Enhancing the Interconnectedness of Open Data, Traffic Engineering, and City Planning Through Utilization of Available Data

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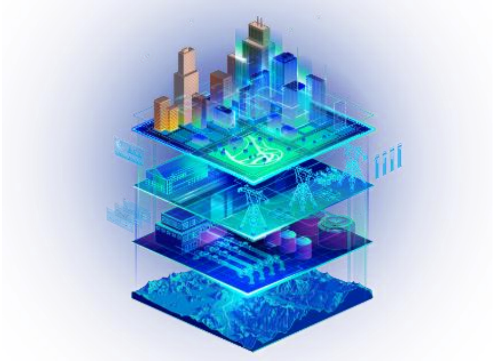
Prepared for TRB Webinar: State-of-the-Art Traffic Signal Simulation Tools and Platforms
Sponsored by TRB’s Standing Technical Committee on Traffic Signal Systems
March 15, 2023

ASU Trans+AI Lab

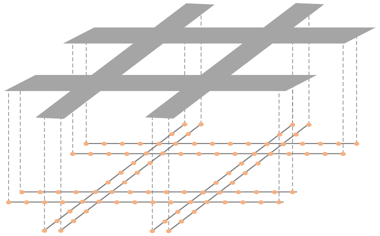
Outline

I. Open Data Specification

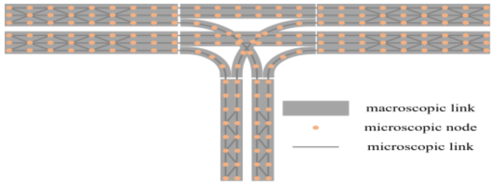


II. Open-Source Tools and MRM Community

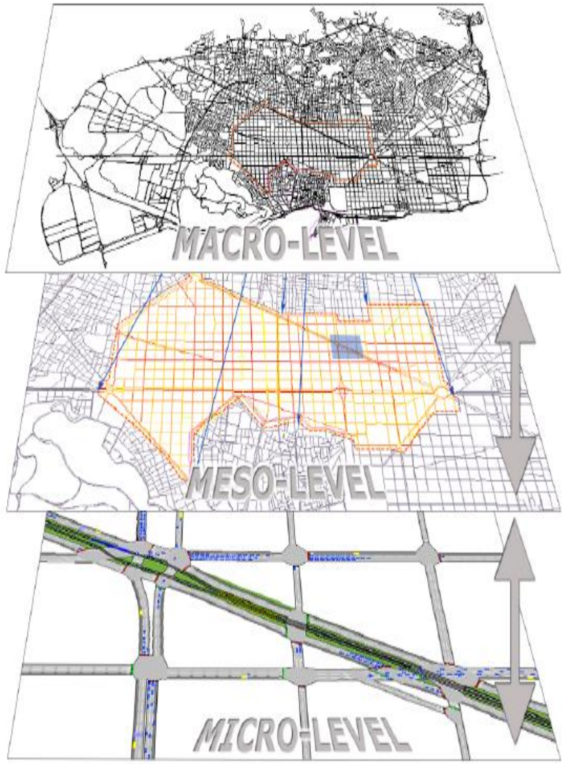
Macroscopic Layer



Microscopic Mesh Layer

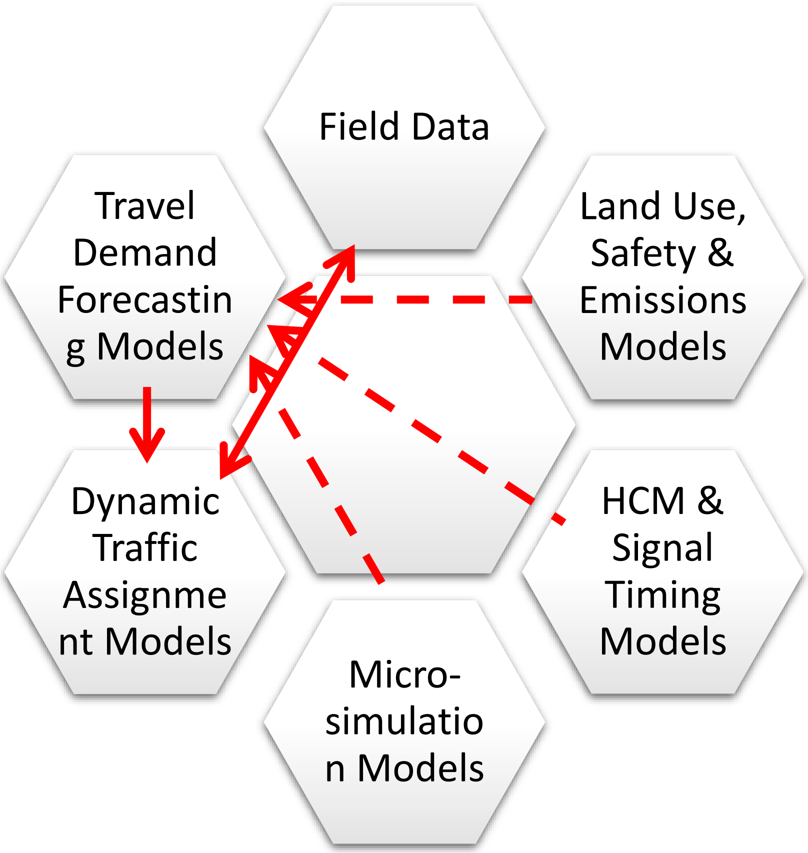


III. Network Simulation Prospective and Case Studies

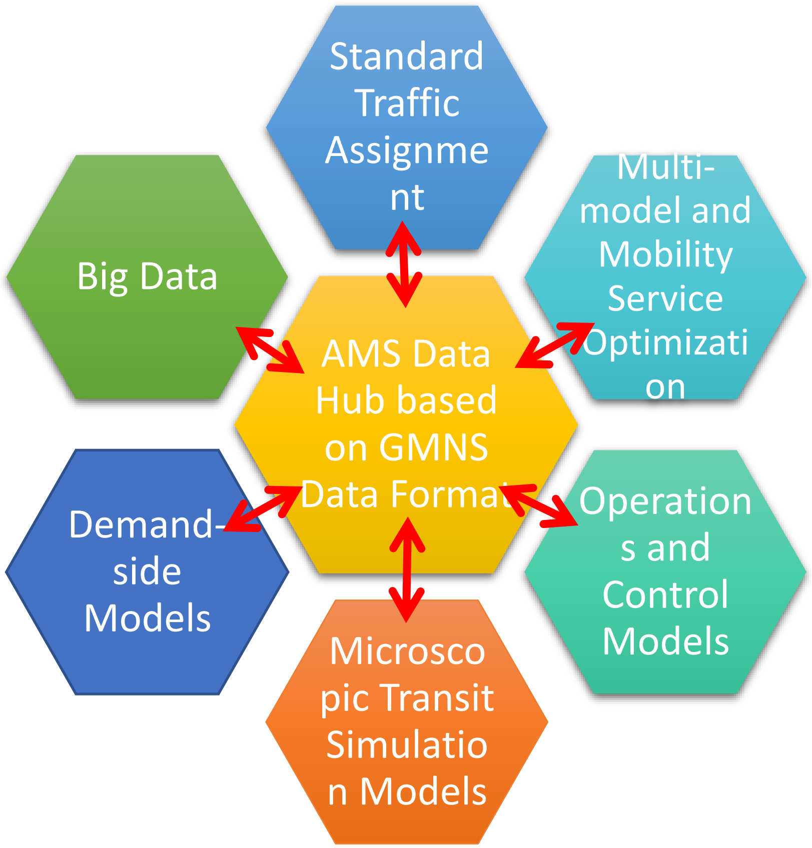


Critical Challenges for Transportation Analysis Modeling and Simulation (AMS) Data Hub

Ad Hoc Connection



Systematic Coupling

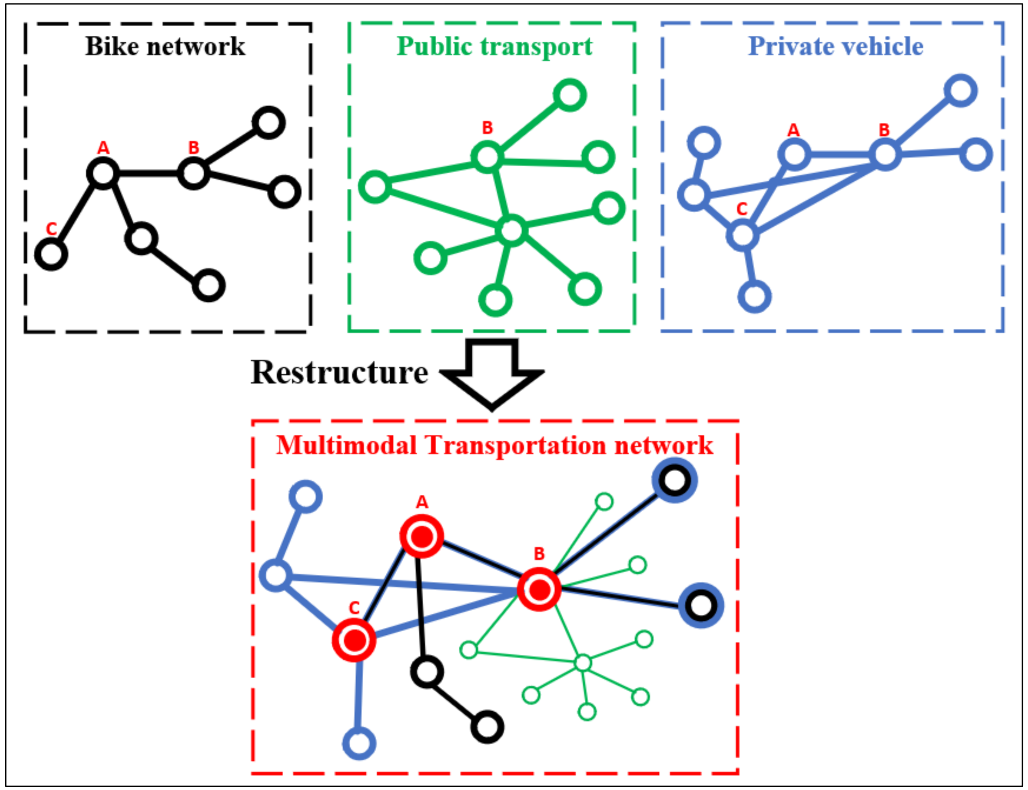


AMS Data Hub for Transportation Planning Applications

Source: Nevers, Brandon L., et al. *The effective integration of analysis, modeling, and simulation tools.* No. FHWA-HRT-13-036. United States. Federal Highway Administration. Office of Operations Research and Development, 2013.

