

# SEE.SENSE<sup>®</sup> Denver Smart Cycling Study



## Foreword

Since Gates Corporation was established over a century ago in Denver, CO, the company has grown from a one-room tire and leather store to a multi-national organization with over 15,000 employees across 30 countries.

Over the years, we have continued to innovate and expand our diverse range of products, and in 2007, we entered the bicycle market with Gates Carbon Drive. Gates Carbon Drive is a belt system, named for its carbon fiber tensile cords, providing a cleaner, quieter, lower-maintenance and more durable alternative to chain drives. Our belt system can be fitted to all types of personal and micromobility vehicles, ranging from bicycles, scooters, motorcycles and power sports vehicles in both their traditional and electric forms.

While Gates supports cycling as a healthy and environmentally-friendly way for people to commute to work, run errands, or recreate, we also recognize that there are opportunities to improve the cycling infrastructure in Denver to make cycling safer, more comfortable, and more accessible for everyone in the city. Though we commend the city for its work to expand our bicycle network through the Community Transportation Networks program, there are still ample opportunities to improve bike routes and reduce bicycle-related

accidents by researching the riding behavior of cyclists using innovative technologies such as See.Sense bicycle lights.

At Gates we believe that innovation can change the world, we seek to continuously improve in everything we do and we strive to make data-driven decisions. These same principles applied in working with the Downtown Denver Partnership and the See.Sense team to use sophisticated technology and leverage data-driven research to improve bicycle infrastructure and keep our city's cyclists safe. As an avid cyclist and regular bicycle commuter, I am personally very proud of the insights you will find in this report and am excited about how they will be used by stakeholders across the city to help make Denver one of the best cycling cities in the world.

*Thomas G. Pitstick  
Chief Strategy Officer  
Gates Corporation*



# VISION ZERO

The data presented in this report highlight significant findings in the everyday safety and experiences for cyclists in the City and County of Denver. People are downtown to access employment, to be entertained, and to be at home – no one should be killed or seriously injured in traffic-related crashes in downtown Denver. The objective of eliminating traffic deaths and injuries in downtown Denver IS achievable with the right design and policy interventions.

The Downtown Denver Partnership acknowledges that the current level of traffic violence is unacceptable. We are committed to working together through public and private partnerships to eliminate serious and fatal traffic crashes and advocate for safe, comfortable, and reliable infrastructure on our streets for all people and all transportation options. Our role in this effort includes data collection and best practice research and reporting, advocacy for project funding, and collaboration through the implementation of safe transportation and public realm projects.

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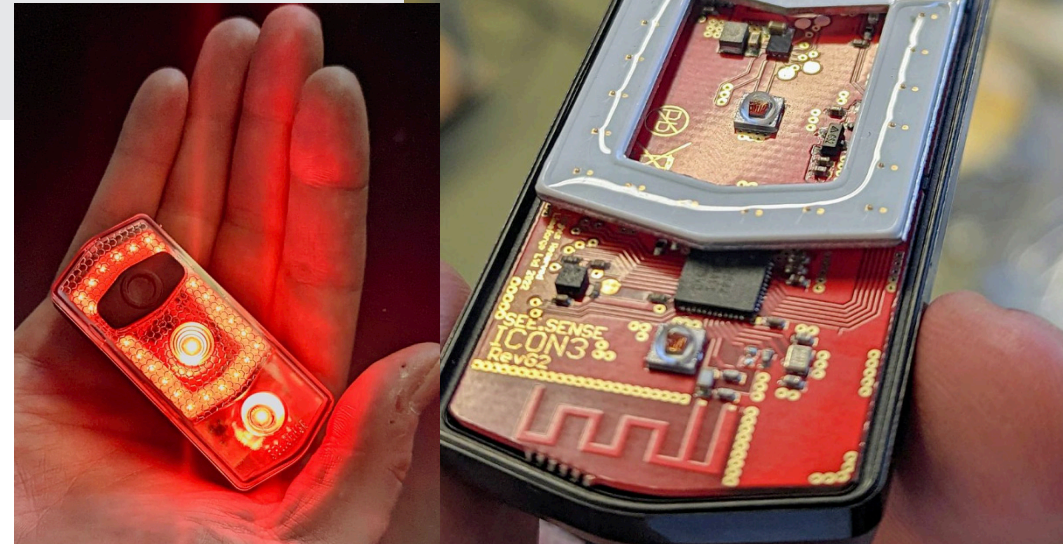
# Project Summary

**Denver is the first city in the US to use this novel technology to study bicycle infrastructure.**

Denver is on the leading edge of cities working to increase the effectiveness of investments in sustainable and equitable transportation options, particularly investments in cycling. With over 300 days of sunshine and few geographic barriers, Denver is the ideal city to ride a bike in. Nonetheless, cyclists only make up about 6 percent of daily travelers, with marginal annual increases in people choosing to ride a bike for daily travel needs. But why?

The Downtown Denver Partnership has a shared interest with the City in understanding why people choose – or don't choose – to ride a bike, particularly in terms of safety and experience. And amid major investments in new bicycle infrastructure in Denver, there are few data resources currently available that can objectively capture cyclist behavior and experience to both evaluate the performance of existing bikeways and influence the design of future bikeways. Traditional safety data resources that focus on crash statistics typically don't provide insights as to the cycling experience until it is too late.

The Partnership's dedication to an economically vital center city is entirely dependent on the City's ability to develop a safe and reliable active mobility network for all ages and abilities. For this reason, the Partnership, in collaboration with See.Sense, a bicycle light, sensor, and accessory company, partnered with Gates Corporation and the City and County of Denver to conduct a pilot study that innovatively tracks cyclist behavior and collects data about cyclist experience during bike rides.



See.Sense ACE bicycle lights

Between April 2021 – April 2022, the Partnership conducted a study to research cyclist behavior in and around the Central Business District using See.Sense ACE rear bicycle lights. In addition to adding visibility, the lights generate highly granular speed, braking, swerving, and road surface data when paired with a smartphone app during a trip made on a bike. The data is passively collected, which removes the perception bias of the user, while also giving users the ability to add comments and notes to their cycling trips.

This data provides insight into the Denver biking experience, noting popular routes that sometimes aren't where you think they are, highlighting the behavioral and experiential differences by varying demographics, and evaluating bikeways once they're installed to see if the newest designs are having the desired impact. Learn more about the general findings and specific analysis from this pilot project in this report.

# SEE.SENSE®

## PROJECT HIGHLIGHTS:

179

ACTIVE CYCLISTS

960

MILLION SENSOR READINGS  
THROUGHOUT STUDY

26,000

MILES COVERED

50,265

LBS. OF CO2 SAVED

## Why Denver, Why Now?

Given the pivotal timing of Denver's commitment to building out bike infrastructure more quickly, implementing safety improvements through Vision Zero, and focusing on an overall mode-shift by 2030, we, as a city, have an opportunity to bring partners together to test cutting-edge technology to inform decisions about Denver's mobility systems. The Partnership was in a unique position to bring public and private partners together to fund the pilot project with See.Sense.

