MORPC Cycling Guide Pilot

AI-Powered Safety Insights from Regional Bicycle Routes

1. Executive Summary

The **MORPC Cycling Guide Pilot** was launched to **evaluate and promote safe cycling routes** throughout the Central Ohio region using **real-world data collected from everyday riders**. The **primary goal** was to **validate specially designed routes for their safety and comfort**, giving planners data-driven insights to guide future network planning and route promotion. Velo AI partnered with MORPC to deploy its Copilot sensing system—an AI-powered platform that captures and analyzes **bicycle-vehicle interactions**—to support MORPC's vision of creating and publicizing **safe, appealing routes for riders of all ability levels**.

> **Safe, low-stress infrastructure** is a **critical enabler** for increasing cycling participation. This pilot proves we can measure safety **objectively** and at **scale** using **AI cameras**.

The pilot deployment included a total of 18 AI cameras distributed across four deployment sites. Each site consisted of two bicycles outfitted with front- and rear-facing cameras, enabling comprehensive capture of bicycle-vehicle interactions along routes, in addition to other valuable ride data.

Data collection rolling out at one of the deployment sites as part of the Cycling Guide Pilot. Each bike is outfitted with two AI cameras.

Volunteer riders played a critical part in the collection of data, recruited and trained on the basic operation of the cameras and accompanying GPS units. Each participant collected one or more loops of a designed route from their assigned starting location. Over the course of two months of data collection, approximately 1,000 miles of total video data were collected.

The pilot has produced several **key outcomes** that demonstrate both the value of the technology and its impact on understanding rider safety:

- **Validated the safety and comfort of the selected routes:** The data confirms that these routes provide a genuinely low-stress experience, underscoring the role of safe infrastructure as a critical enabler for increasing cycling participation.
- **Revealed clear differences between infrastructure types:** By comparing riding on shared streets, multi-use paths, and purpose-built trails, we captured measurable differences in comfort, exposure, and interaction patterns—providing evidence for why a variety of infrastructure options is essential for a complete, connected network.
- **Demonstrated the power of AI sensing for large-scale safety analysis:** The pilot proved that AI cameras can capture unique, high-quality safety data at scale, enabling real-time dashboarding, improved algorithms, and expanded analytic capabilities. This work also laid the foundation for future analyses such as e-bike travel patterns, vegetation assessments, and broader sensor coverage across Central Ohio’s street and trail networks.

Together, these outcomes underscore how **data-driven, infrastructure-focused strategies can transform regional cycling networks**—turning what were once isolated corridors into a **connected**, **safe**, and **inviting** system that **enables more people to ride with confidence.**

2. Introduction

Background: The MORPC Cycling Guide initiative is part of a regional strategy to encourage more people to bike by making it safer, more comfortable, and more accessible across Central Ohio. By identifying and promoting routes that already offer high levels of safety and comfort, MORPC aims to support both daily transportation and recreational use, contributing to mode shift, health outcomes, and regional tourism. The Cycling Guide will serve as a public-facing tool to highlight low-stress, connected bicycle networks for people of all ages and abilities.

The role of AI-enabled sensing in this effort is to bring objective, high-resolution safety data into the transportation planning process. By equipping bicycles with cameras and sensors, the system can capture interactions between bicyclists and other road users—including **passing distances**, **vehicle behavior**, and **infrastructure context**—in a way that complements traditional crash data and surveys. While existing MORPC tools identify routes based on their safety characteristics, the AI camera data **validates** and **augments** this information with **real “wheels-on-the-ground” observations**, providing a cyclist’s-eye view of comfort, exposure, and infrastructure performance.

The objectives of the pilot were to:

- **Detect and characterize** vehicle behavior near cyclists, including overtaking events, passing distances, vehicle types, and relative speeds.
- **Build spatial risk maps** to identify locations with elevated safety risks and infrastructure stress.
- **Provide anonymized, evidence-based data products** to planners and stakeholders to support decision-making and communications around infrastructure and route promotion.

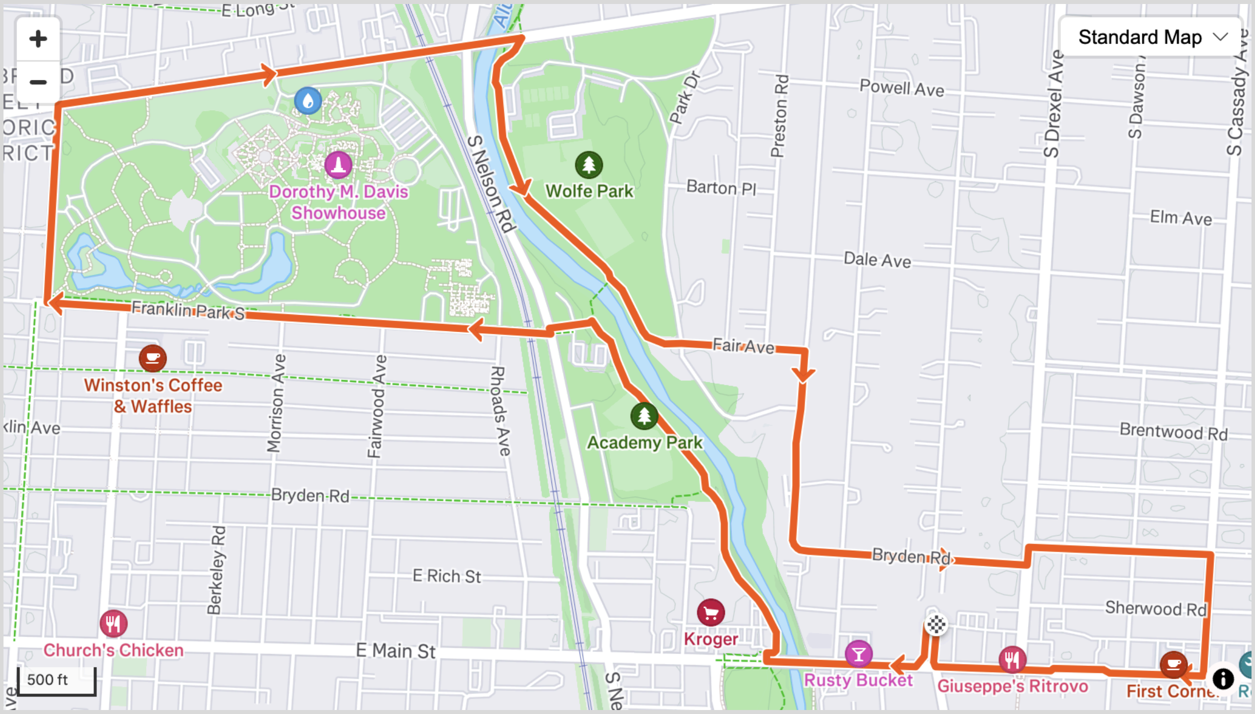
Infrastructure Types: We specifically classify **three primary infrastructure types** to distinguish different riding contexts, with additional subcategories as needed:

- **Road**: Paved streets and roads with **active vehicular traffic**, ranging from **low-volume neighborhood backstreets** to **arterial corridors** sometimes with **painted** or **protected bike lanes**. Riding in this context involves direct or adjacent interaction with motor vehicles.
- **Path**: Multi-use paths (MUPs) built parallel to roadways, typically **8–10 feet wide**, designed to provide a **buffered, shared space** for pedestrians, bicyclists, and other users. While physically separated, these paths are still influenced by **adjacent traffic and intersections**.
- **Trail**: Multi-use paths located on **independent rights-of-way**, fully separated from roadways. These facilities offer the **lowest exposure to vehicular traffic** and are often designed for recreational use, though they also serve as key transportation corridors.

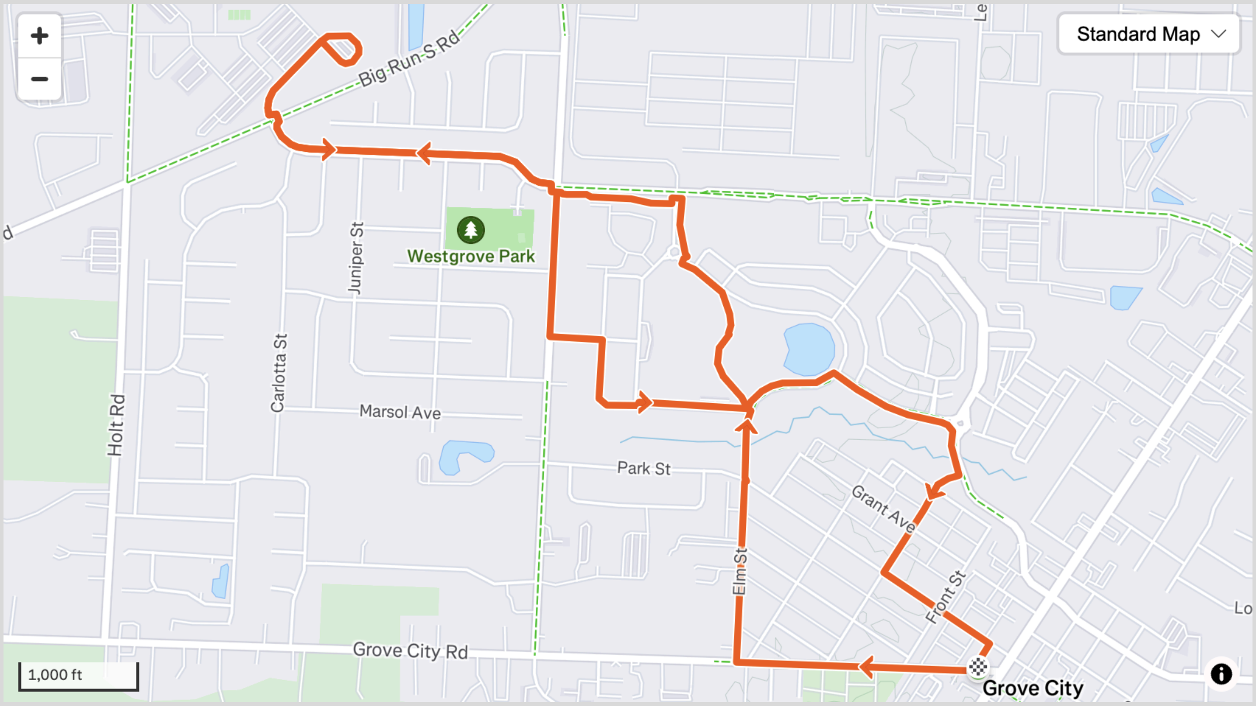
Routes: Four routes were selected to reflect a diversity of riding conditions in the region, including urban street environments, suburban corridors, and multi-use trails. Each route was intentionally designed to offer relatively safe and comfortable conditions, as these will form the backbone of MORPC's regional tourism and cycling promotion materials. The variation across routes also enabled testing how AI sensing performs under different infrastructure contexts. Each route also shows the estimated percentages of different classes of infrastructure type.

Route Name	Total Mileage	% Road	% Trail	% Path
Bexley	4.06 mi	75%	25%	0%
Grove City	4.38 mi	45%	0%	55%
Scioto	4.96 mi	34%	66%	0%
Westerville	5.48 mi	15%	43%	42%

