POPULUS

Final Report: Developing Scalable Models for Safety Insights and Improvements Using E-Scooter Data

July 2022

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Introduction

Transportation is a leading cause of death in the United States; in 2021, an estimated 42,915 died in motor vehicle crashes[1]. According to the most recent national data reported by NHTSA's Fatality Analysis Reporting System, while overall traffic fatalities are beginning to trend down, more vulnerable road users, such as pedestrians and cyclists, are being killed at increasingly higher rates on U.S. roads.

In 2018, pedestrian deaths and deaths of people on bikes or similar non motorized vehicles increased by 3.4 percent and 6.3 percent respectively.[2] With the recent introduction of shared electric scooters and bikes, which dramatically grew in popularity since they arrived in 2017,[3] there are even more vulnerable road users on city streets — making it all the more important to improve transportation safety for multimodal travelers.

Micromobility trips reached a total of 136 million trips in 2019, according to the most recent report from the National Association of City Transportation Officials (NACTO). The majority of these trips are now being delivered by shared scooters - outpacing station-based bikesharing systems by a factor of about 3 to 1 trips.[4] According to the North American Bikeshare Association (NABSA) State of the Industry Report, in 2019, there were 264 cities in the United States with at least one bikeshare or e-scooter system.[5]

The increased diversity and volume of micromobility services in cities has started to dramatically change the composition of who is using roads — increasing the portion of people using roads operating outside of a motor vehicle, particularly along certain corridors. This increase in more vulnerable road users necessitates a reassessment of how our roadways are designed and managed to ensure that all road users, irrespective of mode, can reach their destinations safely.

Government partners still face challenges to understand where people are using micromobility, its relationship to where other road users, including cyclists, pedestrians, passenger cards, and

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[1] National Highway Traffic Safety Administration (NHTSA). *Early Estimate of Motor Vehicle Traffic Fatalities in 2021.* Report No. DOT HS 813 298.
[2] U.S. Department of Transportation Federal Highway Traffic Safety Administration (NHTSA). https://www.nhtsa.gov/press-releases/roadway-fatalities-2018-fars
[3] Clewlow, R. R. (2019). *The Micro-Mobility Revolution: The Introduction and Adoption of Electric Scooters in the United States* (Transportation Research Board Annual Meeting, No. 19-03991).
[4] National Association of City Transportation Officials (NACTO). Bike Share and Shared Micromobility Initiative. Accessed 12/2020: https://nacto.org/shared-micromobility-2019/
[5] North American Bikeshare Association (NABSA). Micromobility State of the Industry Report. Accessed 07/2022. https://nabsa.net/wp-content/uploads/2020/10/NABSA-2020-State-of-the-Industry-Report.pdf

delivery vehicles are located, and how this impacts the safety of our roadways. Understanding traffic volumes of all modes and where people are moving, i.e. the exposure of vulnerable road users, is crucial to better comprehending safety challenges, and accelerating the design of safer roadways.

Regardless of the specific mode (shared or personally owned; bike, e-cargo bike, scooter, or other form factor), the U.S. is continuing to see growth of various forms of small, pedal- or electric-powered small vehicles in cities. The expansion of these mobility options has the potential to accelerate transitions towards less carbon-intensive transportation for passengers and delivery; however, it also increases the need to accelerate safety improvements for a more complex ecosystem of road users, particularly for road users outside of a motor vehicle.

In many of the cities where Populus supports mobility management, transportation officials are seeing a rise in dangerous conflicts between delivery and utility trucks blocking bike lanes, and cyclists or other micromobility users. Many delivery operators, spurred by efforts to reduce their climate emissions, are embarking on initiatives to shift deliveries from trucks to e-cargo bikes, small autonomous delivery vehicles, or other pedal-powered vehicles that might fit in bike lanes. The transportation landscape in cities is becoming increasingly multimodal and complex, raising the likelihood of conflict between different road users, and underscoring the importance of improving transportation safety for all.

Project Overview

Populus Technologies, Inc. (Populus) was selected in September 2020 to participate in Phase 1 of the U.S. DOT Office of the Secretary of Transportation (USDOT OST) Safety Data Initiative (SDI) to discover and better understand new and emerging data sources that can answer the open questions about surface transportation safety. During our Phase 1 project, “Planning for Safety with Mobility Data Platforms,” Populus provided exploratory analysis and a feasibility assessment of two promising new datasets that can provide scalable insights for USDOT and local regional agencies to drive improvements in multimodal transportation safety.

The datasets utilized in Phase 1 included metro level survey data and GPS data from shared scooter vehicle fleets, such as Bird, Lime, and Spin. Populus worked with USDOT staff to explore how these datasets can be used to better understand safety risk, and in particular exposure levels on road networks.

During Phase 2 of this initiative, Populus collaborated with case study cities to leverage and integrate additional datasets, including primarily municipal and regional bike network data, bike master plan data, and crash data from readily available sources to achieve the following objectives:

1. Develop scalable, corridor-level models to determine opportunities for expanded shared micromobility infrastructure based on data representing a large (50%+) samples of comprehensive shared micromobility exposure data;

2. Determine whether data can also be leveraged to assess risk on specific road segments to inform high priority corridors for safety improvements.

