Comparing The Microscopic Behavior Of Bicycle, Scooter, And Cargo Bike Riders Based On Urban Drone Videos

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Introduction & Motivation

The increasing presence of non-motorized vehicles (NMVs) like bicycles and cargo bikes in urban environments presents significant challenges for infrastructure integration, traffic flow management, and safety. This research utilizes high-resolution drone video data collected in Munich, Germany, to conduct a detailed microscopic analysis of riding behavior, examining how these different vehicle types operate in real-world conditions. The study compares speed distributions, acceleration/deceleration patterns, braking behavior, and stopping distances between conventional bicycles and cargo bikes to understand their operational differences and maneuverability characteristics. By analyzing how speed profiles differ between these vehicle types, their respective acceleration and braking capabilities, and how infrastructure can be optimized to safely accommodate both, the research aims to derive statistically-validated insights that can guide urban mobility planning and cycling infrastructure design. The findings provide empirical evidence for transportation planners and policymakers working to effectively integrate these sustainable transportation modes into urban networks, ultimately supporting safer and more efficient multimodal transportation systems that can accommodate the growing diversity of NMVs in urban areas

Data & Methodology

This study examines the microscopic behavior of bicycles and cargo bikes using high-resolution drone footage collected over two days in Munich, Germany. The data was recorded along a 700-meter stretch of Rheinstraße, covering various urban conditions. The dataset included raw footage and annotated videos, where each moving object was assigned a unique track ID and categorized by vehicle type.

Variable	Description
frame	Frame number of the recording
timestamp	Time in seconds
track_id	Unique identifier for each tracked object
category	Object classification (as category 3 represents specific vehicle types such as bicycles)
translation_x/y/z	Position coordinates in 3D space
velocity_x/y/z	Velocity components in each direction
acceleration_x/y/z	Acceleration components in each direction
rotation_x/y/z	Rotation angles around each axis
dimension_x/y/z	Object dimensions

Table 1: Initial Extracted Data Sample from annotated videos

For cargo bikes, the dataset did not include a pre-labeled category, requiring manual verification to extract accurate timestamps and track IDs from raw videos. Frame-by-frame annotation was conducted to ensure precise recognition. Due to temporary obstructions (e.g., passing vehicles or trees), some cargo bikes were assigned multiple track IDs, leading to fragmented trajectories. To resolve this, a Python script merged IDs based on movement continuity and temporal alignment, reconstructing complete trajectories. Each cargo bike was assigned a group identifier to track its behavior during analysis, ensuring accurate data structuring.

To ensure data accuracy, a two-step filtering process was applied for bicycles:

- Temporal filtering removed trips shorter than 10 seconds.
- Spatial filtering excluded trips covering less than 30 meters.

Additionally, outliers in the bicycle dataset were identified through a manual review of annotated videos, cross-checked with visual observations, and further refined using category filtering to exclude non-bicycle data.

The analysis focused on speed, acceleration, and braking behavior, using thresholds to identify free-flow speed and braking events. All data processing, filtering, and statistical analysis of deceleration patterns were conducted in Python. Initially, the study aimed to include scooters, but due to their low representation, the focus remained on bicycles and cargo bikes.

By combining drone observation with manual verification, this research provides a structured dataset that enhances the understanding of non-motorized vehicle behavior. The findings contribute to future urban mobility planning and cycling infrastructure design improvements.

Fig. 1: Selected points along Rheinstraße

Results & Recommendation

Cargo bikes had lower average speeds and higher braking intensity than bicycles, especially at intersections.

Free-flow speeds were higher on dedicated bike lanes compared to shared roads.

Braking events were more frequent in constrained environments, showing infrastructure influence on cyclist behavior.

Cargo bikes require more space and smoother flow conditions due to their braking characteristics.

Urban planning should better accommodate diverse non-motorized vehicles to enhance safety and efficiency.

Future studies should expand datasets for better statistical reliability.

Automated tracking methods for cargo bikes should be improved to reduce manual verification.

Interactions with motorized traffic should be analyzed for comprehensive mobility insights.