

utdf2gmns: A Python Package for Automating Synchro UTDF to SUMO Simulation

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Summary

UTDF2GMNS¹ implements an automated workflow for network coordination, traffic signal integration, and traffic flow conversion from Synchro to SUMO. The process begins with a comparative analysis of network topologies, data representations, and signal timing schemas in both environments. Converting Synchro UTDF data to a network ready for microsimulation poses several challenges, including accurate signal integration, spatial transformation, and preservation of turning flow fidelity. Signal conversion represents a primary bottleneck, as it demands precise mapping of phasing plans, timing parameters, and coordination strategies to ensure valid simulation results. Network conversion is further complicated by translating Synchro's relative coordinate system into georeferenced formats compatible with geographic information system tools. Furthermore, accurate transformation of turning movement data is essential for realistic intersection modeling.

Existing methods address only isolated conversion tasks and lack a fully automated, scalable end-to-end workflow. To fill this gap, we introduce [utdf2gmns](#), an open-source Python library that automates the transformation of Synchro UTDF files into GMNS-compliant SUMO networks. [utdf2gmns](#) provides automatic geocoding, Sigma-X engine integration for intersection analysis, robust SUMO network generation, and extensibility to other microsimulation platforms. Future work will extend support for adaptive signal control, integrate real-time data inputs, and enhance interoperability with additional simulation frameworks to promote reproducibility and collaborative traffic-modeling research.

Statement of need

Traffic microsimulation is essential for evaluating and improving urban transportation systems by providing high-resolution analysis of flow, congestion, and infrastructure performance. Such simulations depend on precise modeling of signal control, network geometry, and turning movements. Although Synchro's Universal Traffic Data Format (UTDF) delivers comprehensive intersection data, converting UTDF into simulation-ready networks remains manual, labor-intensive, and error-prone, limiting seamless interoperability with microsimulation platforms.

Several critical challenges remain when converting Synchro UTDF data into microsimulation-compatible networks, such as those required by Simulation of Urban Mobility (SUMO) (Lopez et al., 2018). First, accurate signal conversion demands detailed extraction and mapping of phasing, timing, and coordination parameters into standardized control formats; errors here can substantially degrade simulation fidelity. Second, network conversion requires transforming Synchro's relative coordinate system into georeferenced longitude–latitude coordinates for seamless GIS integration, a labor-intensive and error-prone process that limits scalability.

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Third, realistic intersection dynamics hinge on precise turning movement conversion, which typically involves extensive manual preprocessing; inaccuracies at this stage can propagate through the simulation, undermining the validity of subsequent analyses.

Prior efforts have addressed individual aspects of Synchro-to-SUMO conversion but have not yielded a unified, automated workflow. Zhang et al. (2024) convert Synchro signal data into a SUMO network but require separate preprocessing of UTDF files and SUMO inputs. Ban et al. (2022) integrate Synchro signals within a vehicle-traffic-demand platform, yet their Synchro and SUMO networks are independently prepared. Coogan et al. (2021) focus on geometry and phasing conversion but rely on relative coordinates and scale only to a few intersections. Udomsilp et al. (2017) and Singh et al. (2017) optimize signal timings in Synchro and then import cycle lengths or green times into SUMO to evaluate performance. Despite these advances, no existing method delivers a fully automated, end-to-end solution.

To address these gaps, we present `utdf2gmns` (Luo and Zhou 2022), an open-source Python tool that automates the conversion of Synchro UTDF files into GMNS-compliant networks (Smith et al., 2020) and generates simulation-ready inputs for SUMO. By leveraging the GMNS, a robust framework for standardized network representation (Berg et al., 2022; Lu & Zhou, 2023; Luo, 2024; Luo et al., 2024), `utdf2gmns` enhances data consistency, reproducibility, and collaboration through four core capabilities: it automates geocoding of Synchro's relative coordinates into accurate longitude–latitude pairs; integrates with the Sigma-X engine (Milan 2022) to extract and optimize key intersection metrics (phasing diagrams, turning volumes, movement capacities, volume-to-capacity ratios, and control delays); generates GMNS-compliant SUMO networks that fully preserve signal coordination, traffic flows, and turning movements; and provides a modular architecture for extension to additional microsimulation platforms, thereby promoting broader standardization and community-driven development.

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