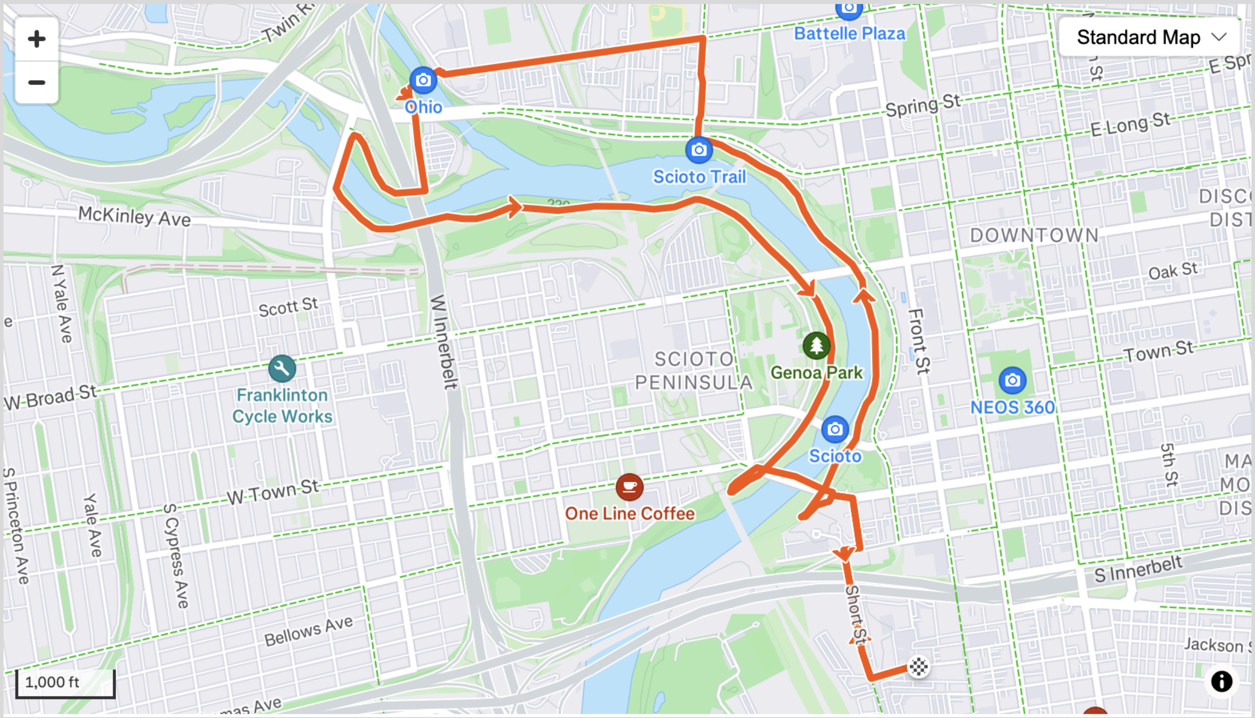
We additionally provide in-depth descriptions of each route.



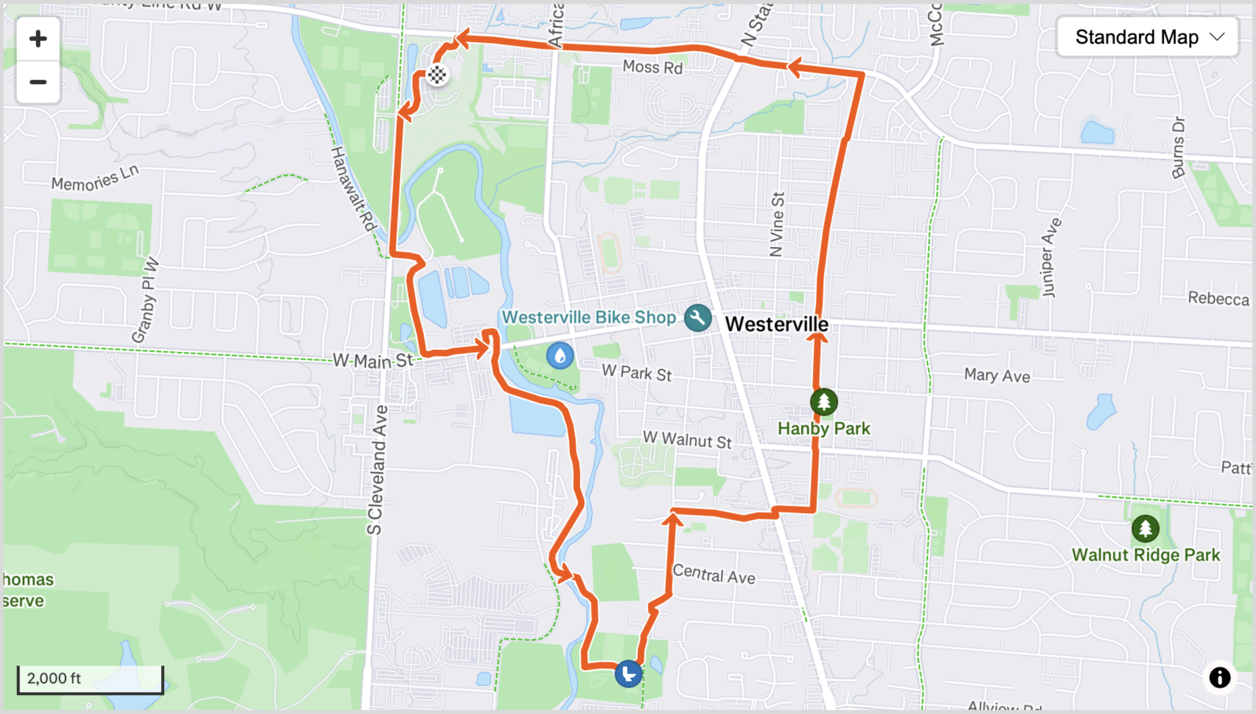
Bexley: An urban loop featuring a mix of street riding through a central business district (CBD), trail segments along the river, a protected bike lane on a major corridor, and lower-stress residential streets. This route illustrates the complexity of navigating a mixed urban environment.



Grove City: A suburban loop consisting of residential street riding with a small segment near the CBD and extensive portions on multi-use paths (MUPs) alongside roadways. This route reflects typical suburban active transportation infrastructure.



Scioto: A route dominated by trail riding along the river, with some portions through downtown corridors. This route represents a largely separated, recreational-type facility with minimal vehicle interaction, other than a small portion riding with vehicular traffic.

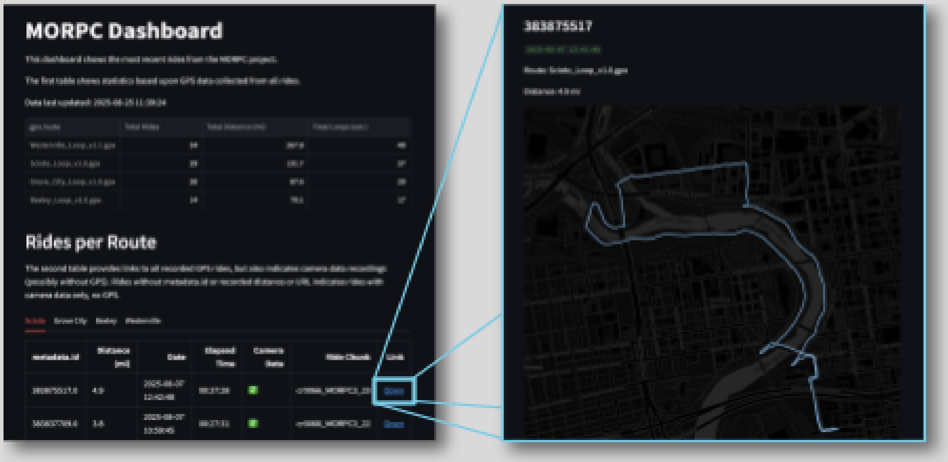


Westerville: Another suburban route primarily on trails and MUPs, with a small amount of low-stress residential street riding. This route illustrates a suburban community with extensive infrastructure for safe cycling and walking.