Specific Challenges in Building Model Specifications

1. Requiring more specific information
2. A wide range of ways to code multimodal network with real-world requirements
3. Non-trivial data structure even for essential information
4. Network manipulation is not being standardized
5. Different data format options
6. Limited recent activities in bicycle or pedestrian network model standardization
7. Needs for cross-mode standards to ensure complete trip interoperability



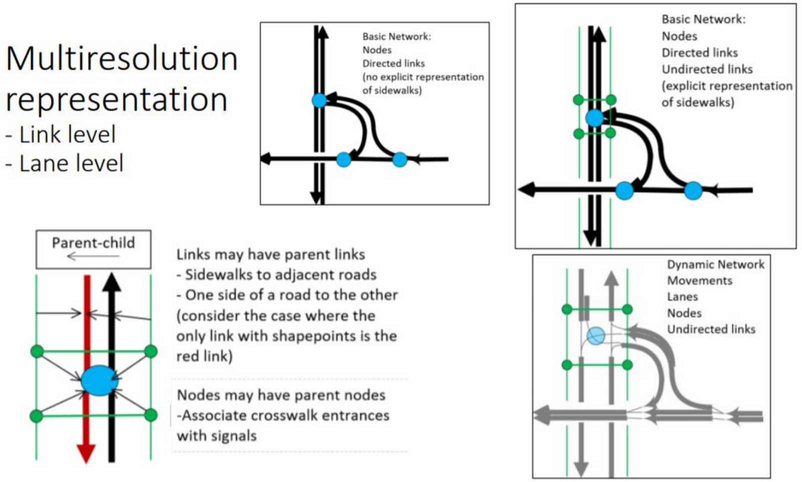
Multimodal network representation

Introducing General Modeling Network Specification (GMNS)

- The objective of the GMNS is to provide **a common human and machine-readable format** for sharing routable road network files.
- The project is overseen by a project management group, with MPO, city, industry, academic and US DOT participation.

github.com/zephyr-data-specs/GMNS

Multiresolution representation
- Link level
- Lane level



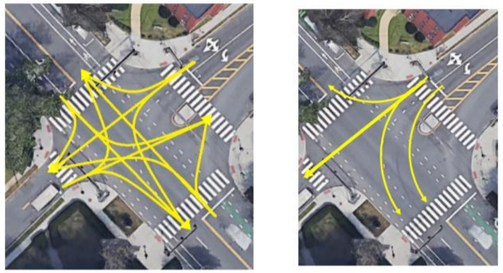
Source: Volpe Center GMNS team

Scott.Smith@dot.gov

Ian.Berg@dot.gov

Movements at an intersection

- Link Level
- Lane Level (for the northeast approach)



Permitted movements may also be time-of-day specific

- Movement attributes
  - Node
  - Inbound link and lane(s)
  - Outbound link and lane(s)
  - Type of Movement
    - left, right, thru, merge, uturn
  - Type of control
    - no_control, yield, stop, stop_2_way, stop_4_way, signal
  - Optionally
    - Right-turn-on-red
    - Penalty
    - Capacity
    - Pct Green Time

Governance

This project is overseen by a board-approved Project Management Group (PMG) as follows:

- Joe Castiglione, SFCTA (chair, board representative)
- Michael Mahut, INRO
- Wu Sun, SANDAG
- Guy Rousseau, ARC
- Chetan Joshi, PTV
- Jeff Frkonja, Portland Metro
- Scott Smith, Volpe
- Natalia Ruiz Juri, University of Texas Center for Transportation Research
- Song Gao, UMass Amherst

GMNS Format (Node and Link)

Basic Data Elements

- node
- link
- geometry
- zone

name	node_id	osm_node	osm_highw	zone_id	ctrl_type	node_type	activity_typ	is_boundar	x_coord	y_coord	main_node	poi_id	notes
	0	41459438			0				-111.928	33.4245			
	1	41520512			0				-111.944	33.42547			
	2	41520515			0				-111.944	33.42432			
	3	41520518			0				-111.944	33.42318			
	4	41520521	traffic_signals		1				-111.944	33.42189			
	5	41520523			0				-111.944	33.42064			
	6	41520525			0				-111.944	33.42035			
	7	41520528			0				-111.944	33.4194			
	8	41520531			0				-111.944	33.41892			
	9	41520533			0				-111.944	33.41778			

node.csv

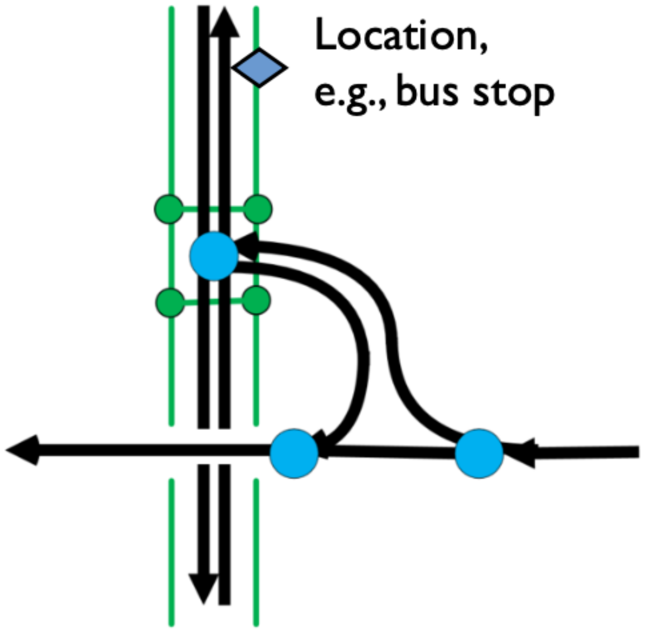
name	link_id	osm_way_i	from_node	to_node_ic	dir_flag	length	lanes	free_speed	capacity	link_type_n	link_type	geometry	allowed_us	from_biwa
South Farn	0	5590095	13	14	1	81.57798	1	25		residential	6	LINESTRIN	auto	1
South Farn	1	5590095	14	13	1	81.57798	1	25		residential	6	LINESTRIN	auto	1
South Farn	2	5590095	14	15	1	80.16146	1	25		residential	6	LINESTRIN	auto	1
South Farn	3	5590095	15	14	1	80.16146	1	25		residential	6	LINESTRIN	auto	1
South Farn	4	5590095	15	16	1	240.2824	1	25		residential	6	LINESTRIN	auto	1
South Farn	5	5590095	16	15	1	240.2824	1	25		residential	6	LINESTRIN	auto	1
South Farn	6	5590095	16	17	1	84.15426	1	25		residential	6	LINESTRIN	auto	1
South Farn	7	5590095	17	16	1	84.15426	1	25		residential	6	LINESTRIN	auto	1
South Farn	8	5590095	17	18	1	83.10715	1	25		residential	6	LINESTRIN	auto	1
South Farn	9	5590095	18	17	1	83.10715	1	25		residential	6	LINESTRIN	auto	1

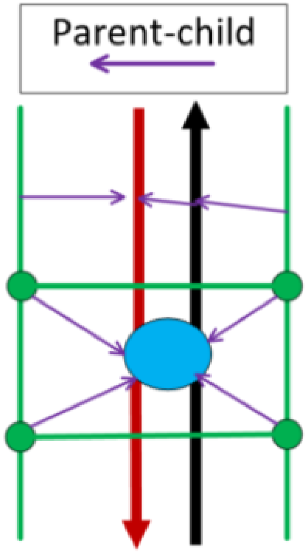
link.csv

Source: https://github.com/zephyr-data-specs/GMNS

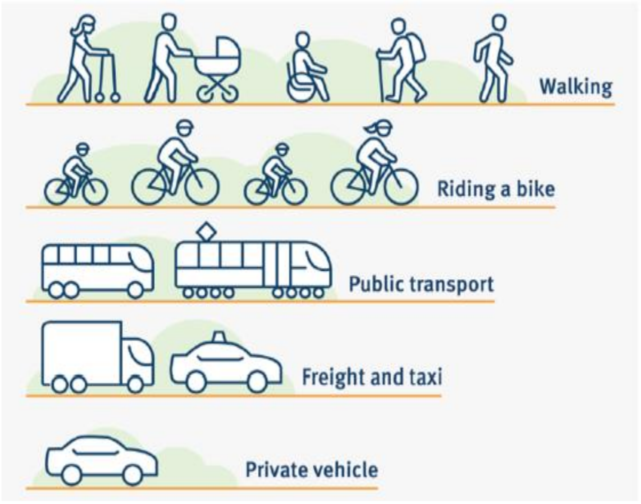
Multimodal Accommodation in GMNS

The **allowed_uses** field indicates what may flow on a **link** or **lane** (e.g., walk, bike, bus, truck, auto, hov2, hov3+), as well as non-travel uses (shoulder, parking)
Location—a point that is associated with a specific location along a link, using a linear reference



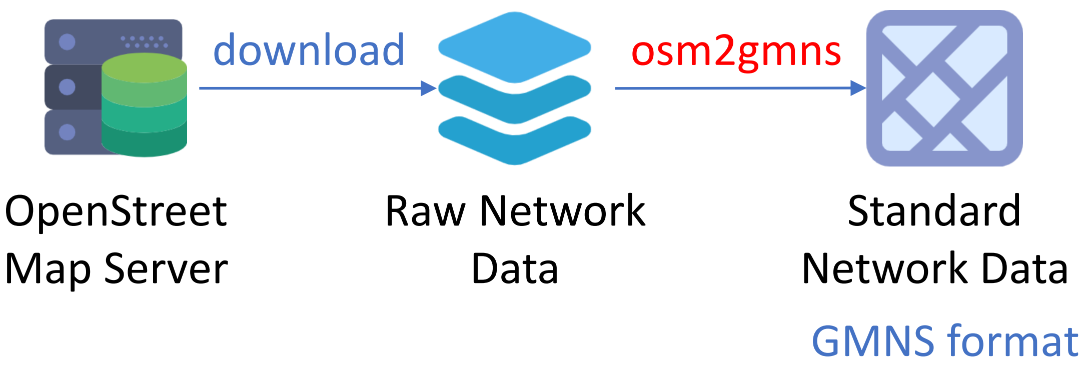


Links include fields for **ped_facility,bike_facility.**
Sidewalks and crosswalks may optionally be handled via their own undirected links. Parent-child relationships:
- Sidewalk with associated road
- Crosswalk and intersection nodes
Separated bike facilities may also be handled as their own pairs of directed links



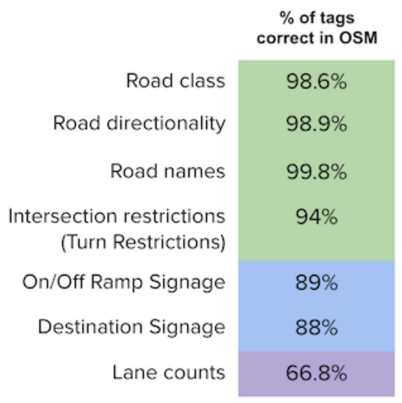
Open Data Source: OpenStreetMap

OpenStreetMap (OSM) is a free, open-source, editable map website that can provide free downloads. osm2gmns, as a data conversion tool, can directly convert the OSM map data to node and link network files in GMNS format. Users can convert and model drivable, walkable, railway, or aero way networks with a few lines of Python code.



Source: https://osm2gmns.readthedocs.io/

Findings: High Map Accuracy across 30 Cities*



We found that core features of OpenStreetMap roads are correct more than 95% of the time relative to what exists in the real world. Data critical to safe navigation, such as left turn restrictions, are correct more than 85% of the time. Nationwide, these estimates are precise to within 5% sampling uncertainty. The regional uncertainty varies more based on region-level dynamics, visible in the figures at the end of this post.

