Silicon Valley Construction Project Web Mapping Application

by

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A Thesis Presented to the
FACULTY OF THE USC DORNSIFE COLLEGE OF LETTERS, ARTS AND SCIENCES
University of Southern California
In Partial Fulfillment of the
Requirements for the Degree
MASTER OF SCIENCE
(GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY)

August 2021

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Acknowledgements

I am thankful for my advisor, Doctor Sedano, for providing writing and technical assistance for this thesis. I am also grateful for my company for providing the inspiration for this project.

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Abbreviations

API	Application programming interface
BART	Bay Area Rapid Transit
CRE	Commercial real estate
CSS	Cascading style sheets
GeoJSON	Geographic JavaScript object notation
GIS	Geographic information system
JS	JavaScript
JSON	Javascript object notation
LLC	Limited liability company
LP	Limited partnership
OGD	Open government data
OSM	OpenStreetMap
R&D	Research and development
RHNA	Regional Housing Needs Allocation
SFR	Single-family residences
SQFT	Square feet
SQL	Structured Query Language
UI	User interface
UX	User experience
VTA	Valley Transit Authority

Abstract

The Santa Clara County economy has fueled demand for commercial real estate (CRE) developments. CRE brokers capitalize on this demand by attracting tenants to newly constructed buildings or by helping property owners sell to developers for future redevelopment opportunities. City planning departments disclose construction project information within their boundaries. Each city has its own property methodology and data release schedule with few sources recording these sources regionally. The main objective is to create a CRE construction web application that tracks construction projects within the major cities of Santa Clara County. This helps save time by standardizing the project data and aggregating all the information into one program. The progress of the CRE development is tracked throughout the pipeline as it goes through the following statuses: pending approval, approved, and under construction. The database also focuses on the following property types: office, hotel, multifamily, retail, and industrial. This construction data is organized and presented to brokers via a web GIS application to enable spatial searches in an easy-to-use interface.

Chapter 1 Introduction

Santa Clara County has enjoyed a strong economy that has explosively grown over this decade, with the labor force increasing from 957,392 in 2010 to 1,035,396 in 2020 (BLS 2020). Economic and demographic pressures have increased demand for commercial real estate (CRE). Developers and investors scour the county, proposing and constructing new developments to satisfy this demand. In this environment, brokers facilitate new relationships between developers and investors that supply new CRE properties and tenants looking to occupy them. Brokers also guide developers towards land parcels for redevelopment opportunities. The thesis objective is developing a CRE construction web application to help brokers track construction projects within this region.

The chapter introduces a project overview, motivation, and methodology for building the construction project web application. Section 1.1 provides an overview of the CRE construction web application, and Section 1.2 describes the motivation behind its creation.

1.1. Project Overview

This thesis project aims to create a web application that helps brokers track CRE construction projects in Santa Clara County. This area is also known as Silicon Valley and serves as the main sales territory for the author's current job at a CRE brokerage. The web application follows the construction project through all steps of the construction pipeline. The initial step is when the development application is proposed. Next, the city planning department must approve the construction project. Afterwards, the developers start construction on the project. Lastly, the construction project is complete.

Figure 1. Study Area

The following property types are tracked through this pipeline: office, industrial, research and development (R&D), retail, hotel, and multifamily. Offices range from multiple high-rise complexes to short 1-story buildings. Industrial properties consist of manufacturing buildings and distribution warehouses. R&D property types are in-between type properties that combine the qualities of 1 to 2-story office buildings with industrial property types (Datastar 2020). The property areas may be 50% office and 50% warehouse. Retail properties include mega-malls, grocery centers, or the first-floor restaurants of new apartment or office buildings. Hotels within these counties tend to be business or extended stay hotels geared towards workers attending conferences or branch offices. Multifamily properties include condominiums, townhomes, and apartment complexes. Mixed developments combine two or more property types in one development. Common examples include mixed developments that combine retail space on the first floor with multifamily or office buildings.

1.2. Motivation

The motivation to create a CRE construction web application stems from working for a CRE brokerage as a research analyst. Brokers request to track leases, sales, existing buildings, and construction projects. This thesis project focuses on satisfying the need to track construction projects within the Silicon Valley region. Brokers desire to know what construction projects are in their sales territories and to track their progression along the construction pipeline. These projects attract tenants demanding top-of-the-line, Class A properties. Proximity to these new developments may also enhance the desirability of existing properties. For example, an obsolete property zoned for multifamily development may look more desirable if multifamily or other construction projects are nearby (Hooper and Rowe 2020). The property can rise in value if it is redeveloped into one better suited for the economy or neighborhood.

Obtaining this information can be quite cumbersome. In the United States, zoning is left to local cities with little state or country regulation (Kim 2020). City planning departments define acceptable and planned land usage spatially through these zoning laws (Brown and Glanz 2018). Each city has their own planning department with a construction project database, rules, and varying levels of transparency. The city of Newark does not disclose CRE construction projects on their city planning websites (Newark 2020). However, the cities of Mountain View and Sunnyvale are very transparent in reporting CRE construction projects with project lists and maps available to search (Mountain View 2020; Sunnyvale 2020). Data releases may be released weekly, monthly, quarterly, or intermittently. COVID-19 worker safeguard measures have also delayed CRE construction project updates. Cities may have their own interpretation of R&D and multifamily property types. New industrial buildings that cater to high tech manufacturing may be labeled as R&D properties. Office buildings that also offer biotech labs may be labeled as R&D properties. City planning departments may differ in multifamily property classification. Single-family residences (SFR) may be recorded with condominiums, townhomes, and other multifamily properties. CRE brokers have little interest in SFR's, so this property type needs to be removed. Cities may also only focus on developments above a certain size (San Jose 2020). This data needs to be standardized, collated, and presented to brokers in an easy to understand medium.

Another goal is creating a regional CRE construction project web application. Cities only focus on construction projects within their borders. Plus, these jurisdictions have their own property type definitions, update schedules, and disclosure standards. CRE brokers may save time by using this CRE construction project web application instead of searching through multiple city planning departments. Other benefits are in tracking developers with multiple construction projects over different counties within Silicon Valley.

1.3. Thesis Overview

This thesis outlines the background, methodology, and decisions made to develop the CRE construction web application. Chapter 2 provides background on related work elaborating on user interfaces and experiences, open government data, and comparable CRE construction web applications. Chapter 3 covers the project methodology. This chapter outlines the necessary requirements and objectives, data sources, necessary software, data preparation, application workflow, and broker survey feedback. Chapter 4 walks through the application results. Chapter 5 includes a discussion on the challenges of the thesis project and ways to improve and scale up the application in future versions.

Chapter 2 Related Work

This chapter describes the related work for the construction project web application. Section 2.1 walks through how a simplified user interface (UI) can improve the user experience (UX). Next, Section 2.2 provides an evaluation on using open government data. Lastly, Section 2.3 goes over examples of city planning department construction project sites.

2.1. User Interface – User Experience

When developing an application, a well-implemented UI leads to a great UX. Creating a UX entails researching and defining the user demands, developing a UI so that the user easily fulfills the requirements, and evaluating if the program meets the user's needs. The UI describes how the user interacts with the application. The user must fiddle with the various buttons, icons, tool placements, and other layouts to obtain the desired information. Usability describes how easy UIs are to navigate. To have great usability, the UI must be easy to learn, perform tasks efficiently, achieve tasks with minimal errors, and be pleasant to use. After assessing the program effectiveness, future versions improve the UI and create a better UX by developing easier methods to accomplish the user objectives.

The main goal of the construction project web application is to have a central source for brokers to efficiently access construction project information in Silicon Valley. This application is akin to having a visual spatial display. These displays can be categorized into iconic, relational, and hybrid displays that combine the iconic and relational displays (Hegarty 2011). Iconic displays represent space within the application as space in the world. Properties displayed like shape and color are also visible in real life. Iconic displays also distort reality by showing three dimensional buildings or structures such as roads as two-dimensional polygons. Relational displays have abstract, non-visual qualities like heat or importance represented visually as colors or icons (Hagerty 2011). Hybrid displays combine qualities of both iconic and relational displays. The web application will use hybrid displays to represent the construction projects. Icons representing the physical location of the construction projects will be plotted on a basemap in an iconic display. Colors representing non-visual qualities such as property type and construction status are shown in a relational display.

Having an easy-to-use interface will help achieve this goal and improve the overall user experience. Simplicity should be the goal, since more complicated UI causes a less efficient UX (Horbinski et al. 2020). Too much realism may clutter the UI and make task-relevant information harder to understand (Smallman and Cook 2010). Adding interactivity also helps add simplicity to the UI. Interactivity means that the map reader is not passive on how the information is represented. The user is empowered to change how the information is viewed to best represent his or her goal (Roth et al. 2017). In the construction web application, the data is filtered by property type, area, city, construction status, and proximity to mass transit. The user can select the ideal combination of these variables to create an optimal view of construction data.

Cybulski and Horbinski did an experiment that compared the user experiences with the Google Maps and OpenStreetMap (OSM) user interfaces. The authors tracked the fixations and saccadic amplitudes of the users (Horbinski et al. 2020). Fixations are areas where the eye lingers and correlate with more complex visualizations. Saccadic angles record eye movements (Horbinski et al. 2020). To make the experience easier to navigate, the program should strive for lower fixations and higher saccadic amplitudes.

Another way to improve the user interface is to present the information in a familiar format for brokers like Google Maps. In a different study comparing Google Maps and OSM, participants were tasked with evaluating button and module placement (Horbinski et al. 2020).

The users recognized the Google Maps geolocation button, OSM change layer icon, and the Search icon. The participants also preferred having the search and geolocation icons in the upper left of the application. Under the proximity compatibility principle, displays relevant to common tasks should be rendered near each other to help comprehension (Wickens and Carswell 1995). For the construction project application, the search and geolocation icons can also be placed in the upper left. A satellite basemap with street labels can also be used to have landmarks and major streets help pinpoint the locations of the construction projects.

2.2. Open Government Data

The construction project web application relies heavily on open government data (OGD) as a source. OGD consists of public sector information or open public data (Saxena 2018). This is an extremely broad definition that includes different genres such as city officer salaries, demographic information, police data, or real estate data. This application focuses on OGD related to construction projects and land parcels. City planning departments provide almost all the data on construction projects and land parcels. Santa Clara County provides supplemental information for land parcels. Each department provides the data in different formats and levels of transparency. These datasets can be categorized based on completeness, formats, and variety (Wilson and Cong 2020). Complete datasets are evaluated if they are categorized, tagged, or have a description. Datasets are also judged if they follow open data formats such as CKAN, Socrata, or ArcGIS Open Data. Variety encompasses city departments such as administration, public safety, city services, finance, and planning.

OGD can be further categorized into three platform types: cognitivist, connectionist, and autopoietic (Danneels et al. 2017). The cognitivist platform equates knowledge with information and that no further interpretation is needed (Danneels et al. 2017). The government worker introducing the data transformation may introduce an unintentional bias that may adversely affect usage from other stakeholders. Under this approach, raw and unmanipulated data is the ideal format (Denis and Goeta 2017). The connectionist platform states that data formats and processing are not universal and vary locally (Danneels et al. 2017). Government agencies may have different levels of disclosure. Sunnyvale may disclose a parcel owner when releasing construction project information (Sunnyvale 2020). However, Santa Clara County does not disclose parcel owners due to privacy concerns (Santa Clara County 2020). The autopoietic platform states that knowledge cannot be directly conveyed from individual to another and must be interpreted (Danneels et al. 2017). There are many different OGD stakeholders and uses may vary widely within the same dataset (Dawes et al. 2016).

OGD has different stakeholders providing their own perspectives. Gonzalez-Zapata and Heeks describe the four main perspectives as bureaucratic, political, technological, and economic (Gonzalez-Zapata and Heeks 2015). The bureaucratic perspective wants OGD to improve public services through a more efficient and effective data management program. The technological perspective desires an improved data infrastructure. This helps tie in with the bureaucratic perspective by providing better data management. The political perspective wants OGD for better transparency, accountability, and participation. The economic perspective wants OGD for more access to new products, services, revenue, profits, and jobs. The construction project web application leans more towards the political and economic perspectives. Increased transparency helps provide more construction project information. This helps brokers potentially generate more revenue by guiding clients towards new developments.

The four main perspectives of OGD have their goals that benefit the overall community, but also face major challenges. Governments face staff and funding constraints in collecting, maintaining, and sharing data (Wilson and Cong 2021). Effective use of OGD also relies on internet access, user technology skills, usable data formats, user knowledge, community resources, and formal government structures (Young and Yan 2017). While having a very open and granular OGD is ideal, privacy concerns may cause cities to not fully disclose landowners or construction project applicants (Zhu and Freeman 2019).

Collating the data and presenting it in a construction project application is similar to how civic hackers use OGD for products and social good applications (Young and Yan 2017). OGD can be evaluated on traceability, currency, expiration, completeness, compliance, understandability, and accuracy (Vetro et al. 2016). Traceability and understandability rely on the presence of metadata. Few cities give descriptive metadata, so the construction project data scores poorly with these metrics. Expiration tracks the ratio between the delay in dataset updates after the expiration of previous versions. Since each city planning department has its own data standards, completeness varies. Missing fields are supplemented through trade journals and title feed programs. Compliance tracks the percentage of standardized columns in a dataset. Although each city planning department has its own data standards, information about the project name, address, property types, building area, multifamily units, and hotel rooms are standardized for every city.

To compile a functional construction project dataset, the OGD needs to be transformed. Datasets from various government agencies are cleaned into a workable format (Denis and Goeta 2017). To clean the information, missing and abnormal information are corrected. Data from each government agency is then standardized. The different errors and standards may not be noticeable within the original datasets, but stand out if uncorrected in the combined dataset (Denis and Goeta 2017).

OGD encompasses a broad range of subjects like census data, neighborhood meetings, and city finances. The government workers assigned to compile and report the data tend to only report in their own local environment. For example, San Jose city officials only tend to disclose OGD pertaining to their city. It is impossible for these officials to cater to all the possible users of this data. To cobble together the necessary data for this project, the information must be gathered from many different departments. The city planning departments have the construction data. Santa Clara County has the parcel and ownership data. The California Secretary of State has the business data that can help verify property ownership. These data sources also must be standardized and doublechecked to create an accurate construction project dataset.

