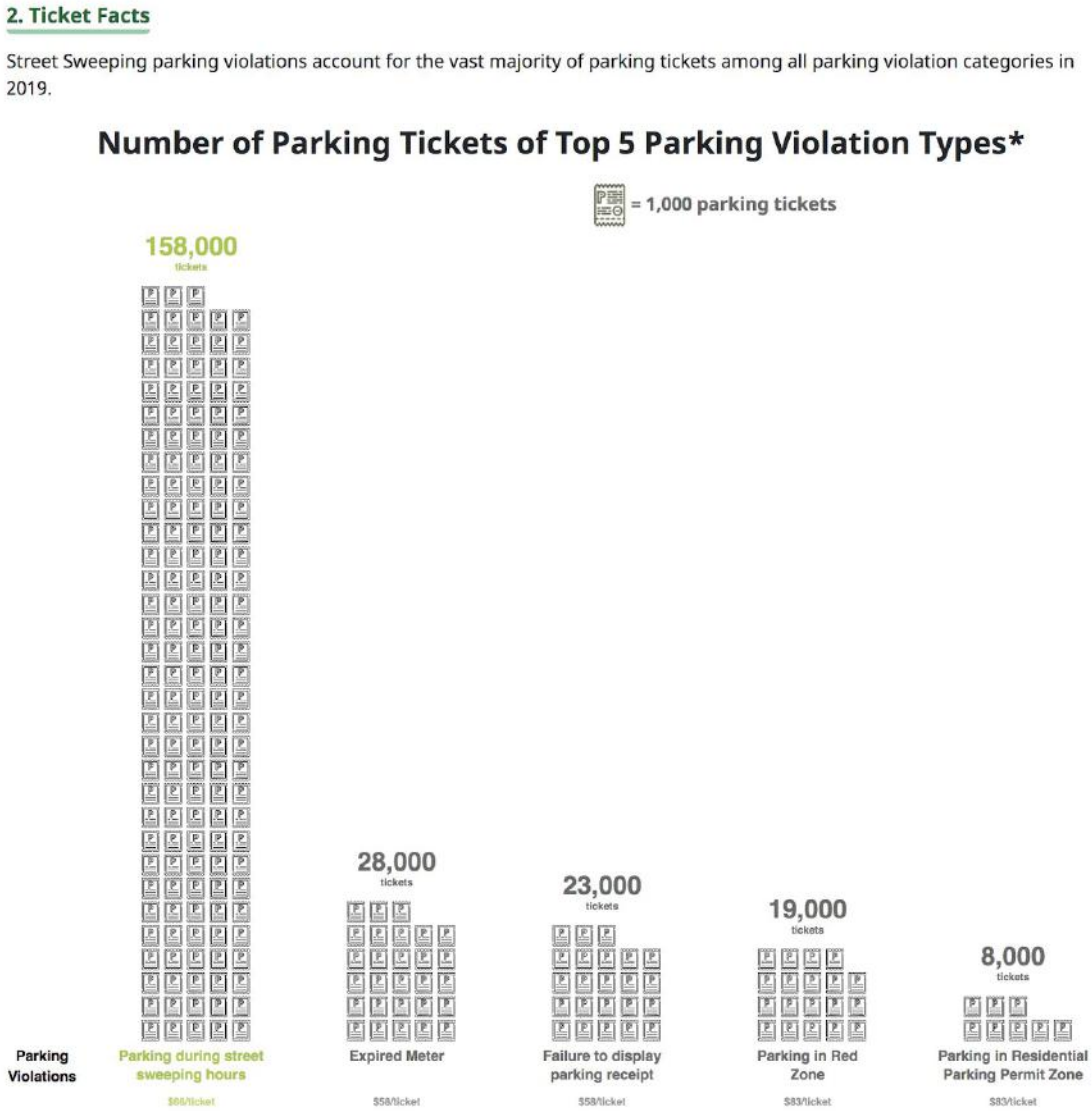
5.2.2. Overview

The overview section presents some statistics of the street sweeping activities in 2019. There are 20 operators on the cleaning operation team. They've worked for 353 days both day and night, have swept 44,800 miles of road, and have cleaned 1,530 tons of garbage. After conducting user usability testing, we realized that readers may not understand how significant those numbers are. Therefore, we decided to convert it to scales that make more sense to most users, such as the distance between the United States West Coast and the East Coast.

