A microscopic model for simulating free riding speed dynamics in bicycle traffic

Pérez Castro, G., Belikhov, D., Titgemeyer, M., Johansson, F., Kaths, H., and Olstam, J.

Foto Jonas Jacobsson, Unsplash

A microscopic bicycle traffic model

Interactions with the infrastructure and/or the environment

- E.g., gradient, curves, wind

Interactions between bicyclists

- E.g., following process, passing maneuvers

Free riding

Speed choice
(human-powered motion)
(need for modeling support)

Interactions with other road users

- E.g., scooters, pedestrians

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Purpose

1. To characterize how elements of the infrastructure impact free riding,
   - Infrastructure/environment: gradients, curves, intersections, wind.
   - Behavior: speed, power output~effort.
2. and how free riding vary within and among bicyclists.
3. To simulate free riding speed dynamics.

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A semi-controlled experiment

Using instrumented bikes (IBs)

Recruitment	Individual characteristics	Instrumentation and calibration	Trip	Post-ride survey
People who commute regularly by bike.	E.g., total weight, bike characteristics. *possible to use own bike *no e-bikes	*fast and easy	To ride (once) on a route. *bike as usual when commuting *report interactions	Problems, insights, and perceived exertion.

- No restrictions on behavior, but control for the route to follow.

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Equipment

Event button, alt. microphone

Accelerometers

Ultrasound distance-to-the-side sensor

Rearview radar for approaching vehicles

Bicycle computer

Dual power meter pedals

Aerometer

Front and back cameras

Cadence sensor

Heart-rate armband

Speed sensor

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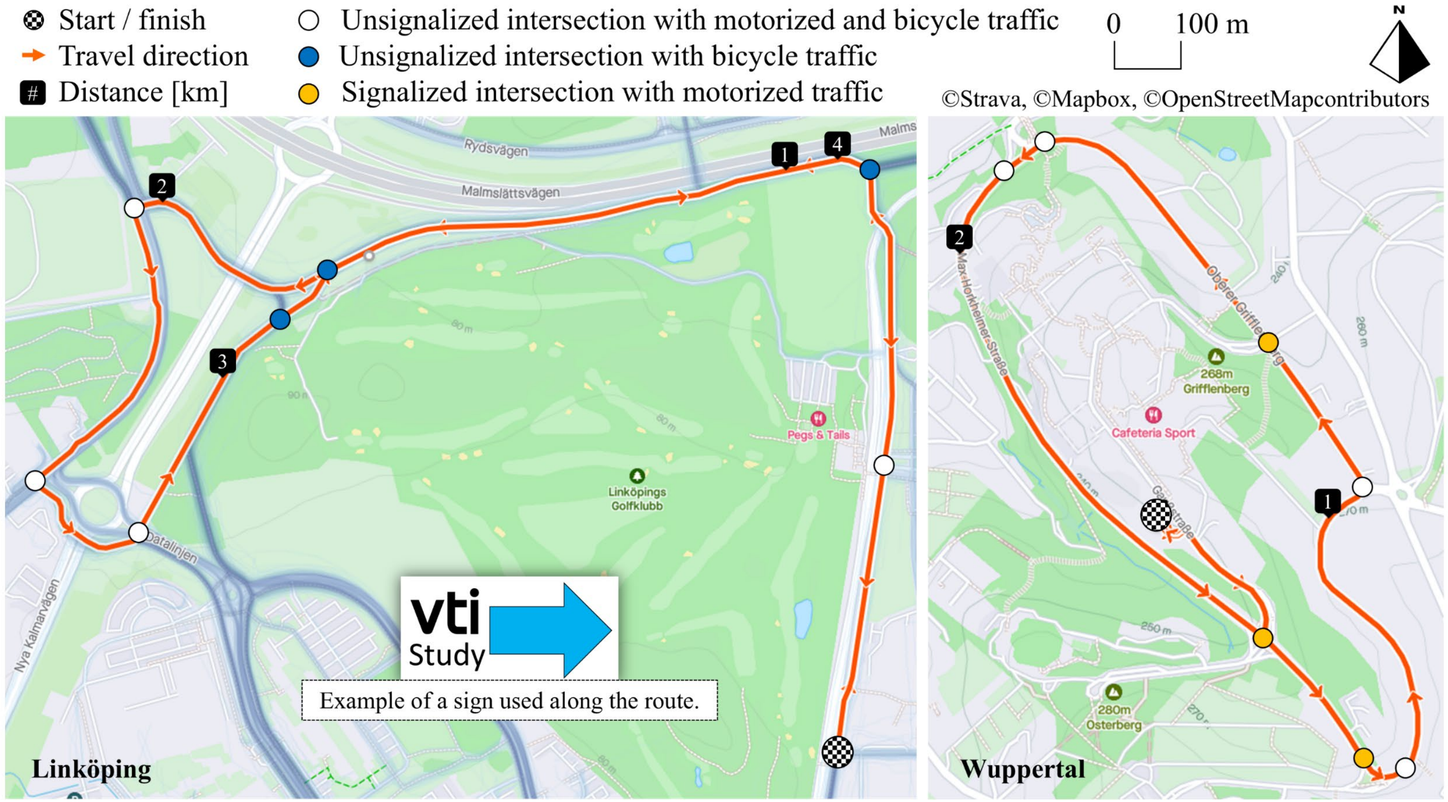
Two case studies