3. Pilot projects with several key cities for safety-related infrastructure improvements to support multimodal transportation.

4. Deliver corridor-level analysis tools for U.S. DOT and specific cities selected during this phase to enhance public agency access and use of data to improve micromobility safety.

Key Research Questions

Our exploration of the data sources address the following knowledge gaps::

1. Utilizing GPS trace data from shared micromobility trips at the corridor level, how might we develop scalable analyses methods to determine what portion of shared micromobility trips utilize existing bike infrastructure?

    a. Do corridor-level exposure data illuminate deviations from existing bike infrastructure that can be used to identify new opportunities for system safety improvements?

2. How can we integrate incident data (with geospatial attributes) and micromobility exposure data to surface new infrastructure opportunities that improve road safety?

Report Overview

In this report we summarize the results from Phase 2 of the Populus SDI project work, and provide a detailed overview of the data and analysis platform created by Populus. We present a summary of the new advancements Populus developed to integrate GPS trace data from micromobility operators, custom road network data, and incident data in order to provide a user-friendly decision analysis solution to accelerate transportation safety improvements.

The remainder of this report is organized as follows. First, we present an overview of all the data sources leveraged in this project. Second, we provide an overview of the key project approaches utilized to integrate multiple datasets for improved transportation safety analysis and planning. Third, we present an overview of the key results from integrating GPS trace data, route data, and incident data. Finally, we present key findings from this work and opportunities for further advancement. The appendix provides an overview of key datasets that are made publicly available for this work, with permission from mobility operators and cities.

Data Summary

Data Sources

Shared Micromobility Exposure Data

Populus is a system of record for city departments of transportation around the world — ingesting data from shared fleets of vehicles, including shared bikes, scooters, mopeds, and cars to improve transportation policy and planning. As the system of record for many U.S. cities, Populus receives recurring GPS data from shared micromobility operators via application programming interfaces (APIs), including vehicle status updates with latitudinal and longitudinal data, as well as GPS trace data for completed trips.

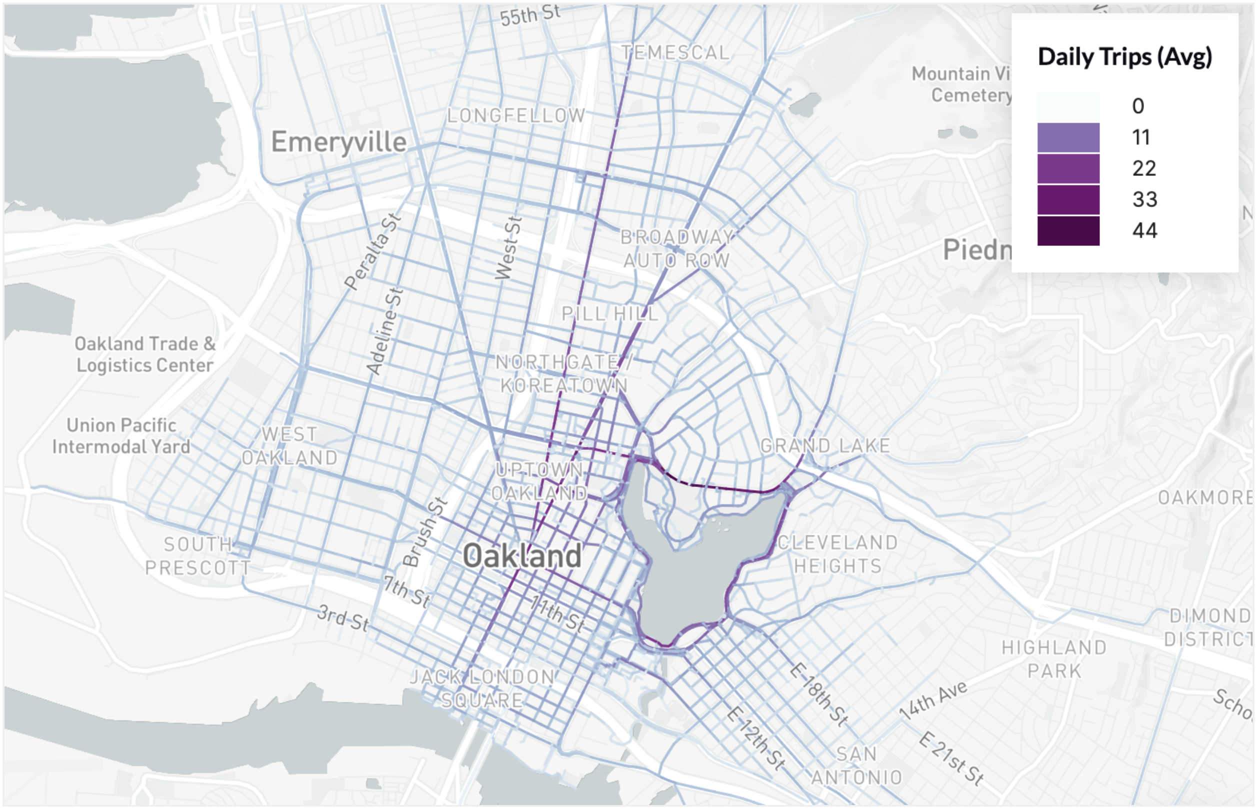
The GPS trace data for trips that Populus receives from shared micromobility operators in a given city represents more than 97% of all the shared micromobility trips that occur in that city. Prior to the availability of such data, in order to plan bike infrastructure improvements, many cities were reliant on bicycle and pedestrian counts that may have only been conducted on specific corridors or at particular intersections due to budget limitations. However, with the introduction of shared, dockless micromobility, many cities now have access to a wealth of exposure data to advance transportation safety, with the help of platforms like Populus.

