Integration Traffic Signal Control From Synchro to SUMO

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Outlines

- > **Introduction & Motivation**
- > **Traffic signal control integration**
- > **Conclusion & Future Step**

Introduction & Motivation

> **Current traffic simulation**

- **Macroscopic:** Focuses on the traffic at a low level of detail where the traffic stream is represented in an aggregated level, such as speed, flow, and density.
- **Microscopic:** Details individual vehicle and pedestrian movements, allowing for the simulation of specific behaviors like car-following and lane-changing.
- **Mesoscopic:** A hybrid approach blending macroscopic and microscopic elements, offering more detailed analysis than macroscopic models but less resource-intensive than microscopic simulations.
- **Submicroscopic:** Provides intricate details of each vehicle, including internal mechanics such as gear shifting, suitable for in-depth vehicle dynamics analyses

Cont.

> **When & Why is simulation integration needed?**

- Large-Scale Simulations
  - Extracting network features from existing simulations vs. manual coding
- Multiscale Simulation Connectivity
  - Seamless connectivity and communication across different simulation platforms are crucial for multiscale simulations.
- Data sharing
  - When data providers offer information from different simulation platforms, it is essential for researchers to adeptly transfer these features to maintain data integrity and relevance.

Therefore

> **The aim of this study**
  - Understand the feasibility and effectiveness of simulation integration, specifically traffic signal timing
  - Identify potential obstacles and problems

> **Case study**
  - Synchro vs. SUMO
  - Traffic signal timing
  - Study area
    - Downtown Seattle, USA

Synchro vs. SUMO

> **Synchro (widely used in public agency) → why we use synchro as feature transform**
  - "Synchro is a macroscopic analysis and optimization software application. Synchro supports the Highway Capacity Manual's (HCM) 6th Edition, 2010 and 2000 for signalized intersections, unsignalized intersections and roundabouts. Synchro also implements the Intersection Capacity Utilization method for determining intersection capacity." specifically in traffic signal optimization

> **SUMO**
  - "Simulation of Urban MObility" (SUMO) is an open source, highly portable, microscopic and continuous traffic simulation package designed to handle large networks. It allows for intermodal simulation including pedestrians and comes with a large set of tools for scenario creation."

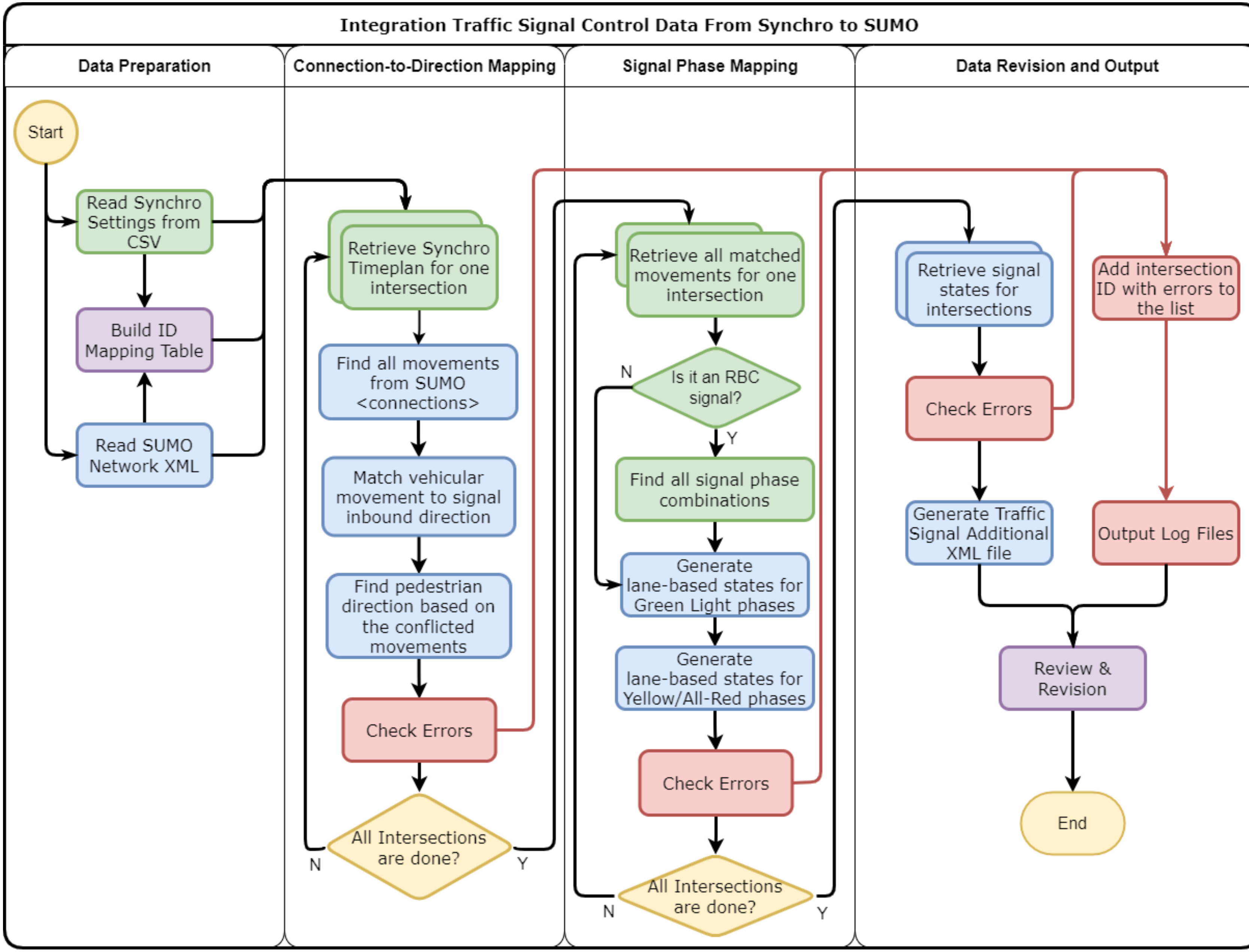
Cont.