2.3. City Planning Department Construction Project Sites

Every city in Silicon Valley differs in how construction projects are tracked and reported. Cities disclose construction projects via OGD through their planning departments. Some cities do not disclose construction project information like Newark, CA. Other cities like Fremont and Sunnyvale are nicely transparent by providing project information with spreadsheets, summaries, web maps, and printed maps. The construction project web application aggregates the development information into one site and standardizes the information based on broker and industry standards.

Fremont and Sunnyvale report on construction projects through spreadsheets and maps (Fremont 2020; Sunnyvale 2020). Spreadsheets are great to track information about building type, area, developers, and construction status. However, this information is not expressed spatially. It is difficult to see how these developments affect local neighborhoods or other cities.

Maps convey the construction project information spatially. Building type, area, and construction status can be easily determined immediately. Santa Clara presents its developments in an Esri story map as shown in Figure 2. Each development has its land area color coded by construction status. Pictures of every development are along the bottom. Clicking on the land area zooms towards the parcel and the corresponding picture appears. The picture also has text descriptions with links to more information about construction projects (Santa Clara 2020).

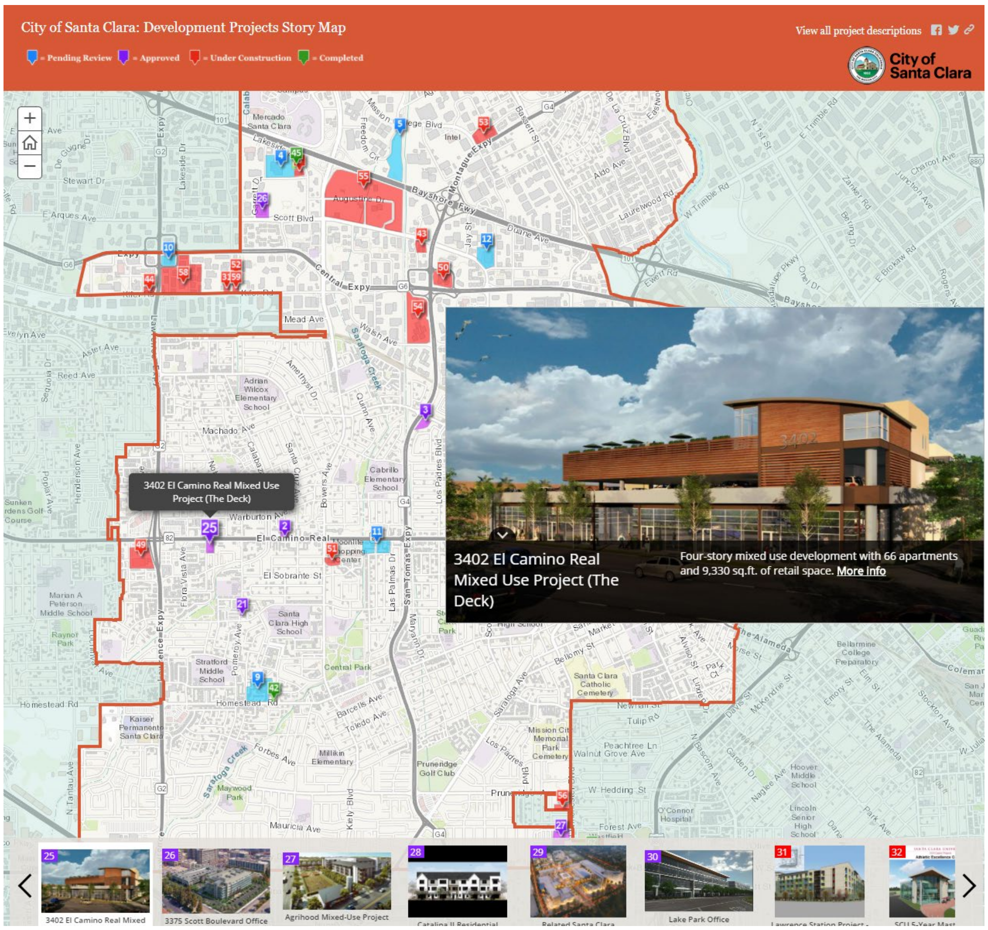

Figure 2. Santa Clara development map. Source: Santa Clara 2020

Sunnyvale also has a development project map as shown in Figure 3 that is color coded by construction status. However, the land areas are not shown. This makes it hard to determine the scope of a construction project. It is also difficult to see the property type without clicking on each dot (Sunnyvale 2020).

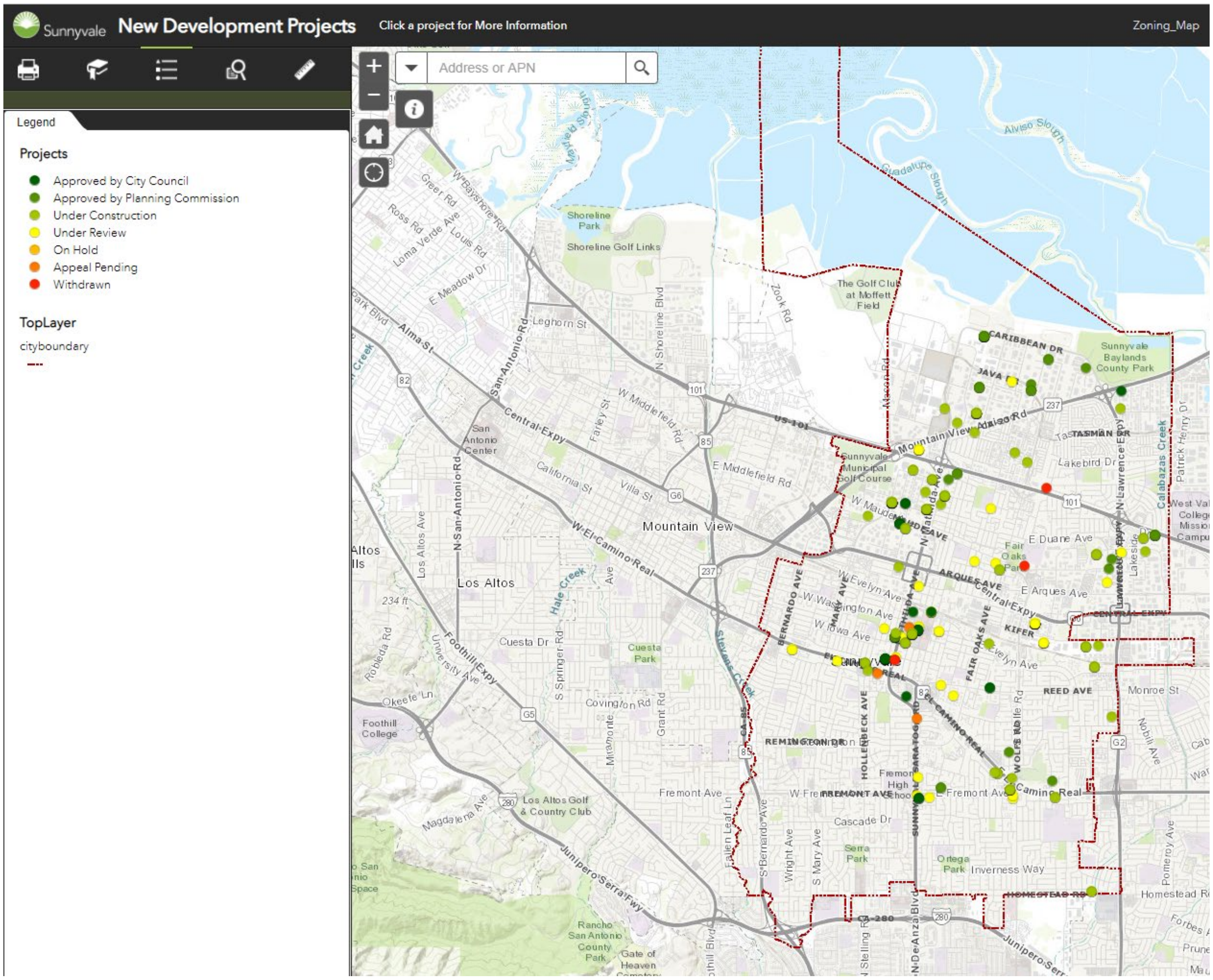

Figure 3. Sunnyvale development map. Source: Sunnyvale 2020

The Cupertino Project Activity Map as shown in Figure 4 tracks development projects in various stages of construction. The projects are presented upon a 3D Map where users can select properties by the construction statuses: applied, approved, under construction, and completed. Clicking the development project by the dropdown or on the map provides a popup with a short summary the project. There is also a link that provides more information like the developer, site plans, and a thorough description of the project. The basemap can also be changed to help give users a better sense of location. Construction projects are also color coded based on status (Cupertino 2020). The city construction project map provides good ideas like having the land area be represented on a map and having the developments color coded by construction status. 3-D buildings can be extruded to see how the construction projects look in relation to the rest of the city. It may be troublesome to create 3-D maps for every development in the study area. However, each construction project can be represented by an icon that describes the property type. This icon can be color coded by construction type.

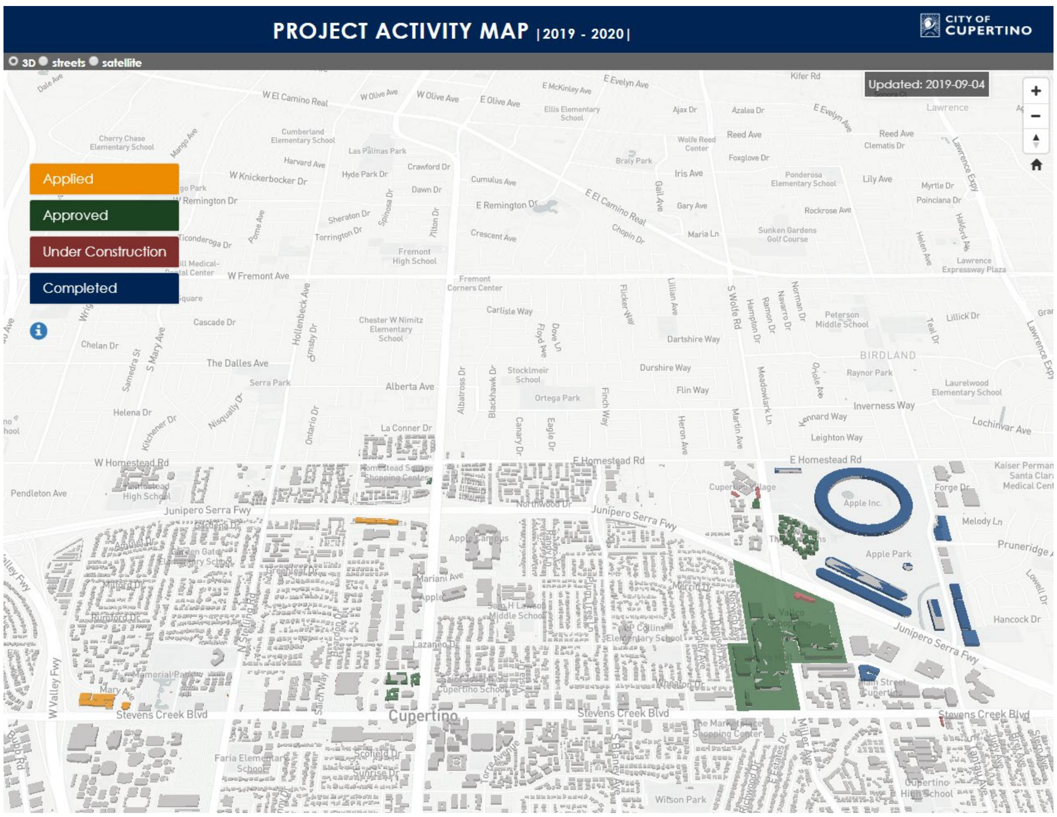

Figure 4. Cupertino project activity map. Source: Cupertino 2020

The San Francisco Development Pipeline Map as shown in Figure 5 has search filters that the CRE construction project web application can implement. Users can filter by project size via non-residential square feet (sqft), multifamily units, and affordable multifamily units. Neighborhoods and circular address buffer searches may also be implemented. The map grants an option to filter by project status. The user can filter for all projects, under construction, building permit approved, planning entitled, and proposed (San Francisco 2020).