As part of delivering our software solutions to cities, Populus aggregates GPS pings from historical dockless bike and scooter trips to road segments. This trip data typically captures a ping from shared micromobility devices every couple of seconds, varying by micromobility operator and the age of vehicles. Populus aggregates trip data to road segments in order to obscure individual trips (potentially personally identifiable information) such that cities and USDOT can leverage insights without compromising individual private or confidential information.

Populus delivers aggregations and visualizations of trip data primarily through our web-based, SaaS platform for departments of transportation planning to leverage for transportation planning and analysis. Populus' public agency customers are able to choose which data to make publicly available through open data portals, which Populus delivers on behalf of cities. Individual agencies can also export data through CSV, ArcGIS-compatible Shape, and GeoJSON files with aggregated trips by location.

In Figure 1, we present an example of aggregated trip data for the City of Oakland from January 1, 2021 through December 31, 2021 representing a total of 201,566 trips.

Figure 1. City of Oakland Trip Data Aggregated to Open Street Map (OSM)



Road Network Data

Populus map-matches trip trace data to Open Street Map (OSM) networks as the primary default in our platform. However, the platform is capable of map-matching to specific base map layers provided by individual public agencies, if for instance a public agency retains its own topography (or topographies) that are not aligned with OSM.

Additional datasets that were leveraged for this initiative, include road network layers of interest provided by individual city departments of transportation. From a micromobility safety perspective, most public agencies are interested in understanding how micromobility trip trace data aligns with (or does not align with) existing bike infrastructure, as well as bike master plans.

Bike network data, representing existing bike infrastructure, are typically available through open data portals. Populus worked with public agencies that included three case study cities, as well as additional cities interested in leveraging our platform solutions to gather bike network data.

Bike master plan data typically represents existing bike infrastructure as well as planned improvements. In many cities, bike network and bike master plan data delineates between fully dedicated bike lanes, protected lanes, or general use roadways. The specific designations in cities may vary, but the majority of large cities distinguish between different types of corridors based on the mix of traffic.

Additionally, many cities have corridors that have been prioritized in their transportation safety plans, such as Vision Zero. In Figure 2, we illustrate a corroridor provided by the City of Alexandria representing high killed or seriously injured crash corridors to prioritize for safety improvements.

Figure 2. Alexandria High KSI Crash Network. Image provided by the city.

Incident Location Data

Incident data is sometimes collected by cities, operators, and other stakeholders (e.g., emergency personnel, hospitals). For the purposes of this project, Populus worked with cities to utilize any incident data that they had collected as well as integrate other publicly available incident data that included temporal and geographical data.

The incident data leveraged in this project included crash and fatality data specifically for bikes and pedestrians that were available in each city. Note that **shared scooter incidents are not included**, largely because this data is not currently consistently collected or reported via municipal or state databases. Thus, incident data for cyclists and pedestrians were selected as the best data to compare against micromobility trip data, which is one of the most comprehensive proxy datasets available to cities to represent vulnerable road user exposure.

Publicly Available Data

As part of this initiative, Populus has produced data dashboards that are made available to the cities included as case study cities. In addition, the following data exports are publicly available to support greater understanding of how micromobility trip data can be leveraged to accelerate safety improvements:

- Extracts of aggregated micromobility trip data in GeoJSON and shapefiles aligned to Open Street Map (OSM) standard routes for three case study cities;
- Extracts of aggregated micromobility trip data in GeoJSON and shapefiles aligned to bike networks for three case study cities;
- Publicly available crash data gathered by three case study cities.

More information about how to download and access these data are available at: http://www.populus.ai/micromobility-safety/public-data-portal

Project Approach

The goal of the Populus SDI project was to accelerate transportation safety improvements by delivering a scalable way to integrate multiple datasets, including trip trace data, custom road network data, and incident data. In the majority of cities, this data — if at all leveraged given the relatively recent availability of micromobility trip data — would need to be combined manually by internal GIS specialists or by consultants in order to inform bike network safety improvements.

Generated Data

Through this project, Populus worked with case study cities and additional agencies to generate new, integrated data surfacing problematic intersections and corridors.