> **Current convert simulations/packages**

- SUMO Netconvert
  - Convert network to SUMO, covers
    - VISUM, VISSIM, MATsim, Shapefile, OSM
  - However
    - Manual work is suggested
- VISSIM import
  - Available to import Synchro files
  - However
    - Requires the latest version of Synchro
    - Multiple errors may occur if actual controller timing sheets not matched

Traffic signal control integration – 4 stages

1. **Data Preparation**
2. **Connection-to-Direction Mapping**
3. **Signal Phase Mapping**
4. **Data Revision & Output**



Integration Traffic Signal Control Data From Synchro to SUMO
Data Preparation
Connection-to-Direction Mapping
Signal Phase Mapping
Data Revision and Output
Start
Read Synchro Settings from CSV
Build ID Mapping Table
Read SUMO Network XML
Retrieve Synchro Timeplan for one intersection
Find all movements from SUMO <connections>
Match vehicular movement to signal inbound direction
Find pedestrian direction based on the conflicted movements
Check Errors
All Intersections are done?
N
Y
Retrieve all matched movements for one intersection
Is it an RBC signal?
N
Y
Find all signal phase combinations
Generate lane-based states for Green Light phases
Generate lane-based states for Yellow/All-Red phases
Check Errors
All Intersections are done?
N
Y
Retrieve signal states for intersections
Check Errors
Generate Traffic Signal Additional XML file
Add intersection ID with errors to the list
Output Log Files
Review & Revision
End

Stage 1: Data Preparation

> **Network data structure in Synchro**

- Format: Comma-Separated Value Table (.csv)
- Network (General settings)
- Nodes (Geo-location of each intersection)
- Links (Settings for links)
  - # of lanes, distance, grade, speed, direction (e.g., NB, SB)
- Lanes (Detailed lane info)
  - Direction (NBL, NBT)
- Timeplans (Signal timing plans for each intersection)
  - Control type, cycle length, offset
- Phases (Signal phases each intersection)
  - Min/Max Green, Yellow, Red, BRP

Stage 1: Data Preparation

> **Network data structure in SUMO**
  - Format: XML
  - Configuration (General settings)
  - Edge (setting for edges)
    - Length, geo-location, ROW
  - tlLogic (traffic light logics)
  - Junction (settings for intersections)
    - Intlanes, location
  - Lane & Connection (relationship between two lanes)
    - Fromlanes, tolanes, direction

Synchro vs. SUMO

Features	Synchro	SUMO
Road Link	X Ped lanes X Bus lanes X light rail Link Lanes Nodes	✓ Ped lanes ✓ Bus lanes ✓ Light rail Edge Lane & Connections Junction
Signal control	Timeplans & Phases	tlLogic
General settings	Network	configuration

