Modelling Bicycle Infrastructure in SUMO

Georgios Grigoropoulos, Leonhard Lücken, Jakob Erdmann, Heather Kaths

SUMO Conference 2019

Berlin, 15.05.2019

Overview

1. Motivation
2. Methodology
3. Simulation Results
4. Conclusions
5. Outlook

Motivation

Motivation

- Study of the bicycle traffic quality and safety in urban bicycle infrastructure
- Analysis of the influence of heterogeneous bicycle traffic composition on bicycle traffic flow
- Assessment of bicycle traffic control measures on traffic flow efficiency
- Realistic simulation of traffic user behaviour and road infrastructure in simulator environments
- Very limited native support or provision of specific guidelines on how to model special bicycle infrastructure in modern simulation software such as SUMO or VISSIM
- Modelling bicycle infrastructure in modern simulation tools requires users to experiment with adjusting existing network design elements and modifying network elements, road user restrictions, traffic signal control elements, bicyclist behavior, or even script solutions through the respective API

Methodology

Methodology

Definition of Intersection Approaches and Review of SUMO Modelling Capabilities

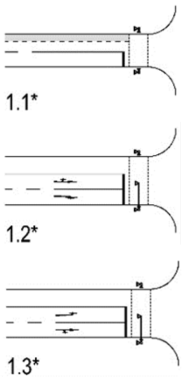
In the German Design Guidelines (FGSV, 2006b, 2010), five categories of intersection approaches for bicycle traffic are identified:

- Intersection approaches with no dedicated bicycle facility (Category 1)
- Obligatory or advisory cycle lanes with advanced stop lines (Category 2)
- Obligatory or advisory cycle lanes with bicycle boxes (Category 3)
- Bicycle lanes (Category 4) or bicycle paths (Category 5) with advanced stop lines and a stop area downstream for accommodating indirect left turning bicyclists

Methodology

Definition of Intersection Approaches and Review of SUMO Modelling Capabilities: Category 1

No dedicated bicycle facility

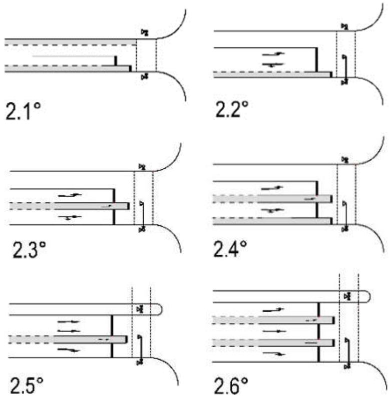


Intersection Schellingstraße/Luisenstraße, Munich, Germany

Methodology

Definition of Intersection Approaches and Review of SUMO Modelling Capabilities: Category 2

Bicycle lanes or advisory bicycle lanes with advance stop lines

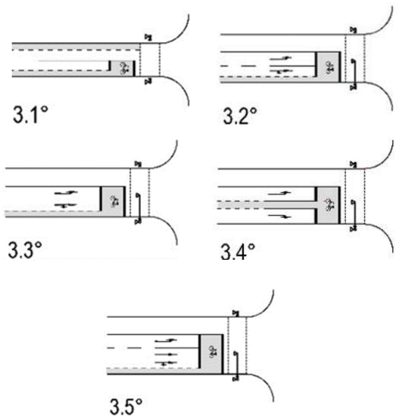


Intersection Eschholzstraße/Basler Straße, Freiburg, Germany

Methodology

Definition of Intersection Approaches and Review of SUMO Modelling Capabilities: Category 3

Bicycle lanes or advisory bicycle lanes with bicycle boxes

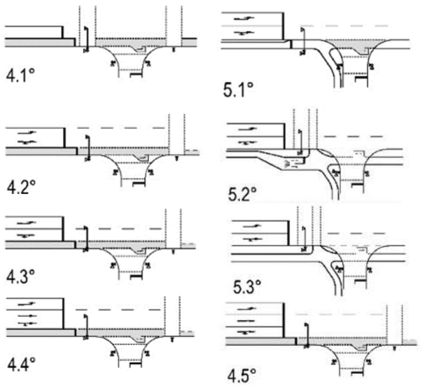


Intersection Oranienburger Straße/Friedrichstraße, Berlin, Germany

Methodology

<u>Definition of Intersection Approaches and Review of SUMO Modelling Capabilities: Category 4/5</u>