## About See.Sense

See.Sense is a small but innovative cycling technology and data company from Northern Ireland. Their mission is to make cycling and micromobility safer and smarter through patented sensor and AI-fusion technology. With their award-winning products, See.Sense has been able to build a community of over 120,000 cyclists around the world. **With approximately 200 cyclists, Denver is the first city in the US to use in this novel technology.** See.Sense bike lights work by generating highly granular sensor data collected by a companion app on your phone. Sensor data is passively collected, which removes perception bias of the user. See.Sense AI profiles each individual rider to determine a normal range of values for each metric based on typical biking behavior. By profiling individual riders, the datasets are standardized, and individual variances are removed. Data displayed throughout the report indicates only the instances outside of normal ranges. For example, in the Braking layer, high braking instances outside of normal ranges are displayed, indicating the areas in the network that struggle most with hard braking.

# Background

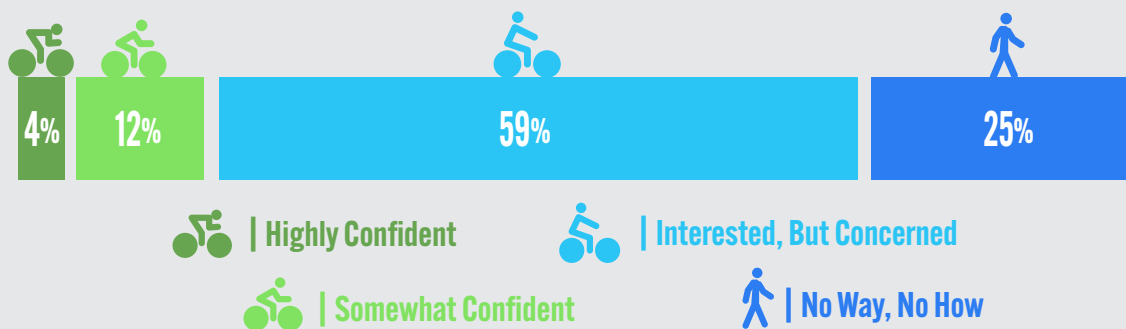
Denver, like many cities around the world, is working toward reducing auto dependency by increasing its investments in cycling infrastructure with a goal of encouraging more people to choose cycling over driving, and thereby reducing congestion, improving air quality, increasing transportation affordability, reducing wear and tear on roadways, and improving public health.

Between July 2018 and September 2022, the city installed over 107 miles of dedicated bike facilities with designs recommending that bicycle facilities installed prioritize comfort and convenience for cyclists. Nonetheless, the actual percentage of Denverites choosing to bike between 2018 and 2022 has remained stagnant at around 2.2%.

To better understand the travel choices of Denver residents, the City and County of Denver identified that nearly 60% of Denverites are interested but concerned to ride bikes within the city and a 2018 survey conducted by the Partnership showed that over 40% of workers downtown would never ride a bike to work. Incidentally, only fatal or serious crashes are captured by the Denver Police Department, meaning that flaws and needed safety improvements in the bicycle network aren't often uncovered until a potentially deadly incident has already occurred.

**In 2021**, four cyclists were killed and another 23 were seriously injured during cycling incidents in Denver. Comparing these data with other transportation and mobility indicators, cycling in Denver is very “safe”, considering cycling fatalities only made up 4% of people killed in transportation-related incidents during this period. However, it is important to also consider how safe cyclists feel while riding a bicycle in Denver. That’s where the See.Sense data comes in.

## Denverites Interest in Biking to Work



Source: Denver's Department of Transportation & Infrastructure's Denver Moves: Bicycle Program



**How safe do you feel cycling in Denver?**

# Methodology

The See.Sense pilot project was a year-long study that occurred between April 2021 and April 2022. In total, the Partnership distributed 200 See.Sense ACE rear bicycle lights to Denverites, focusing on areas of the city where new investments were planned such as downtown Denver and in the Montbello neighborhood of Denver.

Participants were selected to receive a light based on several factors including basic demographic information, as well as information about cycling, comfort and travel purposes. The study consisted of 50% non-white individuals and 50% women, in a mindful effort to incorporate groups that are often underrepresented in cycling and mobility data.

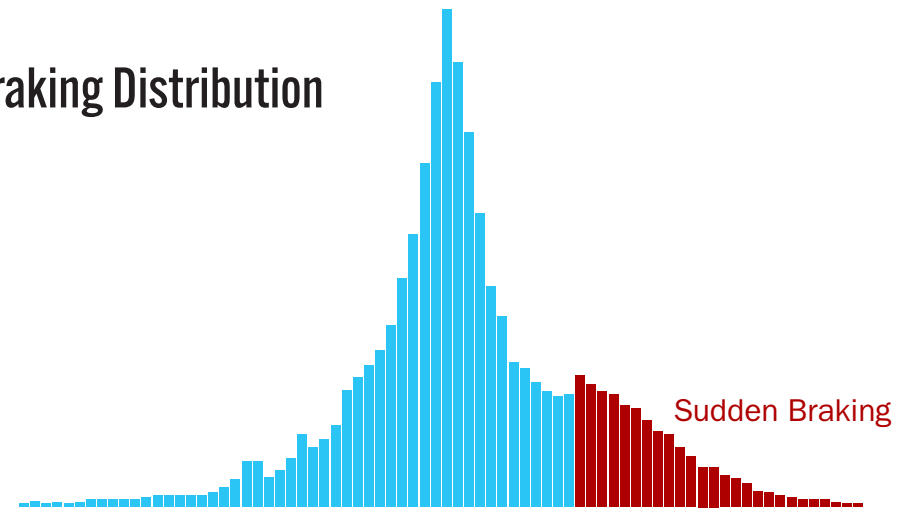
The See.Sense bicycle light tracks a variety of safety metrics – such as speed, braking, swerving, and road surface – during cycling trips. See.Sense AI profiles each individual rider to determine a normal range of values for that rider. The data then records instances where rider behavior deviates from normal riding behavior, making it possible to identify patterns in the way people use the bicycle network.

See.Sense bike lights generate highly granular sensor data that is collected when paired with a smartphone app. The data is passively collected, which removes perception bias of the users, however, users of the See.Sense app can still report incidents they encounter during cycling trips, such as close passes, collisions, potholes, and obstructions in the roadway. The data then populates an online dashboard, making it easy to filter safety metrics and demographics, such as age and gender of the cyclist.