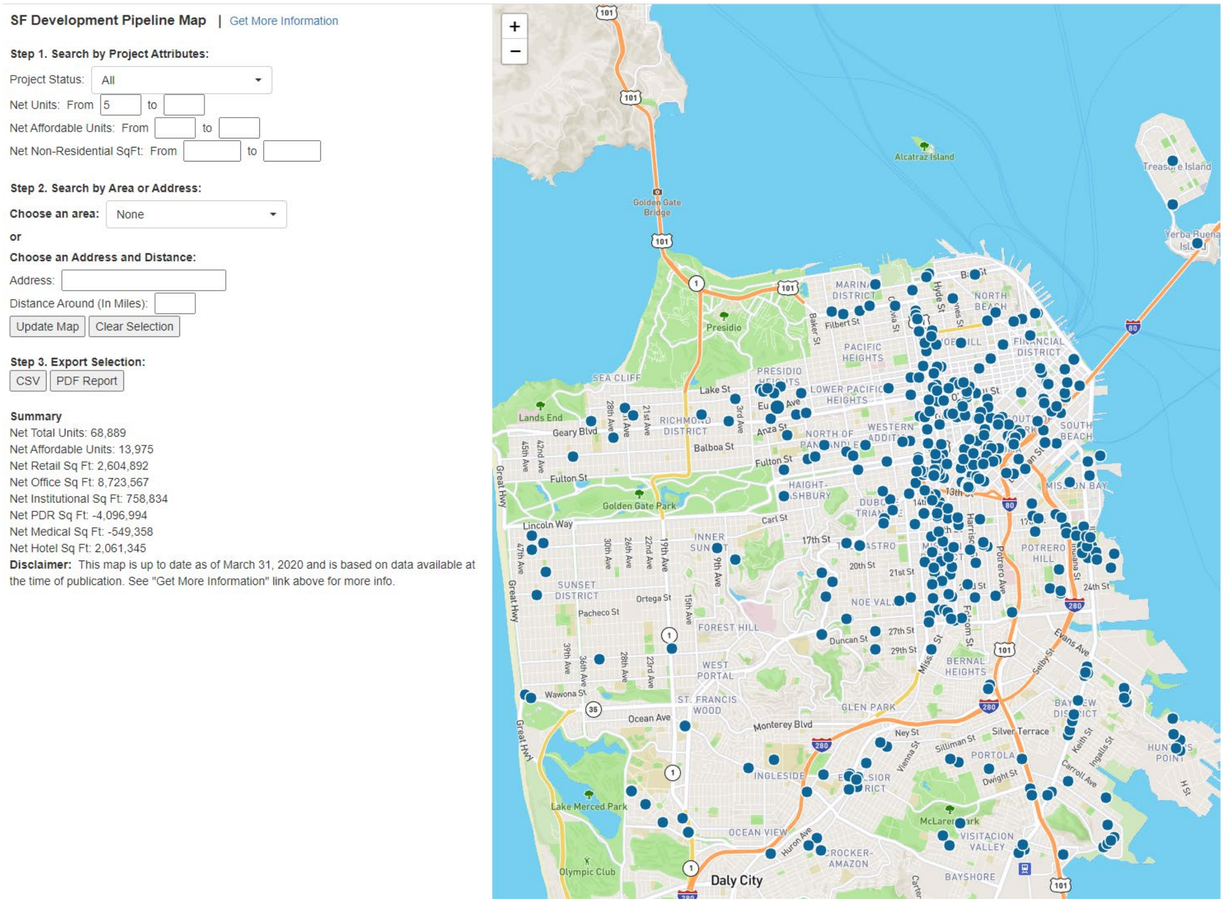

Figure 5. San Francisco development pipeline map. Source: San Francisco 2020

The planning entitled status is unique to San Francisco. It means that the project is approved by the planning department, but has not been granted construction rights. This stems from measures such as Proposition M that limits construction approvals of office projects that are above 25,000 sqft citywide to 950,000 sqft per year. 75,000 sqft of this limit is reserved for construction projects between 25,000-50,000 sqft. The remainder 875,000 sqft is allocated for large cap projects above 50,000 sqft. Unused allocations carry over to the next year (SPUR 2020). On March 2020, voters passed Proposition E that tied construction approval limits for large cap projects to Regional Housing Needs Allocation (RHNA) affordable housing goals (San Francisco Business Times 2020). For the CRE construction project web application, the planning entitled status is equivalent to the proposed status. The building permit approved status counts as approved for the thesis project.

Summarized totals based on the search filters are another feature to implement in the CRE construction web application. If the broker just wants a quick glance of construction project totals per property type or status, then this feature is very convenient. Options to export the data as a CSV or PDF file is also useful for future data analysis. Dots representing construction projects can be clicked for further information that gives multifamily units, office square footage, and links to planning applications (San Francisco 2020). The user experience can be improved by having different icons for each property type.

The construction project sites from these cities offer examples in combining construction project data in different user-interfaces. Santa Clara, Sunnyvale, and Cupertino offer construction project information where the construction status can be determined at a glance. San Francisco gives options to filter by construction status, property area, multifamily units, neighborhood, and proximity to a user-defined address. More information can be gained from clicking on each project icons from all these websites. San Francisco is the only site that allows project characteristic filters, but the dots only show project locations. The thesis construction project hopes to combine the good user-interface examples from these sites like filters to select the desired view and color to easily determine property type and construction status. The project scope is also expanded to include the major cities of Silicon Valley so that construction projects may be presented regionally.

Chapter 3 Methodology

This chapter describes the methodology and requirements necessary to construct the CRE construction project web application. Section 3.1 outlines the requirements and objectives necessary to complete the web application. Next, Section 3.2 describes the data sources. Section 3.3 presents the software used to create the application. Section 3.4 depicts the data preparation necessary to make it accessible in the web application. Section 3.5 goes over the application workflow. Section 3.6 gives a description of survey questions and how broker input shaped the application.

3.1. Requirements and Objectives

The project objective is to create a web application for CRE brokers to track construction projects within the Bay Area. Spatial comprehension is increased when brokers can see the developments plotted on a map. The developments can be filtered by property type, size, city, construction status, and proximity to mass transit. The following requirements are necessary to meet these objectives.

3.1.1. Functional Requirements

Functional requirements for the web application are the specific tasks that users must be able to complete. These tasks were chosen to help users fulfill the business goals of the author's brokerage. The overarching goal of the web application is for users to keep track of construction projects within Silicon Valley. To do so, the web mapping application was designed to serve the following functional requirements:

- Allow users to view a map of properties under construction in the Silicon Valley area, with clear icons that represent property type and construction status

- Allow users to search for properties by inputting addresses into a search bar
- Allow users to zoom and pan around the map
- Allow users to click on property icon and obtain information on:
  - address,
  - property name,
  - property type,
  - owner,
  - construction status, and
  - property size.
- Allow users to filter the map by:
  - property type,
  - property size,
  - city in which the property is located,
  - construction status, and
  - proximity to mass transit.

3.1.2. Accessibility

The application must be shareable throughout the organization over the internet. Brokers are going to use the construction project web application on a desktop. Mobile formats do not have screen real estate to adequately show the development filters and the map. Next, brokers only need an internet connection to use the device. No additional applications are necessary. Lastly, brokers should be able to use the application with minimal training.

3.1.3. Software and Platform

This application is the first draft of a web application that increases in scope and functionality over time. The software used to create the application must be able to show the construction projects on a map to fulfill the spatial requirements. The software should also ideally be available and easily accessible for free. Software with a generous freemium tier meets these requirements. The chosen software should also support data visualizations and be accessible enough for future developers to learn the features quickly.

3.2. Data

The CRE construction project application requires spatial and construction project data. The main spatial datasets consist of parcel shapefiles and point locations of the construction project data. The construction project data includes the project name and details. The spatial and construction project components must be joined to present the information spatially and via popup descriptions. The following sections describe each component more thoroughly. Table 1 summarizes each dataset.

Table 1. Summary of data

DATA SET	SPATIAL RESOLUTION	TEMPORAL RESOLUTION	SOURCE	DATA FORMAT
Construction Projects	N/A	Projects with Construction Statuses: Proposed, Approved, Under Construction from September 2020 – March 2021	City Planning Departments within Santa Clara County	Text
Parcel Ownerships	N/A	Active Companies from September 2020 – March 2021	Planning Departments, Landvision, California Secretary of State	Text
Land Parcels	Parcels	September 2020 – March 2021	Santa Clara County	Polygon
CalTrain Stations	CalTrain Stations	September 2020 – March 2021	CalTrain	Point
BART Stations	BART Stations	September 2020 – March 2021	BART	Point
VTA Light Rail Stations	VTA Light Rail Stations	September 2020 – March 2021	VTA	Point

3.2.1. Construction Project Data

The construction project data has been collected from multiple city planning departments. Each city has its own database and discloses the construction project data in different formats. Some cities do not disclose construction project data, while others report the data in ArcGIS online maps, PDF, CSV, or Excel formats. This data is then manually gathered to obtain the construction project name, owner, property type, property area, multifamily units, hotel rooms, assessor parcel number (APN), address, and construction status.

3.2.2. Spatial Data

Construction projects are built on land parcels. The spatial data for these parcels are collected as shapefiles from Santa Clara County. Some construction projects may not have an address to geocode and provide accurate coordinates. By matching the construction project APN to the Santa Clara County parcel shapefiles, accurate coordinates for the development can be obtained.

Spatial data is also collected for mass transit stations from Bay Area Rapid Transit (BART), CalTrain, and Valley Transit Authority (VTA) Light Rail. This point data is necessary for proximity to mass transit searches.

3.3. Software

This section describes the software necessary to create the construction project application. Mapbox is the main application programming interface (API) used for this web application. Microsoft Excel and ArcGIS Pro are used to organize and process the data into a geographic JavaScript object notation (GeoJSON) format usable by Mapbox. Landvision is a proprietary web application used to confirm parcel and ownership information. The data is then organized with Microsoft Excel or ArcGIS Pro. Atom is a text editor used to program the web application with JavaScript. Section 3.3.1 provides a quick summary of Microsoft Excel, and Section 3.3.2 does the same with ArcGIS Pro. Section 3.3.3 lays out the benefits of using Landvision. Section 3.3.4 gives a short description of Atom. Section 3.3.5 elaborates about the specific Mapbox features used for this project.

3.3.1. Microsoft Excel

Microsoft Excel is a spreadsheet software program created by Microsoft. While there are free options available like Google Sheets, excel is installed on my work and personal computers. Spreadsheet functions used to convert spreadsheets into a CSV format can be done with either open source spreadsheet programs like Google sheets or proprietary ones like Microsoft Excel.

3.3.2. ArcGIS Pro

ArcGIS Pro is a proprietary desktop GIS application from ESRI. This application is provided for free through the USC program. While free GIS applications such as QGIS can provide the necessary project tasks, the author is more familiar using ArcGIS Pro. Helpful tutorials also help explain the spatial programming steps for the construction application.

3.3.3. Landvision

Landvision is a proprietary spatial application from LightBox that provides real estate, sales transaction data, and government information overlaid on a web map (Lightbox 2021). This program is given to all employees at my real estate brokerage and is useful to confirm current ownership and parcel data. Figure 6. provides a screenshot of the Landvision application.

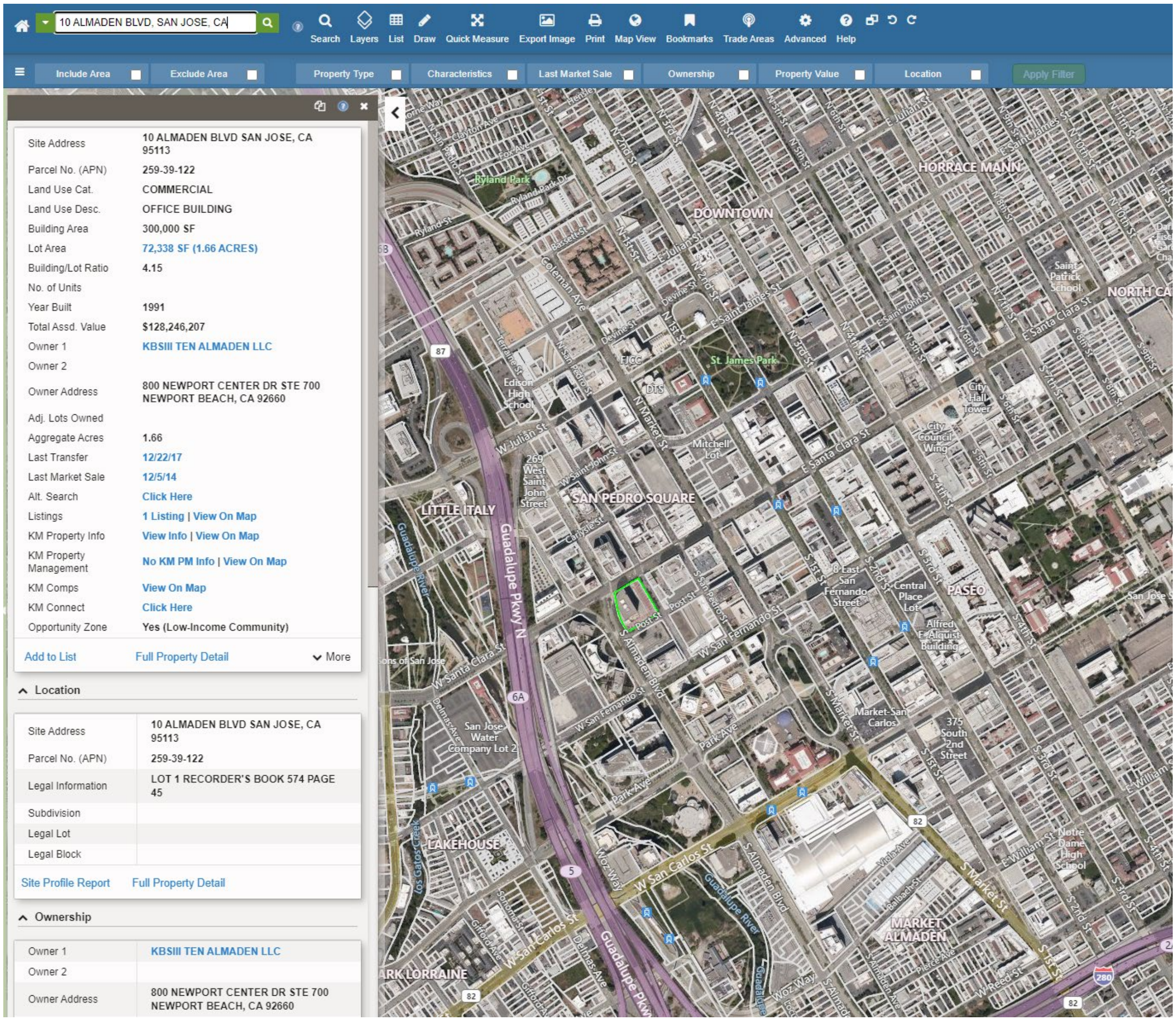

Figure 6. Landvision Screenshot. Source: Landvision 2021

Ownership needs to be validated for three reasons. Santa Clara County gives parcel information for free, but ownership is hidden due to privacy concerns. City planning departments may disclose the initial developer or owner that submitted the project application. Another developer or owner may purchase the development as it gets built. City planning departments may also disclose just the subsidiary company tied to the current parcel. Landvision may provide more information to uncover the actual developer that owns the subsidiary company.

Parcel information also needs to be validated. As the construction project progresses through the construction pipeline, parcels tied to the construction project may be combined into one larger parcel or split into many parcels. These parcel changes warrant new addresses. During the data capture period, the construction project may have recorded the old parcel or one of the newer ones. Landvision helps verify that all parcels tied to a construction project remain tracked.