Bicycle lanes or bicycle paths with advanced stop lines and a stop area downstream for accommodating indirect left turning bicyclists

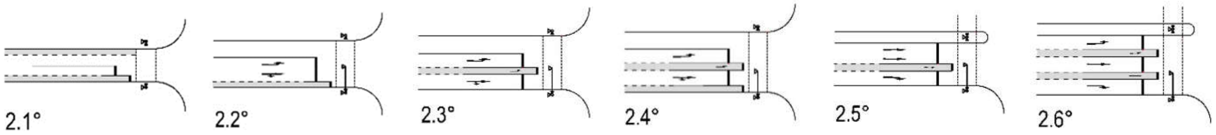


Marsstraße/Seidlstraße
Munich, Germany

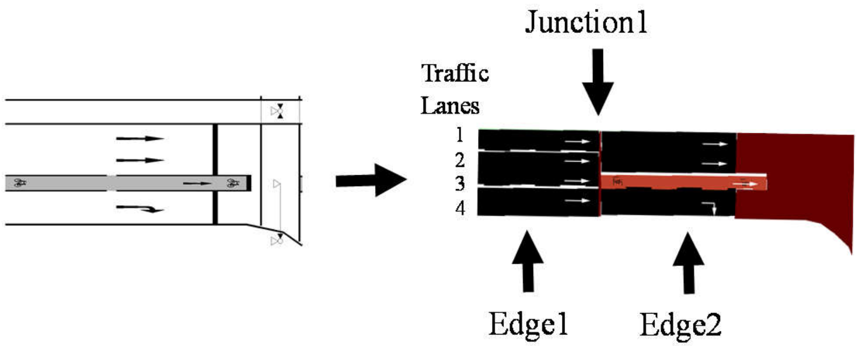
Kapuzinerplatz
Munich, Germany

Methodology

<u>Modelling Bicycle Infrastructure in SUMO: Category 2</u>

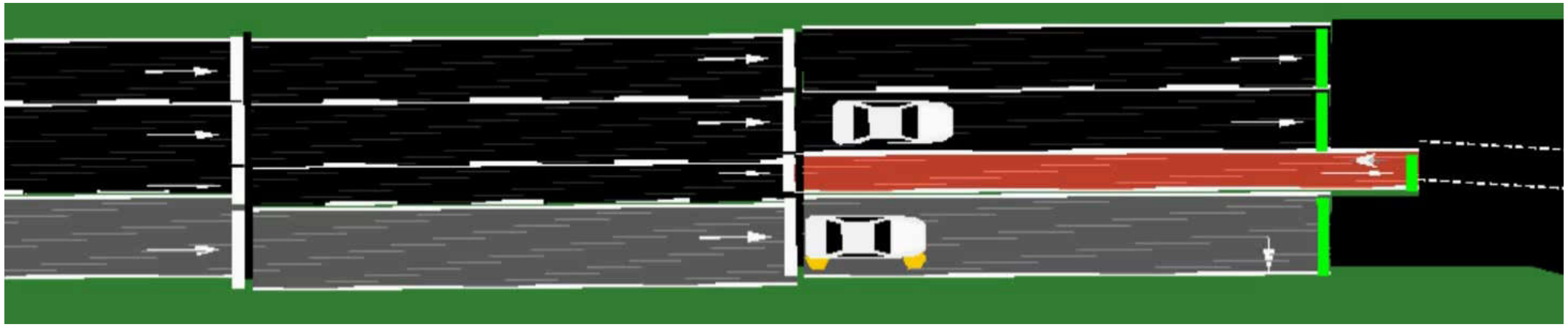


Intersection Approach Type 2.5



Methodology

<u>Modelling Bicycle Infrastructure in SUMO: Category 2</u>



Methodology

<u>Enhancements of the SUMO Software:</u>

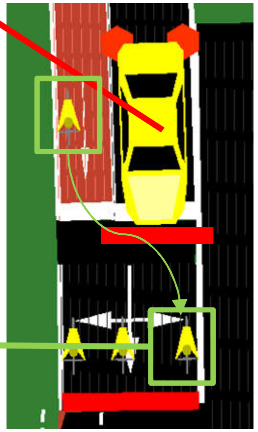
New parameter *stopOffset*

A stopOffset-element may be employed to prevent motor vehicles from entering bicycle boxes within a red phase of the corresponding traffic light and to represent distinct stopping lines for different vehicle classes or on different lanes on the same edge

```
<edge id="approach1">
        <stopOffset value="5.0" vClasses="passenger bus" />
</edge>
```