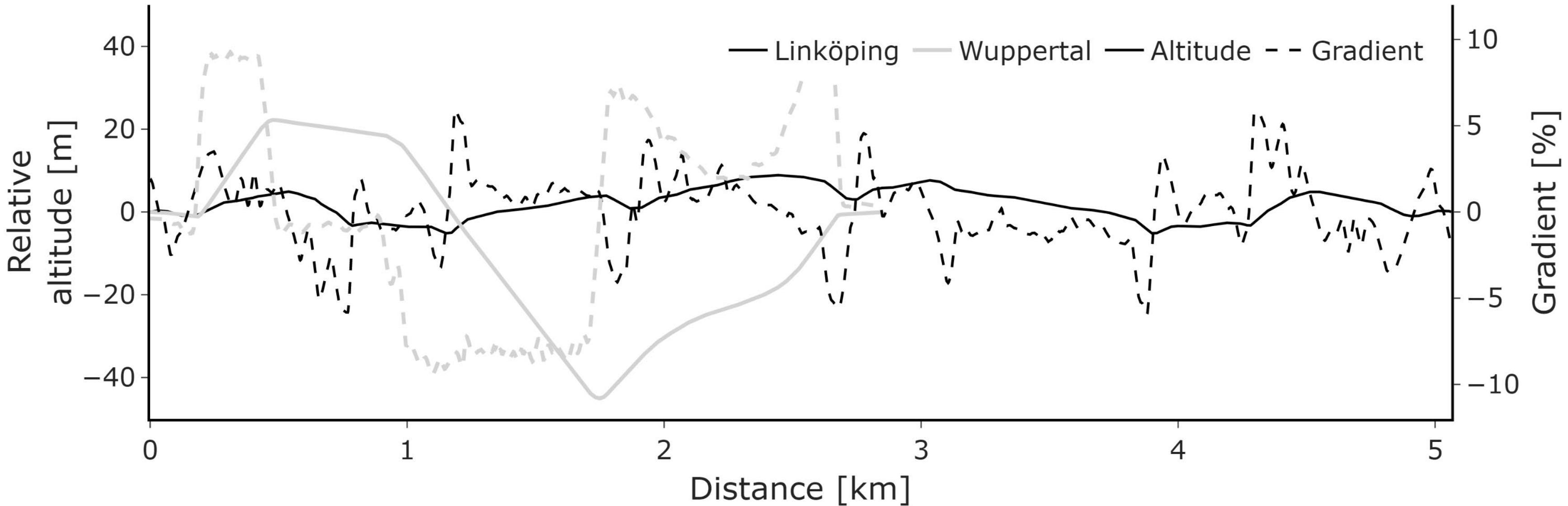
Linköping: 33 participants

- 5-km semi-circuit.
- Off-street bicycle path.
- Hills up to +/- 5%.