3.3.4. Atom

Atom is a free, open source text editor from Microsoft that can edit code in various programming and presentation oriented languages. This editor has plugins and customizable UIs that can make web development more user friendly.

3.3.5. Mapbox

Mapbox provides mapping and location data services through their own proprietary tools like Mapbox Studio and Javascript APIs such as Mapbox GL JS. Mapbox helps people design mapping tools that can be shown over browsers on desktop computers, laptops, or phones. The free tier is generous with up to 50,000 map loads per month (Mapbox 2020). Mapbox also has a temporary geocoding API that allows 100,000 single search queries for places, address, or points of interest per month (Mapbox 2020). The API, shapefiles, and tile sets may be manipulated via JavaScript or through Mapbox Studio. Tutorials are also available to help guide developers on how to use the API.

3.4. Data Preparation

This section recounts the steps to acquire the data and convert it into a format usable for the web application. The main categories of data are spatial data representing the construction projects, spatial data representing mass transit stations, and tabular data describing the construction projects. Section 3.4.1 describes how the spatial data is obtained and manipulated. Section 3.4.2 recounts how the tabular data is chosen, collected, and verified. Section 3.4.3 goes over how the data is formatted into a GeoJSON to present in a web application. Figure 7 shows a flowchart providing an overview of the data preparation process.

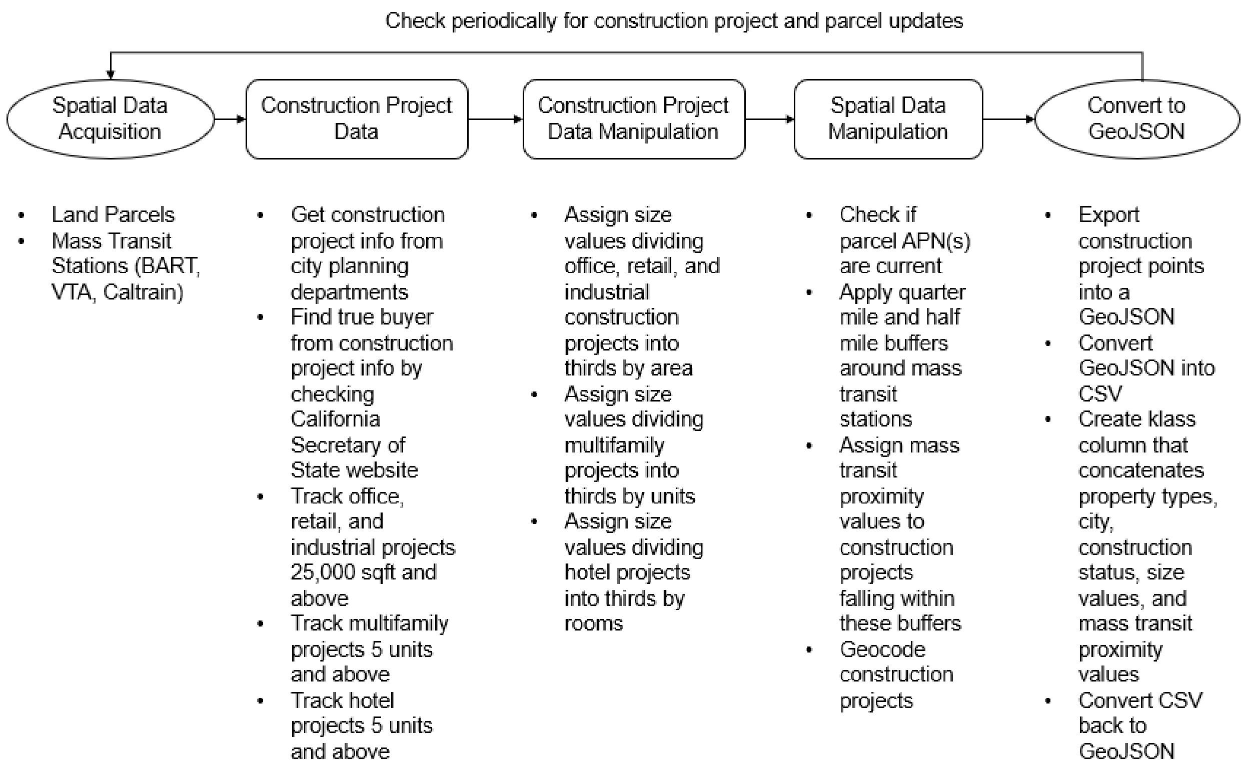

Figure 7. Data Preparation Flowchart

3.4.1. Spatial Data

Land parcel spatial data is obtained from Santa Clara County. This data is stored as polygon shapefiles. Each of the parcel polygons have their own APNs. These are matched with the construction project APNs via a process described in more detail in Section 3.4.2. The matched parcels are then converted into point data. If a construction project contains multiple parcels, then they are merged into one polygon and converted into a representative point. These points serve as the map marker locations for the construction projects.

Mass transit station spatial data are obtained as point shapefiles from the major mass transit options such as BART, Caltrain, and VTA Light Rail. Bus stops are ignored since almost all construction projects are within a half mile of a bus stop. The mass transit station locations are imported into ArcGIS Pro. Quarter-mile and half-mile buffer zones are applied to each station location using the Buffer tool. The quarter-mile distance was picked since this was close to the 500 meter (0.31 miles) ideal distance that people were willing to walk to stations (Zacharias and Zhao 2018). The half-mile distance was chosen since this is the mean distance that people walked to stations in the U.S. (Agrawal, et al. 2008). These buffer zones are used to assign proximity values shown in Table 2 to construction projects.

Table 2. Mass transit proximity values

	BART	Caltrain	VTA Light Rail
Half Mile	halfmbart	halfmct	halfmlr
Quarter Mile	quartermbart	quartermct	quartermlr

3.4.2. Tabular Construction Project Data

Construction project data are obtained from city planning websites. These projects are on plots of land that contain one or more parcels. Each parcel is given an assessor parcel number (APN). The spatial link occurs by tying the APN provided by the city planning websites to the county shapefiles.

This APN needs to be standardized and verified. The APN may have dashes, spaces, or just expressed as a number. APNs are standardized by making them numerical with no dashes or spaces. APNs may also change over time. Cities may split parcels or reassign APNs through the life of the construction project (San Jose 2020). The construction project application only keeps the most recent set of APNs. The correct construction project APNs are cross checked with addresses obtained by construction project information and title websites like Landvision.

Non-spatial data include the construction project attributes like property type, developer, multifamily units, hotel rooms, building area, and land area. The project applicant is represented as a legal entity through a limited liability company (LLC) or limited partnership (LP). Multiple LLCs or LPs may rollup to one developer. The next data collection step is finding the true developer or landowner behind the LLC or LP. The California Secretary of State site has a corporation search program that gives the managing members behind these legal entities. The managing members tend to be executives of the developer or landowner companies. Finding these connections helps ensure that all developer activity is tracked accurately within the study area.

CRE construction projects are chosen based on broker interests. The property types are offices, industrial, retail, hotel, and multifamily. New office, industrial, and retail developments above 5,000 sqft are chosen (Datastar 2020). These criteria are based on quarterly report analytical guidelines for the author's brokerage. Offices range from multiple high-rise complexes to short 1-story buildings. Industrial properties are manufacturing sheds and distribution warehouses. Retail properties may include mega-malls, grocery centers, or the first-floor restaurants of new apartment or office buildings. Purely retail developments are currently rare, so most retail space tracked are part of a larger mixed-use project that includes offices, hotels, or multifamily properties.

Cities disclose hotels and multifamily projects differently. Building areas for these property types are usually not disclosed. Hotels are described with the number of rooms, and multifamily properties are expressed by the number of units. The hotels in the area tend to be business or extended stay hotels where workers can stay for conferences or when working in company branches. Multifamily properties include condominiums, townhomes, and apartment complexes with five or more units (HUD 2020).

These construction projects are tracked through all steps of the construction pipeline. The initial step is when the development application is proposed. Next, the project must be approved. Afterwards, the project is under construction. Lastly, the construction project is complete. Construction projects that do not get approved are removed from the application. These construction statuses serve as the project timeline steps since the time to completion may vary based on project scope, finances, or political concerns. Each step within this construction timeline may take months or even years to complete.

Throughout these steps, the developers and development scope may change. Developers or investors may sell or buy partial interests or the whole construction project. Neighborhood feedback may warrant project changes in the construction development. Construction project building sizes, multifamily units, or hotel rooms may be altered to satisfy traffic concerns or community feedback. Parcels tied to the development may also change. Multiple small parcels may combine into one parcel for a large development. The Miro multifamily construction project in downtown San Jose combined nine parcels into one (San Jose 2017). The number of apartment units also increased from 610 to 630 for this development (San Jose 2020). Conversely, one large parcel may be split into multiple small parcels for condominiums or rowhouses. The Nuevo in Santa Clara is a 988 unit multifamily development. The condominium and townhome portions have been split into individual parcels to sell to the public (Santa Clara 2020). To simplify data collection, only the most current developers and development characteristics are tracked.

Stevens Creek Promenade in San Jose, CA is one example where the developers and development scope changed. Originally proposed by Fortbay in 2016, the development originally was planned to consist of 233,000 sqft of office, 10,000 sqft of retail, and up to 582 multifamily units (San Jose 2020). This development was approved in 2019 by the San Jose Planning Commission (Hall 2019). Miramar Capital purchased Stevens Creek Promenade from Fortbay in 2020 (Avalos 2020). The new owners kept the name but changed the property into a 637 multifamily unit, 250 room hotel, and 6,200 sqft retail development (Niksa 2020; San Jose 2021). Due to the major construction project changes, Steven Creek Promenade changed its construction status from an approved development to one pending approval (San Jose 2021). The application only shows the most current version of the development. Past project characteristics are noted in the project information popup comments.

3.4.3. GeoJSON

The construction project data is stored in the web page in a GeoJSON format. This format stores spatial and tabular features based on the JavaScript Object Notation Format. Figure 8 shows an example of a GeoJSON representing a construction project. The GeoJSON contains fields for the developer or owner, project name, property type, APN, building area, construction status, hotel rooms, multifamily units, and proximity to mass transit. These construction project property characteristics and mass transit data are taken from a period from September 2020 to March 2021. The web application pulls data from the GeoJSON file to filter, present, and provide information for the construction projects.

```
{
  "type": "Feature",
  "geometry": {
     "type": "Point",
     "coordinates":  [ -122.024091,37.41504 ]
  },
  "properties": {
  "OBJECTID":25,
  "Name":"589 W Java Dr",
  "Status":"Approved",
  "Owner":"Google",
  "APN":"110-26-044",
  "Address":"589 W Java Dr",
  "City":"Sunnyvale",
  "klass":"sunnyvale office approved   off2       halfmlr ",
  "retail":0,
  "multifamily":0,
  "office":315000,
  "hotel":0,
  "industrial":0,
  "PropType":"Office"
  }
},
```


Figure 8. GeoJSON

To create the GeoJSON, the construction project data is collated in Excel. Columns are created for the project name, construction status, owner, APN, address, city, and property area. More columns are added to accommodate the mass transit proximity values. Columns are also added to organize construction projects based on size for each property type. The office, retail, and industrial construction projects are divided into thirds by size. Multifamily projects are divided into thirds by units. Hotel projects are divided into thirds by rooms. Table 3 shows examples of the size values for the property types. This CSV file is imported into ArcGIS and geocoded into points using the Geocode File tool. Construction projects within the quarter-mile and half-mile buffers are assigned proximity values as shown in Table 2. The construction project points are exported as a GeoJSON using the Features to JSON tool.

Table 3. Size values

	Lower Third	Middle Third	Upper Third
Office	off1	off2	off3
Multifamily	m1	m2	m3
Hotel	h1	h2	h3
Retail	r1	r2	r3
Industrial	i1	i2	i3

This GeoJSON file is then converted back to a CSV file using the website, convertcsv.com. This CSV is further manipulated in Excel to define the nested klass key within the properties key. The web application relies on the klass values to select and filter construction projects. The klass values consist of a string containing information about the city, property type, construction status, size value, and proximity value. Figure 9 gives an example of a klass value. Each value within the string is separated by a space.

```
"klass":"mountainView retail hotel office underConstruction r1  off2 h2    halfmct   ",
```

Figure 9. Klass example

The filtering process and styling are elaborated further in Section 3.5.2. Once the klass key is defined, the columns for the size and proximity values are not needed anymore and removed. Afterwards, the CSV file is converted back into a GeoJSON.

3.5. Application Development

This section recounts the major code sections of the construction project web application. JavaScript is a programming language used to make web pages dynamic. Filtering construction project views based on characteristics like property type, construction status, city, and proximity to mass transit is not possible without this programming language. JavaScript allows the use of functions, which consist of code snippets that can perform repeated tasks and execute complex actions. JavaScript can be further enhanced with application programming interfaces (APIs).

Section 3.5.1 describes the Mapbox API. Next, section 3.5.2 goes over the filtering code. Section 3.5.3 goes over the cascading style sheets (CSS) filters. Section 3.5.4 goes over the construction project information popups. Lastly, Section 3.5.5 goes over the tips and credits sections.

3.5.1. Mapbox API

Mapbox is a third party API that enables mapping functions in JavaScript. This code is not built into the browser and must be recalled from the Mapbox servers using an access token. To create the web application, Mapbox is used to load the basemap, add the construction projects as a data layer, and define map markers from this data layer for further manipulation with the JavaScript functions. Appendix C contains screenshots of the major Mapbox functions used for this web application.