Statistics section

5.2.3. Parking Citation Distribution By Categories

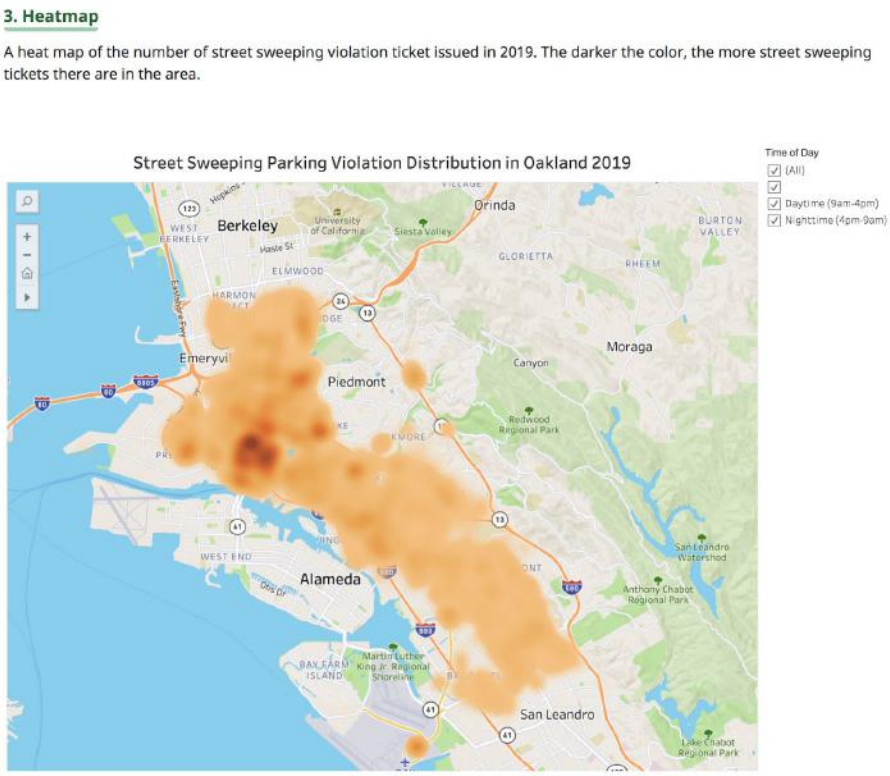
Although the city has done their job keeping the environment clean, it also caused some disruption to the local community in terms of the parking citations. We collected all the parking citation data in 2019 and found that street sweeping violation consists of half of all the parking citations, resulting in more than 10 million dollars of fines in 2019. In this section, we would like to highlight the issue and raise the awareness of the prevalence of street sweeping citations. We designed a bar graph to compare all types of parking citations. In 2019, 158,000 tickets were issued for street sweeping parking violations, and the other categories such as expired meters and parking in red zones incurred far fewer tickets. We added the animation to the bar graph, making all the tickets fly in, to draw readers' attention to the large amount of street sweeping parking violations. It also makes the infographic more visually engaging.



Isotypes Chart

5.2.4. Parking Citation Distribution By Locations and Time of Day

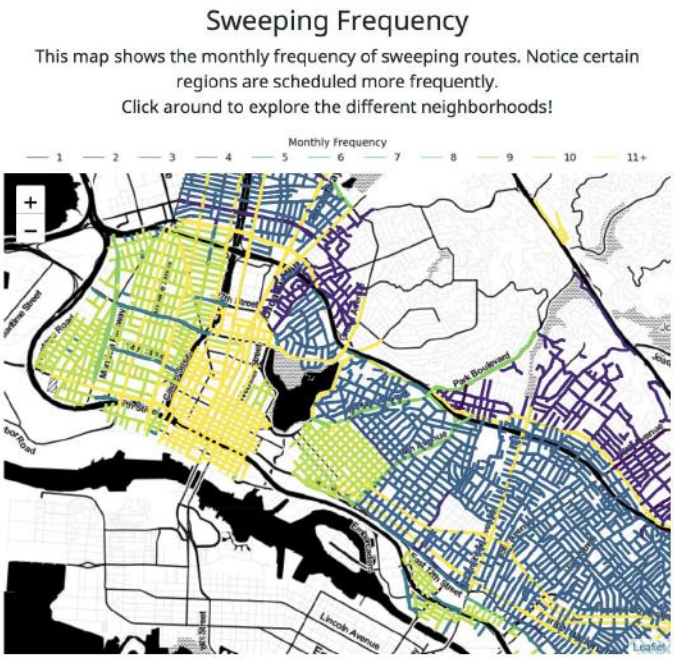
In this section, we aim to dig deeper into where exactly those tickets were issued. We developed a heatmap and plotted the ticket density on the map with color. The heat map shows that the downtown areas incur a lot more tickets than other residential areas. We can also see some hotspots on the map with the darker color. There's a filter on the side that shows the ticket density during daytime or nighttime. The section is meant to give readers an idea of the distribution of the tickets in terms of location and time of the day.