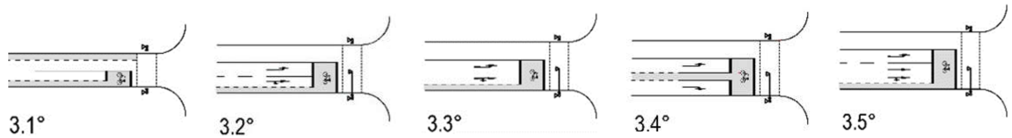
New parameter *lcTurnAlignmentDistance*

This parameter is set as an attribute of the corresponding vType element in the demand configuration. If it is set for a vehicle's vehicle type in this way, it controls the alignment behavior during the approach to an intersection for the given distance prior to the intersection entry.

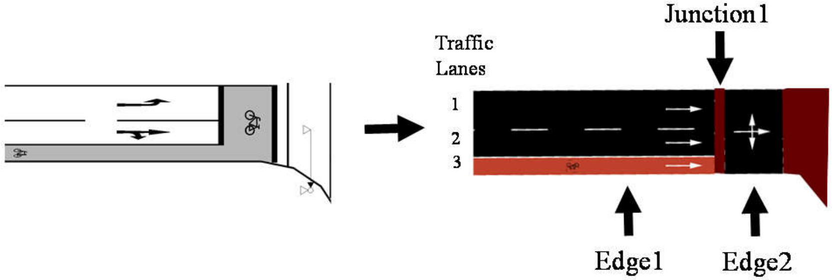


Methodology

Modelling Bicycle Infrastructure in SUMO: Category 3

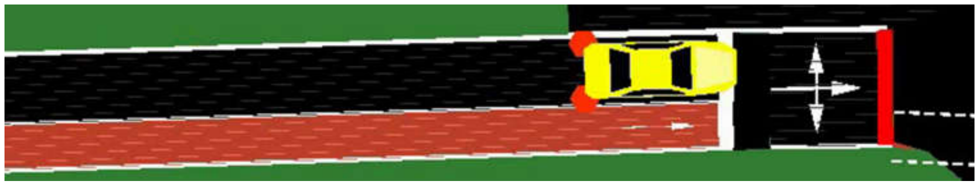


Intersection Approach Type 3.2



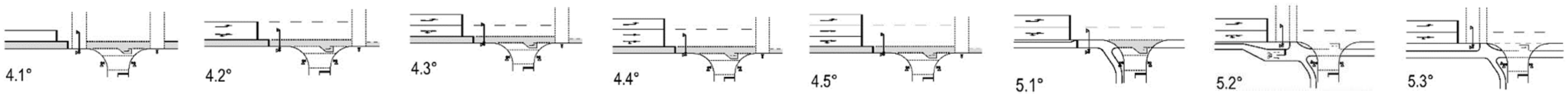
Methodology

Modelling Bicycle Infrastructure in SUMO: Category 3



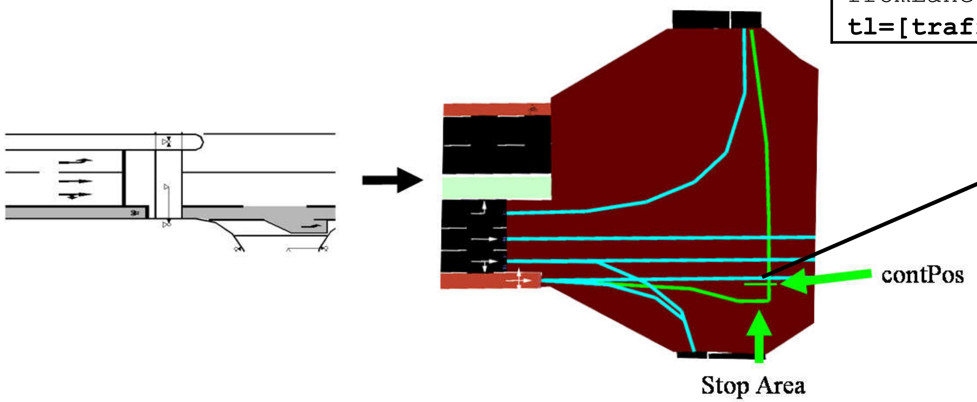
Methodology

Modelling Bicycle Infrastructure in SUMO: Category 4/5



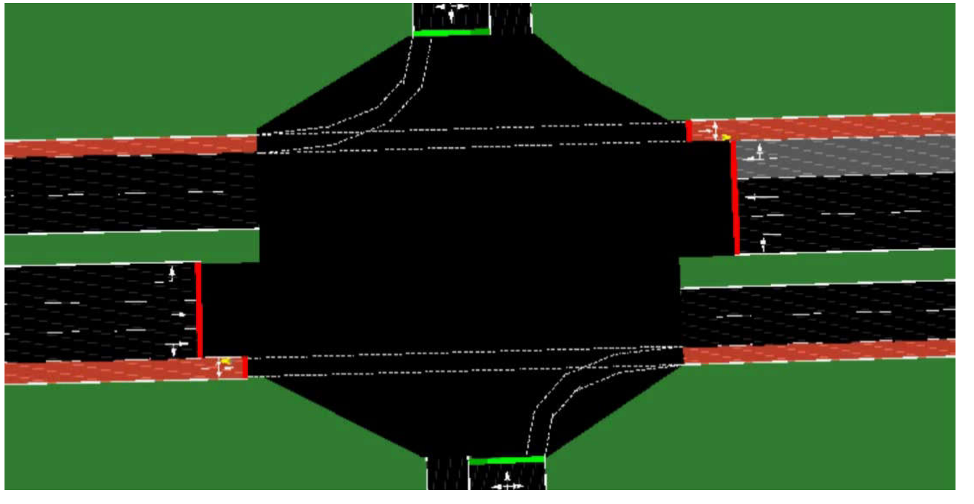

```
<connection dir=[connection direction] from=":[junction
id]_[linkIndex of connection for indirect left turning] "
fromLane=[lane index]linkIndex=[signal group] state="m"
tl=[traffic light id] to=[edge id] toLane=[lane index] />
```

Intersection Approach Type 4.4