The map is created by using a function that defines a container id, “map”, and setting other options like the style, center point, and zoom level (Mapbox 2020). Maps are composed of tilesets, which are comprised of vector or raster tiles. Raster tilesets are a collection of images at different zoom levels that make a map. Vector tilesets contain geographic, geometric, and metadata. These tilesets do not inherently have style properties (Mapbox 2020). The raster and vector tilesets can be manipulated through style documents, formatted in JSON, that defines how the map should be drawn. Colors, labels, and other features can be manipulated through custom map styles. Draw order can also be manipulated to highlight information. The preset map style “satellite-streets-v9” is chosen so that brokers can use freeways, major streets, and landmarks to increase the spatial awareness of the construction projects and neighborhoods. Feature labels help confirm the construction project location. The basemap center point and zoom level are set to have all the construction projects appear when the web application loads. The basemap combines the raster tileset containing satellite imagery with the vector tileset containing the labels, street, and highway data.

User interface elements are also added to the map and serve as a way for the user to manipulate or observe the uploaded construction data. This application uses the following user interface elements: map marker, popup, navigation controls, and geocoder. These elements are all added with separate functions upon map load.

The geocoder and navigation controls are added to the basemap to improve the user experience and ease the navigation of the web application. The positions of these controls within the map can be defined. The geocoder is set to the top left map corner, and the navigation control is to the top right map corner. The navigation control has a compass that points towards true north plus two buttons that lets the user zoom in and out. The compass and zoom buttons can have their visibility toggled to be hidden.

The geocoder uses the Mapbox temporary geocoding API to move the map view to the user defined location. A circle is created and added as a point layer. When the user inputs a location into the geocoder function, the map view moves towards the user defined location. The circle is placed on the center of this map view. A bounding box is also defined for the geocoder that completely encloses Santa Clara County.

The map marker and popup user interface elements are based on the construction project data. To create the data layer, the construction projects are saved as a GeoJSON and defined as a variable, “stores”, in the web application. Each construction project is represented as a point feature within the GeoJSON. “Stores” is then loaded to the map as a point feature data layer and converted into a vector tileset.

The next step is to create map markers from this construction project data layer. A function is used to create a map marker for each construction project. The map marker pulls the coordinates from the geoJSON and plots each one on the map. A class name and event listener is also added for each map marker. The class attributes are styled with CSS and elaborated more in section 3.5.3. Event listeners activate a function based on a user action (Mozilla 2020). In this case, the event listeners, activate information popups that present more information about the construction project when clicked. Popups are described in more detail in section 3.5.4.

3.5.2. Filtering Code

The construction project visibility is controlled by the checkbox section of the web application. The checkboxes are organized by property type, construction status, city, and proximity to mass transit. Each checkbox section has its own name attribute. When the user selects a combination of property type, construction status, city, or proximity to mass transit, a JavaScript function gathers all the selected checkboxes from each section. This function then toggles the visibility of the map markers that correspond to the checked inputs. To clear all the selected checkboxes, the user can click on the “Unselect All” button. When clicked, this button activates a function that refreshes the web application and returns the page view to the initial state.

3.5.3. CSS Filters

This section describes how CSS is used to change the visibility of the construction mapmakers using the class attribute. Section 3.5.3.1 describes how class attributes are assigned to each marker via the GeoJSON. Section 3.5.3.2 shows how colors are assigned via the class attribute.

3.5.3.1. Linking Class to Map Markers

Each construction project is defined as a point feature within the GeoJSON. The CSS for this web app refers to the nested “klass” key within the “properties” key. In Figure 10, the construction project is assigned the following values for the “klass” key: Sunnyvale, office, approved, off2, halfmlr.

```
"klass":"sunnyvale office approved   off2      halfmlr ",
```

Figure 10. “Klass” key example

3.5.3.2. CSS Color Assignments

Depending on the class combinations, the map marker may be assigned various colors. The map markers consist of one color for each property type with a border signifying the construction status.

Editing the different color combinations for property types and construction status quickly becomes tedious. To make future edits easier, the colors for property types and construction statuses are set as global variables. Changing these global variables quickly change any color assignments that reference the global variables. Blur and spread are also defined as global variables. Blur controls how quickly the colors fade in the background. A blur of zero has no effect. Spread controls the size of the map marker border. Appendix A contains examples of global variables and a CSS example.

3.5.4. Construction Project Information Popups

This section describes the coding behind the information popups. Each marker is assigned an event listener. When clicked, a function is activated that zooms the map closer to the construction project. An information popup appears that states the construction project name, address, city, property type, owner, and construction status. Information about the property area, hotel rooms, and multifamily units are saved separately in the GeoJSON. To account for the different construction project property type combinations, a filter is added to not include property area, hotel rooms, or multifamily units with a zero value.

3.5.5. Tips and Credits

The tips section gives two short instructions on how to use the web application. The first suggestion is to click on the checkboxes to filter by property type, construction status, city, and proximity to mass transit. The second suggestion reveals that the icons can be clicked for more information.

Clicking on the Credits button activates an activated slideout menu that provides links to the city planning departments, Santa Clara County parcel shapefiles, and title data. These links are stored as hyperlinks in the web application. The city name corresponds to the planning department. Santa Clara County links towards Santa Clara County GIS page that provides links to the parcels. Selecting Landvision leads the user towards the parcel database used to help verify construction ownership and address data.

3.6. User Survey

A survey was sent to brokers in the author's San Jose office to gauge the requirements for a construction project web application. The survey was sent with an initial draft of the application to help give an idea of the finished product. Figure 11 shows the survey questions.

1. What property types are you most interested in (office, R&D, industrial, retail, hotel, multifamily, etc.)?
2. What property characteristics would you like to be able to search by? Currently, I plan to allow users to search the web map by property type, city, construction status, building area, and ownership.
3. What cities or regions are you most interested to track?
4. If you would like to be able to search by square footage, what size ranges are you most interested in?
5. If you would like to be able to search by hotel rooms or multifamily units, what room/unit range are you most interest in?
6. Are you interested in proximity searches that are near freeways, mass transit, etc?
7. If you are interested in proximity searches, what distances do you believe will be most relevant (within ½ mi., within 1 mi., within 5 mi., etc).
8. How can I make this construction project more useful for your needs?

Figure 11. Survey

Three brokers responded to this survey. The most popular property types were office, research and development (R&D), and industrial. R&D properties consist of a property type that combines office and industrial characteristics. The local brokers discriminate between R&D and industrial property types. Since there are few industrial developments and even fewer R&D developments in Silicon Valley, this application lumps R&D property types with industrial property types. This designation conforms with R&D property definitions from other regions. Los Angeles defines R&D property types as a flex property subset of industrial properties (LaCRE 2017).

Other property types such as retail, hotel, and multifamily are included since they are common property developments in Silicon Valley. The brokers mainly wanted Silicon Valley construction projects. The common desired size ranged from 10,000 to 50,000 sqft. Most construction projects were larger than this, so this range fell within the lower third of the property size selection area. Larger developments were included to help other brokers in the local branch. Common property characteristics requested were property type, location, and building area. When asked about mass transit, every broker answered that they wanted it in the application. This added the checkbox selection for construction projects near mass transit options such as BART, Caltrain, and VTA light rail.

Chapter 4 Results

This chapter provides an overview of the construction project web application. The app may be accessed here: http://gis-web.usc.edu/abidog/draftchecki.html. Section 4.1 goes over the initial view of the application when it first loads. Section 4.2 provides a walkthrough of the checkbox inputs that select different combinations of property types, cities, construction statuses, and proximity to mass transit. Section 4.3 describes the construction project information popups. Section 4.4 goes over the source credits.

4.1. Main Map View

The local branch of the author's brokerage is based in San Jose, CA. This city is within Santa Clara County, so the application is centered over it to minimize scrolling. A satellite basemap with street labels is chosen so that brokers can use freeways, major streets, and landmarks to increase the spatial comprehension of the construction project and neighborhood.

Geocoder and navigation controls are included to increase the user friendliness of the web application. The navigation controls consist of a module containing a plus and minus icon with a compass icon on the bottom. The navigation controls are placed on the upper-right of the map. The broker has the option to zoom in by clicking the plus icon or zoom out by clicking the minus icon. Scrolling the mouse wheel forwards and backwards also accomplish the same effect, but this may not be evident to the broker. The compass icon rotates to show the direction of true north to the user.

The geocoder control allows the broker to input an address and create a place marker on the requested site. This control is placed in the upper-left corner. The search control finds the location with Mapbox's geocoding service and zooms in to a view that includes the inputted location and the nearest development. Brokers may want to see which construction projects are near the selected address. The geocoder control is set to geocode a rectangular area that completely contains Santa Clara County. This helps prevent any stray address choices and keeps the focus on the major business areas of the San Jose office. This helps prevent any errant addresses that are too far from the construction projects and focuses the map view. “Silicon Valley Addresses” is also defined in the geocoder control to suggest to users to only input addresses within the Silicon Valley region. Figure 12 shows the application when it first loads.

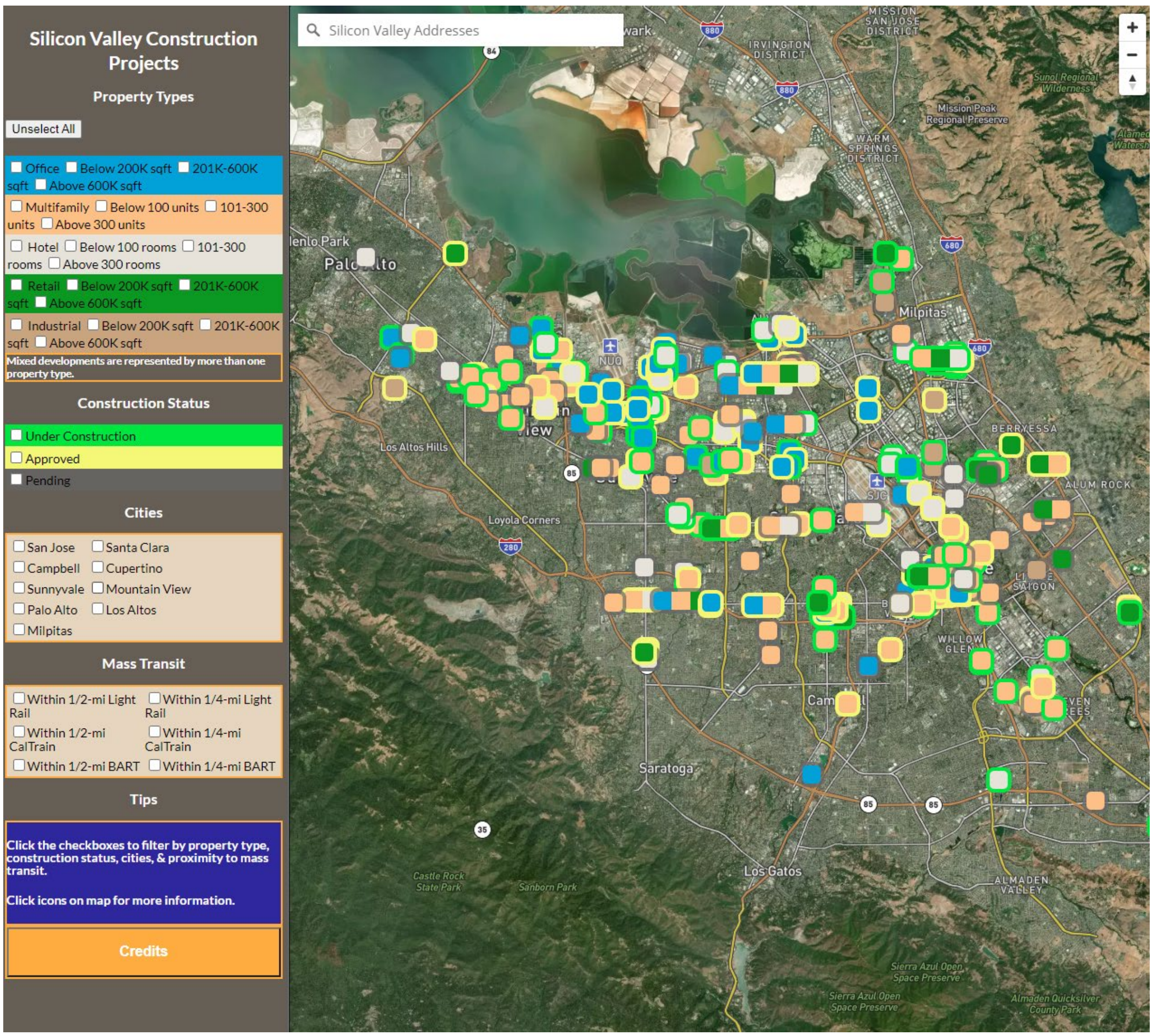

Figure 12. Initial map view

4.2. Checkbox Selection

The web application loads all the construction projects at once, with the default view showing every construction project on the map. This helps convey nearby developments nearby a property represented by a broker. This view is filtered by the section on the left as shown in Figure 12. The broker can choose between different property types, construction statuses, cities, and proximity to mass transit. The user can further select between different size ranges of the property types. Clicking on these checkboxes filters the map view to show only the construction projects meeting the chosen criteria. Everything else is hidden. The user can also choose to clear the selection by clicking on the “Unselect All” button.

Property types and construction statuses are color coded to help show the differences for each one. Figure 13 shows an example of a map marker following this color scheme. In this example, the map marker represents a multifamily development currently under construction.

Figure 13. Multifamily under construction

Construction projects that contain more than one property type are called mixed developments. This is represented by creating a map marker that places each property type side-by-side as shown in Figure 14. In this example, the mixed development comprises of multifamily, retail, and hotel property types.

Figure 14. Mixed development

Figure 15 gives an example of a search of all construction properties that meet the following criteria: all multifamily developments, under construction, in Santa Clara and Mountain View, within a half-mile of CalTrain.