Source: https://eng.lyft.com/how-lyft-discovered-openstreetmap-is-the-freshest-map-for-rideshare-a7a41bf92ec

GMNS Format (Segment, Lane, Signal Timing)

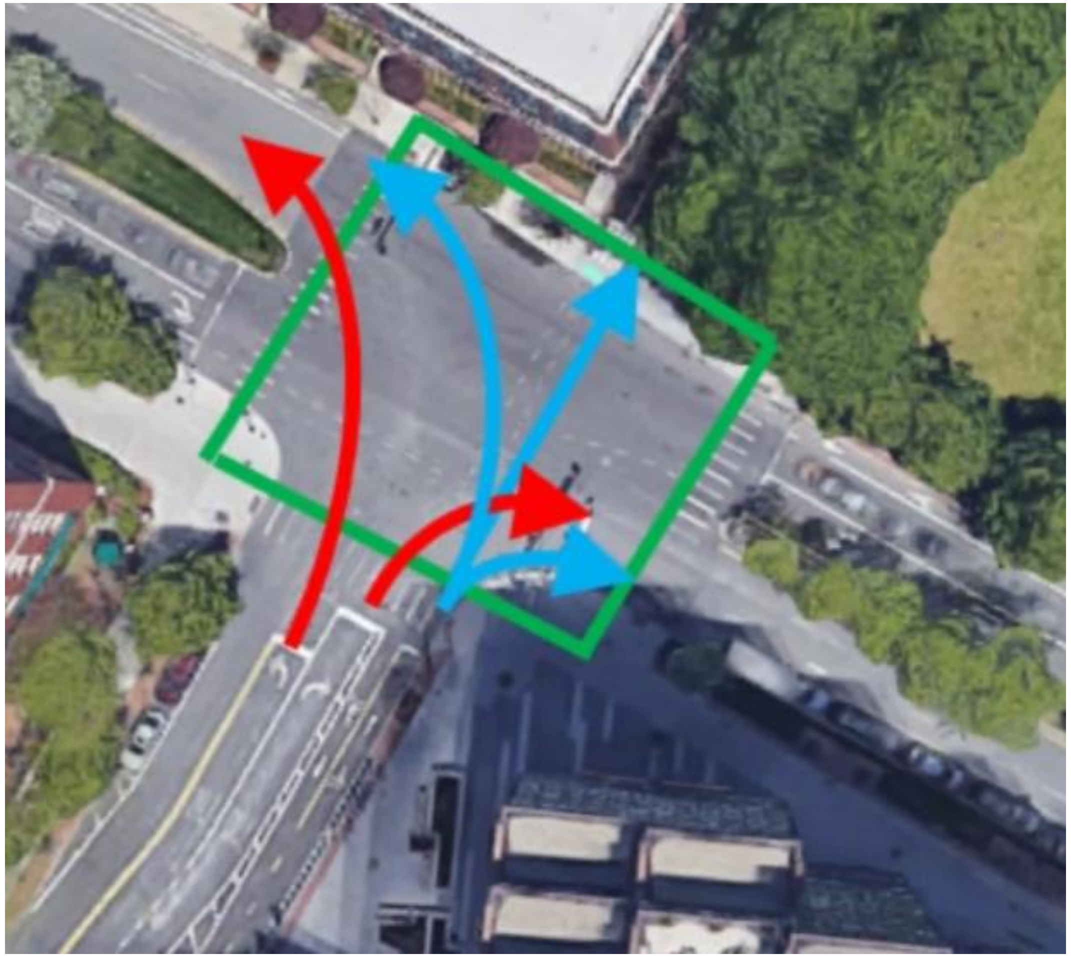
Segments and Lanes:
Segment—portion of a link defined by linear references
Lane— Lanes are numbered left to right with 1 as the left-most through lane. Left turn lane is –1. A bike lane is a lane with allowed uses = BIKE

Turn pockets are defined via segments.

GMNS Format (Movement)

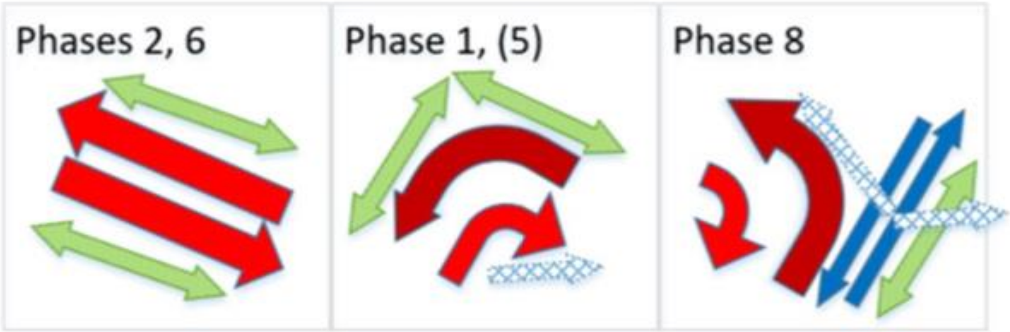
- Movements define connections and traffic control types (none, yield, stop, signal) between inbound and outbound links or lanes at an intersection.

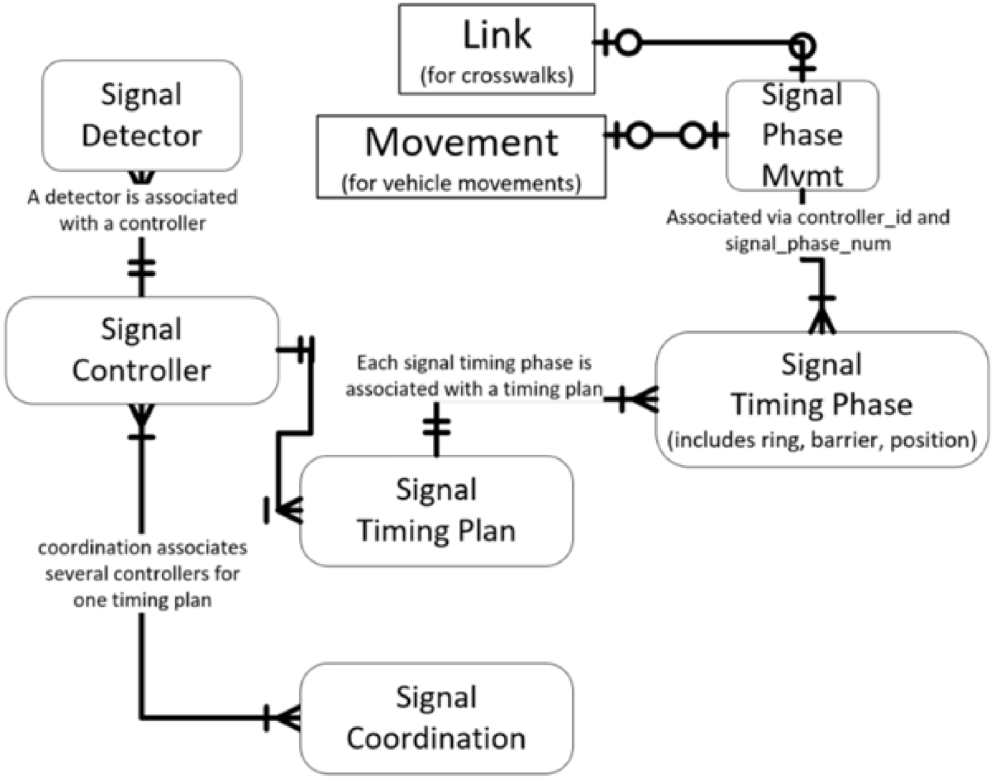
- Example:
  - Pedestrian movements in green
  - General traffic (red) and bike (blue) movements are shown from the south



GMNS Format (Traffic signal)

- **Signal_controller**— association of one or more intersections whose signals use the same controller
- **Signal_phase_mvmt**— signal_phase mapped to its associated traffic movements and pedestrian links (e.g., crosswalks)
- **Signal_timing_phase**— timing and concurrency information for each signal phase
- **Signal_timing_plan**— timing plan for the signal, by controller, time period
- **Signal_coordination**— coordination for several signal controllers, associated with a timing plan
- **Signal_detector**— traffic detector associated with a controller, a phase and a group of lanes

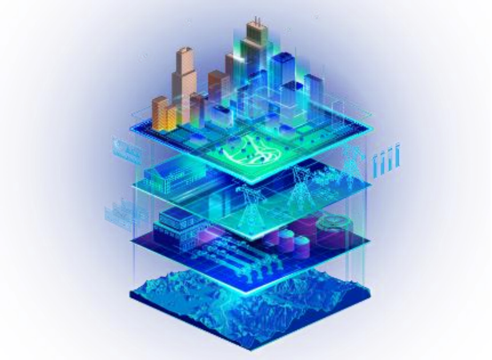




Source: GMNS.

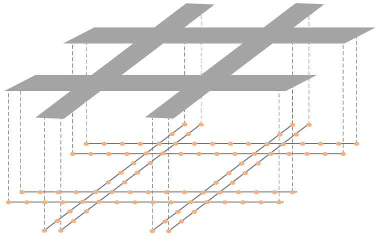
Part II: Open-Source Tools and MRM Community

I. **Open Data Specification**

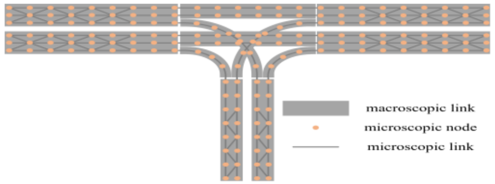


II. **Open-Source Tools and MRM Community**

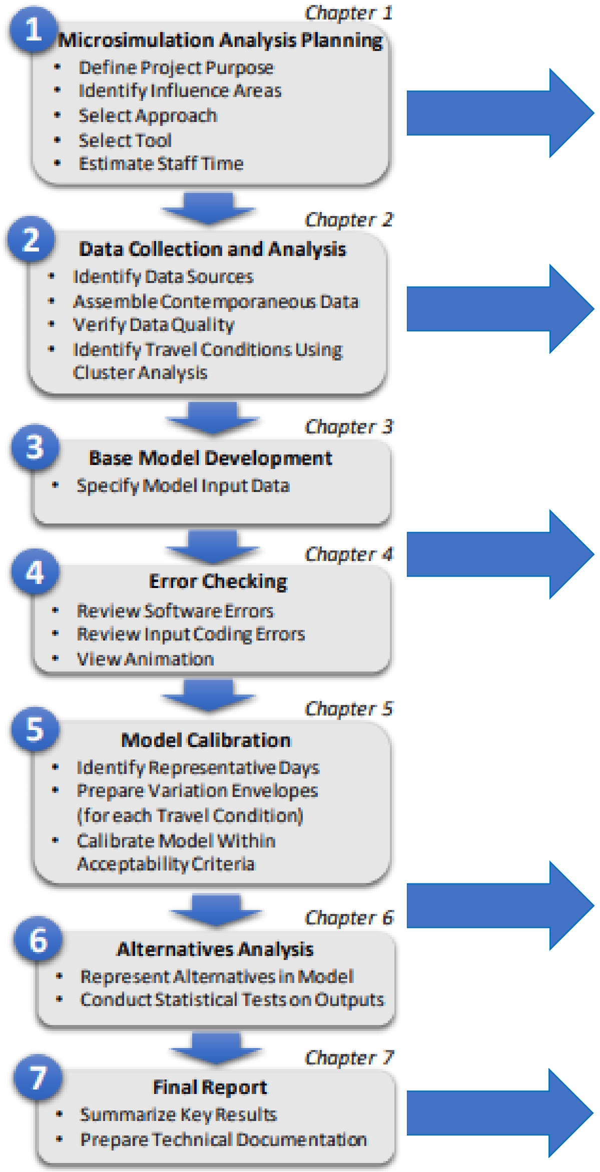
Macroscopic Layer



Microscopic Mesh Layer



General Modeling Microsimulation Modeling Procedure



Assess MRM cost-effectiveness, stakeholders, spatiotemporal scope, risks, performance measures, data requirements, data availability, and level of effort.