3. Deployment & Data Collection

The **Velo AI Copilot system** was deployed on a small fleet of shared bicycles to continuously capture rider-environment interactions during regular trips. Each bicycle included both **front and rear camera units**, each recording at 1080p resolution, enabling the system to observe approaching and overtaking vehicles from multiple perspectives. In addition to video, the device also collected **IMU** (inertial measurement unit) data to detect events such as surface vibrations, braking, and sudden maneuvers, and paired with a Wahoo bike computer to log **GPS location** and ride metadata. Initial processing occurred directly on the device, including detection and indexing of vehicle interactions, with data stored locally. Once units connected to Wi-Fi—when returned to their deployment sites—the data was automatically uploaded to the cloud for further analysis and visualization by the Velo AI team.

The **pilot fleet** and **volunteer riders** formed the **backbone of the data collection effort**. The deployment ran approximately from early June to early August, covering multiple weeks of peak summer cycling conditions. The volunteer pool consisted of both experienced riders familiar with regular cycling and less experienced or recreational riders, reflecting the diversity of future Cycling Guide users. Many volunteers chose to ride in pairs, which improved rider comfort, enabled redundancy in data collection, and allowed for easier coordination across routes.



As part of this pilot, Velo AI developed a real-time dashboard to actively monitor progress, showing both data collection at individual sites, as well as the ability to study individual rides and data.

To support **real-time management of the pilot**, a web-based dashboard was developed to track total miles and route coverage, as well as to allow organizers to investigate individual rides to ensure data quality. This internal tool was utilized for monitoring deployment progress, allowing the team to redirect collection efforts to underrepresented routes as the project progressed, as well as identify when coverage goals had been achieved at individual sites.

Environmental conditions during the pilot were generally favorable. Most rides took place during **midday**, **daytime hours**, with **low traffic volumes** and little to no inclement weather, resulting in a dataset that reflects typical recreational and utility cycling conditions under fair-weather scenarios.

4. Analysis Methodology

This section describes both the data analysis process as well as the specific metrics computed across the dataset. The data, uploaded to the cloud from the AI camera devices and GPS units, is first ingested (matching camera data to GPS data) and prepared for additional processing. This includes first updating the aforementioned dashboard, as well as performing spatial aggregation and computation of individual metrics. These metrics cover a variety of factors affecting both risk and comfort during individual bicycle rides.

Spatial Aggregation: To enable route-level analysis, ride data was spatially matched to each designated route, segmenting rides into aligned and non-aligned portions. The aligned portion of each ride was then used to closely match exact positions along the routes, so that metrics could be computed based upon percentage along each route. The metrics are computed only on these route corridors, thus excluding extraneous travel to and from the routes. This approach allowed for direct comparison between riders and trips, ensuring that aggregated statistics accurately reflected conditions directly along the core routes.

Metrics Computation: Once an individual ride has been aligned to its designated route, we compute a variety of metrics at each point along the route. These metrics are aggregated across a multitude of rides, thus providing an estimate of each value at each point of the ride.

These metrics cover two broad categories that both contribute to measurements of safety and comfort. These categories include (1) analysis of interactions between bicyclists and nearby vehicle drivers and (2) estimates of the ride experience using Copilot data. We provide additional context on how each metric is computed.

Vehicle-Bicycle Interaction Metrics: This first set of metrics are computed using both the data of where and how the bicyclist is riding as well as the locations, distances, and speeds of nearby vehicles. These metrics include:

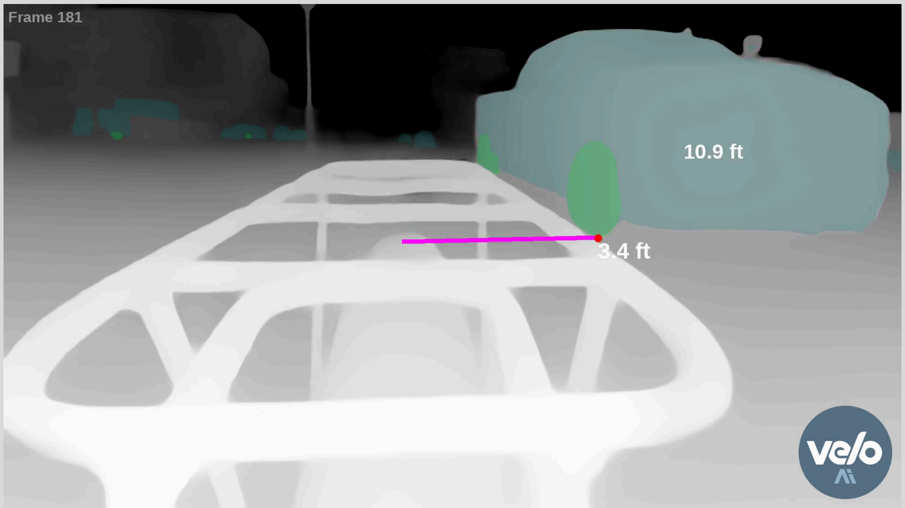
- **Ride Stress:** a measure of perceived stress for the bicyclist, computed from distances and speeds of nearby vehicles. Example values include:
    > 5.0: a busy, arterial road
    > 1.0: a busy, urban street
    > 0.5: an urban street with occasional nearby traffic
    > 0.1: a low stress street, i.e. neighborhood roads
    < 0.1: a very low stress route, i.e. a trail separated from traffic
- **Obstructions:** an estimate of how busy a road is, based upon how often a vehicle is directly in front of the bicyclist, potentially slowing or blocking forward progress.
- **Moving Vehicle Count:** a count of observed vehicles moving in proximity to the rider. This is an estimate of how busy the street or road is.

Ride-Comfort Metrics: This second set of metrics focuses directly on the ride experience, computed using only the data of the cyclists' motion, not including anything about nearby vehicle traffic.