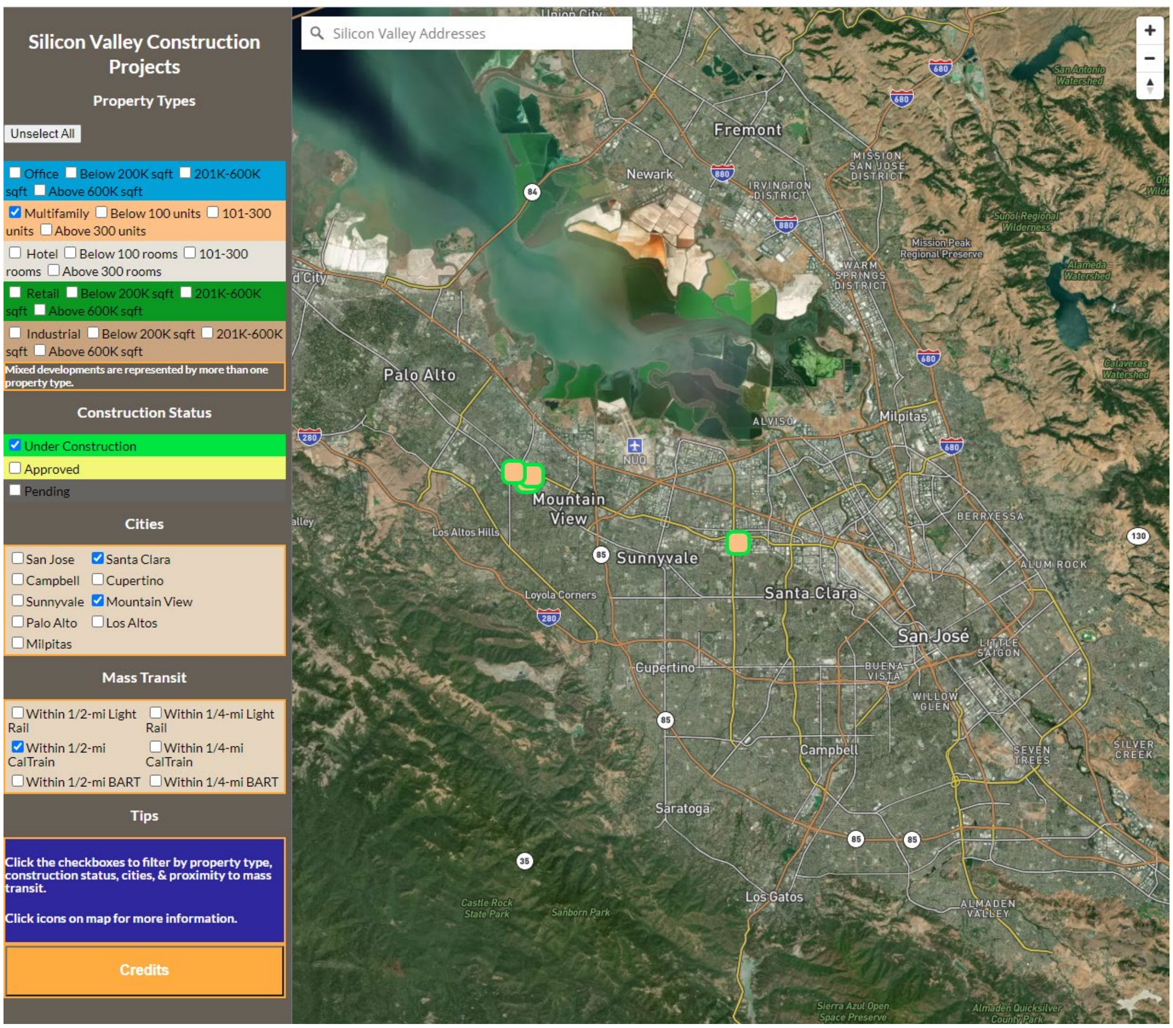

Figure 15. Search example

4.3. Information Popup

For more information, brokers can click on the construction project icon. Each marker is assigned an event listener. When clicked, the map zooms closer to the construction project and an information popup appears. The popup has information that states the construction project name, address, city, property type, owner, and construction status. Figure 16 shows a popup example.

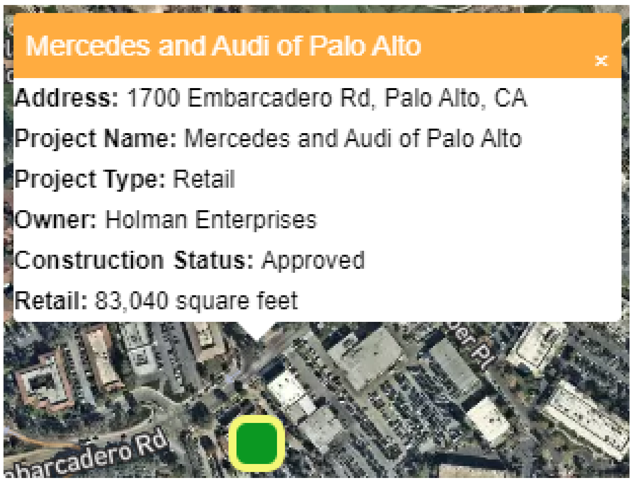

Figure 16. Information popup

In this case, the construction project is purely a retail property type. For mixed property types, the different property types are separated by commas in the property type. This is how it is saved in the GeoJSON. Figure 17 shows an example of a mixed property type popup that contains retail, hotel, and office property types.

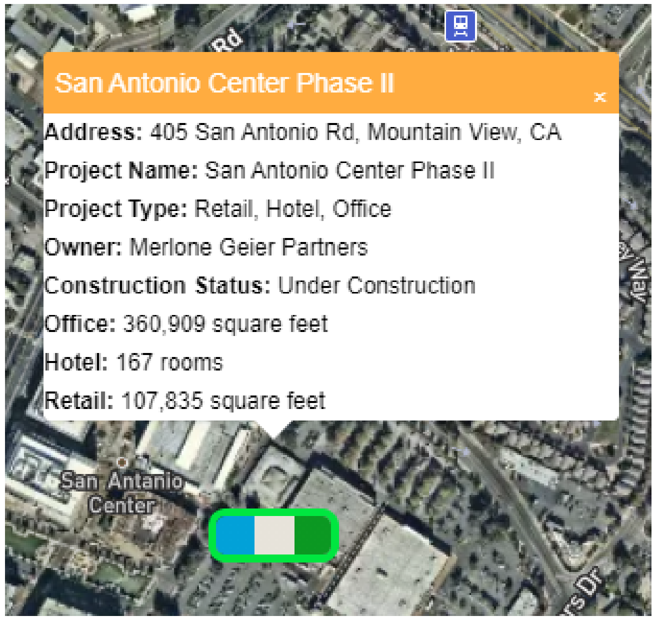

Figure 17. Mixed property information popup

4.4. Tips and Credits

To obtain more information about the data sources, brokers may click on the credits link on the lower left of the web application. This activates a slide out menu with links to city planning websites and a short data collection methodology. The links highlight when the mouse hovers over it to signify that it is clickable. Planning websites offer a way to gather more information about a construction project. The methodology shows that all office, retail, and industrial construction projects above 5,000 square feet are tracked. Also, all multifamily projects above four units and hotel projects above four rooms are recorded. Figure 18 shows the credits slide out menu.

Figure 18. Credits slide out menu

Chapter 5 Discussion

The purpose of this project is to create a construction project web application for commercial real estate brokers. This is achieved by selecting OGD and software that enables users to easily filter by property type, size, city, construction status, and proximity to mass transit. Section 5.1 discusses the challenges and obstacles in creating the web application. Next, section 5.2 reviews options on how to improve the application by scaling it up to track construction projects in more offices within the author's brokerage, suggestions on how to automate the workflow, and other usability features to improve the UX of the web application.

5.1. Challenges

Creating the application to fulfill the requirements was more difficult than expected. The main challenge involved programming and providing workarounds to make the program function. City updates became more infrequent due to COVID-19 staffing measures. Data collection also proved to be very tedious.

5.1.1. Programming

Lack of programming experience was the main challenge for this project. The proposal initially had construction projects stored in a backend database. The backend refers to the part of the web application that the user does not see. The frontend refers to the UI (Techterms 2020). The UI then requests the information using structured query language (SQL). The user could filter the construction data based on developer, property type, city, and area by predefined SQL commands.

This approach failed and the construction projects were stored in a GeoJSON format. This method provided a convenient way to store the construction project data. The GeoJSON has separate fields for the property type, developer, building size, city, proximity to mass transit, and style commands. The application also became read-only where the construction projects are predefined and formatted in the GeoJSON file. Since there is no way to define new construction projects, filtering by GeoJSON fields became the optimal technique.

The GeoJSON conversion process can also be shortened. After assigning mass transit proximity values and size values, the field representing the "klass" key can be edited using the Calculate Field tool in ArcGIS Pro. This tool concatenates the strings representing the city, property types, mass transit proximity values, and size values. This shrinks the original workflow of exporting the construction points as a GeoJSON, converting this GeoJSON into a CSV, editing the klass column by concatenating the strings, and changing the CSV back into a GeoJSON.

Another challenge arose when programming numerical ranges for property area, multifamily units, or hotel rooms. The initial approach was to let the user define minimum and maximum amounts for these values. This failed since there were reference problems in storing the user defined amounts and using these variables to define the minimum and maximum ranges. A workaround was to predefine the property area, multifamily units, or hotel rooms into thirds. These construction projects are then given different class values that correspond to their area. The final product may not work as ideally as the San Francisco construction project site with number inputs for the minimum and maximum values for property area, multifamily units, or hotel rooms, but it is currently a crude approximation (San Francisco 2020).

5.1.2. City Updates

Before COVID-19, city planning departments stuck to a consistent schedule with few delays. Most of the cities disclosed construction updates monthly. After COVID-19, updates became more infrequent. Cities may go months between disclosures due to staffing issues from COVID-19 remote work measures. City staffers may not have the resources to provide frequent updates. Construction projects may also change construction status, but are not disclosed in the city planning websites. San Jose recently approved a planned office development, but did not disclose it on their city planning website. The Mercury News, a local newspaper, disclosed the construction project update (Angst 2021). To get the most current information, OGD like city planning websites may have to be supplemented by local newspapers and trade journals.

5.1.3. Data Collection

Spotty data updates from city planning departments delay construction project information. Data cleanup also causes notable delays. This is inherent since every city discloses construction project information differently. Significant amounts of time are spent standardizing every city's disclosures into a format usable for this web application (Miller 2020). COVID measures may reduce work by shrinking the total amount of construction projects, but this is countered by searching newspapers and trade journals for missing information.

5.2. Future Work

This web application is an ongoing project that helps make it easier to track construction developments. The next steps are to expand the areas to track construction projects, speed up the workflow by automating as many processes as possible, and correct the programming issues to make the application more user friendly. Section 5.2.1 goes over methods on how to scale up tracking construction projects for more regions. Section 5.2.2 walks through steps that can be automated. Section 5.2.3 goes over new program features to make the application more user friendly.

5.2.1. Scaling Up

More people are necessary to scale up the application. To ensure that every relevant feature gets tracked, the survey detailed in Section 3.6 can be distributed to other offices within the author's brokerage. There may be regional quirks that one office may prioritize over another like the planning entitled status in San Francisco (San Francisco 2020) or R&D property types in the Silicon Valley (Datastar 2020). Once the construction project qualities are defined, the specifications can be sent to the local team of research analysts within the author's brokerage for data collection. The research analysts are then tasked with gathering the construction project data from their area and maintaining it for any construction updates. These updates include changes in construction status, project type and size, or even developer if the project sells. This data is then aggregated into one large GeoJSON and fed into the web application.

Another approach to scale up and hasten the workflow process is to introduce the application amongst my peers in the local CRE research analyst group, Datastar. Every researcher in the group already tracks construction project developments. Sharing access to the application benefits everyone involved and greatly speeds up data collection and maintenance. Local trade journals also track development projects. For example, the Silicon Valley Business Journal (2021) has the "Crane Watch" web map that tracks major developments in San Jose. Sharing the application expands the scope to include all CRE developments in Silicon Valley and greatly expands the size of the audience from solely within the author's brokerage to the public. Trade journals report on larger developments quicker than city planning departments. This application collects details about smaller projects throughout the region that may not be as newsworthy. Combining these updates provide convenient access to construction project information that increases public awareness of future regional developments.

The web application also needs to be hosted on company or third-party servers such as Amazon Web Services, Google Cloud, or Microsoft Azure. This thesis project is currently stored in USC servers and will be offline at the end of the GIST Masters program. A workaround is to store the web application on an individual computer, but the application cannot be shared to other teams of researchers and brokers. This severely hampers the usability of the web application.

5.2.2. Automation

To save time, the manual data entry and maintenance steps of the web application needs to be minimized or removed. Automation can remove these repetitive tasks though functions that let the computer accomplish these tasks. This frees up time and resources to work on other aspects of the application. In ArcGIS Pro, ModelBuilder can be used to automate tasks such as finding out which construction projects fall within a half mile or quarter mile of a mass transit station, the geocoding process, splitting the property types into thirds by area, defining the klass key in the GeoJSON for the CSS filters, and exporting the features as a GeoJSON.

Automation also makes it easier to timestamp data updates. As a project moves through the construction pipeline, it is easier to keep track of when the construction status changes. If the property type or size is modified, then timestamping makes it easier to track these edits.

Silicon Valley cities currently disclose construction projects in formats that are not machine-scrapable friendly. As of the current version of the application, only Sunnyvale releases an up-to-date version in a Microsoft Excel spreadsheet format (Sunnyvale 2020). As this application scales up, other cities like Fremont discloses construction projects in machine readable formats (Fremont 2020). Automating the construction project updates from cities that provide updates in machine readable formats can greatly speed up the data entry and maintenance of the web application.

5.2.3. New Program Features

Application updates may be added to increase the functionality and user experience. Initial changes are directed to improving the search filters. Numerical input boxes may be used instead of checkboxes to enable users to define the preferred ranges for property area, multifamily units, hotel rooms, or proximity to mass transit. Text inputs for name searches can also be added to search for all projects that involve a particular developer. Polygon searches can also be used so that the application can show only projects within a user-defined area or neighborhood. The usability of these different search options may be further augmented by letting the user export the results in a CSV or pdf file for further analysis.

Other usability features to include involve data layers such as parcels and passenger counts in mass transit stations. The construction projects are currently represented by point icons on the web application. Adding a layer of all parcels involved for each construction project helps communicate the scope of the development to the user. Construction projects near mass transit stations help optimize usage as people use public transportation for their work commutes, reduce road traffic, and create walkable urban areas (Zykofsky 1998). Multifamily, hotel, office, and retail developments benefit from increased valuations and asking rents if they are in walkable urban areas and attract future development in these districts (Loh et al. 2019).