Obtain MRM input data, origin-destination (O-D) data, and bottleneck data.

Develop workflow for data importing and conversion, disaggregate trips, improve the O-D matrix, specify traffic control, specify transportation system management and operations strategies and emerging technologies, and develop multiscenario datasets.

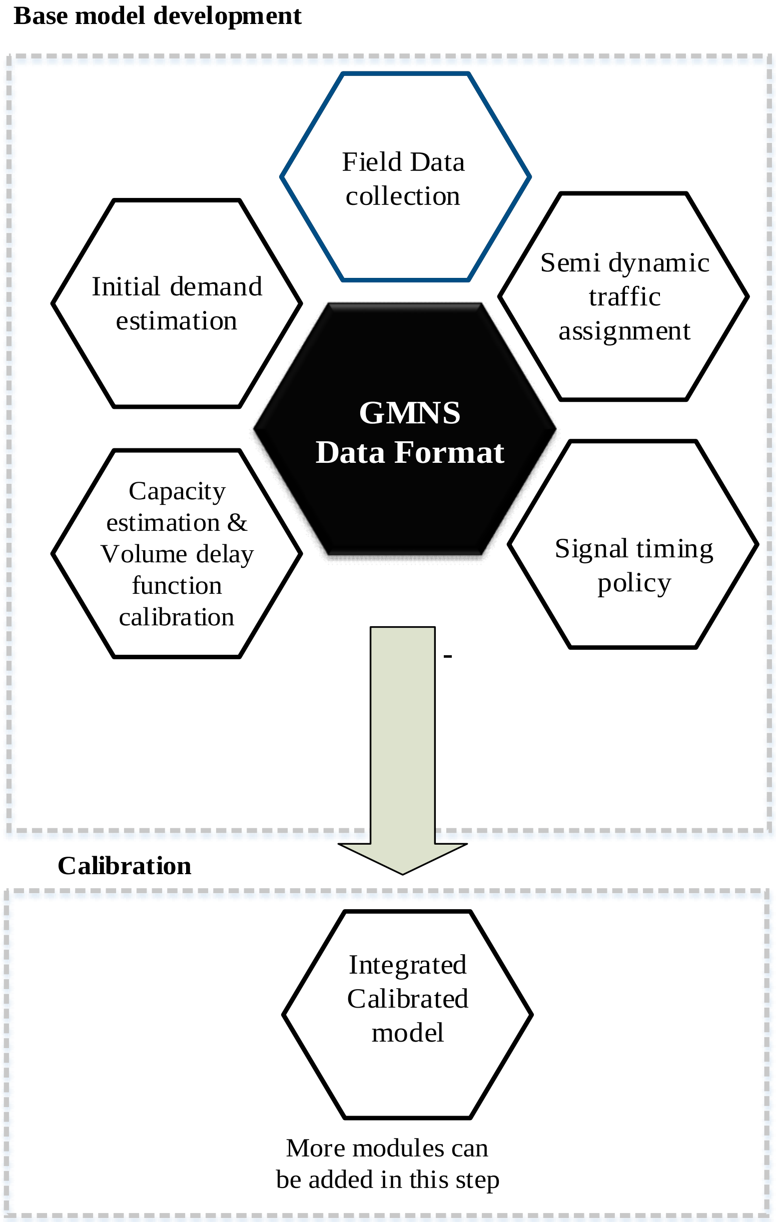
Calibrate demands, bottlenecks, and traffic flow models at all resolutions.
Assess convergence to ensure quality of traffic assignment.
Ensure consistency between ABM, DTA, and all resolutions.

Estimate future demands and signal timings.
Perform sensitivity analysis and account for model stochasticity.

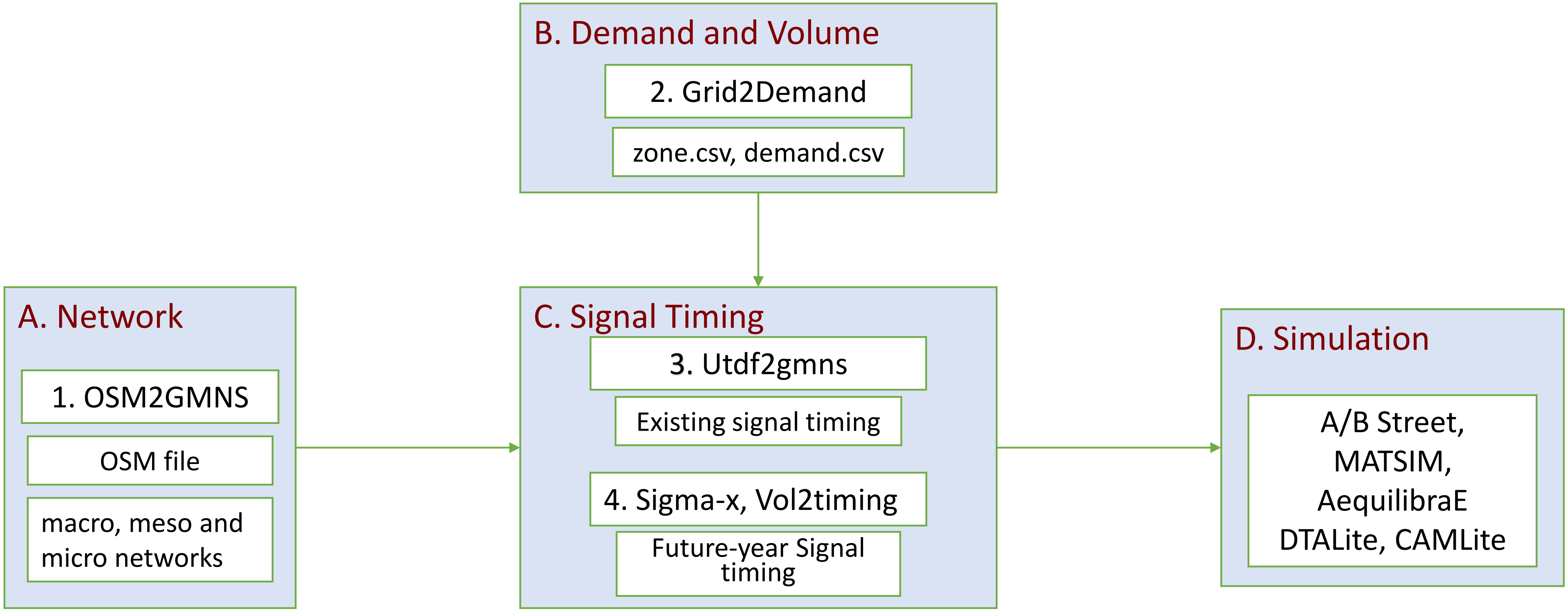
Source: FHWA. (Wunderlich et al. 2019)

MRM Benefits and Applications for Traffic Signal Simulation

- Use of different resolutions to supplement each other.
- Improved dynamic traffic assignment via mesoscopic modeling.
- Overall results more defensible.
- Meso-to-microscopic model consistency
- Unique insights into strategic driver behavior.
  - Important for emerging technologies and transportation system management and operations (TSMO) strategies.
- Robust analysis of subnetwork interaction.



It Takes a Community For Building Tools That Work with GMNS



- **Sigma-X: Excel-based computational engine for signalized intersections Vol2Timing as Python API**