Wuppertal: 29 participants

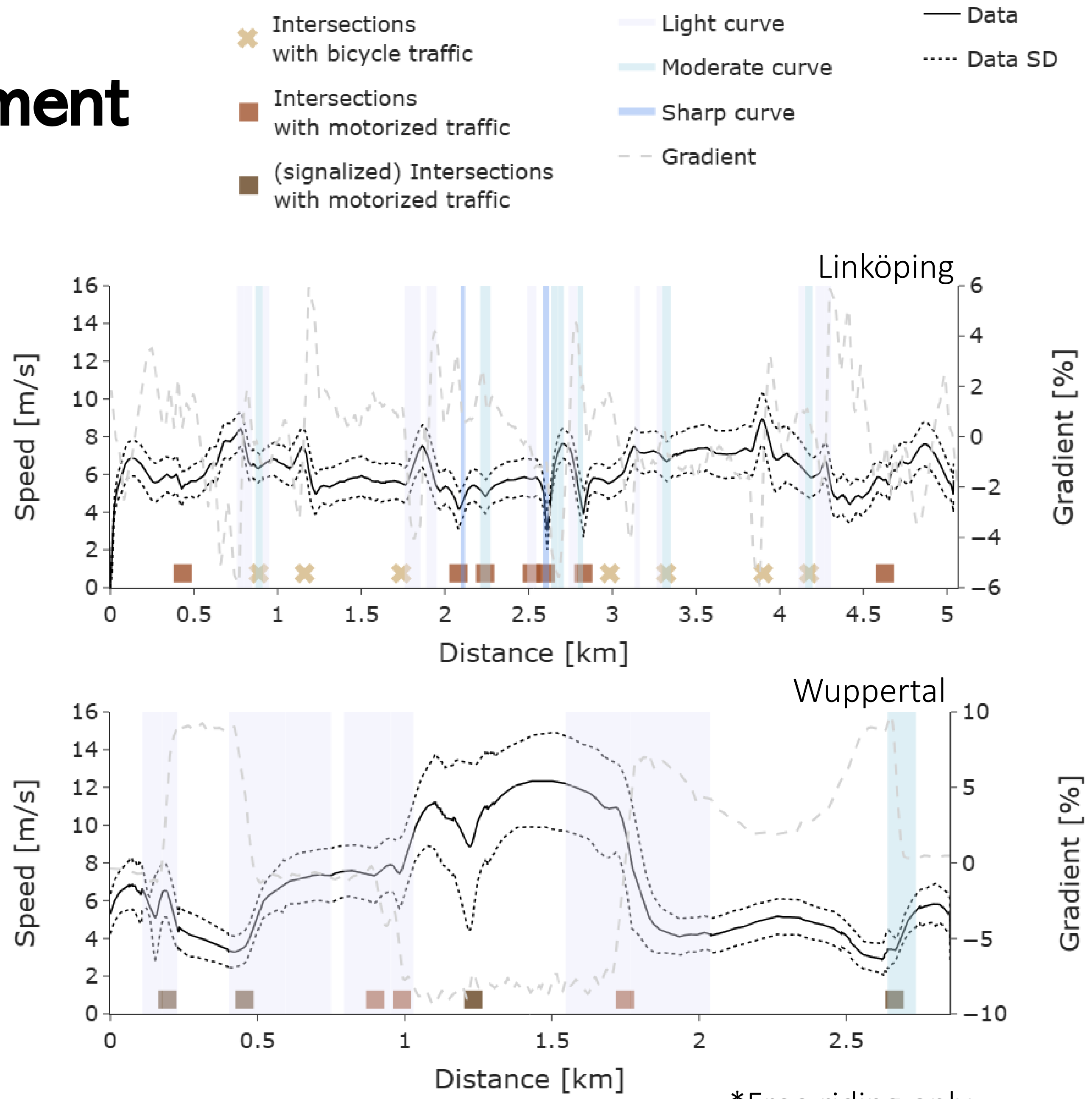
- 3.2-km circuit.
- On-street (no bicycle lane).
- Hills up to +/-13%.





Key findings from the experiment

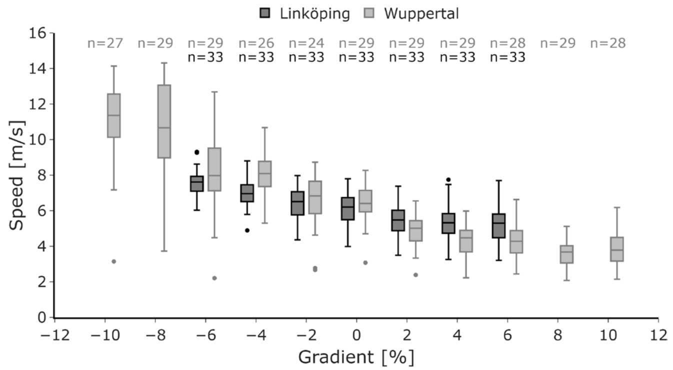
- Significant variability in speed/power throughout the trip:
  - 70%-85% explained by trip features (topography, curvature, intersections and wind) and differences among bicyclists.
    - 30%-60% explained by differences among bicyclists.
- Bicyclists adapt power output in relation to gradient, and wind.
  - Trade-off between minimizing travel time and managing physical exertion.
- Discrete tactical choices in downhill-to-uphill transitions (boosting vs coasting)



