

Traffic Analysis project description

Microscopic traffic simulation of bicycle traffic

Background

Infrastructure design has a strong influence on the speed of bicyclists, particularly in urban areas where infrastructure may change significantly over a trip, e.g., featuring sharp curves or steep inclines. Microscopic simulation is a valuable tool in the planning of an efficient traffic system since it offers a safe and cost-effective way to evaluate traffic performance and the impact of infrastructure design changes, but existing behavioral models oversimplify the heterogeneous and adaptive desired speed choices bicyclists make in relation to infrastructure, and without the influence of other road users. The lack of advanced desired speed modeling (also referred to as free riding models) limits the reliability of bicycle traffic simulations, and their usefulness for efficient and attractive infrastructure planning. Reliable simulations require microscopic models that accurately capture context-dependent speed choices shaped by bicyclist preferences and infrastructure features.

Three advanced free riding speed models—a regression-based model, a physics-based model that estimates speed from power output preferences, and SUMO's gradient-sensitive KraussPS model—have been evaluated against observed speed patterns on a busy bidirectional bike path in central Stockholm [Pérez Castro et al., 2025]. With the City of Stockholm now planning to upgrade this bicycle path, there is an opportunity to explore how these models could be applied to evaluate the impact of infrastructure improvements such as wider lanes, milder gradients, and smoother curves. The project aims to provide insights on how advanced free riding speed modeling can inform design decisions to reduce delays, supporting the planning of efficient bicycle infrastructure.

Project aim and purpose

The aim is to analyze and quantify the impact of improving geometry—widening paths, reducing slope steepness, and increasing curve radii—on travel time and speed patterns in congested bicycle traffic. By simulating an alternative infrastructure layout for an existing high-demand bicycle path in central Stockholm, you will evaluate whether using advanced free riding models reveal design solutions that more efficiently accommodate bicycle demand.

Organization

Project supervisor: Guillermo Perez Castro, guillermo.perez.castro@liu.se

Co-supervisor: Johan Olstam, johan.olstam@liu.se

Examiner: Tatiana Polishchuk, tatiana.polishchuk@liu.se

Project Group

The project should be conducted by a group of at least three and at most five students.

Goals and requirements

The task is to apply free riding models to a proposed alternative design scenario and analyze how changes in design impact traffic performance metrics compared to the baseline (existing infrastructure). The project covers the following steps:

- Implement the alternative design. Using Simulation of Urban Mobility (SUMO), you will create a simulation model that reflects the improved geometric characteristics (width, curves, slopes) of the bicycle path. The SUMO representation of the existing infrastructure model will be available as a starting point, and all necessary design specifications will be provided.
- Generate traffic demand scenarios. Build a demand profile, which should include a traffic composition of the three most prevalent types of bicycles: conventional bikes, e-bikes, and racing bikes. For example, demand could represent a typical morning peak-hour period.
- Calibrate the simulation model. Use trajectory data to calibrate the model by adjusting parameters (e.g., following distances, minimum lateral clearance, etc.) to ensure simulated behavior (e.g., lateral position, speed, acceleration, etc.) closely match the real-world observations at the baseline scenario. Students should iteratively adjust these parameters and compare outputs to find a good fit. Trajectory data sets for three full weekdays will be provided.
- Traffic simulation analysis. Compute and compare traffic-related metrics using simulation outputs for both the alternative and baseline scenarios. Students should include aggregate measures such as mean speed, density, and flow, as well as distributions, for example, histograms of speed and travel times.
- Sensitivity analysis. Perform sensitivity analyses of using different free riding models, and to systematically explore changes in design features affect traffic performance outcomes. For example, identify at which gradient threshold we can expect significant changes in speed, flow, or congestion emerge. This will help reveal which infrastructure features most strongly influence bicycle traffic.
- Document the findings, including discussion and conclusions, and any identified limitations.

Project grading

Except for the common requirements related to course grading specified in the course information, project specific grading is given according to the scale Fail; 3,4, or 5 (or the corresponding ECTS grade).

For grade 3, at least the following steps have to be carried out:

- A detailed project specification and time plan, carefully written in English.
- Create an alternative design and traffic demand of the simulation model.
- Present and discuss descriptive analysis of traffic-related metrics in relation to at least 1 element of the infrastructure (slopes or curves), for one demand profile (e.g. morning peak), using 1 free riding model.

- Quantify errors in simulation by comparing simulation output vs observed trajectory data.
- A final report carefully written in English and an oral presentation of the project results.

For the grade 4, the grade 3 steps have to be carried out with very good results and the following steps have to be carried out:

- Present and discuss the calibration process.
- Present and discuss sensitivity analysis of using all three free riding models, in relation to at least 1 infrastructure feature.
- Demonstrate an understanding of the implications of using advance free riding models. The students should discuss differences in the application of different free riding models and how they may influence design choices.

For the grade 5, the grade 3 and 4 steps have to be carried out with extremely good results and the following steps have to be carried out:

- Present and discuss a sensitivity analysis of how infrastructure features influence traffic performance by gradually making changes in at least 1 infrastructure feature. This step requires creating additional design layouts.
- Demonstrate an understanding of how changes in the infrastructure affect traffic performance.
- Identify and discuss specific gaps in the chosen software capabilities and suggest directions for further research or software development.

References

Pérez Castro, Johansson, F., and Olstam, J. (2025) “The role of advanced free riding behavior models in microscopic simulation of congested bicycle traffic”. Working paper.