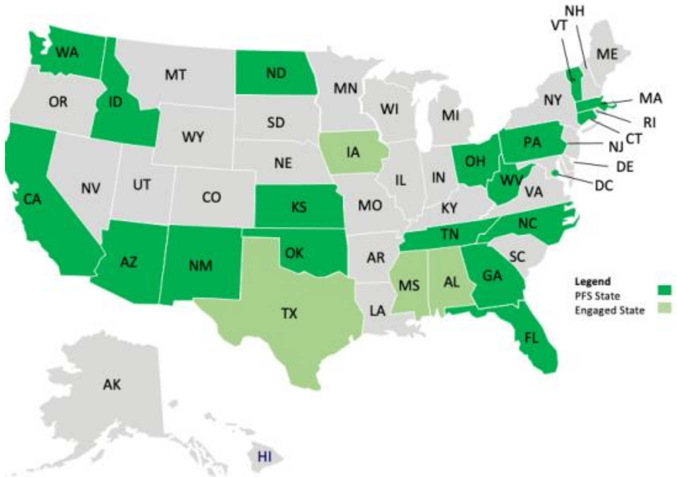
Excel->GMNS, Synchro UTDF -> GMNS

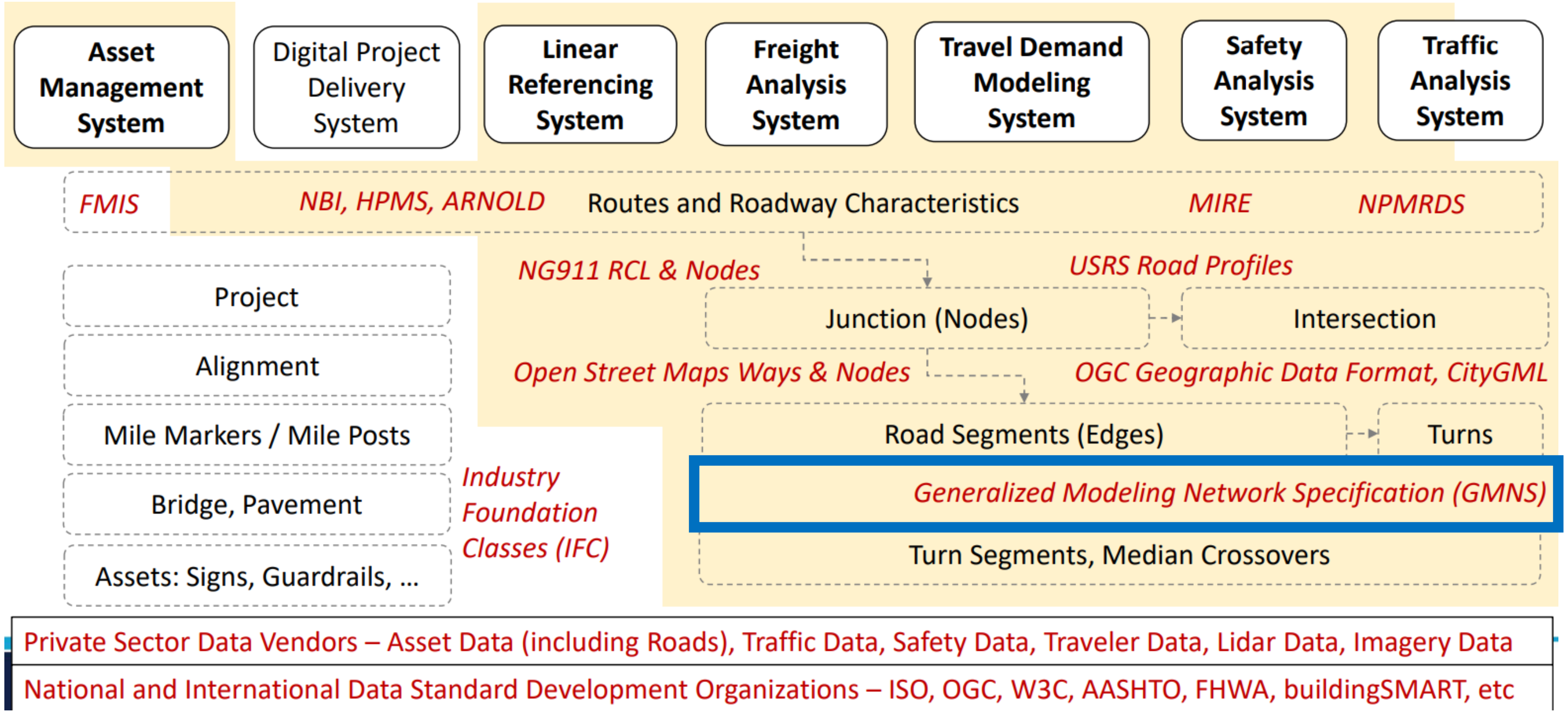
https://github.com/milan1981/Sigma-X

Contributor: Milan Zlatkovic

Broader Effort for Incorporating GMNS Into Applications Of Enterprise GIS In Transportation (AEGIST) Framework

Pooled Fund Study (PFS):
FHWA and States
Enterprise Data Management and Governance
Standards, Processes, Tools and Technology





www.gisintransportation.com

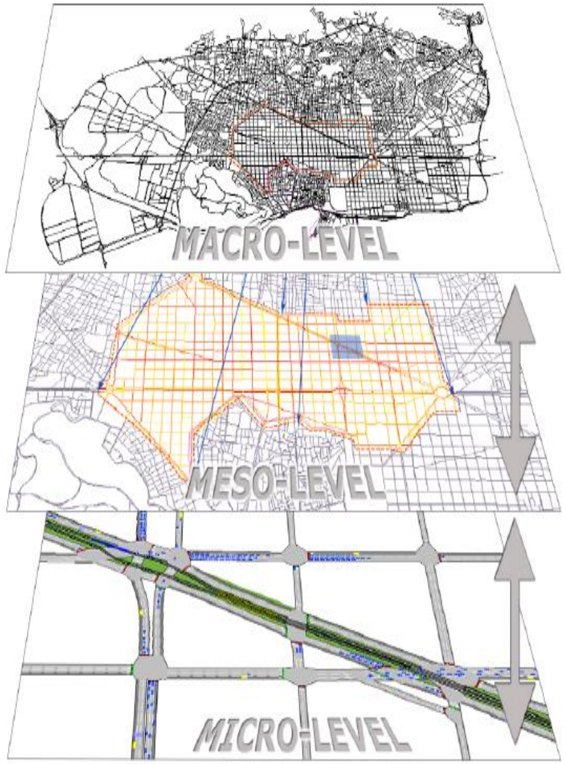
Source: AEGIST Pooled Fund Study (PFS)
FHWA Contact: Joe Hausman, Joseph.Hausman@dot.gov

Part III: Case Study of MRM

I. Open Data Specification

II. Open-Source Tools and MRM Community

III. Network Simulation Prospective and Case Studies

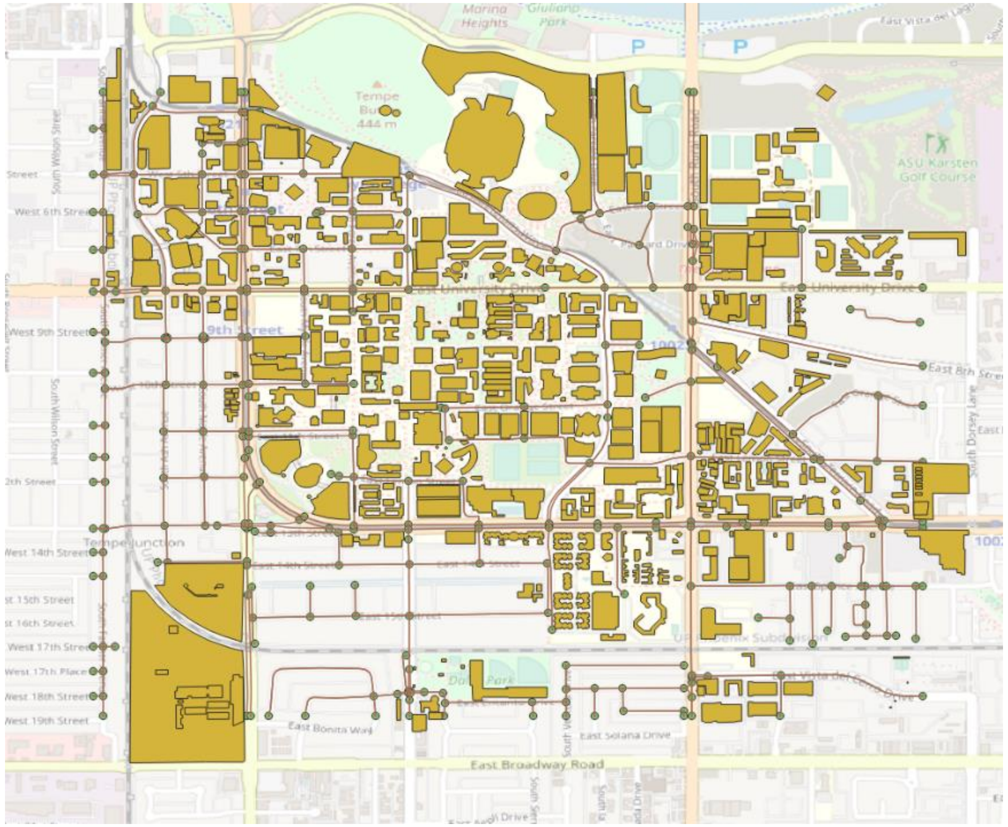


Streamlined workflow to be demonstrated using open-source tools

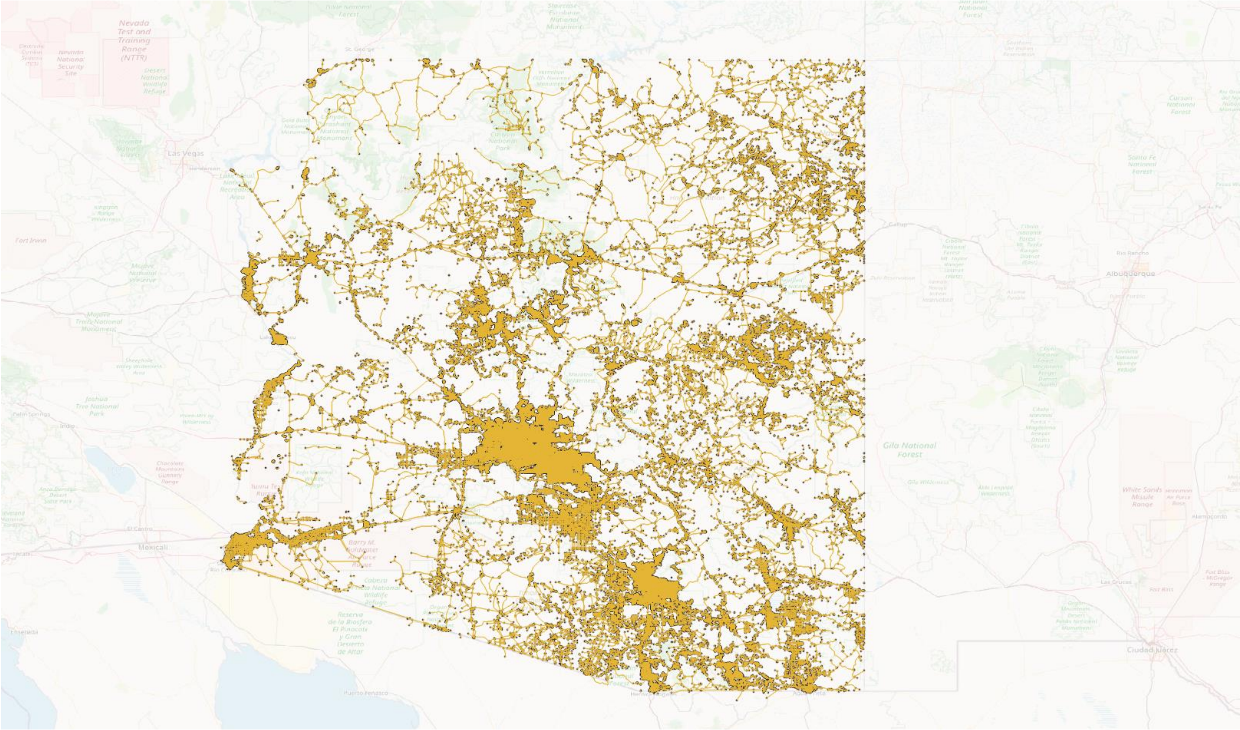
	Open-source tool(s)
1. Data download from online mapping database.	OSM
2. Convert OSM downloaded data into the GMNS format.	OSM2GMNS
3. Define zone-to-zone travel demand.	Grid2demand
4. Establish base-year traffic signal timing inventory	Utdf2gmns
5. Generate future-year traffic signal timing	Vol2timing, Sigma-X
6. Perform traffic simulation.	A/B Street, DTALite, CAMLite
7. Visualize results.	QGIS, NeXTA, A/B Street

A/B Street = traffic simulation game (GitHub 2021).
DTALite = queue-based mesoscopic traffic simulator (Zhou and Taylor 2014).
GMNS = General Modeling Network Specification (Zephyr Foundation 2021).
Grid2demand = data conversion tool (PyPI 2021). Utdf = data conversion tool (PyPI 2021).
NeXTA = Network EXplorer for Traffic Analysis (Zhou and Taylor 2014).
OSM = OpenStreetMap®.
OSM2GMNS = data conversion tool (PyPI 2021).
QGIS = geographic information system (qgis.org 2021).
Sigma-X = spreadsheet-based computational engine for signalized intersections (Zlatkovic 2021).
Vol2timing = GMNS-based signal timing generation tool for multi-resolution modeling (PyPI 2021).