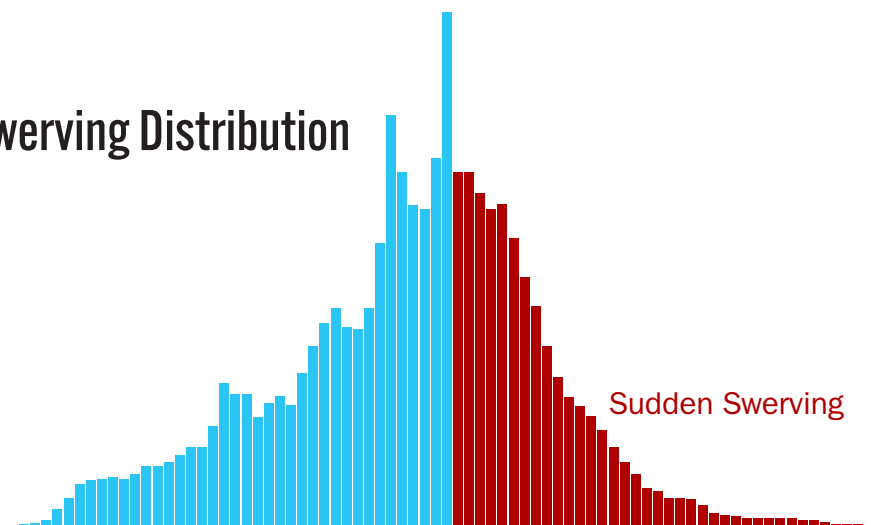
## Braking and Swerving Distribution

Each See.Sense light creates a unique profile of the user's cycling behavior. Collecting braking and swerving data is not necessarily important to examine how hard someone brakes or swerves, but rather how suddenly they brake or swerve hard. Thus hard braking and swerving is not necessarily an indication of an issue, but unexpected and sudden braking and swerving is likely to be.

### Braking Distribution



### Swerving Distribution



# Cycling Data Insights

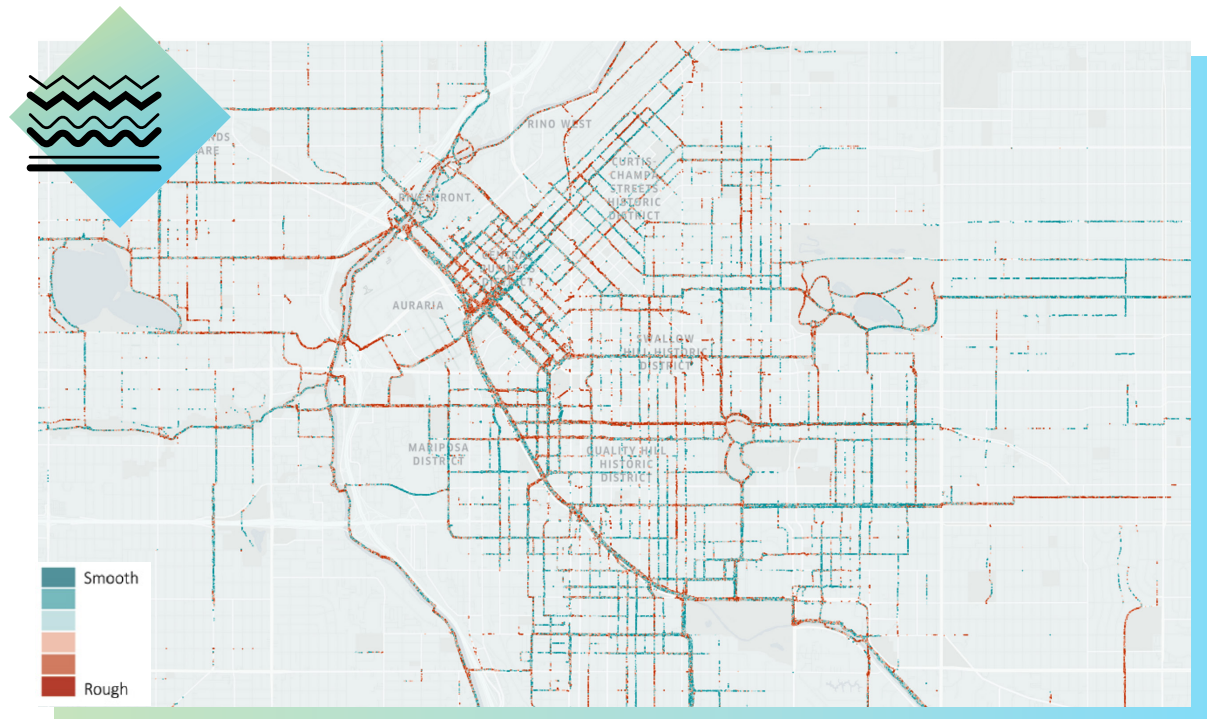
Gathering ridership data through See.Sense bike lights gave the Partnership a unique mechanism to analyze Denver's cycling infrastructure in an efficient, and yet holistic, way. Collecting bicycle data can oftentimes be expensive and time-consuming work, leaving much to be desired in our understanding of cyclist experience. By collecting qualitative and quantitative data from participating cyclists in the See.Sense pilot project, a more comprehensive picture of Denver's cycling network is available and it's easier to quickly identify areas of the city that would benefit from infrastructure improvements the most. The following maps highlight the ridership metrics collected through the See.Sense bike lights – compare the maps and try to identify Denver's most dangerous streets and intersections for cyclists!



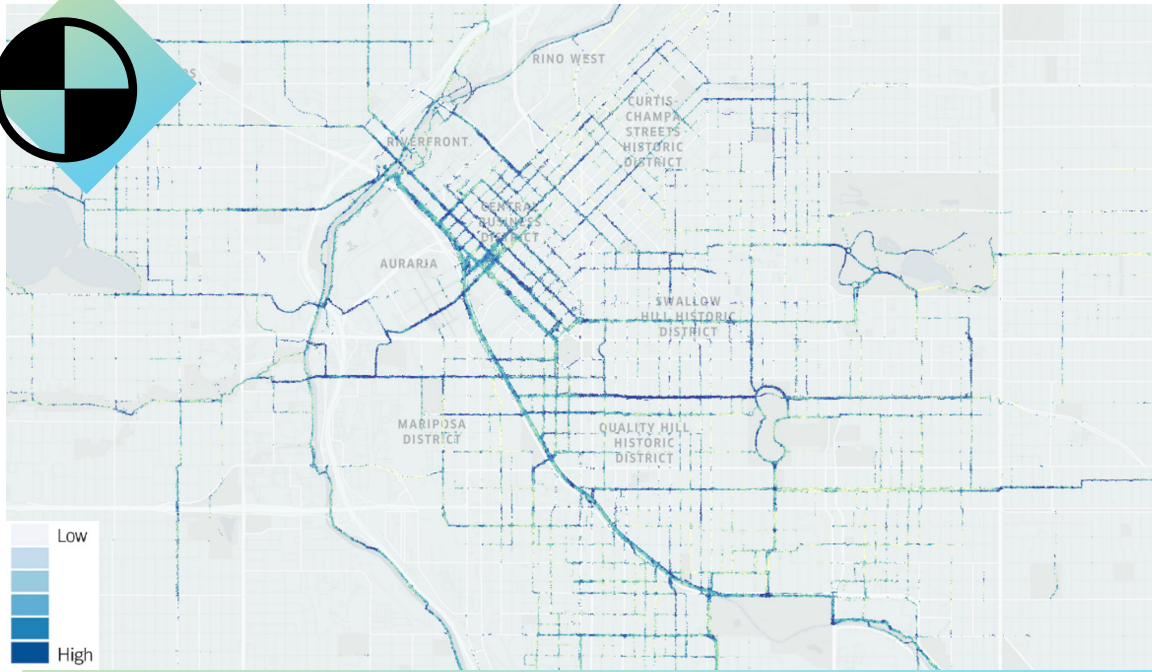
## Road Surface

See.Sense lights track road surface roughness from the experience of the cyclist. Road surface can be used to identify segments in cycling infrastructure that need maintenance the most. Roads that experience a high volume of cyclists, or areas where cyclists experience heavy braking, swerving, collisions, or other negative impacts should be prioritized from a risk management approach.