The primary new generated data that Populus delivered as part of this work includes:

- Micromobility exposure data linked to unique road networks;
- Micromobility exposure data linked to bike networks and master plans;
- Visualizations of micromobility exposure data and incident data for vulnerable road users;

Methods for Data Analysis

Our method includes primarily developing trajectory data processing algorithms to transform raw, noisy, GPS data into clean trip data, combined with map matching algorithms that can integrate this GPS point data with existing road network information. Provided with large, nearly wholly representative exposure data sourced from the raw GPS data of shared micromobility devices, our desired outputs are clean trip trace data that have been map matched to municipal road networks, including specifically bike infrastructure such as protected bike lanes, shared bike lanes, etc.

Vehicle trajectory data received by Populus include point data of latitude and longitude and timestamps that are recorded regularly during travel. This information across different mobility operators is quite variable, including inconsistent recording frequency of GPS data points, even within the same operator. Further, GPS inaccuracies can be caused by limited signals to lower-quality GPS devices placed on vehicles. In order to better extract the trip geometry information, the data must be processed and cleaned to map accurate trip information to existing networks.

During the data cleaning, anonymization, and map-matching process, the range of trips that are must be dropped from our analysis varies based on the following dimensions: 1) the quality of micromobility operator data (e.g., the latency and accuracy of GPS on vehicles); and 2) the level of detail provided in maps via OSM or a city-provided base map layer. Currently, Populus finds that we can accurately map GPS trip trace data for 70.1% to 94.6% of trips.

Our approach was to leverage map-matching algorithms on raw, disaggregated point data to align this data to base layer networks that are of greatest interest and important to surface key safety insights for transportation safety infrastructure improvements. For this analysis, we focused on integrating raw GPS trip point data to bike infrastructure, which is typically utilized by shared scooters (as well as shared bikes).

Data Collection Period

Populus primarily utilized existing historical data for our analysis. Given the recent arrival of shared micromobility services, this limited trip data to 2018 to the present time. Incident data was collected primarily for 2021. Due to the dramatic changes in travel behavior in 2020 when COVID first arrived, the data for the 2021 year was more representative of normal activity.

Our analysis used the most recent bike network data unless there were upgrades made to a network that was important to incorporate into the analysis (alongside the data of these network changes).

Shared mobility trip data is continuously collected by Populus for the cities and other entities we work with. While we limited the time frame for this study to 2021, public agencies that are customers of Populus are able to re-process trips, incident, and network data within our platform for any time frame that data is available..

Key Results

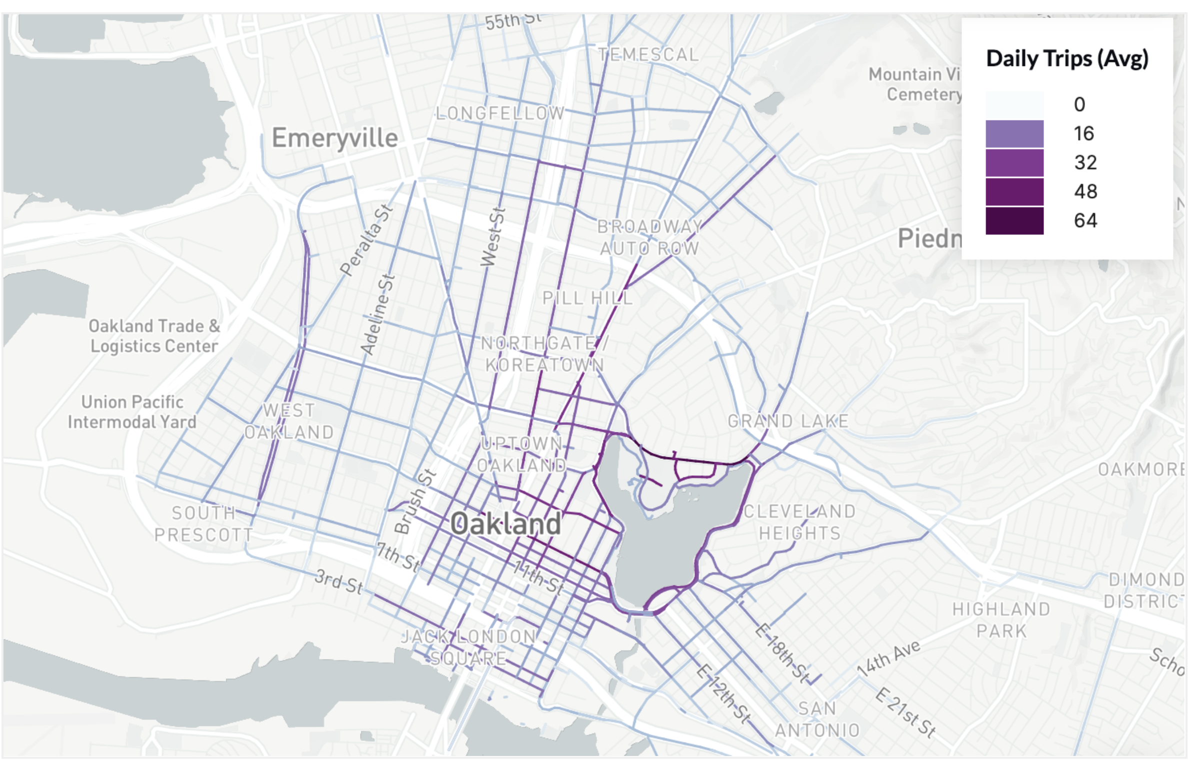
Map-Matching to Custom Road Networks

In the first phase of this project work, Populus gathered custom road network data from case study cities to expand our map-matching from default Open Street Map (OSM) networks to key local networks of interest, including existing bike infrastructure and bike master plans.