1: Network from OSM: with POIs and Activity Locations



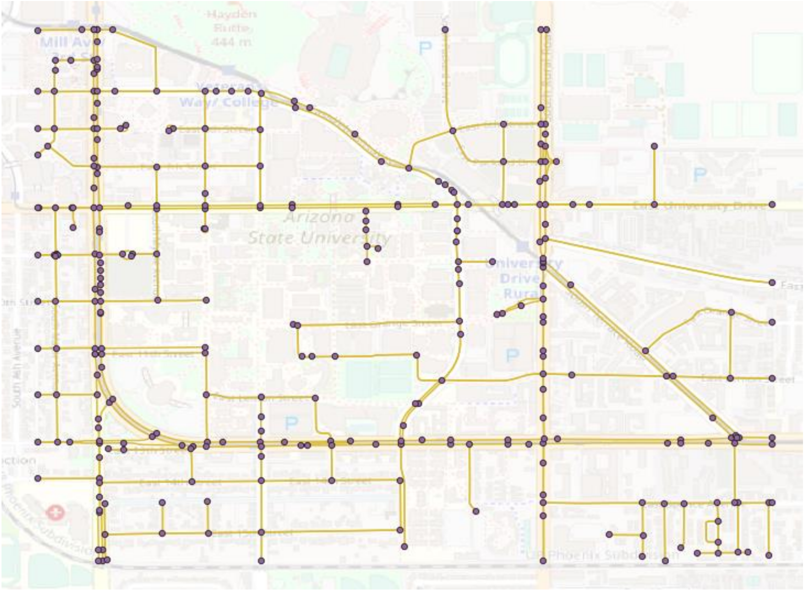
Network with POIs (Point of Interest)



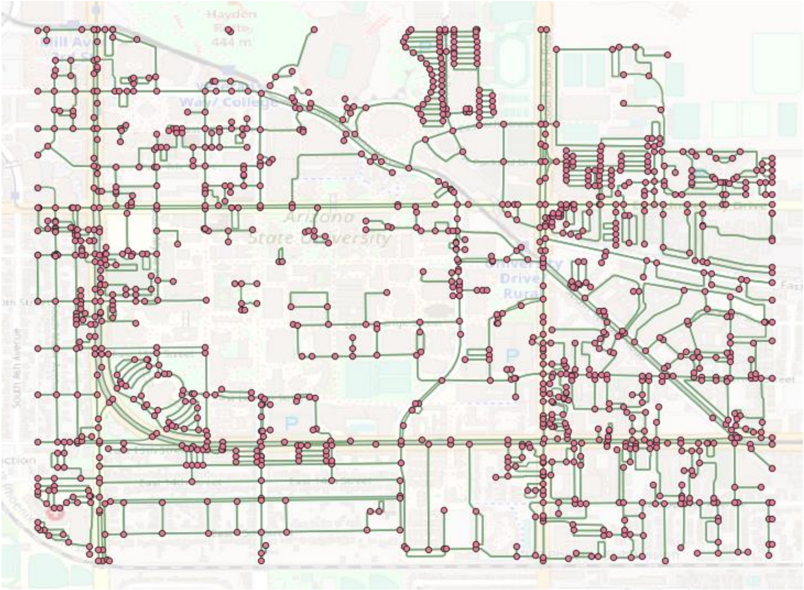
Arizona, U.S.

More sample networks. Contributor: Jiawei Lu at ASU
https://osm2gmns.readthedocs.io/en/latest/sample-net.html

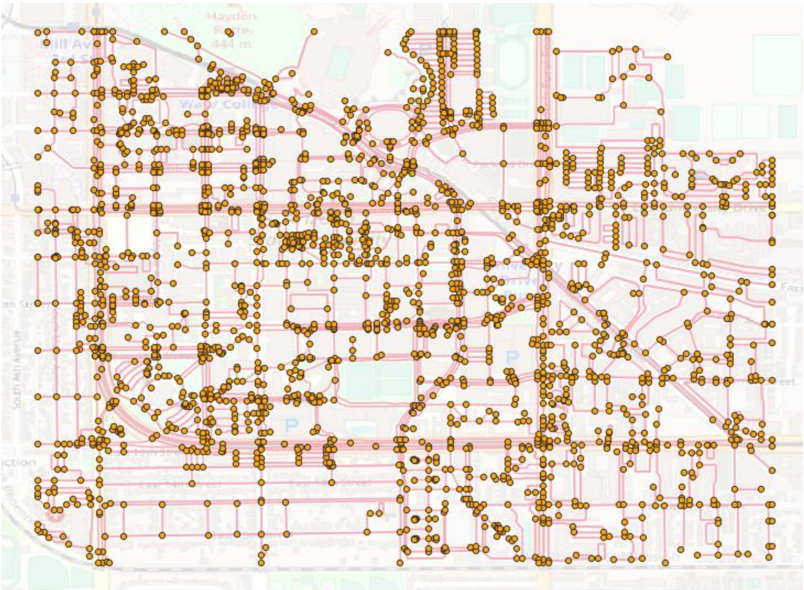
Multimodal Networks



Drivable network
320 nodes, 619 links



Bikeable network
1282 nodes, 2989 links

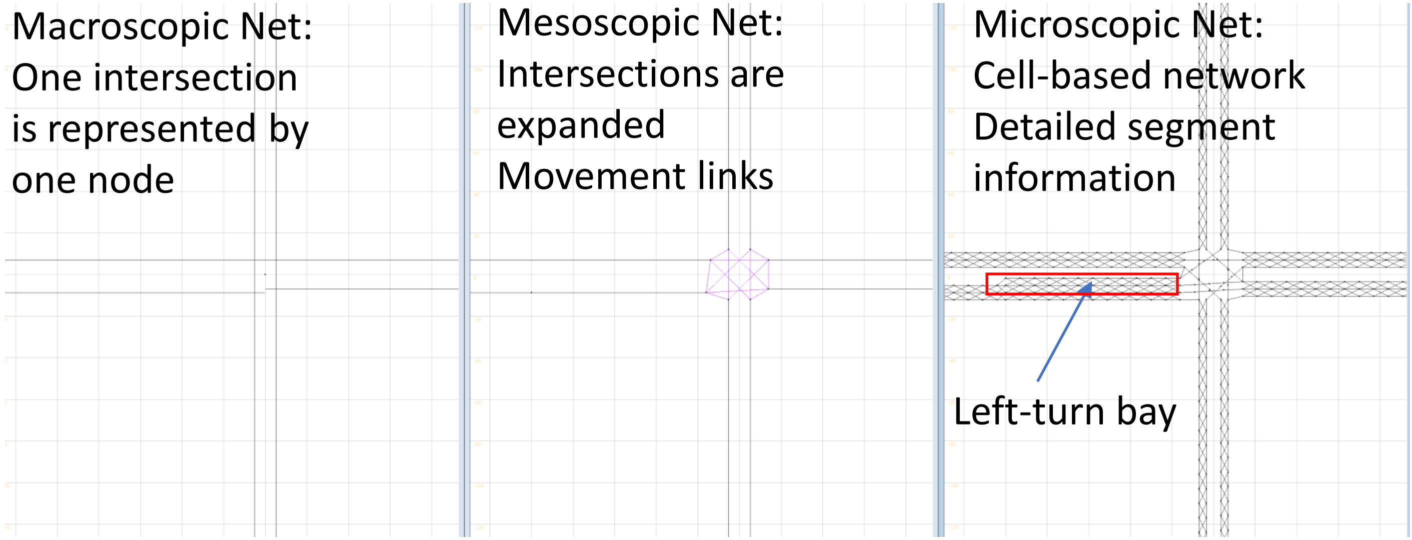


Walkable network
2426 nodes, 5019 links

More sample networks
https://osm2gmns.readthedocs.io/en/latest/sample-net.html

2. Convert OSM Downloaded Data into The GMNS Format (Multi-resolution Network)

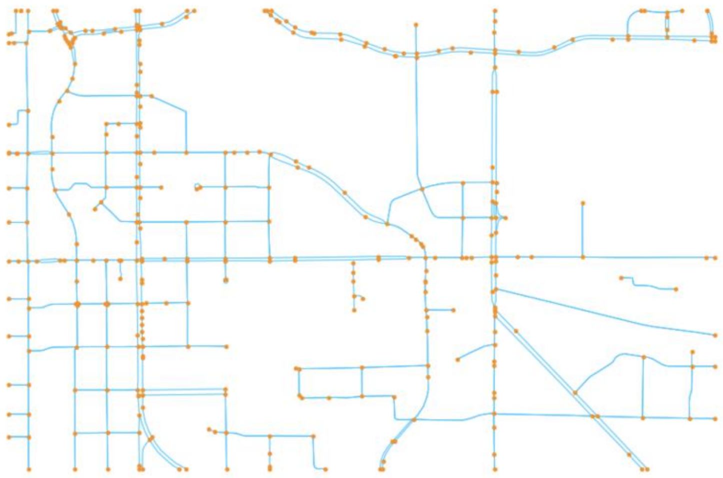
- OSM2GMNS helps users automatically generate hybrid (macroscopic, mesoscopic and microscopic) transportation networks to accommodate different modelling needs.