By improving road surface, you can improve cyclists' comfort and perception of safety and help reduce accidents.

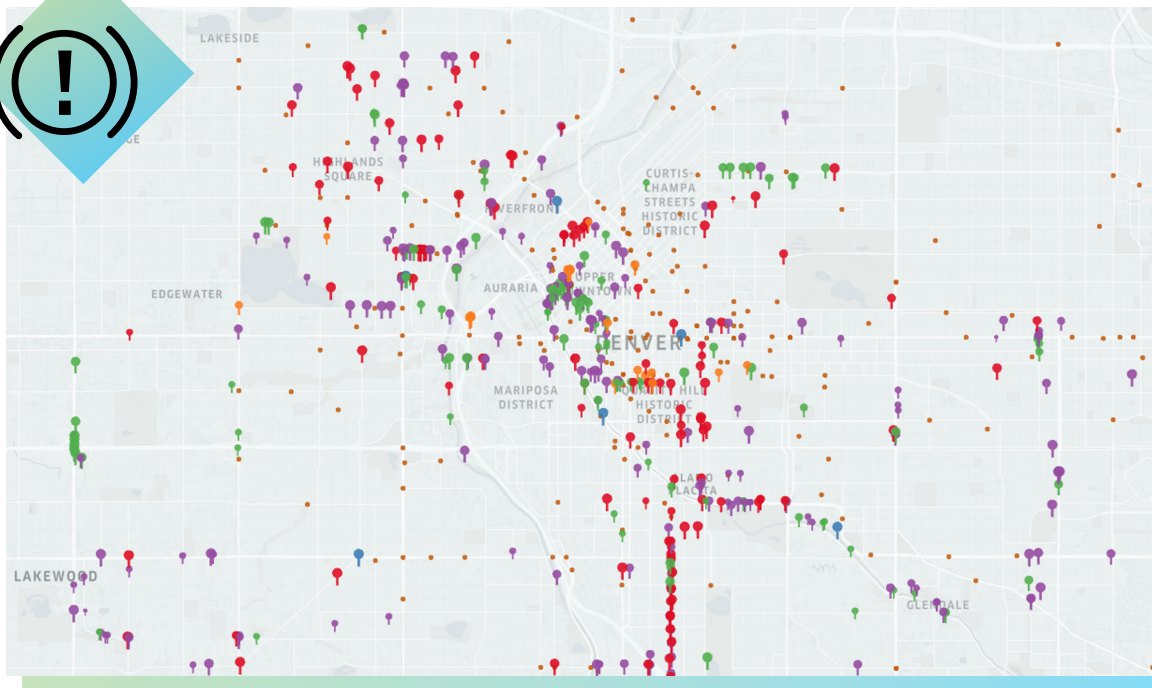






## Braking

Heavy braking indicates that cyclists are having to react to something on short notice with sudden or sharp braking. We can examine a particularly heavy-braking road segment and try to determine what could contribute to this. For example, imagine a person driving a vehicle cuts across a bike lane to make a right turn at the last minute; how do you react? Areas that have high volumes of vehicle traffic or road segments that lack adequate cycling-related signage can influence heavy braking for cyclists.

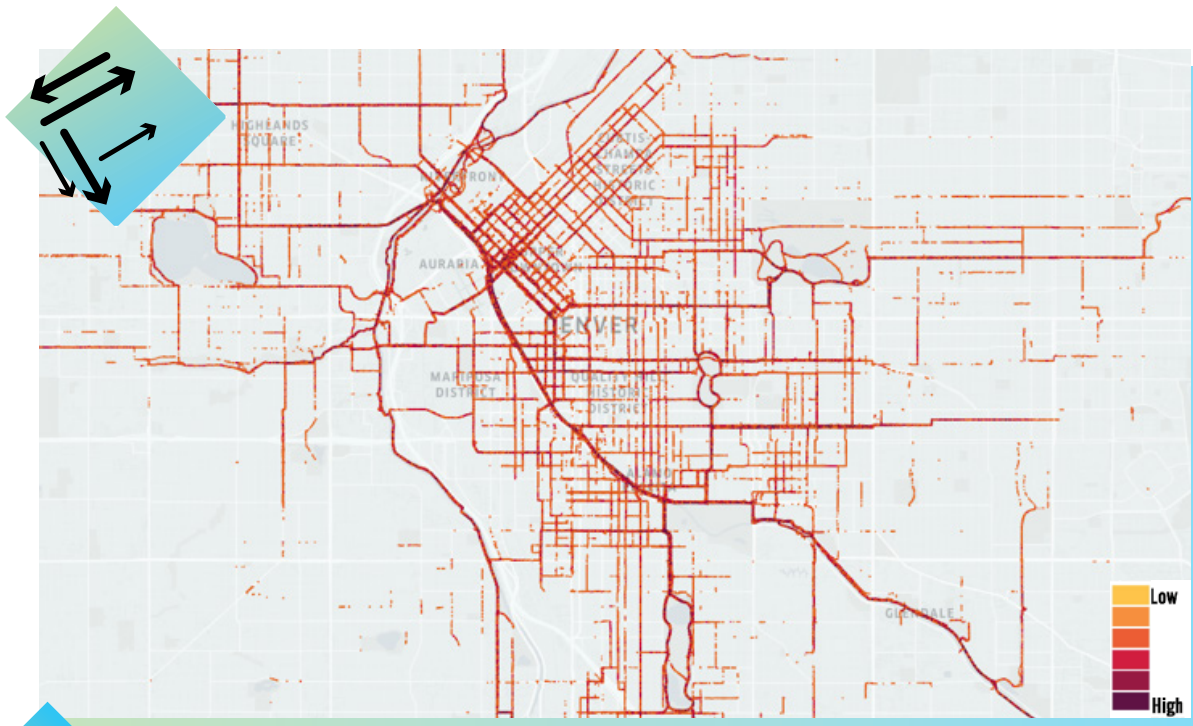
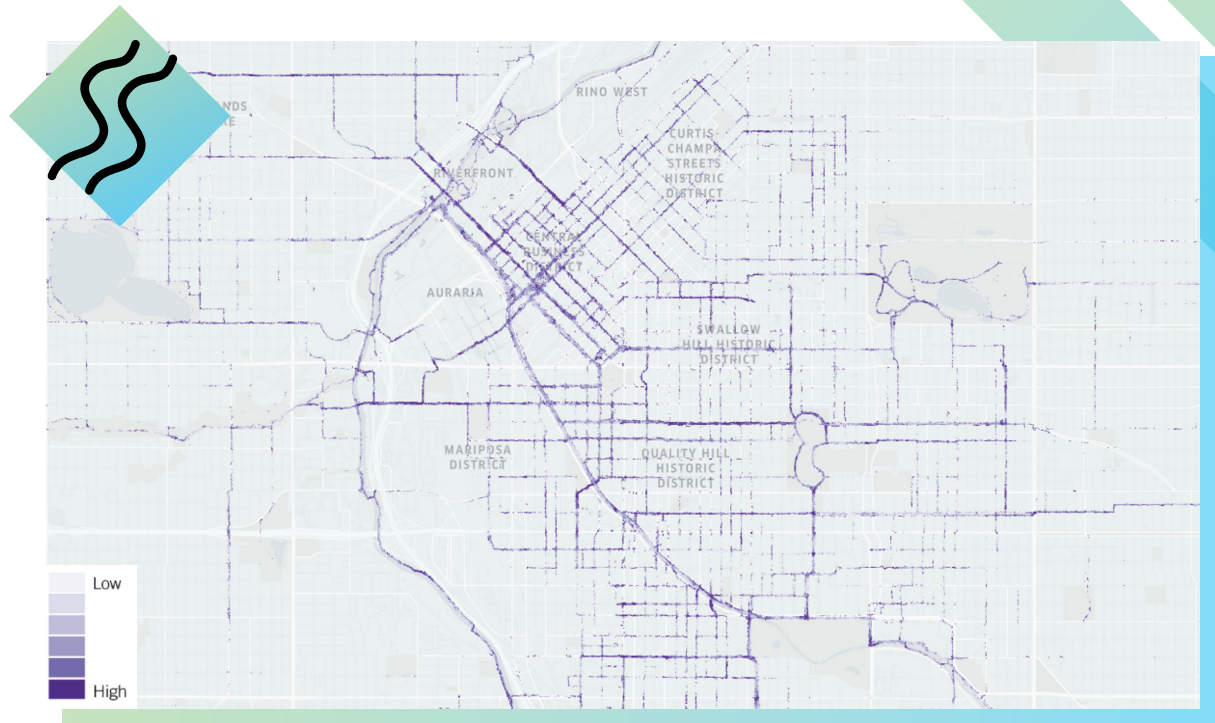