Heatmap

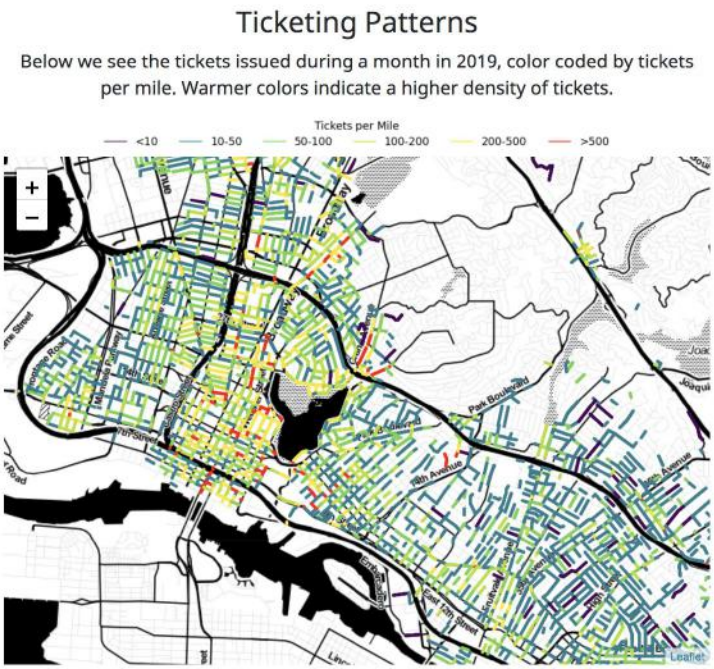
5.2.5. Sweeping Frequency and Tickets per Mile

In this section, we want to look at the area in finer granularity and reason about why some areas incur more tickets than others. We first broke down the schedule by sweeping frequency. As shown on the map, the downtown areas are swept pretty often so it makes sense that it would incur more tickets. Some major roads outside of the downtown area are swept more often than residential areas (with yellow lines).



Frequency map

The next graph we color-coded the number of tickets per mile to account for different lengths of the streets. In this graph, the streets are broken down into small segments so that it's obvious which segments of the same road incurred more tickets than the others.

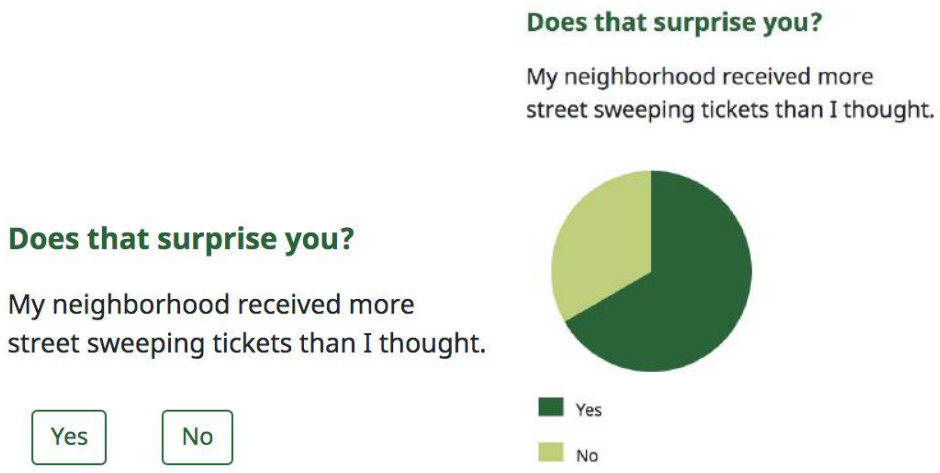


Ticket density map

The two maps above are interactive so users can navigate to their neighborhood to look at a specific street and the number of tickets issued.

5.2.6. Interactive Votes

On the right of the previous two maps, we ask the readers about their opinions on whether their neighborhood is swept too often and whether it incurs more tickets than they thought. The result will be shown to readers once they have voted. The survey result will serve as a little feedback for the city to improve future decision making.



Vote & pie chart

5.2.7. Feedback Channels

Since one of the main goals of this website is to solicit feedback from the residents after understanding the current situation, we hope to make the channel clear and accessible to readers. Therefore, in the very last section, we provide feedback channel information that readers can use to reach out to the Department of Transportation if they have any suggestions regarding the current sweeping schedule.