STA DTA Simulation

Macroscopic Net Mesoscopic Net Microscopic Net

- OSM2GMNS Tool, ASU Network



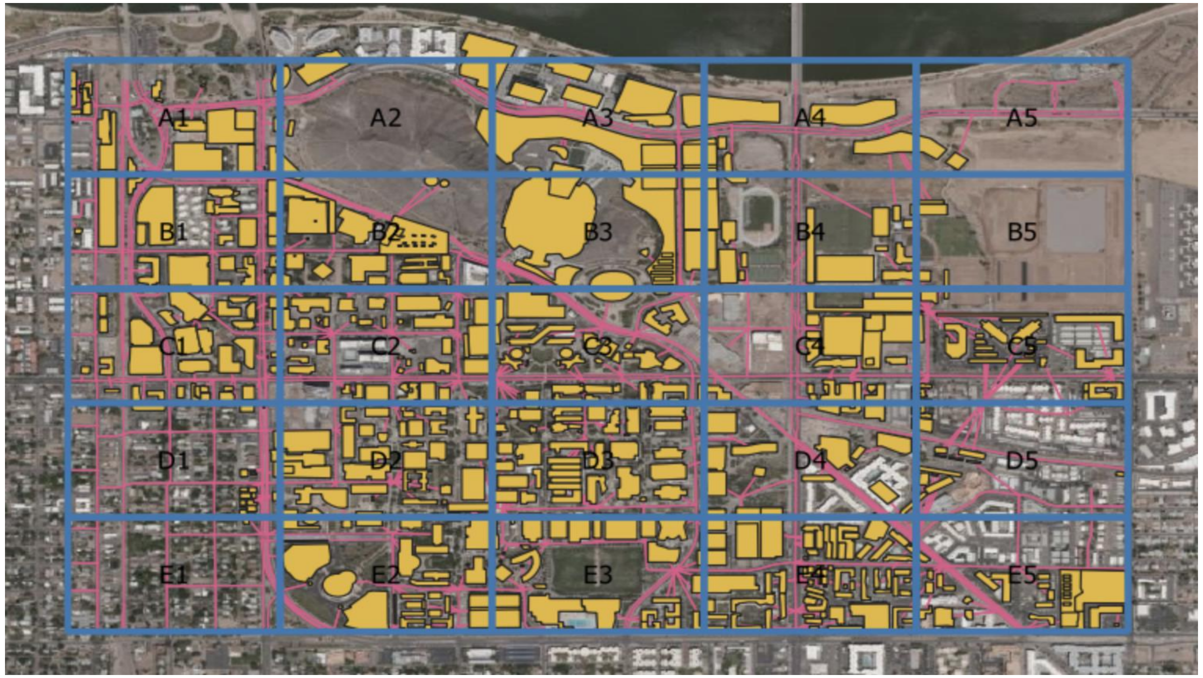
Macroscopic Network

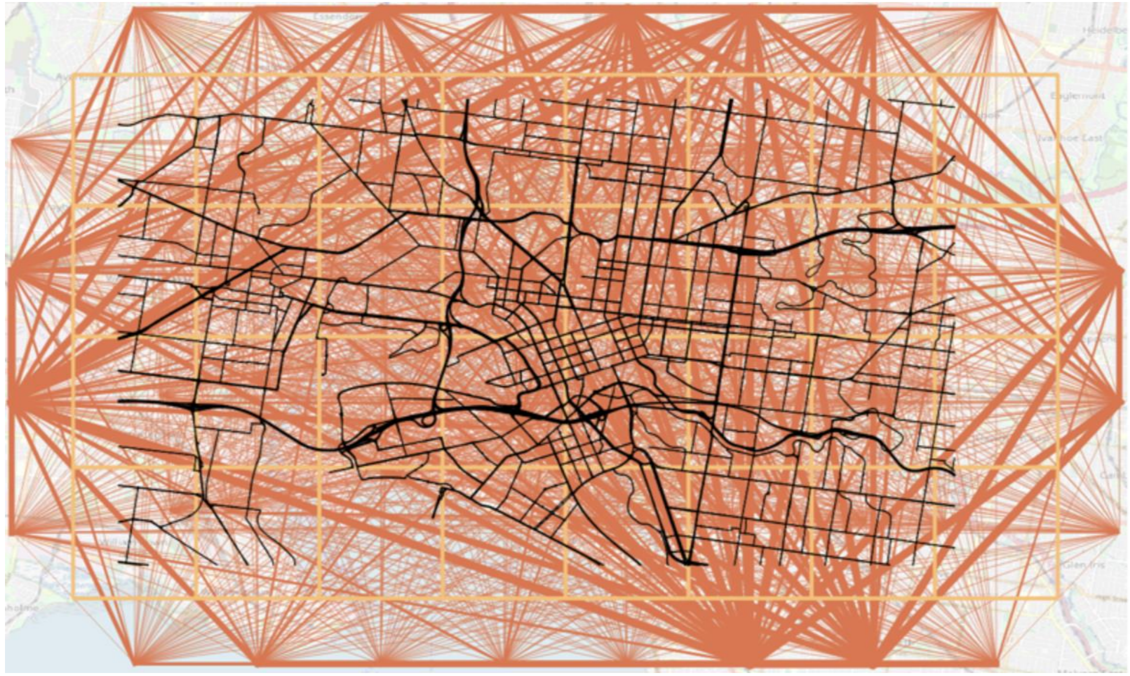
Microscopic, virtual-track based Network

2. Define Zone-to-zone Travel Demand

- Creating grid zones, based on POI data from OpenStreetMap to analyze the resident locations and other land use properties

- Quickly generate initial origin-destination transportation demand based on land use propertaies for engaging traffic simulation games such as A/B street and DTALite

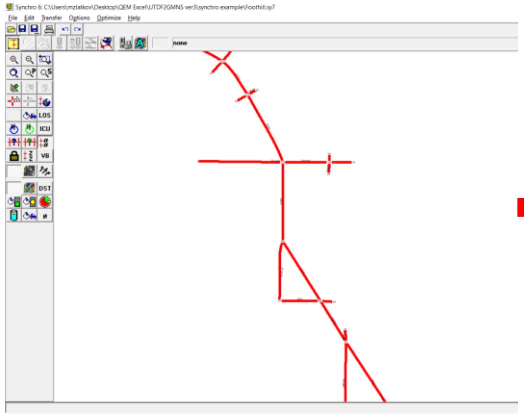




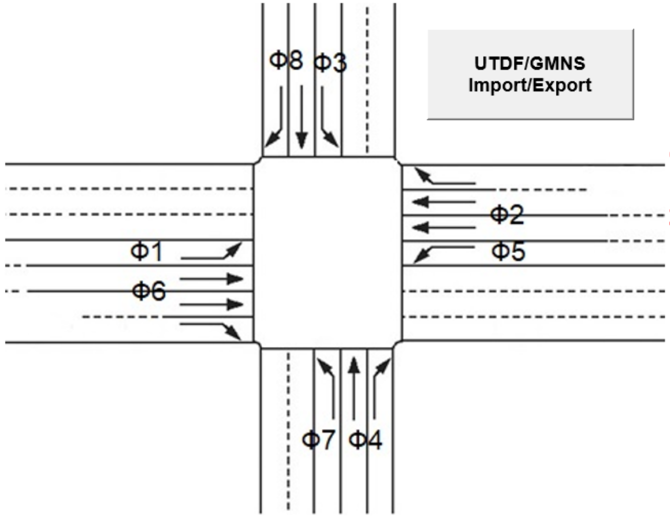
- Grid2demand Tool, ASU Network

4. Establish Base-year Traffic Signal Timing Data Inventory

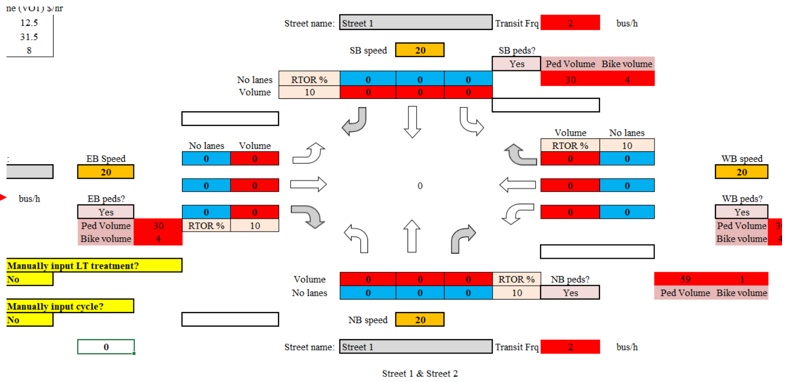
- **Meso and micro network**
- Convert UTDF file data into GMNS format (turn movement)
  UTDF Input-GMNS Output
- Turning Volume Inventory (e.g. from Gridsmart, MS2 traffic counts and from existing synchro files)