*Free riding only

Simulation (3) approaches

1. Dynamic speed distributions (gradient-based)



- Based on empirical speed distributions
- Adjust speeds for gradients by maintaining cyclist's relative percentile rank.
- Interpolation for smoothed transitions.

2. Speed model

- A mixed-effects model for speed as a function of:
  - baseline (desired) speed
  - gradient
  - curvature
  - intersections
  - elevation gain
  - wind speed
- Predict speed every time step.

3. Physics model (power-based)

- A mixed-effects model for power as a function of:
  - baseline (desired) power
  - gradient
  - curvature
  - intersections
  - elevation gain
  - boosting tactic
  - wind speed
- Predict power every time step.
- Compute changes in kinetic energy.
  - A bicycle dynamics model (Martin et al., 1998).
- Compute speed.

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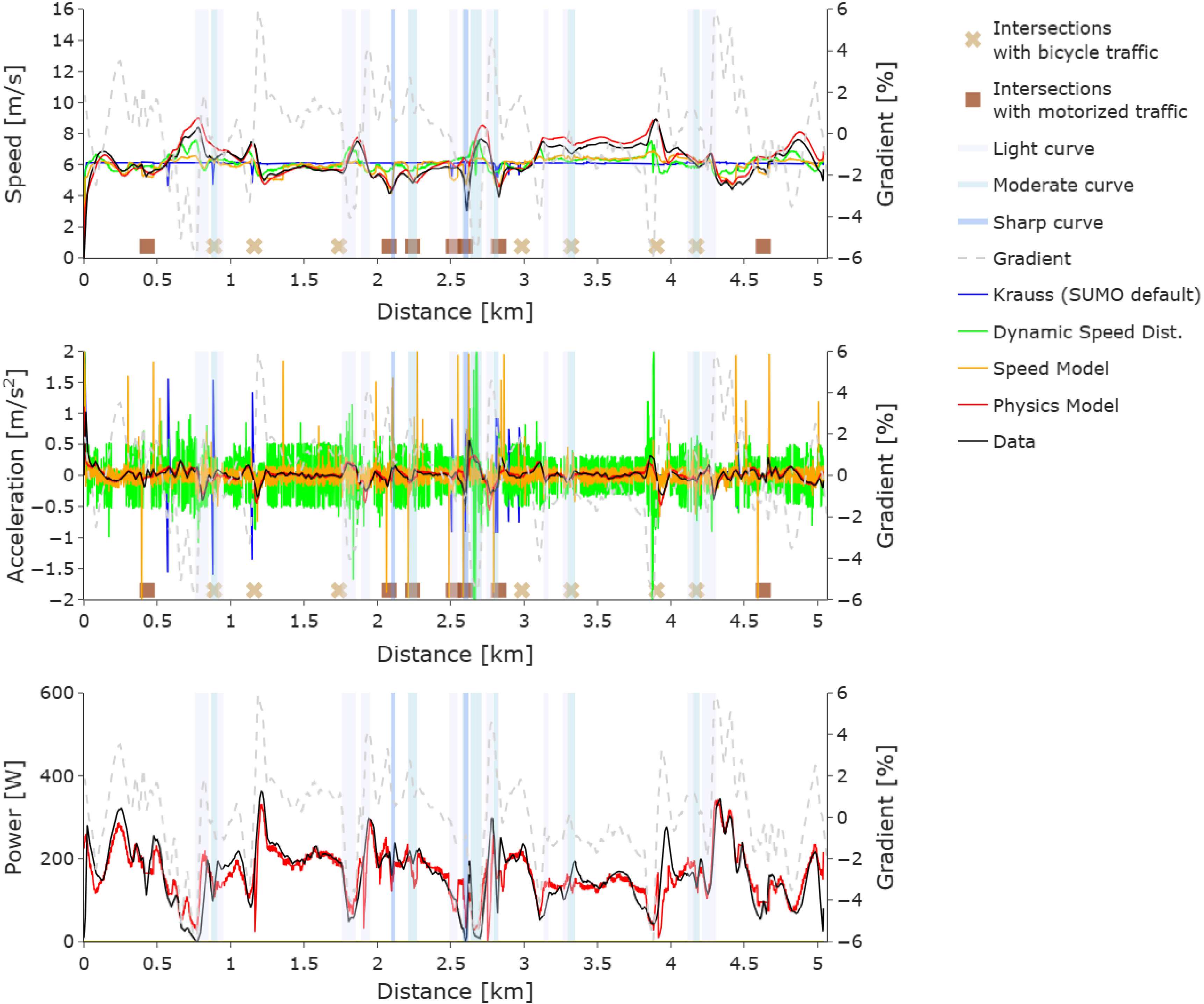
*All implemented in SUMO
*Comparison with Krauss (default)