## Perception

While road surface, braking, and swerving data were all passively collected via the See.Sense companion app, perception data was also collected through the app, allowing cyclists to document in their own words collisions and other first-hand incidents experienced while cycling. Examples of perception data captured includes potholes in the street, obstructions in bike lanes, or even collisions with vehicles or other cyclists.

## Swerving

Cyclists can swerve suddenly in response to unexpected vehicle or pedestrian movements, traffic lights, poor road surface quality, or even other cyclists or scooter riders. A driver opening a car door along a bike path or an unanticipated pothole in the street are just a couple of examples of what can prompt intense swerving.



## Route Popularity

See.Sense data tracks where cycling trips occur the most in Denver. See.Sense data populates on the dashboard map relative to precise geolocation, which means that the tighter the line on the dashboard, the more cyclists are using the same space to connect in the network.

# Findings

The year-long pilot study produced **960 million sensor readings**, creating endless opportunities to research Denver's existing road network and learn about cyclist experiences on a variety of road types. To achieve the study's goal to promote safe bicycle infrastructure, the Partnership prioritized its focus on why certain bicycle routes were more popular than others, how cycling patterns change before and after infrastructure improvements, and analyzing how demographics influence cyclist behavior. Here are potential future use cases for this data that were highlighted in the pilot project:



## Before/After Evaluation

Collecting data over a year allowed the Partnership to research cycling behavior before and after construction occurred on certain bikeways (e.g. 13th Avenue). **This data is important for measuring the success of infrastructure improvements** and has the potential to optimize and iterate future improvements with community engagement and support.

## Confirming Routing for Bicycle Network

The See.Sense data populates areas where cyclists chose to ride in Denver, highlighting the city's most popular routes while also revealing other routes that may be under-performing. **This information has the potential to reveal what types of cycling infrastructure are most effective or expose hazards that may deter ridership.**

It also offers an opportunity to gather more public feedback outside of traditional outreach processes to determine the best current locations for people biking in Denver, as well as identify potential opportunities for additional bikeways.

## Demographics in Network

Analyzing downtown cycling behavior by gender reveals that there are noticeable differences in the way that men and women bike in Denver. **This data can be used to better understand how to make our bicycle network more comfortable and welcoming for all Denverites who choose to bike.**

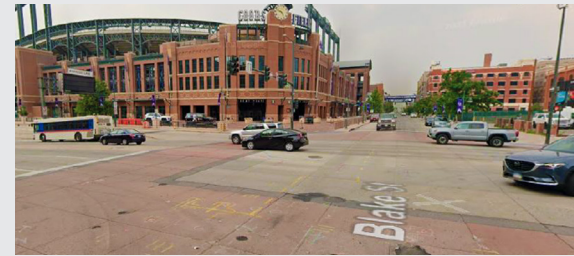
## 20th and Blake Streets

Between June 2020 and July 2021, three bicycle collisions occurred at or near the intersection of 20th and Blake Streets. The See.Sense data confirms the danger of this corridor, displaying much higher rates of swerving and braking among cyclists than on adjacent downtown streets. Although 20th Street is a vital connector between the Lower Highland neighborhood and Downtown Denver, no bicycle infrastructure currently exists on the corridor between Central Street and Blake Street. This lack of infrastructure forces cyclists who travel along 20th Street to either cycle on the separated pedestrian path or alongside heavy vehicular traffic on the street level, which becomes increasingly congested near the intersection of 20th and Blake Streets. Since the conclusion of the See.Sense study, a new protected bike lane was installed on Blake Street that will aim to reduce the safety issues previously identified at this intersection.



## Busy Intersection

During Colorado Rockies game days, fans swarm to Coors Field, located at the intersection of 20th and Blake Streets. While the stadium is conveniently located adjacent to popular transit hubs and parking lots, shared micromobility devices such as Lyft and Lime scooters and bikes have become an increasingly popular way for fans to get to and from games.