References

Andersen, Ted. 2020. "Vacancy tax, limits on office developments win support of city voters at polls." San Francisco Business Times, March 4. Accessed December 3, 2020. https://www.bizjournals.com/sanfrancisco/news/2020/03/04/vacancy-tax-limits-on-office-developments-win.html.

Angst, Maggie. 2021. "San Jose: 18-Story Glass Office Tower with Rooftop Gardens Approved Downtown." *The Mercury News.* April 14, 2021. Accessed May 7, 2021. https://www.mercurynews.com/2021/04/14/san-jose-approves-iconic-18-story-downtown-san-jose-office-tower-with-rooftop-gardens.

Attard, Judie, Fabrizio Orlandi, Simon Scerri, and Sören Auer. 2015. "A Systematic Review of Open Government Data Initiatives." Government Information Quarterly 32 (4): 399–418. https://doi.org/10.1016/j.giq.2015.07.006".

Avalos, George. 2020. "Big mixed-use San Jose complex moves forward with property deal." *The Mercury News*. July 28, 2020. Accessed May 15, 2021. https://www.mercurynews.com/2020/07/28/big-san-jose-property-real-estate-office-housing-retail-tech-develop/

Bay Area Rapid Transit. 2020. Geospatial Data. Accessed February 7, 2021. https://www.bart.gov/schedules/developers/geo

Brown, Greg and Hunter Glanz. 2018. "Identifying potential NIMBY and YIMBY effects in general land use planning and zoning." Applied Geography 99 (2018) 1-11.

City of Cupertino. 2020. "Project Activity Map [2019-2020]." Accessed September 16, 2020. http://gis.cupertino.org/webmap/pam/#14/37.33024/-122.02733/0/45.

City of Fremont. 2020. "Development Activity." Accessed December 3, 2020. https://fremont.gov/411/Development-Activity.

City of Milpitas. 2018. "Development Projects." Accessed September 27, 2020. http://www2.ci.milpitas.ca.gov/economicdev/home/developmentprojects/.

City of Mountain View. 2020. "Active Projects." Accessed September 27, 2020. https://www.mountainview.gov/depts/comdev/planning/activeprojects/default.asp.

City of Newark. 2020. "Specific Plans & Master Plans." Accessed September 27, 2020. https://www.newark.org/departments/community-development/specific-plans-master-plans.

City of Palo Alto. 2020. "Pending and Approved Projects." Accessed September 27, 2020. https://www.cityofpaloalto.org/gov/depts/pln/current/projects/default.asp.

City of San Francisco. 2020. "SF Development Pipeline Map." Accessed December 3, 2020. http://sfplanninggis.org/pipeline/.

City of San Jose. 2017. “SP17-009 Special Use Permit.” Accessed May 15, 2021. https://www.sanjoseca.gov/Home/ShowDocument?id=55858

City of San Jose. 2020. “Development Projects.” Accessed December 3, 2020. https://www.sanjoseca.gov/your-government/departments/planning-building-code-enforcement/planning-division/data-and-maps/development-monitoring/new-planning-applications/-folder-491.

City of San Jose. 2021. “Newly Filed Projects 01/04/2021 to 01/08/2021.” Accessed May 15, 2021. https://www.sanjoseca.gov/Home/ShowDocument?id=68866

City of Santa Clara. 2020. “Development Projects Story Map,” Accessed October 25, 2020. https://www.arcgis.com/apps/MapTour/index.html?appid=5afdbed13fad458cb6288c46a0bad060.

City of Sunnyvale. 2020. “Development Reports.” Accessed September 27, 2020. https://sunnyvale.ca.gov/business/projects/devreports.htm.

County of Santa Clara. 2020. “Available GIS Map Data.” Accessed September 27, 2020. https://www.sccgov.org/sites/gis/GISData/Pages/Available-GIS-Data.aspx

Cybulski, Paweł, and Tymoteusz Horbiński. 2020. “User Experience in Using Graphical User Interfaces of Web Maps.” ISPRS International Journal of Geo-Information 9 (7): 412. https://doi.org/10.3390/ijgi9070412.

Danneels, Lieselot, Stijn Viaene, and Joachim Van den Bergh. 2017. “Open Data Platforms: Discussing Alternative Knowledge Epistemologies.” Government Information Quarterly 34 (3): 365–78. https://doi.org/10.1016/j.giq.2017.08.007.

Datastar Research Group – Silicon Valley. “Real Estate Definition Comparison Chart for Silicon Valley Brokerages.” Data* Working Group Notes. Unpublished.

Dawes, Sharon S., Lyudmila Vidiasova, and Olga Parkhimovich. 2016. “Planning and Designing Open Government Data Programs: An Ecosystem Approach.” Government Information Quarterly 33 (1): 15–27. https://doi.org/10.1016/j.giq.2016.01.003.

Denis, Jérôme, and Samuel Goëta. 2017. “Rawification and the Careful Generation of Open Government Data.” Social Studies of Science 47 (5): 604–29. https://doi.org/10.1177/0306312717712473.

Fan, Bo, and Yupan Zhao. 2017. “The Moderating Effect of External Pressure on the Relationship between Internal Organizational Factors and the Quality of Open Government Data.” Government Information Quarterly 34 (3): 396–405. https://doi.org/10.1016/j.giq.2017.08.006.

Gonzalez-Zapata, Felipe, and Richard Heeks. 2015. "The Multiple Meanings of Open Government Data: Understanding Different Stakeholders and Their Perspectives." Government Information Quarterly 32 (4): 441–52. https://doi.org/10.1016/j.giq.2015.09.001.

Hall, Meghan. 2019. "Fortbay's 10-Acre Stevens Creek Promenade Project Receives Unanimous Approval from San Jose Planning Commission." *The Registry*, January 18, 2019. Accessed May 15, 2021. https://news.theregistrysf.com/fortbays-10-acre-stevens-creek-promenade-project-receives-unanimous-approval-from-san-jose-planning-commission/

Hegarty, Mary. 2011. "The Cognitive Science of Visual-Spatial Displays: Implications for Design." Topics in Cognitive Science 3 (3): 446–74. https://doi.org/10.1111/j.1756-8765.2011.01150.x.

Hooper, Tyler, and Chris Rowe. 2020. "355-365 1st St Los Altos, CA Offering Memorandum." Kidder Mathews. April 20, 2020.

Horbinski, Tymoteusz. 2019. "Progressive Evolution of Designing Internet Maps on the example of Google Maps." Geodesy and Cartography 68 (1): 177-190. http://orcid.org/0000-0002-9681-6762

Horbiński, Tymoteusz, Paweł Cybulski, and Beata Medyńska-Gulij. 2020. "Graphic Design and Button Placement for Mobile Map Applications." The Cartographic Journal 57 (3): 196–208. https://doi.org/10.1080/00087041.2019.1631008.

Karlinsky, Sarah, Szambelan, Sarah Jo, and Kristy Wang. 2017. "Room for More." Spur Report August 2017.

Kim, Minjee. 2020. "Upzoning and value capture: How U.S. local governments use land use regulation power to create and capture value from real estate developments." Land Use Policy 95 (2020) 104624: 1-12.

Lightbox. 2021. "Landvision." Accessed April 7, 2021. https://www.lightboxre.com/.

Loh, Tracy Hadden, Leinberger, Christopher B., and Jordan Chafetz. 2019. "Foot Traffic Ahead: Ranking Walkable Urbanism in America's Largest Metros." Center for Real Estate and Urban Analysis The George Washington University.

Los Angeles Commercial Real Estate (LaCRE) 2017. "Types of Industrial Properties Explained." Accessed April 6, 2021. https://lacre.net/wp/types-of-industrial-properties-explained/779/.

Mapbox. 2021. "Mapbox." Accessed April 7, 2021. https://www.mapbox.com/.

Miller, Casey. "Los Angeles Times California Wildfires Map." Webinar from Mapbox. San Francisco, CA. September 24, 2020. http://info.mapbox.com/v1Sf0zD20u0KNHV3X00R000

Mozilla. 2021. "EventListener." Accessed April 7, 2021. https://developer.mozilla.org/en-US/docs/Web/API/EventListener.

Niksa, Matthew. 2020. "Developer swaps out office space with hotel for mixed-use project along San Jose's Stevens Creek Boulevard." *Silicon Valley Business Journal*. Accessed May 15, 2021. https://www.bizjournals.com/sanjose/news/2020/12/18/fortbay-miramar-capital-stevens-creek-boulevard-sj.html

Roth, Robert E., Arzu Çöltekin, Luciene Delazari, Homero Fonseca Filho, Amy Griffin, Andreas Hall, Jari Korpi, et al. 2017. "User Studies in Cartography: Opportunities for Empirical Research on Interactive Maps and Visualizations." International Journal of Cartography 3 (sup1): 61–89. https://doi.org/10.1080/23729333.2017.1288534.

San Mateo County. 2016. "Caltrain Stations." Accessed February 7, 2021. https://data-smcmaps.opendata.arcgis.com/datasets/8b8f2f498353438eb41c09e618f68be1_1?geometry=-123.716%2C37.009%2C-120.252%2C37.773.

Sánchez, David, and Alexandre Viejo. 2017. "Personalized Privacy in Open Data Sharing Scenarios." Online Information Review 41 (3): 298–310. https://doi.org/10.1108/OIR-01-2016-0011.

Santa Clara Valley Transportation Authority. 2008. "Light Rail Stops." Accessed February 7, 2021. https://data.vta.org/datasets/light-rail-stops?geometry=-122.366%2C37.229%2C-121.500%2C37.420.

Santa Clara Valley Transportation Authority. 2020. "Bus Routes and Stops January 2020." Accessed February 7, 2021. https://data.vta.org/datasets/bus-routes-and-stops-january-2020?geometry=-123.591%2C36.832%2C-120.128%2C37.597.

Saxena, Stuti. 2018. "Summarizing the Decadal Literature in Open Government Data (OGD) Research: A Systematic Review." Foresight 20 (6): 648–64. https://doi.org/10.1108/FS-07-2018-0074.

Silicon Valley Business Journal. 2021. "San Jose Crane Watch." *Silicon Valley Business Journal*. Accessed May 16, 2021. https://www.bizjournals.com/sanjose/maps/silicon-valley-crane-watch

Smallman, Harvey S., and Maia B. Cook. 2011. "Naïve Realism: Folk Fallacies in the Design and Use of Visual Displays: Topics in Cognitive Science." Topics in Cognitive Science 3 (3): 579–608. https://doi.org/10.1111/j.1756-8765.2010.01114.x.

TechTerms. 2020. "Backend." Accessed April 20, 2021. https://techterms.com/definition/backend

U.S. Bureau of Labor Statistics. 2021. "Economy at a Glance." Accessed April 7, 2021. https://www.bls.gov/eag/eag.ca_sanjose_msa.htm.

U.S. Department of Housing and Urban Development (HUD). 2020. "Multifamily Properties – Assisted." https://hudgis-hud.opendata.arcgis.com/datasets/83d334f8b4614cce9e67b0e0a1105520_0.

Vetrò, Antonio, Lorenzo Canova, Marco Torchiano, Camilo Orozco Minotas, Raimondo Iemma, and Federico Morando. 2016. "Open Data Quality Measurement Framework: Definition and Application to Open Government Data." Government Information Quarterly 33 (2): 325–37. https://doi.org/10.1016/j.giq.2016.02.001.

Weinstein Agrawal, Asha, Marc Schlossberg, and Katja Irvin. 2008. "How Far, by Which Route and Why? A Spatial Analysis of Pedestrian Preference." Journal of Urban Design 13 (1): 81–98. https://doi.org/10.1080/13574800701804074.

Wickens, Christopher D., and C. Melody Carswell. 1995. "The Proximity Compatibility Principle: Its Psychological Foundation and Relevance to Display Design." Human Factors: The Journal of the Human Factors and Ergonomics Society 37 (3): 473–94. https://doi.org/10.1518/001872095779049408.

Wilson, Bev, and Cong Cong. 2020. "A Survey of Municipal Open Data Repositories in the U.S.:" International Journal of E-Planning Research 9 (4): 1–22. https://doi.org/10.4018/IJEPR.2020100101.

Wilson, Bev, and Cong Cong. 2021. "Beyond the Supply Side: Use and Impact of Municipal Open Data in the U.S." Telematics and Informatics 58 (May): 101526. https://doi.org/10.1016/j.tele.2020.101526.

Young, Meg, and An Yan. 2017. "Civic Hackers' User Experiences and Expectations of Seattle's Open Municipality Data Program." Proceedings of the 50th Hawaii International Conference on System Sciences 2017. http://hdl.handle.net/10125/41480.

Zacharias, John, and Qi Zhao. 2018. "Local Environmental Factors in Walking Distance at Metro Stations." Public Transport 10 (1): 91–106. https://doi.org/10.1007/s12469-017-0174-y.

Zhu, Xiaohua, and Mark Antony Freeman. 2019. "An Evaluation of U.S. Municipal Open Data Portals: A User Interaction Framework." Journal of the Association for Information Science and Technology 70 (1): 27–37. https://doi.org/10.1002/asi.24081.

