# Poster: Enabling Comparable and Reproducible Simulations for V2X Research

Tobias Hardes*†‡, Dalisha Logan*†, Christoph Sommer‡, and Florian Klingler*
*Paderborn University, Dept. of Computer Science, and †Software Innovation Campus (SICP), Germany
‡TU Dresden, Faculty of Computer Science, Germany
https://www.cms-labs.org/people/ { hardes , dalisha.logan , sommer }
https://www.fklingler.net

***Abstract*—Simulations are a prime performance evaluation technique for new Vehicle to Everything (V2X) methods and approaches. However, after decades of simulation-backed research, comparability and reproducibility of simulation studies is still low. In this work, we first survey road traffic simulation parameters (that is, scenarios) employed in recent scientific publications, revealing that many publications still do not adequately describe simulation scenarios to make the results comprehensible. As just one example, over 40 % of the simulations using either a Manhattan Grid or Chicago Grid do not provide information about the number of lanes. At the same time, our survey reveals that, even though employed road traffic scenarios are very use case specific, there exist many commonalities. We therefore advocate basing research on use case specific variants of a set of these common standard road traffic scenarios. We accompany this recommendation with *Simple Synthetic Scenarios for Sumo (*SSS4S*)*, a simple reference implementation to generate such variants.**

## I. Introduction

Simulations are often the means of choice to study the effects of various changes on a system. Still, such studies are often not sufficiently documented and comprehensible to others.

For instance, Perrone et al. [1] reported back in 2013 that a lack of information regarding parameterization in simulation studies is a problem regarding credibility that needs to be solved by the scientific community. Similarly, Joerer et al. [2] examined the design of simulation studies for Vehicle to Everything (V2X) research and showed that the used models in the literature are improving and getting more realistic. However, a major problem regarding traceability and comparability of different studies persists. For this, an accurate description of the simulated road traffic scenario is required, e.g., in terms of road topology, road traffic, or radio obstacles.

In general, road traffic scenarios arise in three different ways.

First, road traffic scenarios are being rebuilt from related work. Such road traffic scenarios can be rebuilt provided the description is accurate enough, but the needed level of accuracy requires that a substantial portion of a publication is dedicated to parameter descriptions.

Second, studies are built on available Open-Source road traffic scenarios. For SUMO, one of the most famous simulators for road traffic, the most known road traffic scenario is the LuST scenario [3]. Such scenarios have detailed documentation and are often based on peer-reviewed publications. However, such scenarios usually are far too extensive and complex for many road traffic simulation studies.

Third, new road traffic scenarios are created and used only for a single simulation study. SUMO offers different options like *netgenerate* or SUMO*Py*, but also generators like *ActivityGen* [4] are available. Such approaches are only comprehensible if there is correspondingly extensive documentation in the publication. However, this requires a considerable effort.

As a first step to address these drawbacks, we conduct a literature survey and analyze simulation studies that have been published in the field of V2X communication. We investigate the description of road traffic scenarios with respect to their accuracy and their comprehensibility. The study covers the years 2017 to 2019. We reveal that different studies often use very similar road traffic scenarios, but that the documentation of them is often not sufficient to comprehend the studies.

Based on the survey, we propose to use a set of standard scenarios that are customized with a limited set of parameters. For this proposal, we offer an open-source reference implementation named *Simple Synthetic Scenarios for Sumo (*SSS4S*)*[1]. SSS4S is capable of generating variants of the most widely used road traffic scenarios for SUMO, while it ensures comprehensible parameterization and documentation.

Our main contributions can be summarized as follows:

1) We reviewed an extensive set of publications and journals, including IEEE VNC, IEEE VTC, and IEEE TVT from three years regarding road traffic simulation scenarios.
2) We identify commonalities of road traffic scenarios, but also that the documentation of used scenarios often hinders comparability and reproducibility.
3) Based on our findings, we propose to use simple variants of a set of standard road traffic simulation scenarios to address the problem. As a first concept, we provide an open-source reference implementation SSS4S for SUMO.

## II. Literature Review and Evaluation

We selected publications from various prestigious journals and conferences covering research areas in the context of cooperative mobile systems and vehicular networks to study the used simulation scenarios and environments being used. These publications include IEEE VNC, IEEE VTC, IEEE GLOBECOM, IEEE INFOCOM, IEEE ICC, IEEE LCN, IEEE ICNC, IEEE TMC,

[1]http://www.cms-labs.org/research/software/sss4s/



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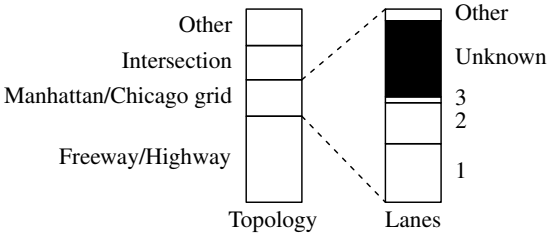


Figure 1. Variants of freeways/highways, Manhattan/Chicago Grids, and intersections make up the majority of synthetic scenarios. Yet, more than 40 % of papers that used a synthetic grid scenario did not provide information regarding the number of lanes.