Feedback section

6. Conclusion and Future Work

In this project, our comprehensive solution explored various aspects of addressing the street sweeping ticket issue in the city of Oakland. Starting from November 2019, we have been working closely with the Department of Transportation, Civil Design Lab and the street sweeping planning team from problem definition, research, design thinking, to design iterations with real user feedback. Our final solutions span from actionable route optimization recommendations, to a digital operational intelligence tool with a public website introducing the street sweeping related activities with transparency and equity. While there is still a lot of space to improve our solutions, we have received very positive feedback from our clients. Quoting some comments from our user and key stakeholder, the street sweeping team supervisor: " (the sweep smart) tool is great. We cannot wait (to use it) .... (the website) may mean a lot more work for us, but this is the right thing to do." Although the final implementation of sweep smart on the client server has been delayed due to COVID-19 situation in 2020, we will continue to work with the technology department of the city of Oakland to launch our product for the users in the city of Oakland.

There are some fine-tuned adaptations left due to lack of time, which we plan to implement in the next couple of weeks, including migrating voting data of the website to firebase, implementing more data refresh after put requests, etc.. Future work is also on our radar, including implementing visualization of live citation data (depending on citation data refresh frequency and data pipeline availability), as well as tracking more granular street sweeping completion rate once the completion GIS service is integrated. The live data visualization could potentially help the city monitor unusual spikes in the ticketing activity and promote communication between the ticketing department and the street sweeping planning team.

Appendix

Research & Design

Needfing meetings:

- Interview guide: https://docs.google.com/document/d/1pdbSYNTDEcIKNjoqath4s6ulAPQKUgk3VVEZ_HQN_J0/edit?usp=sharing
- Interview notes: https://docs.google.com/document/d/14LcYyYbMcvF4-c3-pi5H3yXYIBYE5tVAN5CBiN0BlX0/edit?usp=sharing https://docs.google.com/document/d/1qLSNkFal7D35z-vFKLhQMrBSC2sqOK6RIB_MFLYYY50/edit?usp=sharing

Quantitative Research on Violation Ticket & Route Completion

Link to Tableau workbooks: https://drive.google.com/drive/folders/1_Nm3IQPm21WwaCU40QQFJAc1hwHEkfnW?usp=sharing

1-1 Qualitative Interview with Citizens

- Interview guide: https://docs.google.com/document/d/1c4eVfTyvA6dvCUSCjzJT4NYJVzv93D8YJcm79Nx0r4g/edit?usp=sharing
- Interview notes & recordings:https://docs.google.com/document/d/16wTBZY-VVVsKL1_65tVyzX-tRCz5Umpyz4iO3tgRzcw/edit?usp=sharing

https://drive.google.com/drive/folders/1CNbSTcz1gHV9uxW1r7nrk6QYQZF84we5?usp=sharing

Interview & Observation Study with SSU

Guide & notes:
https://docs.google.com/document/d/1f7bImzAzgj3uETxMM6JZ39unvdYdEvfC1b99T_RrhHM/edit?usp=sharing

Design Iterations of Sweep Smart Tool

- User Flow Chart: https://whimsical.com/ubHzrAY33JAwX9YY35tCF
- Low-fidelity: https://drive.google.com/drive/folders/1saSecAgoVBbiSoMXotTqj7X8-ZDTrY96?usp=sharing
- Wireframe: https://whimsical.com/JokMYhTZpjWReVR218g2j9
- Design: https://www.figma.com/file/uJypMpG5cRyVH9nAjRY53T/BCOT?node-id=587%3A5
- Usability testing and feedback sessions with SSU notes: https://docs.google.com/document/d/1yZPXAWA8uj9do-Lrz6AIPYzBwm5IUcdn3w95vsh8wDs/edit?usp=sharing

Design Iterations of Public Website

- Iteration of designs: https://www.figma.com/file/uJypMpG5cRyVH9nAjRY53T/BCOT?node-id=587%3A5
- Usability testing guide and notes: https://drive.google.com/drive/folders/1E7dfZfFHDuFs35ZEFiWX8Hq9WNERpz9B?usp=sharing

Research Results from UXR Team

Link to the slides:

https://docs.google.com/presentation/d/1DpmKick_s8JxbcQPt6tADP-0brb2wAFdd8E_xHTEvUM/edit?usp=sharing

Route Optimization

Hot Spot Areas and Recommendations

https://docs.google.com/spreadsheets/d/1rJx8HVaiT6J0FUY0ocOYvoj79mMXhq9sAZTW1PSu8nQ/edit#gid=1514015191

Sweep Smart Application

Sweep Smart Application

https://github.com/yi-gai/sweepsmart

Information Visualization Site

Data Visualization Website

http://sweepsmart.github.io/