Zykofsky, Paul. 1998. "Why Build Near Transit?" Local Government Commission. Accessed May 17, 2021. https://www.lgc.org/resource/why-build-near-transit/

Appendix A CSS Examples

Global Variable

```css
/* Property Type and Construction Status Color Definition */
:root {
/*Construction Status Border and Color Variables*/
 --blur: 0px;
 --spread: 4px;
 --underConstructionColor: rgba(0, 230, 64, 1);
 --approvedColor: rgba(244, 247, 118, 1);
 --pendingColor: rgba(102,102,102 ,0.7);

/*Property Type Color Variables*/
 --officeColor: rgba(2, 161, 216, 1);
 --multifamilyColor: rgba(253, 192, 134, 1);
 --hotelColor: rgba(231,227,218, 1);
 --retailColor: rgba(11,152,34,1);
 --industrialColor: rgba(201,164,127,1);
    }
```

Single Property CSS Example

```css
.marker.office.approved {
border: none;
  cursor: pointer;
  height: 20px;
  width: 20px;
  background-color: var(--officeColor);
      box-shadow:
    0 0 var(--blur) var(--spread) var(--approvedColor);
    }
```

Mixed Property CSS Example

```css
/* Mixed */
/*2 property types*/
.marker.office.hotel {
  border: none;
  cursor: pointer;
  height: 20px;
  width: 40px;
  background: /* background-image: url('Images/proptwo.png'),*/
      linear-gradient(to right, var(--officeColor) 0%, var(--officeColor) 50%,
         var(--hotelColor) 50%, var(--hotelColor) 100%);
    }
```

Appendix B Checkbox Section

These screenshots contain the checkbox code within the sidebar on the left-hand side of the application.

```
<div class='sidebar'>
    <h2>Silicon Valley Construction Projects</h2>
    <h3>Property Types</h3>
    <h4><button onClick="window.location.reload()">Unselect All</button></h4>
    <div>
      <div class="off labelcs">
          <input type="checkbox" name="propertyTypes" value="office" id="office"><label
          for="office">Office</label>
          <input type="checkbox" name="propertyTypes" value="off1" id="off1"><label for="off1">Below 200K
          sqft</label>
          <input type="checkbox" name="propertyTypes" value="off2" id="off2"><label for="off2">201K-600K
          sqft</label>
          <input type="checkbox" name="propertyTypes" value="off3" id="off3"><label for="off3">Above 600K
          sqft</label>
      </div>
      <div class="multi labelcs">
          <input type="checkbox" name="propertyTypes" value="multifamily" id="multifamily"><label
          for="multifamily">Multifamily</label>
          <input type="checkbox" name="propertyTypes" value="m1" id="m1"><label for="m1">Below 100 units</label>
          <input type="checkbox" name="propertyTypes" value="m2" id="m2"><label for="m2">101-300 units</label>
          <input type="checkbox" name="propertyTypes" value="m3" id="m3"><label for="m3">Above 300 units</label>
      </div>
      <div class="hot labelcs"><input type="checkbox" name="propertyTypes" value="hotel" id="hotel"><label
      for="hotel"> Hotel</label>
           <input type="checkbox" name="propertyTypes" value="h1" id="h1"><label for="h1">Below 100 rooms</label>
           <input type="checkbox" name="propertyTypes" value="h2" id="h2"><label for="h2">101-300 rooms</label>
           <input type="checkbox" name="propertyTypes" value="h3" id="h3"><label for="h3">Above 300 rooms</label>
      </div>
      <div class="ret labelcs"><input type="checkbox" name="propertyTypes" value="retail" id="retail"><label
      for="retail"> Retail</label>
           <input type="checkbox" name="propertyTypes" value="r1" id="r1"><label for="r1">Below 200K sqft</label>
           <input type="checkbox" name="propertyTypes" value="r2" id="r2"><label for="r2">201K-600K sqft</label>
           <input type="checkbox" name="propertyTypes" value="r3" id="r3"><label for="r3">Above 600K sqft</label>
      </div>
      <div class="ind labelcs"><input type="checkbox" name="propertyTypes" value="industrial" id="industrial">
      <label for="industrial"> Industrial</label>
            <input type="checkbox" name="propertyTypes" value="i1" id="i1"><label for="i1">Below 200K
            sqft</label>
            <input type="checkbox" name="propertyTypes" value="i2" id="i2"><label for="i2">201K-600K sqft</label>
            <input type="checkbox" name="propertyTypes" value="i3" id="i3"><label for="i3">Above 600K
            sqft</label>
      </div>
```

```
  <h5>Mixed developments are represented by more than one property type.</h5>
</div>
<div>
<h3>Construction Status</h3>
  <div class="uc labelcs"><input type="checkbox" name="Status" value="underConstruction"
  id="underConstruction"><label for="underConstruction">Under Construction</label></div>
  <div class="approve labelcs"><input type="checkbox" name="Status" value="approved" id="approved"><label
  for="approved">Approved</label></div>
  <div class="pend labelcs"><input type="checkbox" name="Status" value="pending" id="pending"><label
  for="pending">Pending</label></div>
</div>
<h3>Cities</h3>
  <div class="cities">
<table>
<tr>
  <td><div class="labelcs"><input type="checkbox" name="sVcities" value="sanJose" id="sanJose"><label
  for="sanJose">San Jose</label></div></td>
  <td><div class="labelcs"><input type="checkbox" name="sVcities" value="santaClara" id="santaClara"><label
  for="santaClara">Santa Clara</label></div></td>
</tr>
<tr>
  <td><div class="labelcs"><input type="checkbox" name="sVcities" value="campbell" id="campbell"><label
  for="campbell">Campbell</label></div></td>
  <td><div class="labelcs"><input type="checkbox" name="sVcities" value="cupertino" id="cupertino"><label
  for="cupertino">Cupertino</label></div></td>
</tr>
<tr>
<td><div class="labelcs"><input type="checkbox" name="sVcities" value="sunnyvale" id="sunnyvale"><label
for="sunnyvale">Sunnyvale</label></div></td>
  <td><div class="labelcs"><input type="checkbox" name="sVcities" value="mountainView" id="mountainView">
  <label for="mountainView">Mountain View</label></div></td>
</tr>
<tr>
<td><div class="labelcs"><input type="checkbox" name="sVcities" value="paloAlto" id="paloAlto"><label
for="paloAlto">Palo Alto</label></div></td>
<td><div class="labelcs"><input type="checkbox" name="sVcities" value="losAltos" id="losAltos"><label
for="losAltos">Los Altos</label></div></td>
</tr>
<tr>
<td><div class="labelcs"><input type="checkbox" name="sVcities" value="milpitas" id="milpitas"><label
for="milpitas">Milpitas</label></div></td>
</tr>
</table>
  </div>
```

```
<h3>Mass Transit</h3>
<div class="masstransit labelcs">
    <table>
    <tr>
        <td><input type="checkbox" name="masstransit" value="halfmlr" id="halfmlr"><label
        for="halfmlr">Within 1/2-mi Light Rail</label></td>
        <td><input type="checkbox" name="masstransit" value="quartermlr" id="quartermlr"><label
        for="quartermlr">Within 1/4-mi Light Rail</label></td>
    </tr>
    <tr>
        <td><input type="checkbox" name="masstransit" value="halfmct" id="halfmct"><label
        for="halfmct">Within 1/2-mi CalTrain</label></td>
        <td><input type="checkbox" name="masstransit" value="quartermct" id="quartermct"><label
        for="quartermct">Within 1/4-mi CalTrain</label></td>
    </tr>
    <tr>
        <td><input type="checkbox" name="masstransit" value="halfmbart" id="halfmbart"><label
        for="halfmbart">Within 1/2-mi BART</label></td>
        <td><input type="checkbox" name="masstransit" value="quartermbart" id="quartermbart"><label
        for="quartermbart">Within 1/4-mi BART</label></td>
    </tr>
  </table>
</div>

<h3>Tips</h3>
<div class="tips">
<h4>Click the checkboxes to filter by property type, construction status, cities, &amp; proximity to mass
transit.</h4>
<h4>Click icons on map for more information.</h4>
</div>
```

Appendix C Major Map Functions

Map load with zoom control

```
// This adds the map to your page
var map = new mapboxgl.Map({
  // container id specified in the HTML
  container: 'map',
  // style URL
  style: 'mapbox://styles/mapbox/satellite-streets-v9',
  // initial position in [lon, lat] format
  center: [-121.996504, 37.352842],
  // initial zoom
  zoom: 10.5

});

//text box
//<div class="filter-ctrl">
//<input id="filter-input" type="text" name="filter" placeholder="Filter by name">
//</div>

// Add zoom and rotation controls to the map.
map.addControl(new mapboxgl.NavigationControl());
```

Geocoder control

```
var geocoder = new MapboxGeocoder({
  accessToken: mapboxgl.accessToken, // Set the access token
  mapboxgl: mapboxgl, // Set the mapbox-gl instance
  marker: false, // Do not use the default marker style
  bbox: [-122.177436, 37.110047, -121.597782, 37.591748], // Set the bounding box coordinates
  placeholder: 'Silicon Valley Addresses'
});

map.addControl(geocoder, 'top-left');

map.addSource('single-point', {
  type: 'geojson',
  data: {
    type: 'FeatureCollection',
    features: [] // Notice that initially there are no features
  }
});

map.addLayer({
  id: 'point',
  source: 'single-point',
  type: 'circle',
  paint: {
    'circle-radius': 10,
    'circle-color': '#FFAC40',
    'circle-stroke-width': 3,
    'circle-stroke-color': '#fff'
  }
});
```

Assigning map markers to construction projects

```
// This is where your interactions with the symbol layer used to be
 // Now you have interactions with DOM markers instead
 stores.features.forEach(function(marker,i) {
   // Create an img element for the marker
   var el = document.createElement('div');
   el.id = "marker-" + i;
   el.className = 'marker'+' '+marker.properties.klass;

   new mapboxgl.Marker(el)
       .setLngLat(marker.geometry.coordinates)
       .addTo(map);

   //el.owner = marker.properties.Owner;
   //layerIDs.push(el.owner);
   // Add markers to the map at all points

   el.addEventListener('click', function(e){
       // 1. Fly to the point
       flyToStore(marker);

       // 2. Close all other popups and display popup for clicked store
       createPopUp(marker);

       // 3. Highlight listing in sidebar (and remove highlight for all other listings)
       var activeItem = document.getElementsByClassName('active');

       e.stopPropagation();
       if (activeItem[0]) {
          activeItem[0].classList.remove('active');
       }
   });
 });
```

Information popup code

```
//Property Description
function createPopUp(currentFeature) {
  var popUps = document.getElementsByClassName('mapboxgl-popup');
  // Check if there is already a popup on the map and if so, remove it
  if (popUps[0]) popUps[0].remove();

  //shorten numerical property values
  var o = currentFeature.properties.office;
  var m = currentFeature.properties.multifamily;
  var h = currentFeature.properties.hotel;
  var r = currentFeature.properties.retail;
  var indus = currentFeature.properties.industrial;

  //Cleanup zero values (Office will not have retail square feet unless in mixed property.)
  var officeCleanup = '';
  var multifamilyCleanup = '';
  var hotelCleanup = '';
  var retailCleanup = '';
  var industrialCleanup = '';

//toLocaleString is used to place commas in large numbers to make them easier to read.  If the office, retail, or industrial area
equals
//zero, then the corresponding property information is hidden.  If the multifamily units or hotel rooms, then the corresponding
property
//information is hidden.

  if (m > 0) {
     multifamilyCleanup = '<h4><b>Multifamily: </b>' + m.toLocaleString(m) + ' units </h4>';
  }

  if ( o > 0) {
     officeCleanup = '<h4><b>Office: </b>' + o.toLocaleString(o) + ' square feet </h4>';
  }

  if (h > 0) {
      hotelCleanup = '<h4><b>Hotel: </b>' + h.toLocaleString(h) + ' rooms </h4>';
  }

  if (r > 0) {
      retailCleanup = '<h4><b>Retail: </b>' + r.toLocaleString(r) + ' square feet </h4>';
  }

  if (indus > 0) {
      industrialCleanup = '<h4><b>Industrial: </b>' + indus.toLocaleString(indus) + ' square feet </h4>';
  }

//setHTML returns a string format.  Easier if HTML cleanup happens before this stage.
  var popup = new mapboxgl.Popup({ closeOnClick: true })
    .setLngLat(currentFeature.geometry.coordinates)
    .setHTML('<h3>'+currentFeature.properties.Name + '</h3>' +
      '<h4><b>Address: </b>' + currentFeature.properties.Address + ', '+ currentFeature.properties.City +', CA</h4>'+
      '<h4><b>Project Name: </b>' + currentFeature.properties.Name + '</h4>' +
      '<h4><b>Project Type: </b>' + currentFeature.properties.PropType + '</h4>' +
      '<h4><b>Owner: </b>' + currentFeature.properties.Owner + '</h4>' +
      '<h4><b>Construction Status: </b>' + currentFeature.properties.Status + '</h4>' +
      multifamilyCleanup +
      officeCleanup +
      hotelCleanup +
      retailCleanup +
      industrialCleanup)
    .addTo(map);

  }
```

Appendix D Visibility Filter Code

```
// not exactly vanilla as there is one lodash function
// Property Type, Construction Status, and City filter portion

var allCheckboxes = document.querySelectorAll('input[type=checkbox]');
var allProperties = Array.from(document.querySelectorAll('.marker'));
var checked = {};

getChecked('propertyTypes');
getChecked('Status');
getChecked('sVcities');
getChecked('masstransit');

Array.prototype.forEach.call(allCheckboxes, function (el) {
  el.addEventListener('change', toggleCheckbox);
});

function toggleCheckbox(e) {
  getChecked(e.target.name);
  setVisibility();
}

function getChecked(name) {
  checked[name] = Array.from(document.querySelectorAll('input[name=' + name + ']:checked')).map(function (el) {
    return el.value;
  });
}

function setVisibility() {
  allProperties.map(function (el) {
    var propertyTypes = checked.propertyTypes.length ? _.intersection(Array.from(el.classList), checked.propertyTypes).length :
    true;
    var Status = checked.Status.length ? _.intersection(Array.from(el.classList), checked.Status).length : true;
    var sVcities = checked.sVcities.length ? _.intersection(Array.from(el.classList), checked.sVcities).length : true;
    var masstransit = checked.masstransit.length ? _.intersection(Array.from(el.classList), checked.masstransit).length : true;
    if (propertyTypes && Status && sVcities && masstransit) {
      el.style.display = 'block';
    }
      else {
      el.style.display = 'none';
    }
  });
}

//Credits
function openNav() {
  document.getElementById("mySidenav").style.width = "20%";
  document.getElementById("main").style.marginLeft = "20%";
}

function closeNav() {
  document.getElementById("mySidenav").style.width = "0";
  document.getElementById("main").style.marginLeft= "0";
}
```