Micromobility trip data (which represents more than 95% of shared micromobility trips in a city where Populus is the system of record), is an important data point for the total exposure of vulnerable road users in a city. While not representative of personally owned bikes or micromobility devices, this data is readily available in many cities and can be leveraged as a proxy for where vulnerable road users are making trips.

Populus leveraged algorithms to map-match data for case study cities and other agencies to their existing bike network data. For example, in Figure 3, we show the map-matched data for the City of Oakland for the 191,532 trips that occured on their existing bike network. Conversely, one could evaluate where large volumes of micromobility trips are occurring on road segments that currently lack protected infrastructure for these road users.

Figure 3. City of Oakland Trip Data Aggregated to Bike Network



Integrated Route Data and Incident Data

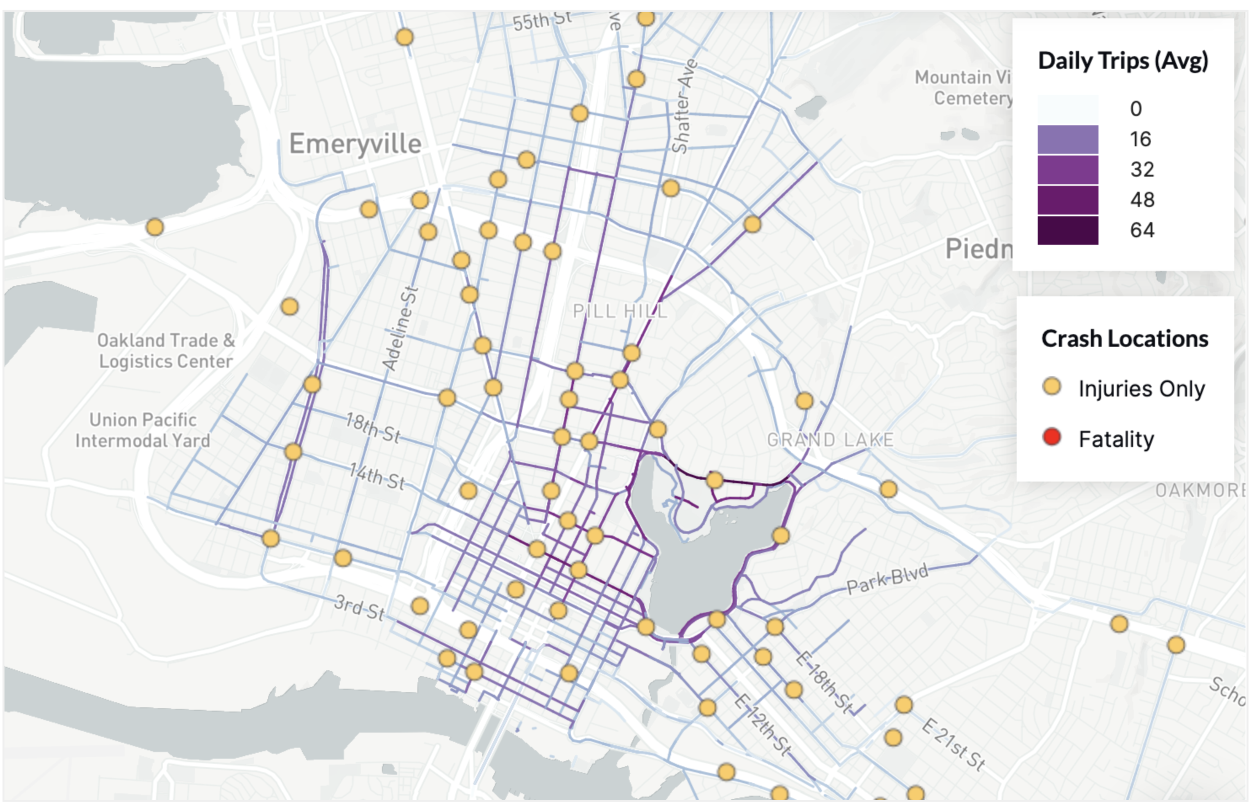
In the second step of our project work, Populus worked with cities to gather and analyze incident data, including crashes and fatalities. Incident data was brought into our software visualization platform including the geospatial attributes of the incident (latitude and longitude), date, and time. A summary of the incident data available from case study cities are summarized in Table 2 below.