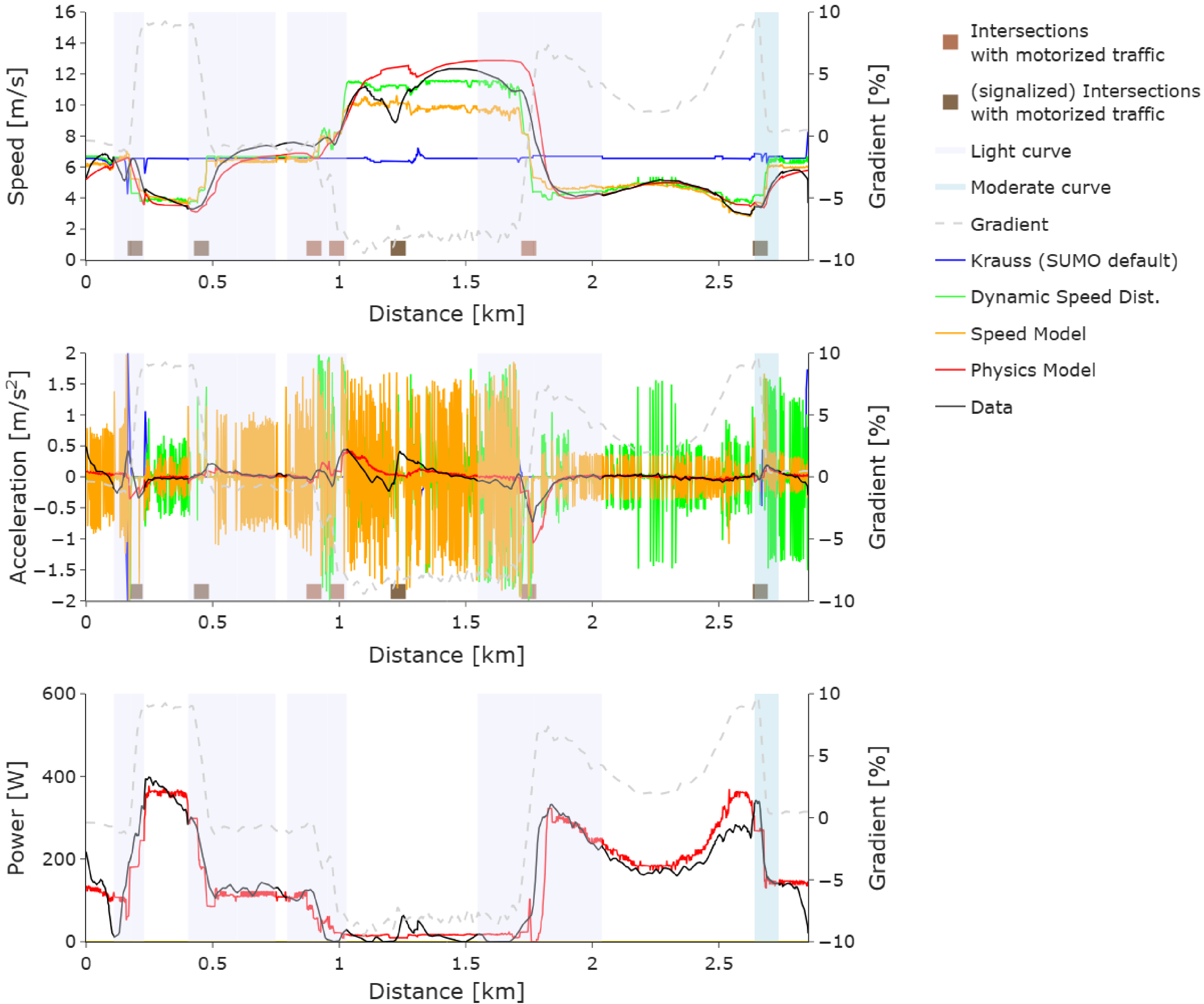
Simulation results

Mean over the population, along the route [Linköping]