IEEE TVT, and IEEE T-ITS. Our data collection period covers more than 270 simulation studies from the years 2017 to 2019.

We classified the gathered data based on synthetic and real-world scenarios. Real-world scenarios include, for example, the LuST scenario, but also road traffic scenarios that might have been extracted from OpenStreetMap or similar resources. Synthetic road traffic scenarios are created manually.

As shown in Figure 1, the most common synthetic road traffic scenarios are freeways or highways, followed by scenarios that represent a Manhattan Grid or Chicago Grid, followed by intersections. The distinction between Chicago Grid and Manhattan Grid is an example of the importance of accurate description. Many publications use the terms Chicago Grid (four equal side lengths for buildings) and Manhattan Grid (two different side lengths for buildings) interchangeably. The same is true for the distinction between freeway (no at-grade crossings) and highway (at-grade crossings). It is also remarkable that approx. 40 % of all publications employing either a Manhattan Grid or a Chicago Grid are not even specifying their number of lanes.

Both the distinction of Manhattan Grid and Chicago Grid as well as the number of lanes are examples of properties that heavily influence the traffic and mobility pattern. The number of lanes in a road network and the density of intersections have a direct impact on traffic throughput, travel time, traffic density, and other metrics that evaluate traffic. In turn, as node density increases or decreases, the impact regarding V2X communication also changes. This is compounded by changes in propagation characteristics brought about by the widths of roads and distances between intersections. Consequently, the number of lanes and the density of intersections heavily impact all metrics that are evaluated concerning wireless communication.

The lack of this information can have several reasons. One reason can be that the submission of papers for conferences and journals is bounded to a limited number of pages. Thus, descriptions of simulation scenarios become shorter and not very detailed. A second reason might be that the importance of the information is misjudged.

One solution approach can be a collection of validated and common road traffic scenarios that researchers can refer to. Since the road traffic scenarios are clearly defined in that collection, an exact description is given and comprehensibility by peers is ensured. This is the case for the LuST scenario and similar approaches. However, that this is not possible for any permutation of artificial road traffic scenarios.

Another solution would be to generate variants of a common set of *default* road traffic scenarios. We follow this approach with our implementation of SSS4S[1], which we describe below.

## III. Reference Implementation

*Simple Synthetic Scenarios for Sumo (*SSS4S*)*[1] is capable of generating variants of several standard simulation scenarios that have emerged from our literature survey. The catalog of scenarios includes freeways, consecutive intersections, and various grid scenarios. It is a Python-based command line application that supports SUMO starting from version 1.0.

SSS4S offers parameterizations such as the number of lanes, the length of the roads, and the direction of the roads or polygons which are often used in road simulation studies. It is also possible to create traffic lights and to generate road traffic.

SSS4S is a reference implementation for SUMO and represents a first idea to optimize the problem of comprehensibility, comparability, and reproducibility in scientific publications relying on road traffic simulations.

## IV. Conclusion

In this paper, we conducted a literature survey regarding the used road traffic scenarios in simulation studies. For that, we analyzed conferences and journals from the field of Vehicle to Everything (V2X) communication from 2017 to 2019.

Our survey reveals that, likely for the sake of brevity, much of the published work does not accurately describe the used road traffic scenario, hindering reproducibility and comparability of research. Critically, published work often does not document values for parameters that heavily influence road traffic and propagation characteristics. As an example, we showed that approx. 40 % of studies with a grid scenario did not provide information regarding the number of used lanes.

In addition, however, our work shows that while road traffic scenarios employed in V2X research are, by necessity, tailored to specific use cases, they are often very similar.

As a step towards improving reproducibility and comparability, we propose to base work on variants of a set of standard scenarios that are specific to V2X research. We also provide a reference implementation of a tool for generating such variants to the community.

## References

[1] L. F. Perrone, Y. Yuan, and D. M. Nicol, "Simulation of Large Scale Networks II: Modeling and Simulation Best Practices for Wireless Ad Hoc Networks," in *Proceedings of the 35th Conference on Winter Simulation: Driving Innovation, ACM*, ser. WSC '03, New Orleans, Louisiana: Winter Simulation Conference, 2003, pp. 685–693.

[2] S. Joerer, F. Dressler, and C. Sommer, "Comparing Apples and Oranges? Trends in IVC Simulations," Association for Computing Machinery, 2012.

[3] L. Codeca, R. Frank, and T. Engel, "Luxembourg SUMO Traffic (LuST) Scenario: 24 Hours of Mobility for Vehicular Networking Research," in *IEEE Vehicular Networking Conference (VNC)*, IEEE, 2015.

[4] L. Codecà, J. Erdmann, V. Cahill, and J. Härri, "SAGA: An Activity-based Multi-modal Mobility Scenario Generator for SUMO," in *SUMO User Conference 2020*, Virtual Conference, Oct. 2020.