Micromobility crash and incident data, specifically for shared bikes, scooters, or other micromobility devices (outside of bicycles), is not consistently collected in cities across the United States. Thus, for the purposes of this study, we gathered crash and fatality data for bikes and pedestrians.

The key advancements of our platform include the ability for cities to easily view this data within a user-friendly application, turn on/ off specific data points for greater usability, and export it for further analysis.

In Figure 4, we show a view for the City of Oakland data with integrated trip data map-matched to the bike network, alongside incident data in which crashes and fatalities are clearly distinguished.

Figure 4. City of Oakland Trip Data Matched to Bike Network with Visualized Crash Data



Advanced Data Filters and Processing

For many public agencies, their bike master plans and other custom road network data are constantly evolving, based on implemented improvements. Within the Populus platform, cities have the ability to leverage various filters (e.g., vehicle type, operator, time of day, date) within our route views to support robust transportation planning.

New data that was brought into the Populus platform, including custom road network data and incident data, were integrated to leverage our advanced filtering and data reprocessing solutions. Public agencies can apply filters to reprocess and reanalyze trip data (including millions of individual trips, each with numerous GPS pings per trip) to match to new timeframes (e.g., 1/1/21 to 6/30/21), days of week, and hour.

Many other agencies rely on manual processing of micromobility route data, or limited views based on specific pre-populated months of the year. The filters implemented in the Populus platform not only reprocess individual trip data, but also the integrated views of bike master plans and incident data.

Additional attributes for exporting the data were also made available so that public agencies can more easily leverage segment IDs, node IDs, and other key attributes to support transportation safety planning.

Case Studies

Populus worked with the USDOT to select the following three case study cities representing different geographic areas and population sizes: Nashville, San Jose, Washington DC, and Alexandria. An overview of these cities is provided in the section below, including a link to the final case study for each respective city.

Table 1 provides a high level summary of the bike network data and Table 2 provides a high level summary of the crash data integrated into the Populus platform.

Table 1. Overview of Bike Networks by City

	Alexandria	Nashville	San Jose*	DC
Number of Segments	569	464	2,772	1,260
Average length of segments (miles)	0.17 miles	0.69 miles	0.18 miles	0.09 miles
Total mileage	96 miles	320 miles	487 miles	92 miles
Includes installation year?	No	Yes	Yes	No/Yes

Table 2. Case Study City Crash Data Overview

	Alexandria	Nashville	San Jose	Washington, DC
Bike or Pedestrian	571	2797	1492	17,162
Dates	January 1, 2014 - June 30, 2021	January 1, 2014 - October 31, 2021	January 1, 2019 - December 31, 2021	January 1, 1970 - May 2, 2021