Methodology

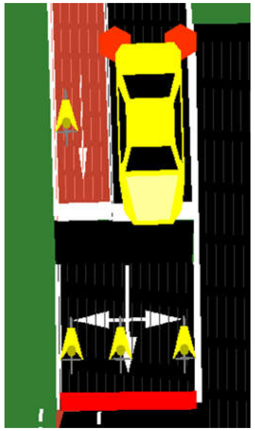
Modelling Bicycle Infrastructure in SUMO: Category 4/5



Methodology

Modelling Bicycle Infrastructure in SUMO: Restrictions

- Category 3: Left turning bicyclists will not make use of the traffic lanes for motor vehicle traffic to align themselves on the left side of the bicycle box if the traffic situation at the intersection approach permits it and will always access the bicycle box through the bicycle lane.
- Category 3: In SUMO, right turning bicyclists sometimes align themselves on the left side of a bicyclist riding straight across the intersection while remaining on the right side of the bicycle box. This bicyclist tends to block crossing bicyclists once the green phase begins.
- Indirect left turning in Category 4/5: Queuing bicyclists should distribute themselves inside the stopping box area or around it without blocking bicyclists crossing the intersection of the same approach. The simulation of this complex bicyclist behavior in SUMO is not possible and would require a significant expansion of the Junction Model.