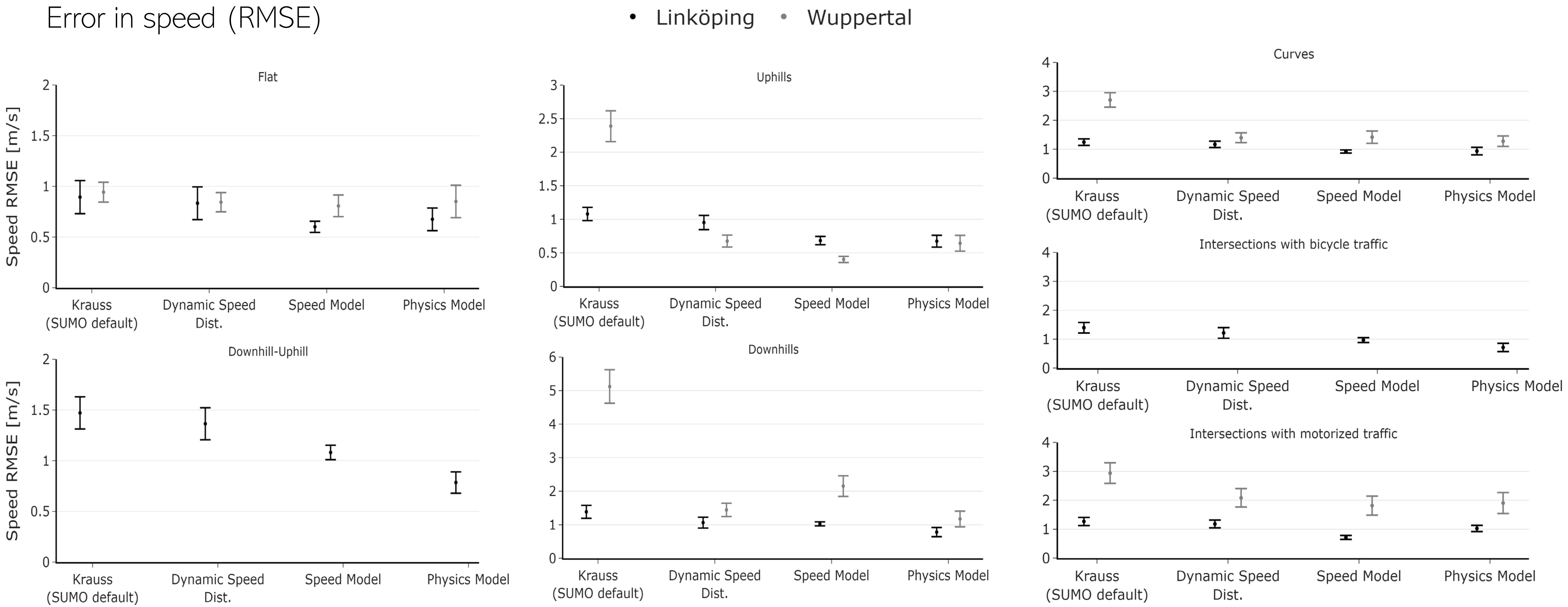
Simulation results

Mean over the population, along the route [Wuppertal]



Simulation results

Error in speed (RMSE)