- **Stoppage Time**: the probability of the rider being stopped at a given point on the route.

- **Roughness:** a measurement of the roughness of the pavement surface, indicating either smoothness/roughness of the surface itself or the presence of cracks / potholes. This metric is computed directly from vibrations measured by the onboard IMU. Example values include:
    - > 15.0: rough trail or gravel surface
    - > 10.0: pavement with significant bumps, potholes, cracks
    - > 5.0: pavement with an occasional pothole, crack
    - > 1.0: smooth pavement
    - < 1.0: extremely smooth surface / ride

Full metric results are provided and described in the appendix.



Copilot is capable of measuring distances and speeds of nearby vehicles, using state-of-the-art computer vision technologies. These measurements contribute directly to our estimates of safety and risk.

Video Clip analysis: In addition to metrics, a selection of other quantities were studied to attempt to identify outlier events. Representative video clips were generated through outlier event analysis. Events exceeding a three-sigma threshold on the following measures were flagged and manually reviewed. This process produced a curated library of illustrative near-miss or discomfort events:

- **High stress events**: individual high stress events as indicated by the above metric.
- **Hard brake events**: Copilot's onboard IMU indicated that the rider decelerated much faster than typical.
- **High jerk events**: Copilot's onboard IMU indicated a particularly rough bump / impulse event.

5. Results by Route

The results in this section highlight how infrastructure type and surrounding traffic environment directly shape rider experience and safety across the four MORPC pilot routes. Each corridor represents a different mix of road, trail, and path (cycletrack) facilities, providing a useful cross-section of the regional network.

Using Copilot's sensor and video data, we measured stress levels, vehicle interactions, surface quality (roughness), and obstruction rates for each segment type. Across all four routes, trail segments consistently provided the lowest-stress conditions, while road segments were associated with the highest levels of exposure to moving vehicles. Paths (cycletracks) generally reduced interactions compared to roads but did not fully eliminate rider stress, often due to adjacent traffic and frequent crossing points. It is worth noting that the reported stress values reflect sensor-derived estimates rather than direct rider feedback. Future work incorporating surveys or structured rider interviews would help confirm how accurately these measurements capture the real stress experienced by cyclists on these routes.

These findings reinforce the importance of infrastructure design in shaping rider experience: separation from traffic meaningfully reduces exposure and stress, but surface quality and interaction points remain critical factors in delivering truly comfortable and safe routes. The following sections provide a route-by-route breakdown, revealing the distinct patterns and infrastructure impacts for Scioto, Grove City, Westerville, and Bexley.

Route	Metric	Road	Trail	Path
Bexley	Stress	0.720	0.090	
	Stop Time	0.024	0.019	
	Roughness	7.499	7.592	
	Obstructions	0.478	0.032	
	Moving Vehicles	10.690	1.202	
Grove City	Stress	0.200		0.179
	Stop Time	0.014		0.012
	Roughness	3.047		2.638
	Obstructions	0.307		0.081
	Moving Vehicles	5.300		3.783
Scioto	Stress	0.386	0.066	
	Stop Time	0.064	0.023	
	Roughness	3.826	3.204	
	Obstructions	0.530	0.040	

	Moving Vehicles	5.565	0.545	
Westerville	Stress	0.145	0.106	0.458
	Stop Time	0.013	0.004	0.023
	Roughness	6.311	6.872	6.933
	Obstructions	0.228	0.074	0.204
	Moving Vehicles	2.982	1.477	5.932

Comparison table showing metrics results per route and per infrastructure type. Lower values are better. Lowest (green) and highest (red) values are shown across routes for each infrastructure type. Routes with a significant number of lowest values are thus safest and most comfortable.

Bexley: Bexley's network is dominated by road segments, with sections of trail infrastructure. This route exhibits the **highest road stress of all corridors** (0.72) and the highest vehicle interactions (10.7), indicating a strongly car-dominated environment for the on road segments. Trail segments provide some reduction in stress and vehicle exposure but cover only a portion of the route. Roughness is elevated on both facility types, suggesting **surface conditions** are an additional contributor to **rider discomfort**. Bexley represents a high-exposure corridor with limited separation from traffic and fewer sections with protected infrastructure. It is important to note that a portion of this route includes a protected bike lane that was installed as part of a quick build tactical urbanism research project via SS4A funds. The safety of that protected bike lane is currently under study.

Grove City: Grove City is defined by a clear division between road and protected path facilities, but with no fully separated trail infrastructure. Stress levels on road and path segments are roughly similar, indicating that although paths offer physical separation, riders may still experience induced stress from adjacent traffic or frequent crossing points. Moving vehicle counts are lower on the path than on the road (3.8 vs. 5.3), suggesting some buffer from traffic flow. Roughness and obstruction levels are also lower on paths, pointing to **better surface quality and fewer obstacles**. Grove City stands out as a path-oriented corridor, relying on protected facilities rather than trails to reduce direct vehicle conflict. Grove City also stands alone amongst the routes as arguably the **safest and most comfortable**.

Scioto: The Scioto route is characterized by a mix of road and trail segments. Stress values are modest on the road and even lower on the trail, reflecting a **meaningful reduction in rider exposure** when moving off-road facilities. Obstruction rates and roughness levels are moderate but manageable on both facility types. Notably, moving vehicle interactions are ten times higher on road segments than on trail segments (5.6 vs. 0.5), reinforcing the **protective benefits of the trail infrastructure**. This route represents a traditional road-to-trail corridor, where trails play a crucial role in reducing exposure to motor vehicle traffic.

Westerville: Westerville features the most diverse mix of facilities, with road, trail, and path segments all well represented. Paths account for the largest share of the route, followed by trail, with minimal road exposure. Interestingly, stress levels are highest on the path segment—likely due to traffic adjacency and interactions at crossings—while road segments have the lowest measured stress—from use of neighborhood backstreets. Moving vehicle counts on the path (5.9) exceed both trail (1.5) and road (3.0), which may indicate high exposure from parallel roadways or frequent intersections. Roughness is high across all modes, suggesting generally uneven pavement conditions. Overall, Westerville demonstrates a **complex, multi-facility network**, balancing reduced road exposure with challenges related to surface quality and interface points.