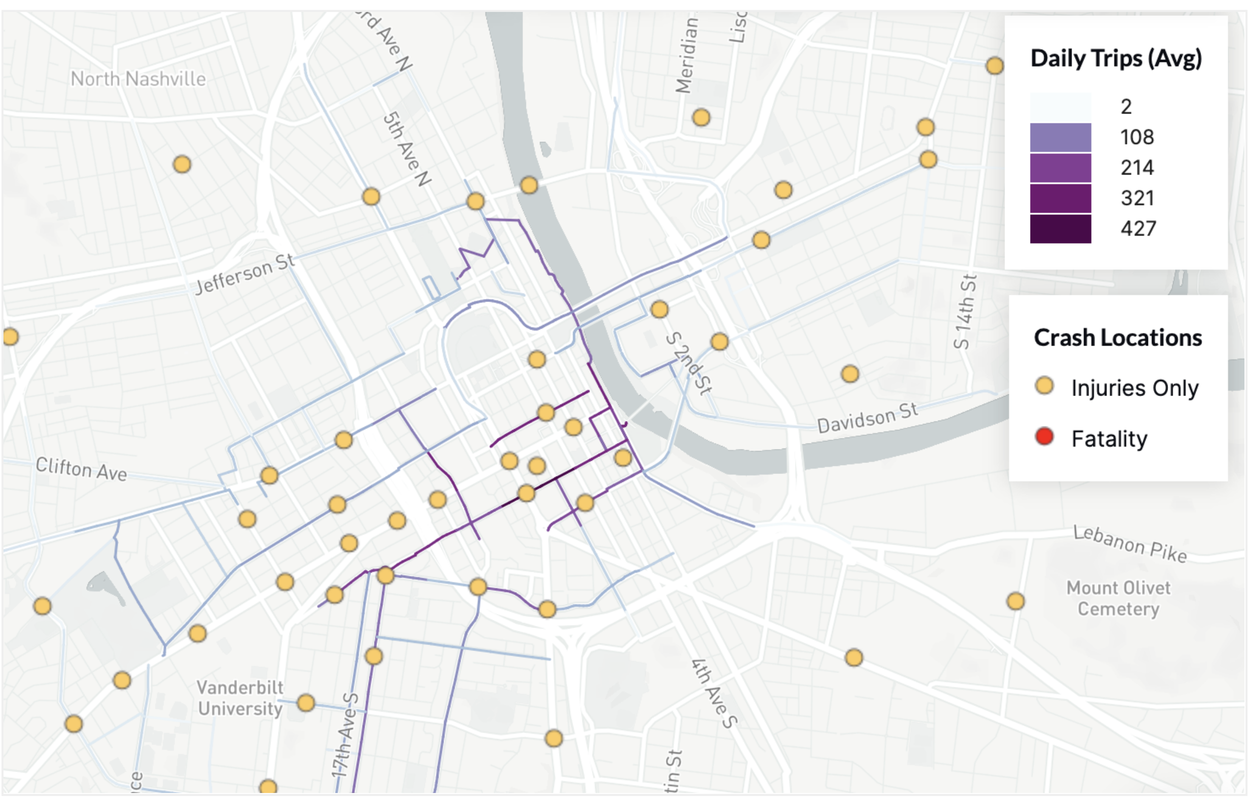
Nashville, Tennessee

Region: Midwest/South
Population: 693,000
Number of Operators: 3 e-scooter operators
Link to final case study

Nashville has had e-scooters on the ground since 2018. Currently, they have three operators - Bird, Lime, and Spin - under a more permanent program process. Populus is the data management platform selected by the city, and therefore we already processed their trips data from the operators.

Nashville is currently undergoing Vision Zero planning and was interested in determining how e-scooters fit into their planning process. Bike network and crash data are available through their Open Data Portal and GIS team. The city had made national news due to e-scooter related crashes and fatalities. E-scooter activity tends to be centralized in the already congested and popular areas of the city, and the city continues to look for solutions to ensure a safe travel space for everyone.

Figure 5. City of Nashville: Integrated Trip, Bike Network, and Crash Data



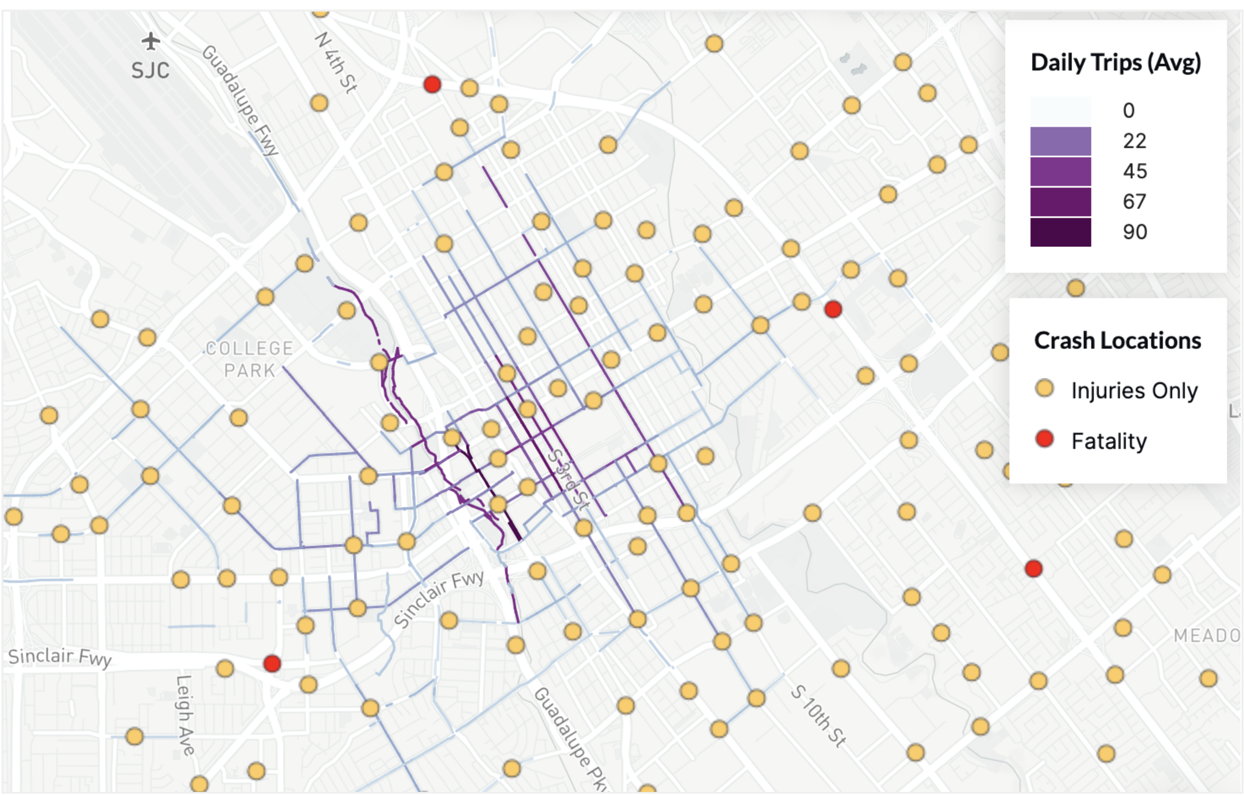
San Jose, California

Region: West
Population: 1,030,000
Number of Operators: 4 e-scooter operators
[Link to final case study]

San Jose has four e-scooter operators, many in operation since 2019. The city is large in population and also in area. E-scooter program managers are interested in technology and data and how they can help the city to make better informed policy decisions.