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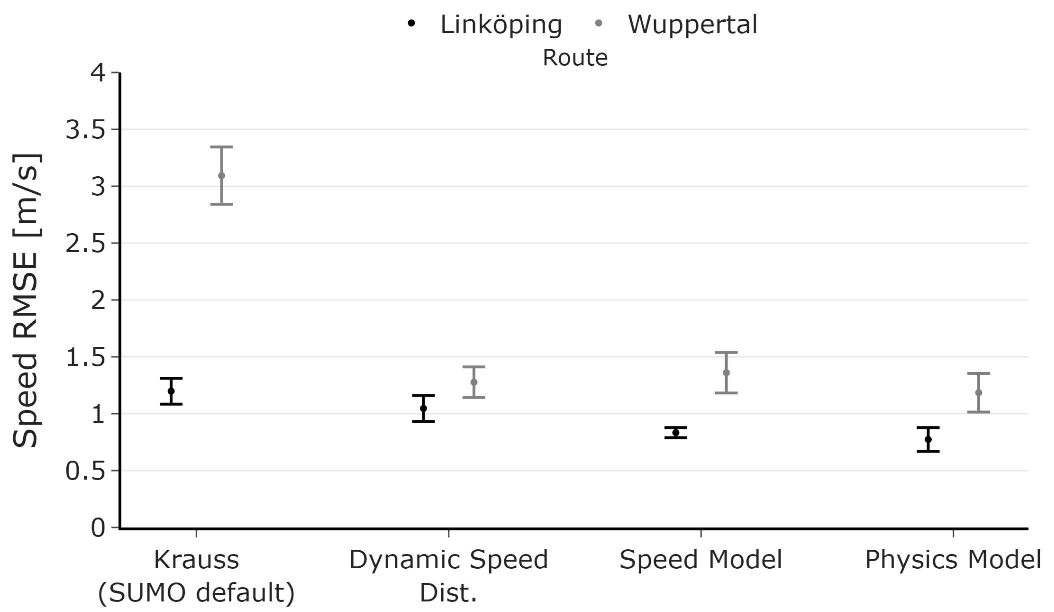
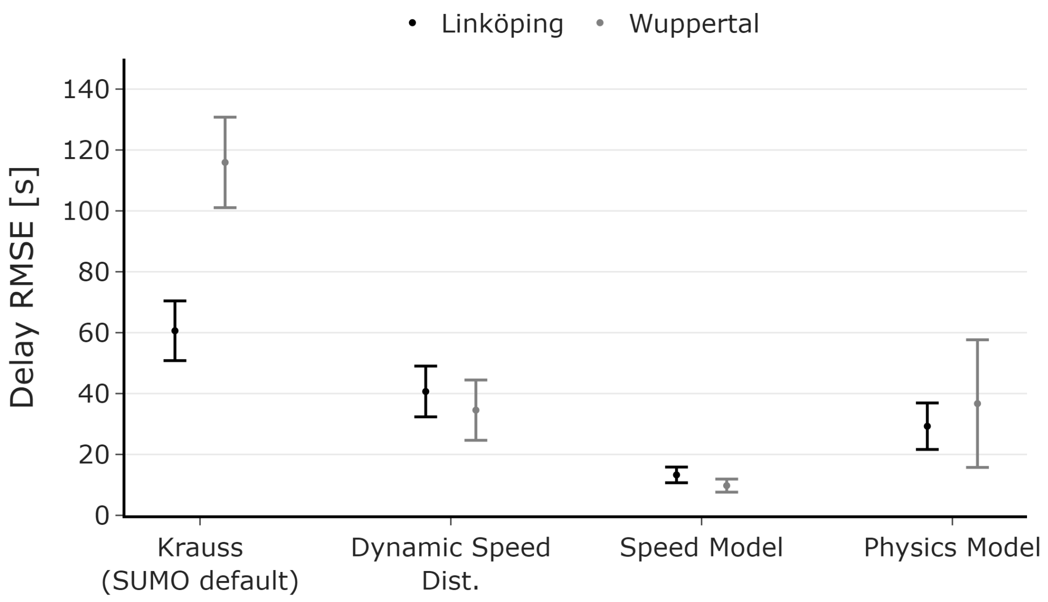
Simulation results

Error in speed (RMSE)



Error in delay (RMSE)



Conclusions

- Speed choice of bicyclists is highly trip context-dependent:
  - Gradients, curves, intersections, and wind.
  - Large variation due to heterogeneity in bicycle traffic.
- Simulation approaches are suitable. Accurate simulation of free riding allows for:
  - Analysis of infrastructure standards (e.g., acceptable gradients, curve radii).
  - Analysis of speed/acceleration at uphill/downhill approaches.
  - [physics model] Analysis of energy expenditure.
- Future research:
  - Validation [applicability to other locations].
  - Effects of infrastructure/wind on interactions with other road users.

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Thank you!

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