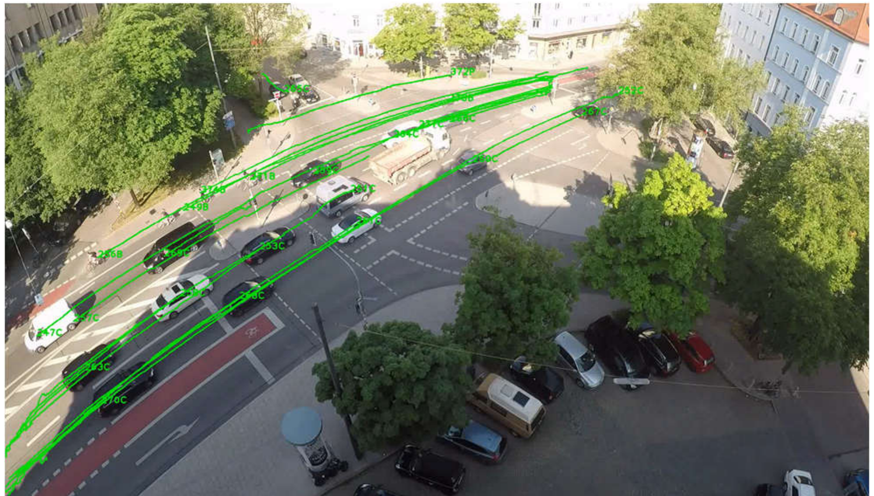
Methodology: Simulation

- Traffic signal programs are calculated for both intersection types according to the HBS (FGSV, 2015) using motor vehicle traffic volumes resulting in a minimum Level of Service (LOS) B.
- First the modelled intersections are calibrated only for motor vehicle traffic according to the recommendations of (FGSV, 2006a) using the average waiting time as the measure of performance.
- Four simulation studies with increasing bicycle traffic flows are conducted in order to vary the number of arriving and stopping bicyclists in each cycle time. Each cycle time has a duration of 90 seconds and a total of 150 cycle times are evaluated for each intersection.

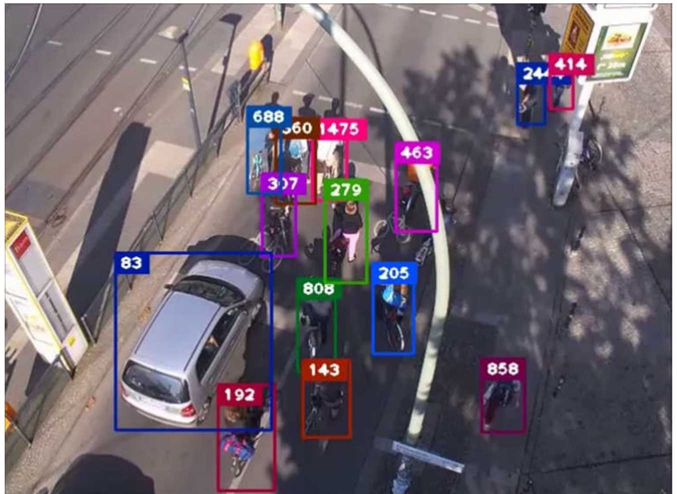
Lehrstuhl für Verkehrstechnik
Ingenieurfakultät Bau Geo Umwelt
Technische Universität München

Methodology: Simulation

For all intersections, two-hour video segments with a particularly high volume of bicycle traffic were selected. The trajectories of the road users were subsequently extracted.



Kapuzinerplatz
Munich, Germany



Oranienburger Straße/Friedrichstraße,
Berlin, Germany

Methodology: Measures of Performance

Bicycle traffic behavior is calibrated by adjusting the car-following and lane-changing model attributes in SUMO and using the bicycle queue density as the measure of performance for the calibration and the average queue dispersion time of bicyclists as the measure of performance for the validation

$$k_{b,queue} = \frac{n_{stop}}{l_{queue} b}$$

Where:

$k_{b,queue}$ = Bicycle queue density at a bicycle path, bicycle lane or advisory bicycle lane [bicycle/m²]

n_{stop} = Number of bicyclists queued at the start of the green time [-]

l_{queue} = Bicycle queue length at the start of the green time [m]

$$t_{dt,bicycle} = \frac{t_n}{n}$$

Where:

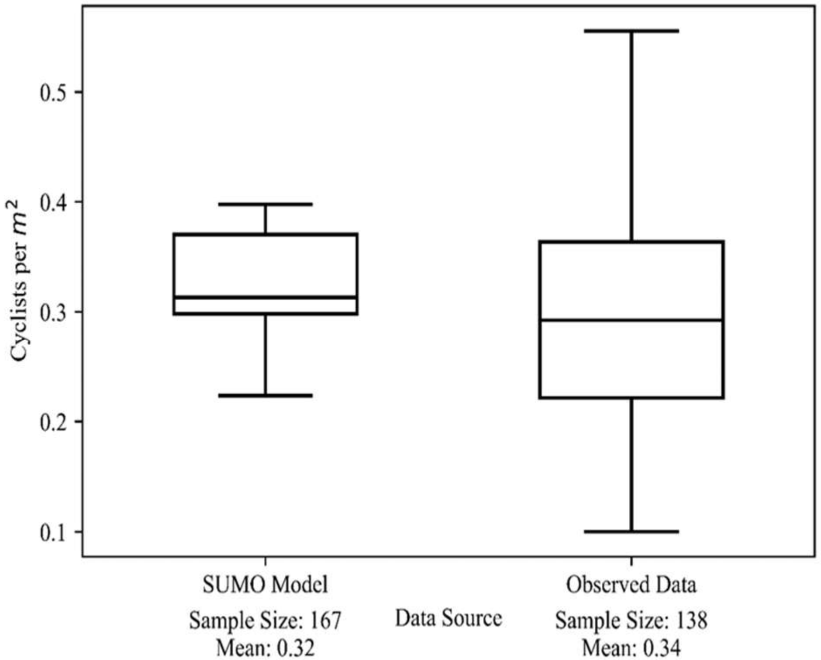
$t_{dt,bicycle}$ = average queue dispersion time [s]

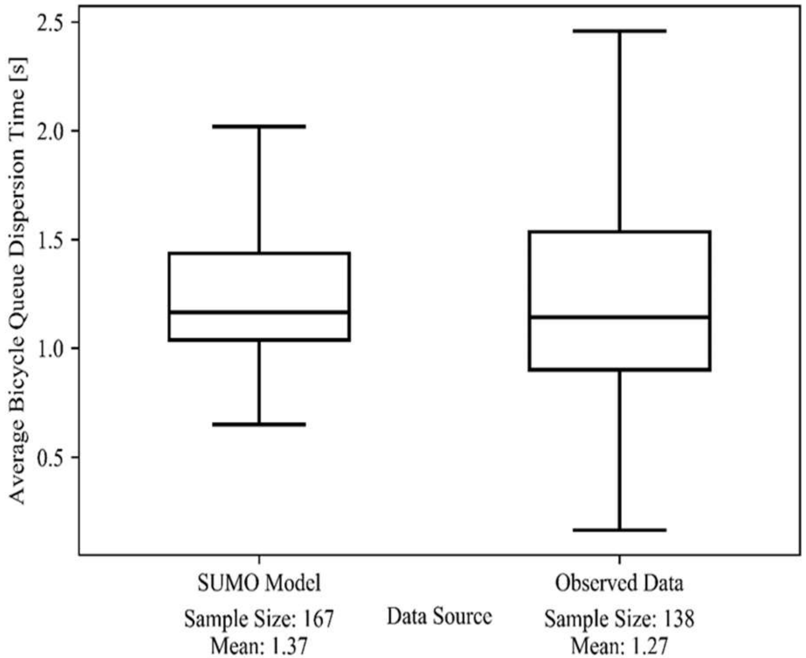
t_n = Time from the start of the green time until the last (n^{th}) bicyclist crosses the stop line [s]

n = Number of bicyclists waiting at the start of the green time [-]