In addition to the above metric analysis, we analyzed hard brakes and high jerk events, as well as high stress events. These individual events were used to qualitatively verify the metrics results as well as indicate outlier events. Results included:

- **Hard brake events:** by and large, the most extreme hard brake events occurred with routine bicycle riding, i.e. braking in order to reverse at a turnaround point, or braking when approaching a crosswalk. None indicated a severe braking event to avoid a collision, thus further supporting analysis that these four routes are very safe.
- **High jerk events:** by and large, these events corresponded to large obstacles in the path of the bicyclists, for example a berm or large crack across a trail surface, or a bicyclist hopping off of a curb. Again, none of these corresponded to crashes or fall events.
- **High stress events:** these events were largely normal routine vehicle-bicycle overtakes, where a fast approaching vehicle passes a bicyclist on a road. These events were not particularly different from overtakes observed in other cities and locales, further supporting the safety of the chosen routes.

We summarize our results with the following key findings:

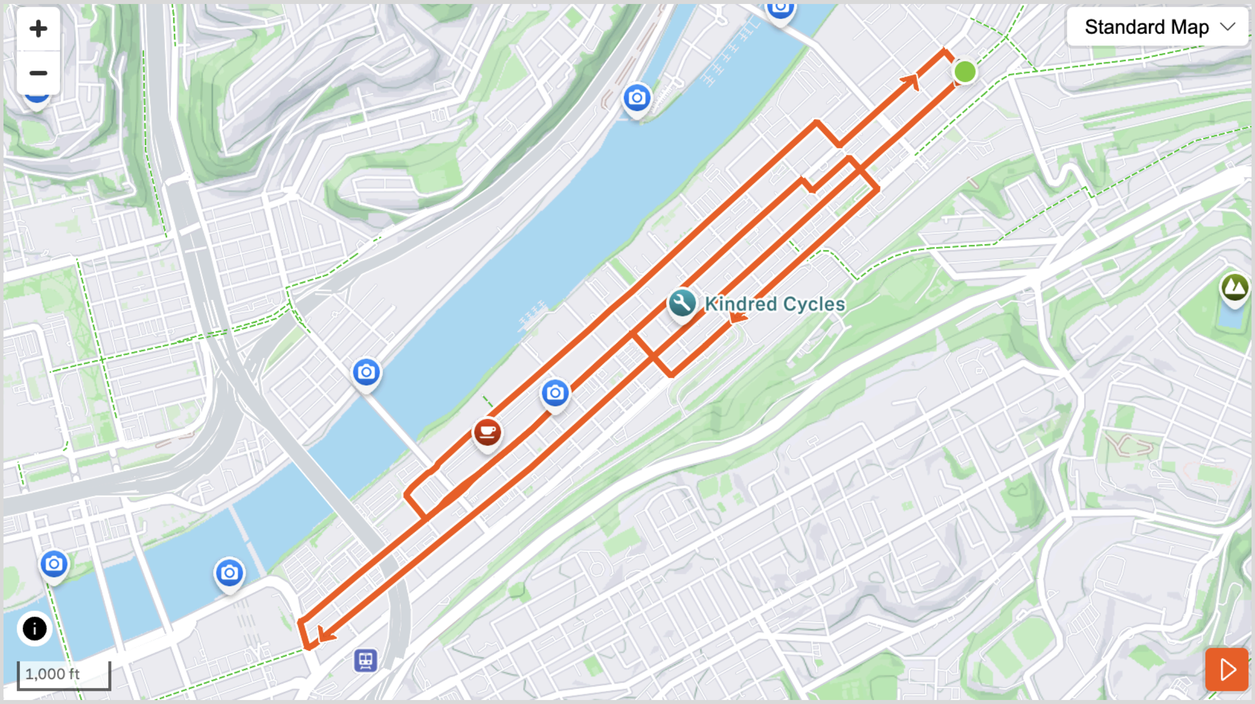
- **Trail segments** consistently show extremely **low stress levels**, underscoring their value in creating high comfort networks for bicyclist travel.
- **Path segments** (typically alongside road networks) **reduce vehicle interactions**, but do not fully eliminate stress as trails do. This highlights the importance of buffers, intersection treatments, and traffic separation.
- **Road segments** are universally associated with **higher levels of stress** and vehicle interactions, with the exception of neighborhood backstreets, which were typically low stress.
- **Roughness levels vary** widely from route to route and between infrastructure types, suggesting potential to use this data to **isolate** and **fix pavement issues**.
- **Hard brake** and other **outlier analysis** revealed **no significant concerns** of near-misses or other dangerous road encounters.

Trails consistently show **extremely low stress** levels—demonstrating their **central role** in building **safe** and **comfortable** regional networks.

6. Comparisons with Past Data

To provide a regional context for interpreting the Columbus pilot data, we compared the MORPC routes with findings from a parallel study conducted in Pittsburgh's Strip District as part of Velo's USDOT SBIR project. That effort similarly collected approximately 1,000 miles of rider data using the same Copilot sensing technology, but in a denser urban environment characterized by heavy commercial activity, complex traffic patterns, and limited separated infrastructure.

This comparison allows us to contrast infrastructure-driven safety in Columbus—where routes were intentionally selected for comfort—with a contrasting corridor in Pittsburgh. While Columbus routes differ mainly by facility type (road, trail, path), the Pittsburgh corridor shows dramatic differences within a single corridor depending on adjacent land use, street utilization, commercial zones, and traffic operations. This provides a valuable reference point for understanding how infrastructure, environment, and street activity interact to shape the real-world experience of cyclists.



Pittsburgh Strip District Route: This route was designed for Velo's USDOT SBIR, and consisted of bicycle travel along four parallel streets in Pittsburgh's Strip District neighborhood.