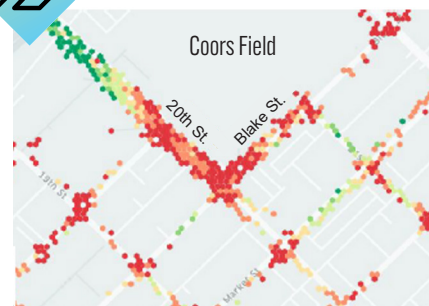
## Micromobility Devices on Rockies Game Days



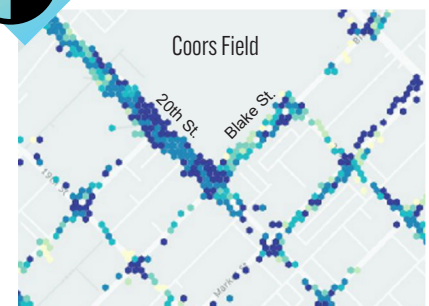
Source: Denver's Department of Transportation & Infrastructure's Shared Micromobility Program



## Speed



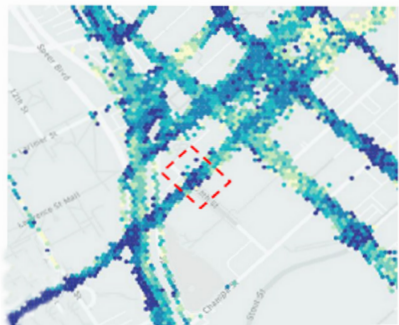
## Braking



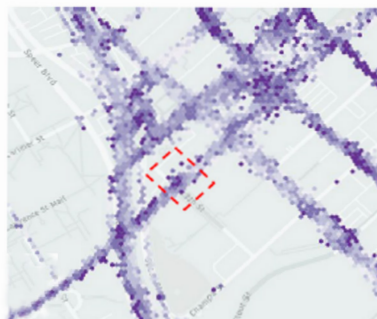
## 13th and Arapahoe Streets

SeeSense data helps to more effectively evaluate facilities that are already installed and see how they perform within the network. At 13th & Arapahoe Streets, the Arapahoe Street protected bike lane that runs through downtown crosses Speer Boulevard into Auraria campus. This is a main south running route that sees a lot of activity, but it is notable that many cyclists turn off Arapahoe Street at 14th or 15th Streets, before reaching Speer Boulevard. Several parking lots and garages, as well as a vehicular turn lane that crosses the bike lane at Speer Boulevard may lead to some cyclist discomfort on the route. This is supported by the braking and swerving data. Additionally, the nearest connection to the Cherry Creek Trail is between Lawrence and Larimer Streets. Considering that Arapahoe Street is one of the only southern routes in this area of downtown, additional wayfinding and safe connections to the Cherry Creek Trail may help some cyclists better realize a network connection.

**Higher levels of braking and swerving at 13th and Arapahoe Streets than at surrounding junctions could explain why more cyclists prefer to travel along Lawrence Street.**



Braking



Swerving

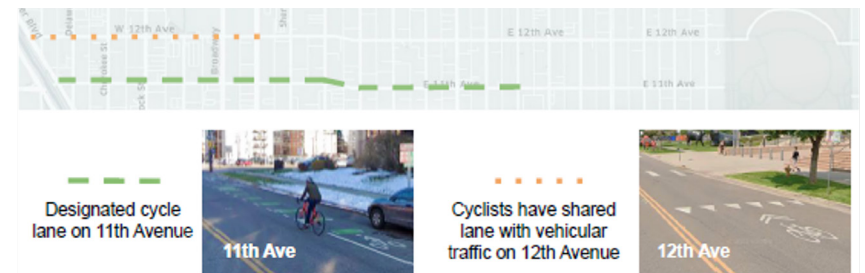


# 11th and 12th Streets

While some streets have more bicycle infrastructure than others, the See.Sense data reveals that this doesn't necessarily affect route popularity. An example of this is 11th and 12th Avenues between Speer Boulevard and Cheesman Park. Currently, 11th Avenue has a designated cycle lane from Speer Boulevard to Emerson Street, while 12th Avenue has a much shorter shared lane with vehicular traffic from Speer Boulevard to Lincoln Street. Despite the differences in bicycle infrastructure, route popularity remains consistent between 11th and 12th Avenues.

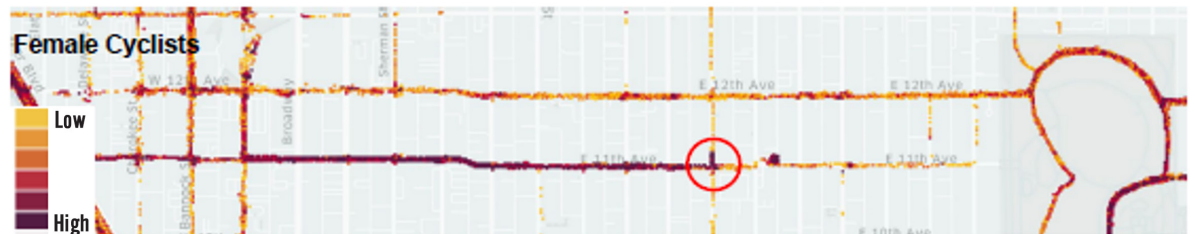
## Route Popularity

Routes popularity is roughly the same on 11th and 12th Avenues between Cheesman Park and Speer Blvd despite differences in bicycle infrastructure.



## Male/Female Cyclists Comparison

11th and 12th Avenues exposed how ridership behavior differs between male and female cyclists. Female cyclists prefer to travel along 11th Avenue on the designated cycle lane between Speer Blvd and Emerson, while male cyclists do not appear to have a preference between the two corridors. Both male and female cyclists prefer to connect to Cheesman Park via the cycle track on 12th Avenue. However, female cyclists prefer to cycle along 11th Avenue to connect to cycling infrastructure.

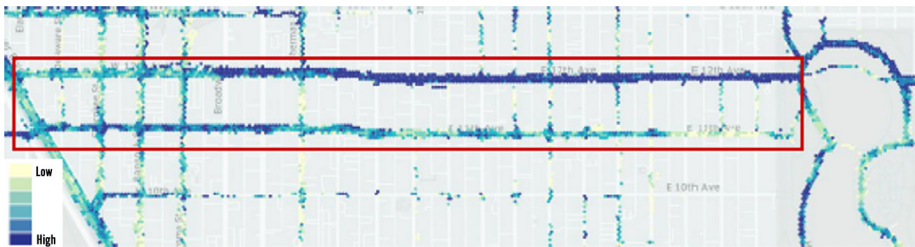




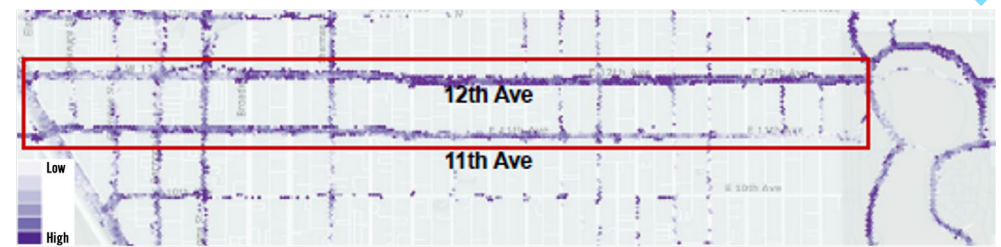
## Braking & Swerving

Although 11th and 12th Avenues are traveled fairly equally, cycling conditions are quite different on these corridors. Levels of heavy braking are on average 2.5 times higher on 12th Avenue compared to 11th Avenue. Similarly, levels of heavy swerving are on average 1.5 times higher on 12th Avenue compared to 11th Avenue. This may be explained by the character of these streets. On 12th Avenue from Cheesman Park to Lincoln Street, cyclists share the street with not only vehicles, but also with buses that travel along the corridor. This differs from 11th Avenue, which does not host any bus routes and has designated cycle lanes from Speer Boulevard to Emerson Street, eliminating some conflict between cyclists and vehicles.