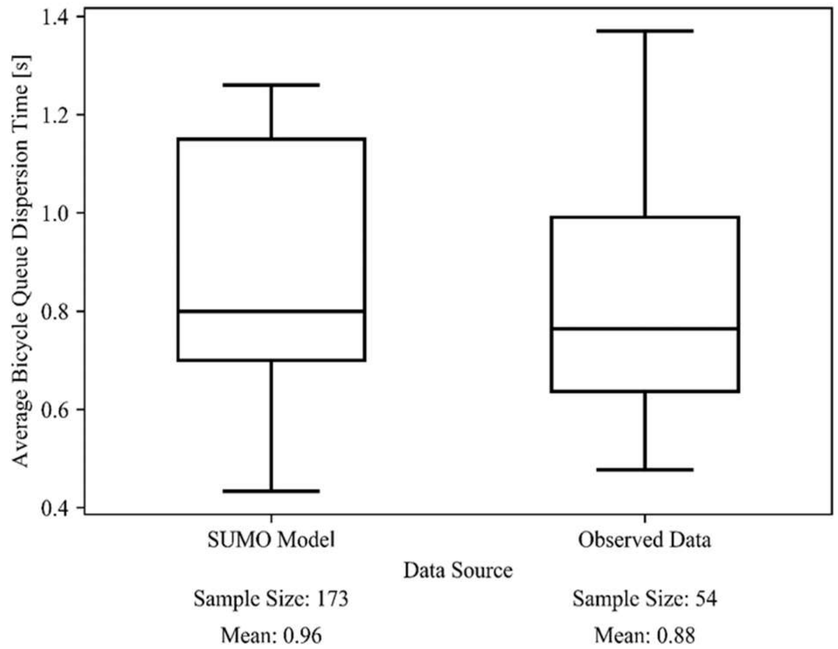
Simulation Results

Simulation Results: Category 2





Simulation Results: Category 3



Simulation Results

Intersection Approach Type	Measure of Performance	Mean Observations	Mean Simulation	Percent Error (PE)	p-value	α	H_0
2.5	Bicycle Queue Density	0.32	0.34	7.0%	0.16	0.05	accepted
2.5	Av. Bicycle Queue Dispersion Time	1.37	1.27	7.4%	0.17	0.05	accepted
3.1	Av. Bicycle Queue Dispersion Time	0.96	0.88	8.3%	0.38	0.05	accepted

Conclusions

Conclusions

- Results show that the proposed modelling solutions and new functions introduced to SUMO can be used to simulate bicycle traffic using dedicated bicycle infrastructure.
- The proposed methodology is, however, applicable only to specific traffic scenarios mainly due to limitations of the SUMO Junction Model and since the proposed solutions still do not rely on dedicated SUMO network design elements specifically designed to accommodate simulated bicycle traffic
- The natively developed supported solutions in the simulation software, reduce the workload and effort for the modeler

Outlook

Outlook

- Future extensions of the SUMO Model can modify the lateral gap requirements for bicyclists depending on their speed in order to simulate the bicycle queue density more realistically.

- The potential of utilizing existing provisions in the SUMO Model for preferred lane usage, which are currently not in use, will be investigated. These might potentially enable motor vehicles to change across bicycle lanes and bicycles to use vehicular lanes to enter the modelled bicycle facilities such as advanced stop lines of bicycle boxes.

- Finally, further additional software development can improve the strength and quality of SUMO in simulating non-motorized user behavior and provide a valuable tool for further research in understanding the effects of the interactions non-motorized and motorized users on traffic efficiency and safety with respect to special urban road infrastructure.

References

Erdmann, J., & Krajzewicz, D. (2013). *SUMO ' s Road Intersection Model. Lecture Notes in Computer Science* (Vol. 8594). Berlin, Heidelberg: Springer.

FGSV. (2006a). *Hinweise zur mikroskopischen Verkehrsflusssimulation -Grundlagen und Anwendung-*. Köln: Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.).

FGSV. (2006b). *Richtlinien für die Anlage von Stadtstraßen (RASt)*. Köln: Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.).

FGSV. (2010). *Empfehlungen für Radverkehrsanlagen (ERA)* (2010th ed.). Köln: Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.).

FGSV. (2015). *Handbuch für die Bemessung von Straßenverkehrsanlagen (HBS)*. Köln: Forschungsgesellschaft für Straßen- und Verkehrswesen (Hrsg.).

Lopez, P. A., Behrisch, M., Bieker-walz, L., Erdmann, J., Fl, Y., Hilbrich, R., … Wießner, E. (2018). Microscopic Traffic Simulation using SUMO, 2575–2582.

National Association of City Transportation Officials. (2014). *Urban Bikeway Design Guide*. Island Press.

Saunier, N., & Sayed, T. (2006). A feature-based tracking algorithm for vehicles in intersections. In *Third Canadian Conference on Computer and Robot Vision*. IEEE.

Twaddle, H., Schendzielorz, T., & Fakler, O. (2014). Bicycles in Urban Areas: Review of Existing Methods for Modeling Behavior. *Transportation Research Record: Journal of the Transportation Research Board*, (2434), pp 140–146. https://doi.org/10.3141/2434-17

Thank you!

Contact:

Georgios Grigoropoulos M.Sc.

Technische Universität München
Lehrstuhl für Verkehrstechnik
Univ.-Prof. Dr.-Ing. Fritz Busch
Arcisstr. 21, 80333 München

Tel. +49 (89) 289 - 28584
george.grigoropoulos@tum.de