Metric	Route Overall	Terminal Market	Railroad Street
Stress	0.629	0.978	0.312
Stop Time	0.066	0.049	0.037
Roughness	7.866	6.739	7.734
Obstructions	1.729	2.546	0.396
Moving Vehicles	6.266	10.026	3.216

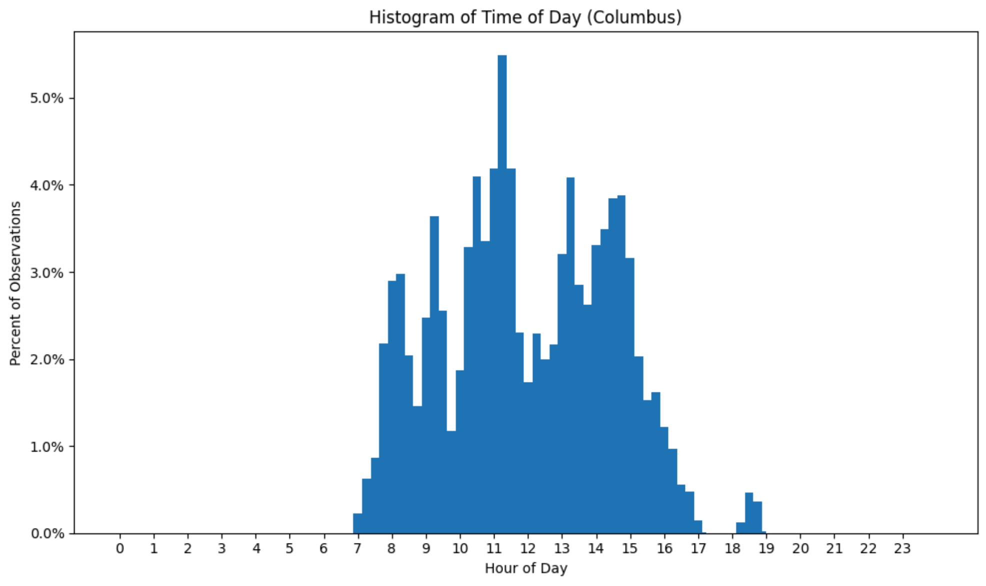
Pittsburgh metric results. These metrics allow comparison between the Columbus-region routes to an urban cycling experience in the Strip District of

Pittsburgh. The Terminal Market section is a dense urban street, whereas Railroad is a quieter backstreet.

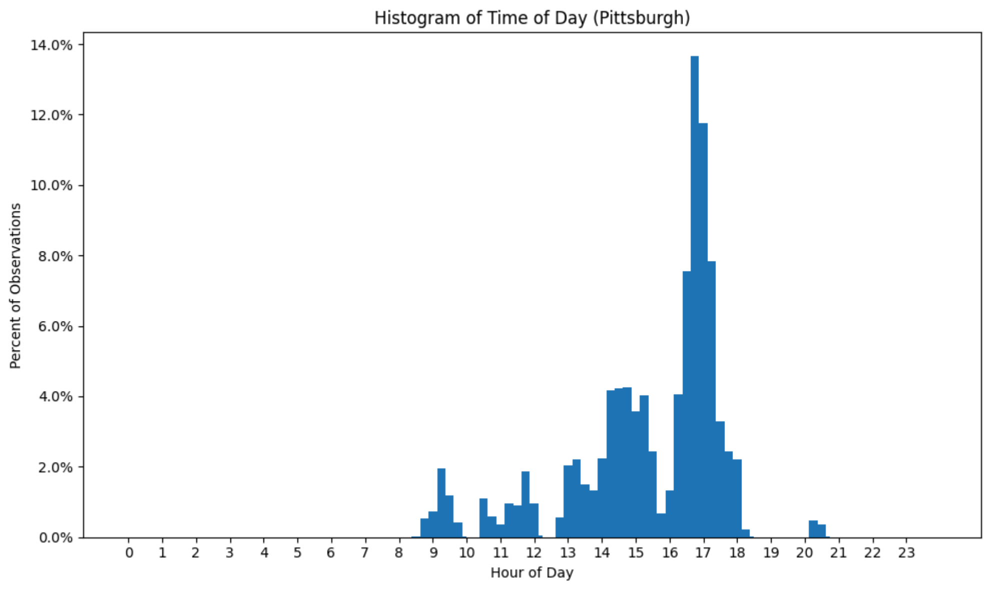
The overall Strip District corridor in Pittsburgh exhibits moderate-to-high stress levels (0.63), which are higher than those observed on most Columbus routes except Bexley. Obstructions and vehicle interactions are significantly elevated (1.73 and 6.27, respectively), reflecting the dense, mixed-use character of the neighborhood, where cyclists share space with vehicle traffic.

The Terminal Market segment along Smallman Street stands out as a particularly high-stress environment. Its stress score of 0.98 and moving vehicle count exceeding 10 per segment represent the highest values across all observed routes, both in Pittsburgh and Columbus. This aligns with the terminal market's role as a busy commercial corridor, where curb conflicts, turning vehicles, and lack of separated infrastructure are common. Obstruction levels are also more than double those of any Columbus corridor, highlighting the intensity of nearby vehicle traffic patterns.

By contrast, the Railroad Street backstreet segment shows a much lower stress level (0.31), low obstruction rates, and a relatively low vehicle interaction rate (3.2). This is more comparable to trail segments in Columbus, particularly Scioto's lower-stress portions. This sharp contrast within a single 6-mile corridor underscores how facility context and surrounding land use can dramatically change rider experience.



Time-of-day distribution of rides in Columbus. Columbus rides occurred broadly throughout daytime summer hours.



Time-of-day distribution of rides in Pittsburgh. Pittsburgh rides—collected in winter—were concentrated in the late-afternoon "after work" period.

To contextualize these differences, we compared the distribution of ride times between the two datasets. The Columbus rides—collected during summer months—occurred broadly throughout the daytime, with a balanced spread from mid-morning through late afternoon. By contrast, the Pittsburgh dataset was collected in winter and shows a strong concentration of rides clustered around the 5–6 pm after-work period. This temporal skew reflects both seasonal daylight constraints and rider availability, and helps explain some of the higher stress levels observed in the Pittsburgh data, since evening peak traffic volumes and winter lighting conditions can amplify exposure compared with midday summer riding.

Some key aspects in our comparison between the MORPC routes and Pittsburgh's Strip District:

- Pittsburgh's Terminal Market section **exceeds** the **stress** and **exposure** levels of **all Columbus routes**, including Bexley.
- Railroad Street offers a **lower-stress alternative**, with metrics aligned more closely with some of Columbus's routes.
- While Columbus corridors show strong differentiation based on facility type (**road** vs. **trail** vs. **path**), Pittsburgh's variation occurs within a single roadway environment, driven by **roadway design** and **traffic intensity.**

7. Key Outcomes

The Velo Copilot system proved to be a highly effective tool for collecting active transportation data at a scale and level of detail not previously available through traditional planning methods. Beyond simple GPS traces, the system provided rich multimodal data streams that capture ride comfort, safety interactions, and infrastructure quality, offering planners new quantitative insights into the lived experience of cyclists.