UTDF

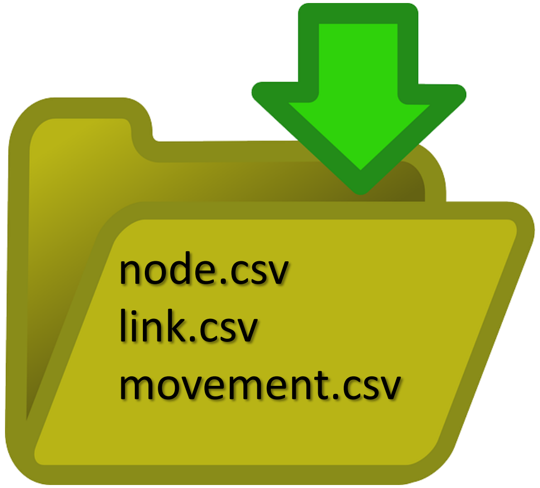


Output for simulation

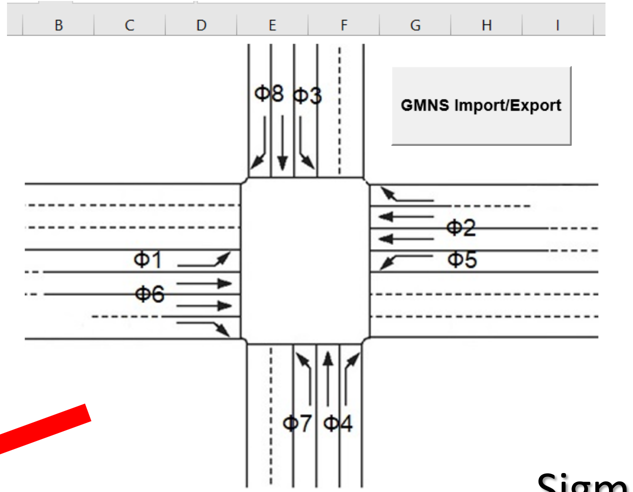


Synchro **UTDF2GMNS** **Movement_utdf.csv**

5. Establish Future-year Traffic Signal Timing Scenario

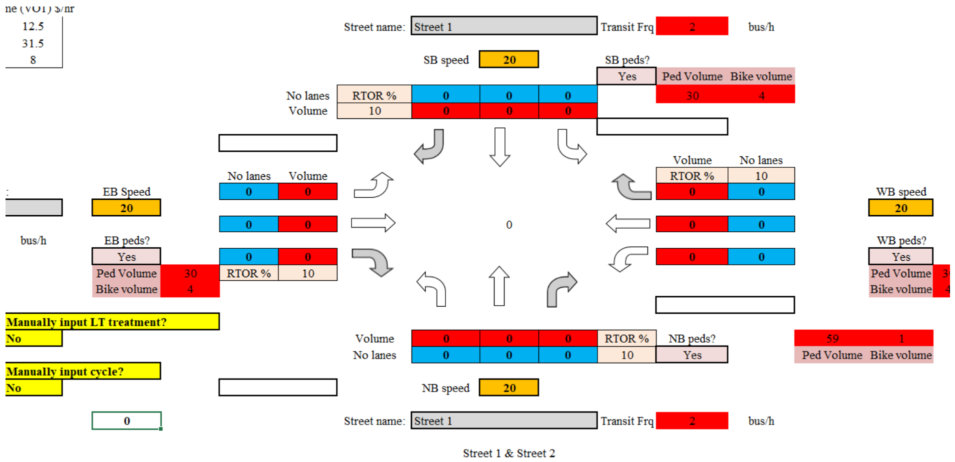


Geometry, volumes



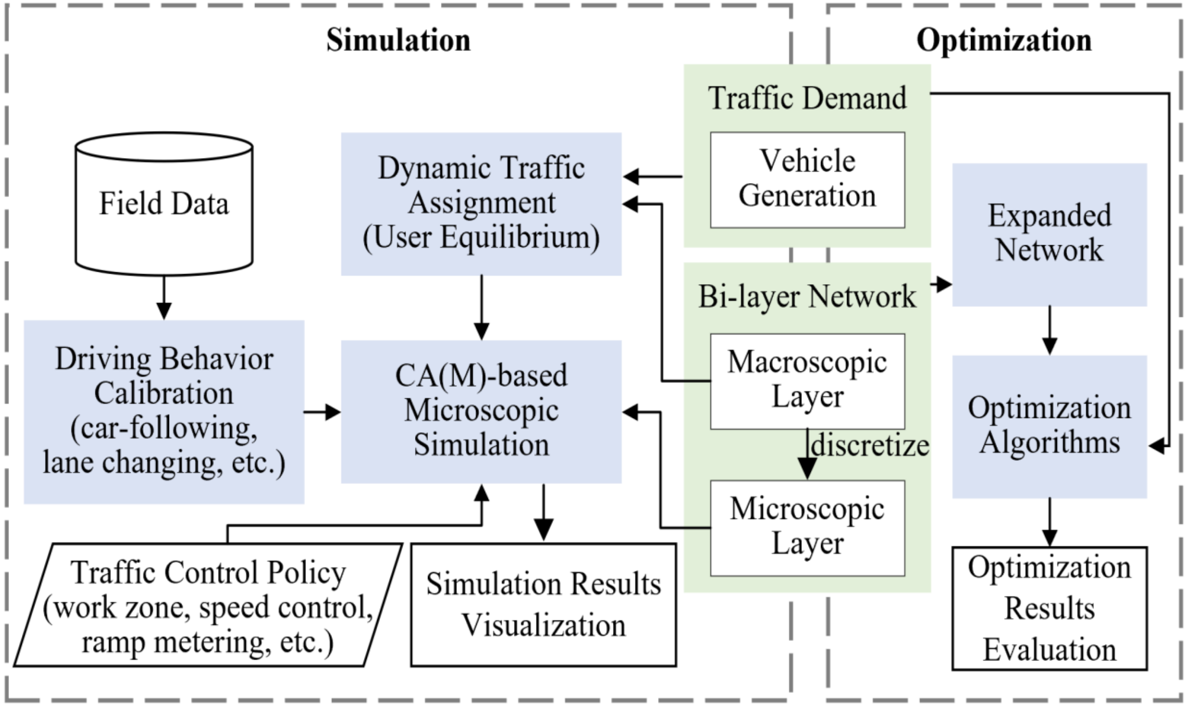
SigmaX2GMNS

Input conversion

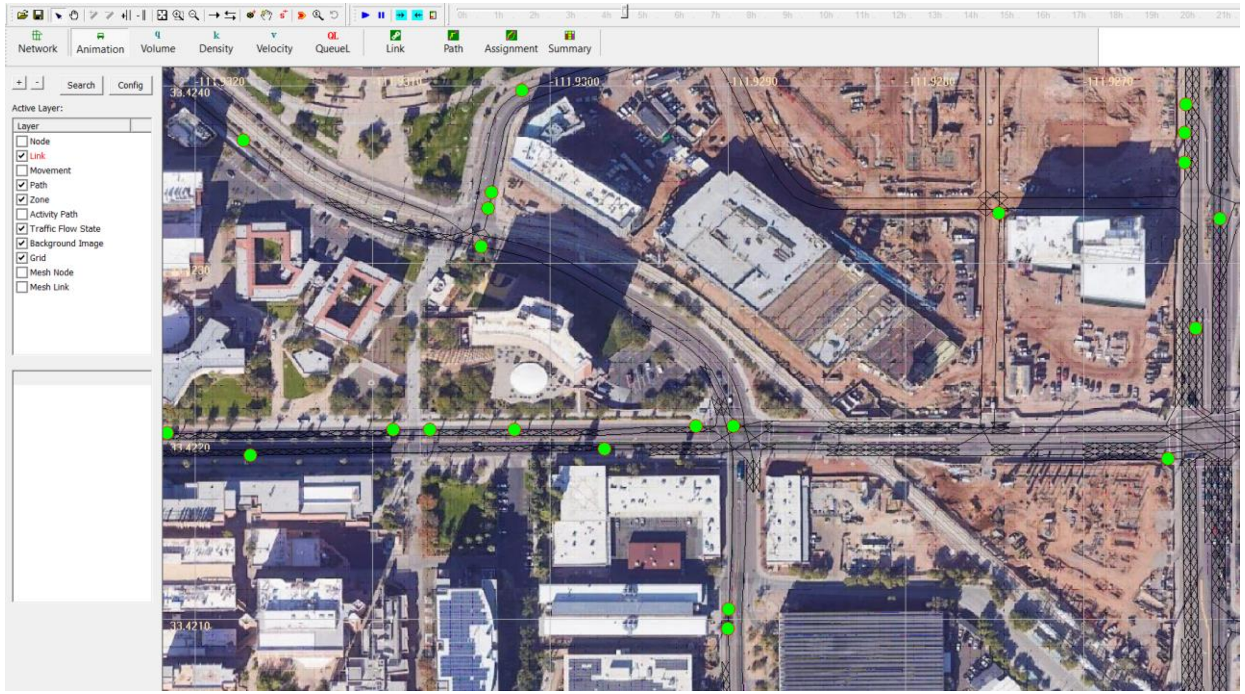


Output

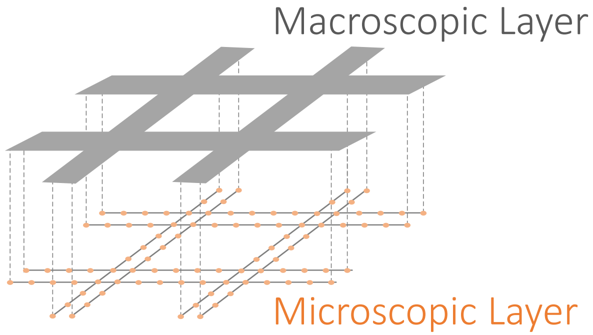
6. Perform Traffic Simulation,
Open-source CAMLite: Virtual-Track-based Modeling Framework:

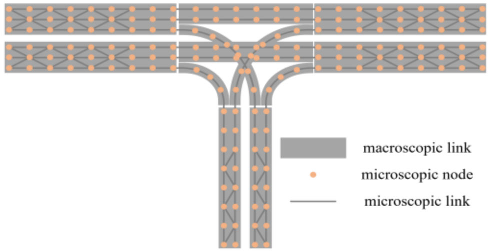


System architecture overview



Simulation Results from CAMLite





- CAMLite Tool, ASU Network

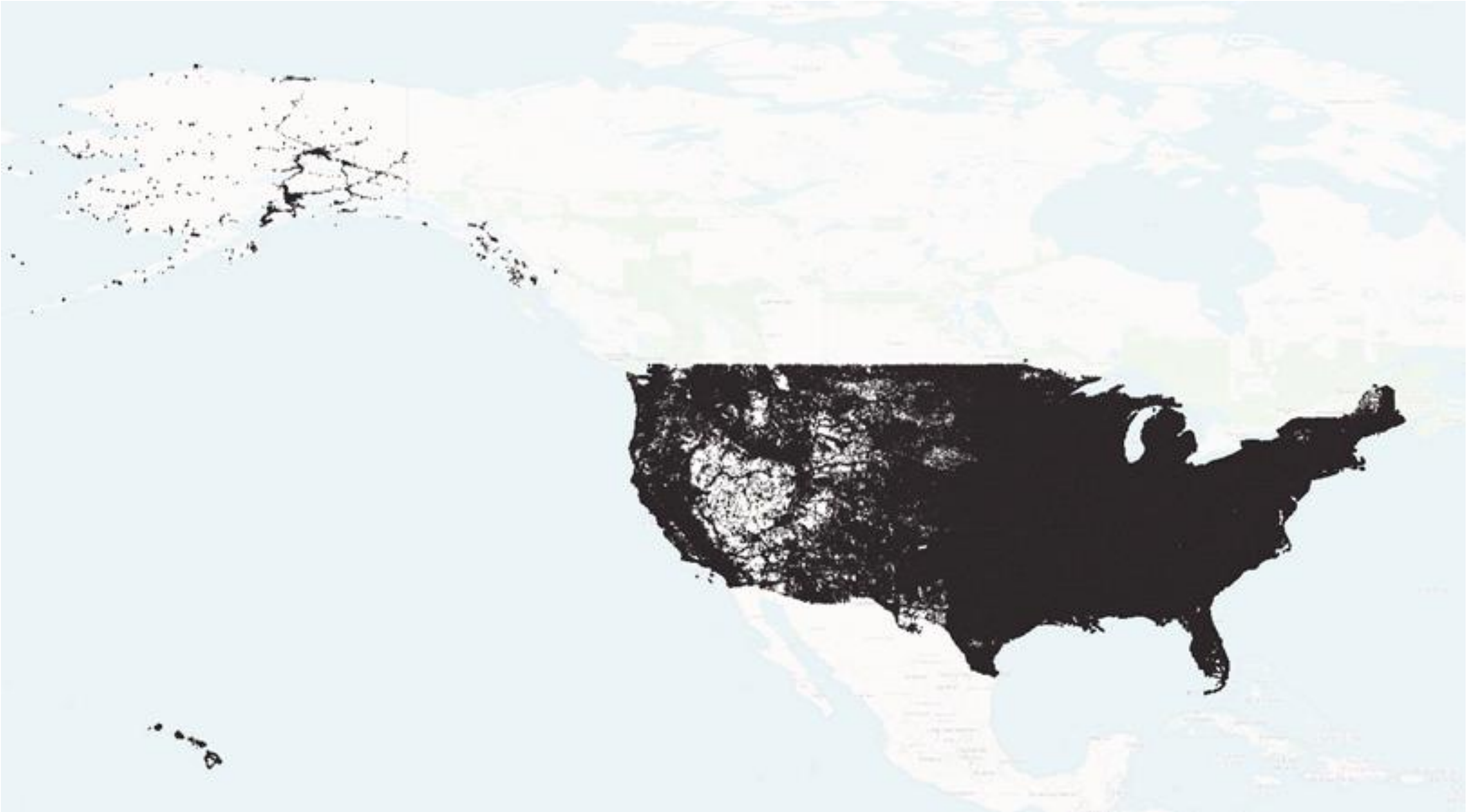
7. Visualization through AB Street

https://github.com/a-b-street/abstreet

Source: https://github.com/a-b-street/abstreet, Special thanks to Dustin Carlino (dabreegster@gmail.com)

Challenges Addressed	Opportunities for state DOTs and MPO stakeholders
1. Map intersections to OpenStreetMap GIS layer	- Utilize machine learning algorithms to automatically map intersections to OSM, instead manually.
2. Manage # of links and counts for each movement in a unified data base	- Develop a data validation process to ensure accuracy of counts and links.
3. Integrate Synchro files in one GIS database, through UTDF reading interface	- Use a transportation management software to generate UTDF files automatically.
4. . Automate the signal timing update process using HCM methodology	- Implement a standard signal timing update process to ensure consistency and efficiency.
5. Future data connection with TranSync for corridor and city levels	- Define the data requirements for corridor-based trajectory-based performance assessment.

To bridge connections between open data, traffic engineers, and city planners, we need the collective effort of a community coming together to build the necessary tools.



Using ASU research computing facilities, we are able to produce the entire U.S. driving network from OpenStreetMap with 20 million nodes.
https://github.com/asu-trans-ai-lab/asu-trans-ai-lab.github.io

PyPi link	https://pypi.org/project/osm2gmns/
Total downloads	55,000
Total downloads - 30 days	2,747
Total downloads - 7 days	538