Interestingly, levels of heavy braking on 11th Avenue intensify between Sherman Street and Speer Boulevard and appear to be higher than the same stretch on 12th Avenue, even though 11th Avenue has protected bike lanes and 12th Avenue has shared bicycle lanes. However, qualitative data entered in the See.Sense app by project participants suggests that this may be due to cars having to cross the cycle lanes to park, suggesting that there may be opportunities to enhance signage that increases driver awareness for cyclists.



Braking

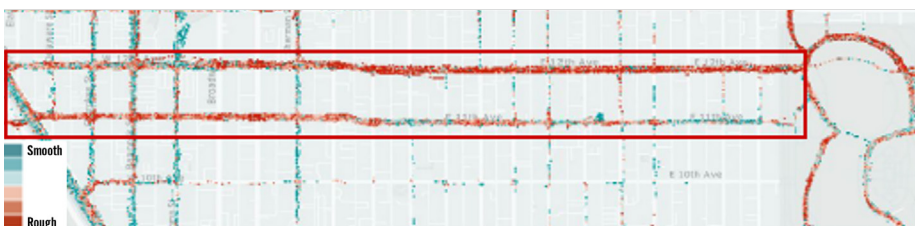


Swerving



## Road Surface

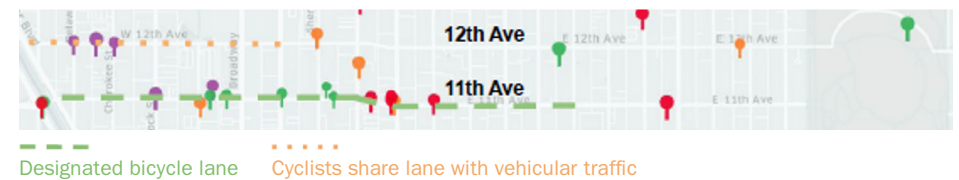
Higher levels of rough road surface were experienced by cyclists on 12th Avenue compared to 11th Avenue




## Perception

*"Cars swerved into the bike lane in front of me to park...drivers seem very unaware there is a bike lane here."*

*"There needs to be more awareness made of cyclists especially on streets with bike paths like 11th. More signs maybe?"*

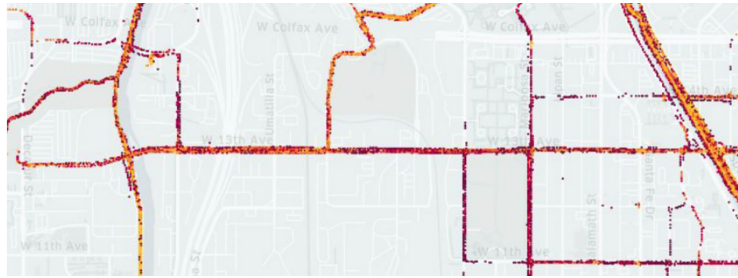


# W 13th Ave Protected Bike Lane

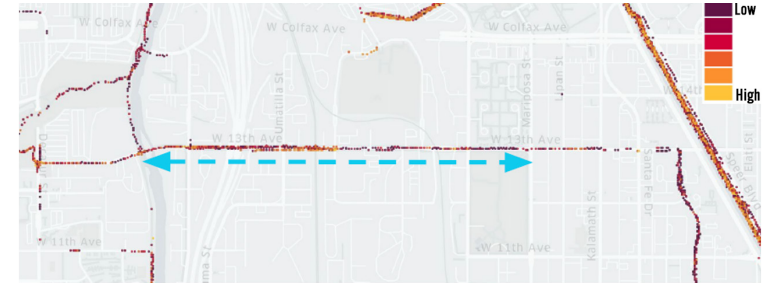
During the pilot project, Department of Transportation and Infrastructure (DOTI) installed a protected bike lane (PBL) along W 13th Avenue between Platte River Trail and Mariposa Street, where no prior bike infrastructure existed. This allowed a unique opportunity to leverage the See.Sense data and understand behavioral changes for cyclists riding along this corridor before, during, and after construction of the protected bike lane.

As stated previously, See.Sense data populates on the dashboard map relative to precise geolocation. Based on Initial data, it appears that cyclists are using the new protected bike lane versus sidewalks because the data is much more aligned to one route. Prior to the infrastructure upgrades, cyclists were more likely to use side streets and sidewalks to connect to safe routes between West Denver and downtown. See.Sense data also indicates that there may be an increase in usage of the bike network, with cyclists continuing 23% longer on this route than before the installation of a protected bike-way in the street. For example there was an average usage of 2.3 miles/cyclist before the PBL was constructed; after the PBL was constructed, the average usage was 3.0 miles/cyclist.

## Route Popularity



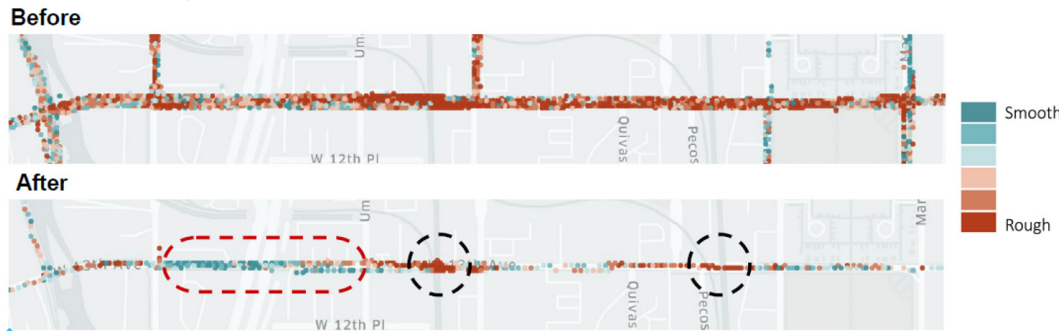
Before PBL - 2.3 miles traveled/cyclist



After PBL - 3.0 miles traveled/cyclist

## Road Surface

While road surface has greatly improved along the route with the installation of the cycle lanes, you'll notice that the two problematic locations where road surface has not improved are located at the rail crossings.