Infrastructure and Safety Outcomes: Our results show **clear and consistent safety and comfort improvements when bicycles are separated from vehicles**. Trail segments exhibited the highest levels of rider comfort and safety, followed by multi-use paths that run alongside roadways. On-road segments generally exhibited lower comfort levels, particularly where cyclists were exposed to higher vehicle speeds and volumes.

On-Road Riding Conditions: Within the on-road category, several distinct patterns emerged:

- Protected bike lanes on busy corridors provided good physical separation and wide passing distances, though our sensor systems still measured increased stress from the proximity of high-speed vehicle traffic.
- Neighborhood streets and quieter residential roads typically posed little or no measurable risk, reflecting their suitability as part of low-stress network connectors.

These findings align closely with qualitative rider feedback from other studies, reinforcing the importance of infrastructure typology in determining perceived and actual safety.

Regional Data Collection and Comparability: By collecting data across four distinct deployment sites, the pilot demonstrated comparative safety analysis across regions. This regional perspective is critical for scaling up to broader networks and integrating results into planning tools like the Cycling Guide.

Overall Route Safety: All of the routes included in this pilot were intentionally chosen as high-safety and high-comfort routes—the type of corridors that will anchor MORPC's promotional and tourism efforts. Analysis confirmed that these routes are objectively very safe. When compared to urban routes in the City of Pittsburgh, these Central Ohio routes showed significantly lower overtaking risk and higher average comfort scores, underscoring the value of dedicated infrastructure in building safe regional cycling networks.

8. Challenges and Lessons Learned

While the pilot successfully demonstrated the **technical and operational feasibility** of using a fleet of AI cameras for **active transportation planning**, several practical and technical challenges emerged that provide clear guidance for future deployments.

GPS Data and Upload Workflow: The original plan to use volunteers' personal smartphones via Strava or RideWithGPS proved impractical given the multitude and variety of volunteers. The team switched to Wahoo GPS bike computers, pre-installed on each bike, to simplify the GPS process. As a new system, this approach still encountered issues:

- Upload delays sometimes occurred, typically due to connectivity issues or devices not automatically syncing correctly when within Wi-Fi range.
- The use of a hidden Wi-Fi network at the Bexley site caused connection issues, requiring manual device swaps to ensure GPS tracks were regularly uploaded.
- Occasional mismatches between ride end times and upload windows created lag in dashboard reporting.

Future deployments will benefit from integrating GPS functionality directly into the Copilot device, removing reliance on a secondary system.

Volunteer Cadence and Data Collection Variability: Volunteer groups varied across sites, creating inconsistent ride cadence and data volumes. Some routes filled quickly, others lagged. This variability led to the creation of the real-time dashboard, which helped identify gaps and redirect efforts. Future deployments may benefit from structured scheduling, reminders, or light incentives to ensure steadier coverage across all sites.

Algorithmic Improvements: While the Copilot system successfully captured vehicle proximity, speed, and relative motion, the underlying algorithms are still evolving—especially in how they interpret *contextual protection* provided by infrastructure. For example, on segments with protected bike lanes or paths parallel to streets, the cameras correctly detected the presence of nearby cars, but the current model does not explicitly incorporate the physical barrier, buffer width, or lateral separation when computing stress. As a result, some protected facilities may appear more stressful in the sensor data than they feel to riders in practice. We highlight this in potential future challenges:

- Stress/comfort estimation methods can be further refined to better reflect subtle differences between infrastructure types, and further validated via user surveys.
- False vehicle interaction detections occurred in path/trail segments with dense parked vehicles (where stationary vehicles are sometimes mistaken as moving).
- Metrics could be further improved with additional understanding of each metric's behavior in a variety of traffic and roadway conditions.

These findings highlight clear priorities for algorithmic refinement in future Copilot software updates.

9. Future Work & Recommendations

The MORPC Cycling Guide Pilot demonstrated that AI-enabled sensing provides planners with a powerful, scalable method to understand and improve the safety and comfort of active transportation networks. Building on these results, future work should focus on improving deployment workflows, expanding analytical capabilities, and broadening the types of insights that can be drawn from the data.

> Integrating **near-miss detection** with regional models unlocks **proactive safety planning**—not just reactive crash response.

Future Analysis Methods: Velo's analytical capabilities continue to expand, particularly around near-miss detection and regional safety modeling.

- **Near-misses:** New methods will better capture and interpret traffic maneuvers at the actor level, enabling more precise mapping of close interactions and conflict zones—especially on higher-stress roadways.
- **Regional models:** In partnership with Carnegie Mellon University, Velo is developing a predictive safety map grounded in observed sensor data, extending insights to unmeasured corridors.

Future Types of Data Analysis: We also see opportunities to expand the kinds of data we collect and analyze:

- **Trail user studies:** Use AI detections to estimate trail usage, speed, and mode mix, complementing existing counter systems with richer observational data.
- **Vegetation monitoring:** Leverage imagery to identify invasive species or overgrowth, supporting environmental maintenance alongside safety planning.
- **Higher-risk networks:** Deploy on busier on-street corridors to capture true near-miss events, adding a critical layer to comfort and safety mapping.

Future Deployment Workflows: Streamlining deployment will increase scale and reduce costs.

- **V2 hardware:** A smaller, lighter, weatherproof device designed for fast installation and swapping will improve deployment flexibility, available in 2026.
- **Rider mix:** Pairing expert riders on complex routes with casual riders on everyday corridors provides broader network coverage.
- **Active safety:** Enabling onboard alerting features could offer real-time rider protection, increasing volunteer buy-in.
- **Bikeshare integration:** As shown in Pittsburgh, bikeshare fleets provide broad, unbiased coverage with minimal operational effort.
- **Trail towns:** Deploying Copilot in small trail-adjacent communities can map local safety, support trail town branding, and contribute to a regional safety network through a network of safety-conscious volunteers and riders.

Together, these recommendations outline a **clear and actionable pathway** for scaling and deepening the use of **AI-enabled sensing** in regional **active transportation planning**. By combining **improved technology, structured operational workflows**, and **advanced analytics**, MORPC can develop a **comprehensive, data-driven foundation** for expanding **safe, comfortable bicycle networks**—while simultaneously unlocking new applications in infrastructure planning, trail town development, and environmental monitoring.