The City agreed to share e-scooter trip data for the safety project, and also provided access to the bike network and crash data sets. San Jose has an active Vision Zero program, who coordinated with the Populus team. San Jose is also implementing a Sidewalk Riding Technology Demonstration Pilot, which they required all shared e-scooter providers to participate in.

Figure 6. City of San Jose: Integrated Trip, Bike Network, and Crash Data



Alexandria, Virginia

Region: East
Population: 161,000
Number of Operators: 5 e-scooter operators
Link to final case study

Alexandria represents a smaller city in order to provide another perspective on e-scooter programs. They are also one of a few smaller cities that has multiple operators due to proximity to the Washington, D.C. area. Although located near Washington, DC, Alexandria is located far enough away to have its own distinct program.

Populus is the data management platform selected by the city, and therefore we already process their trips data from the operators. The city also has a very active Vision Zero team that is working to accelerate safety improvements. Bike network and crash data were provided by the city's Vision Zero team, which has been actively involved in evaluating the e-scooter program.

Figure 8. City of Alexandria: Integrated Trip, Bike Network, and Crash Data

Conclusions

In three separate case study cities, as well as numerous other cities interested in leveraging Populus' advanced safety visualization tools, we successfully integrated multiple datasets with temporal and geospatial data to support faster decision-making for transportation safety.

The Populus platform processes millions of trip data points in a user-friendly web-based software solution, allowing public agencies to map-match messy GPS pings from individualized trips to important road segments of interest. Through this initiative, we worked closely with cities to map-match micromobility trip data to their bike networks, bike master plans, and bike and pedestrian incident (crash and fatality) data to provide a comprehensive view for transportation planners to easily identify areas of safety risk on their networks.

Key Challenges

With the introduction of shared micromobility fleets and associated policies for operators to provide data to cities, the availability of very comprehensive data for this mode of transport can be leveraged to accelerate safety improvements. However, key challenges for this type of analysis include the following:

- Micromobility incident data (for crashes or fatalities) are inconsistently gathered across cities and states. For example, in many state databases, it may be impossible to know if a crash is associated with a sit-down electric scooter (sometimes referred to as a moped) versus a shared stand-up electric kick scooter (e.g. Lime or Bird).

- Bike and pedestrian count data is not as comprehensive or as consistently collected as shared micromobility data. However, one could add this less comprehensive bike and pedestrian data to provide a more complete view of vulnerable road users.

Lessons Learned

Many cities' bike master plans and Vision Zero planning efforts are very dynamic, in cities large and small. These plans are consistently evolving in order to take into account new traffic patterns and new modes of transportation. The Populus platform aims to make it easier for cities to easily leverage new, immediately accessible data (such as micromobility), alongside their evolving bike and road networks.

Key Opportunities

The transportation landscape in cities is becoming increasingly multimodal and complex, raising the likelihood of conflict between different road users. For example, in many of the cities where Populus supports mobility management, cities are seeing a rise in dangerous conflicts between delivery and utility trucks blocking bike lanes, and cyclists or other micromobility users. Some of these delivery operators are embarking on initiatives to shift deliveries from trucks to e-cargo bikes, small autonomous delivery vehicles, or other pedal-powered vehicles that might fit in bike lanes.

In order to accelerate improvements in transportation safety, future promising work should incorporate datasets from growing fleets of vehicles that put pressure on curb spaces and introduce more conflicts with vulnerable road users. Fleets such as on-demand delivery services, parcel delivery, and ridehailing utilize our roads in ways that many city streets were not designed to accommodate. Populus is working with cities to better understand where demand and conflicts are occuring, so that public agencies have more data on hand to drive data-driven safety improvements.

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The U.S. Department of Transportation (DOT) is leading a Safety Data Initiative (SDI), to enhance the analysis and visualization that informs safety policy decisions. Populus was selected to perform analysis and assess the quality of leveraging GPS trip trace data from micromobility operators such as Lime, Bird, and Superpedestrian (LINK), to serve as a reliable source of exposure data.

Using a year's worth of GPS trip trace data from multiple micromobility operators in several cities, Populus developed map-matching algorithms to align GPS trip trace data to custom maps of bike networks and bike master plans in cities. Populus additionally gathered bicycle and pedestrian crash data, including injuries and fatalities, to produce more comprehensive visualizations of micromobility data analysis to support accelerated network improvements for vulnerable road users, including pedestrians, bicyclists, and increasingly diverse micromobility device users.

With the introduction of dockless, shared micromobility cities have access to more extensive data than ever before to accelerate safety improvements. Through this project, Populus demonstrated how scalable models to map-match detailed GPS trip trace data to networks of interest can be overlayed with reported crash data for key safety insights. This scalable tool is designed to help transportation policymakers and planners make faster, data-driven decisions to improve safety and reduce traffic fatalities for an increasingly diverse set of road users.</td></tr>
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