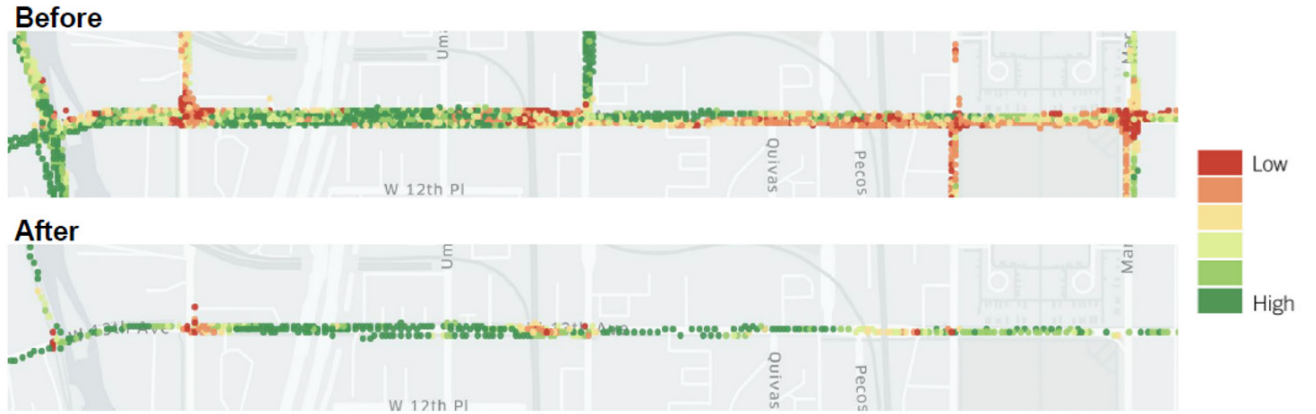


Rail crossing on 13th Avenue



## Speed

The average speed of cyclists along W 13th Avenue has increased from 12.4 mph to 14.6 mph since the introduction of the cycle lanes, indicating cyclists may feel safer and therefore more confident to travel at higher speeds.



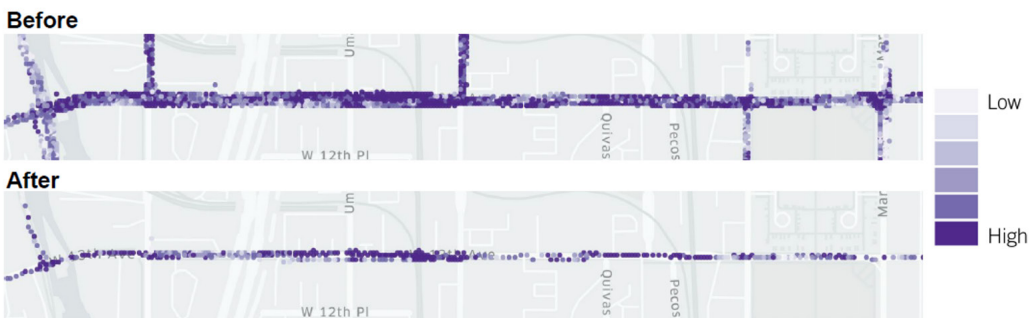
## Braking & Swerving

Again, difficult to tell if the cycle lane introduction has had an effect until data builds further. Initial areas of heavy swerving and braking seem to be appearing in the same locations as before, around the railway tracks

### Braking



### Swerving



# Recommendations

A major goal of the See.Sense pilot project was to test potential applications and use cases for greater data around cycling experience in Denver, as well as to outline recommendations for next steps to leverage this broader dataset. Given the City's Vision Zero goal for no traffic deaths on Denver's streets by 2030, as well as commitments from DOTI to quickly implement additions to the bicycle network by 2023, there is much to learn from this See.Sense data to more quickly and more precisely make improvements to Denver's transportation system with safety and comfort in mind.

These recommendations detail next steps for further leveraging the data collected during the April 2021 to April 2022 pilot project, as well as identify opportunities to continue and expand data collection through See.Sense lights.

1

## **Leverage academic researchers to study the predictive nature of See.Sense data when paired with crash analysis.**

In partnership with local research institutions and universities, study the statistical relevance and predictive nature of the experiential data collected by See.Sense lights. In other words, what indicators within the See.Sense dataset can serve as predictive markers for needed safety improvements when overlaid with crash data? As findings are compiled, identify opportunities to incorporate See.Sense data into bike planning standards and public messaging at the City.

2

## **Consider application of See.Sense lights in community engagement and data collection for capital projects and infrastructure planning projects.**

Review the cost estimates drafted by this pilot project and consider possibilities to incorporate See.Sense light distribution and data analysis as part of the community engagement process for DOTI bike infrastructure projects. This can help to remove individual bias and inform data-driven conversations with the community, while also identifying opportunities to improve the network that might not immediately come to mind when the community is asked for their experience. This also provides an opportunity to connect community members with bike lights who may not otherwise have access to them and serves as an educational opportunity for bike safety in the community among cyclists and drivers alike. Additionally, the See.Sense app allows for survey data so there are quantitative datasets behind qualitative comments.

3

## **Update standard details at the City using findings and major takeaways from the See.Sense pilot project.**

Review the findings in this report and leverage local research institutions in the first recommendation above to understand statistically valid and standard issues with certain current bike facility designs, particularly at intersections and railroad crossings. Use this information to update DOTI standards and improve bikeway designs.

4

## **Pair See.Sense data with tactical urbanism, quick-build projects to test concepts ahead of final construction.**

Consider the opportunity to test temporary infrastructure to solve complex problems in the bicycle network and evaluate with See.Sense lights given to groups of people that regularly ride this route. This can help to quickly understand issues within the network and iterate innovative solutions with individual bias removed from the process.

# Meet the Team



## **Andrew Ittis, AICP | Vice President, Planning & Community Impact**

Andrew leads the urban planning, design and mobility programs at the Downtown Denver Partnership directing collaborative planning activities that invigorate the downtown core and foster neighborhood vitality. An urbanist and outdoor enthusiast at heart, Andrew takes every opportunity to share a local secret, lead a bike tour, and blivate about the magic of cities.

## **Ellen Forthofer | Senior Manager, Urban Planning**

Ellen Forthofer is the Senior Manager of Urban Planning and Design and Downtown Denver Partnership. Her work focuses on projects that activate the public realm and engage the community, as well as long-term planning and policy efforts that shape downtown Denver. Ellen is passionate about creating support for more transportation options.



## **Max Gesten | Specialist, Community Impact & Mobility**

Max is the Mobility Specialist on the Planning and Community Impact team at the Downtown Denver Partnership. Focusing on the Partnership's TMA duties, Max works closely with businesses and organizations to optimize TDM strategies and promote alternative transportation modes in the downtown area. Max also supports the Partnership's work in activating the public realm and promoting publicly accessible bicycle parking.






# SEE.SENSE<sup>®</sup> Denver Smart Cycling Study



In partnership with:



? Questions about mobility in Downtown Denver? Contact: [mobility@downtowndenver.com](mailto:mobility@downtowndenver.com) for more information.

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