Stage 2: Connection-to-Direction Mapping

Synchro sample

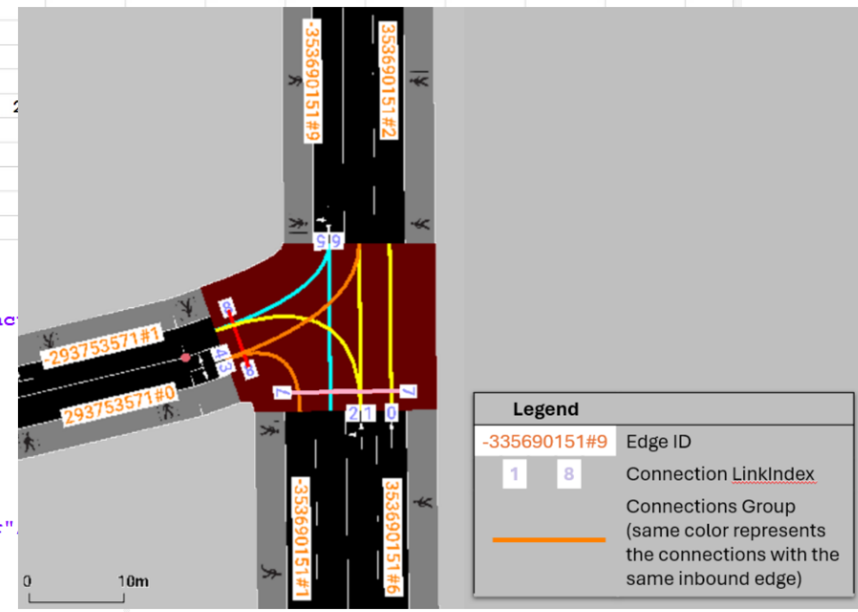
[Lanes]																		
RECORDN	INTID	NBL	NBT	NBR	NBR2	SBL2	SBL	SBT	SBR	EBL	EBT	EBR	EBR2	WBL2	WBL	WBT	WBR
Up Node	6	8	8	8			7	7	7	3	3	3			9	9	
Dest Node	6	3	7	9			9	8	3	7	9	8			8	3	
Lanes	6	0	0	0			0	1	0	1	2	0			1	1	
Phase1	6							4		5	2				1	6	
PermPhas	6						4			6					2		
Allow RTO	6	1	1	1			1	1	1	1	1	1			1	1	

[Timeplans]		
RECORDN	INTID	DATA
Control Ty	6	3
Cycle Len	6	60
Offset	6	52

[Phases]								
RECORDN	INTID	D1	D2	D3	D4	D5	D6	D7
BRP	6	111	112	211	212	121	122	2
MinGreen	6	5	7		7	5	7	
MaxGreen	6	8.5	17.5		21.5	6.5	19.5	
VehExt	6	3	0.2		2	2	0.2	
Yellow	6	3.5	3.5		3.5	3.5	3.5	
AllRed	6	0	1		1	0	1	

SUMO sample

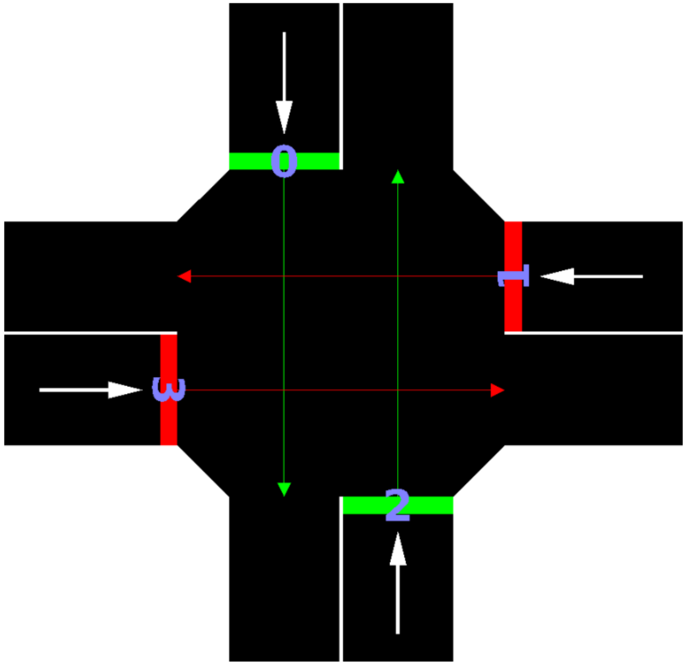
```
<tlLogic id="0" programID="my_program" offset="0" type="ac
  <param key="max-gap" value="3.0"/>
  <param key="detector-gap" value="2.0"/>
  <param key="passing-time" value="2.0"/>
  <param key="vTypes" value=""/>
  <param key="show-detectors" value="false"/>
  <param key="file" value="NULL"/>
  <param key="freq" value="300"/>

  <phase duration="31" minDur="5" maxDur="45" state="GrGr"
  ...
</tlLogic>
```



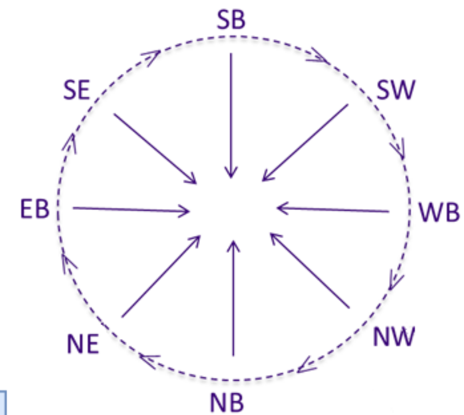

```
ane="1"
'/>
ane="2"
'/>
ne="1"
/>
ne="2"
/>
ne="1"
/>
ne="2"
/>
ane="1"
/>
ane="0"
<connection from=":53073250_w2" to=":53073250_c1" fromLane="0" toLane="0"
 tl="53073250" linkIndex="8" dir="s" state="M"/>
```

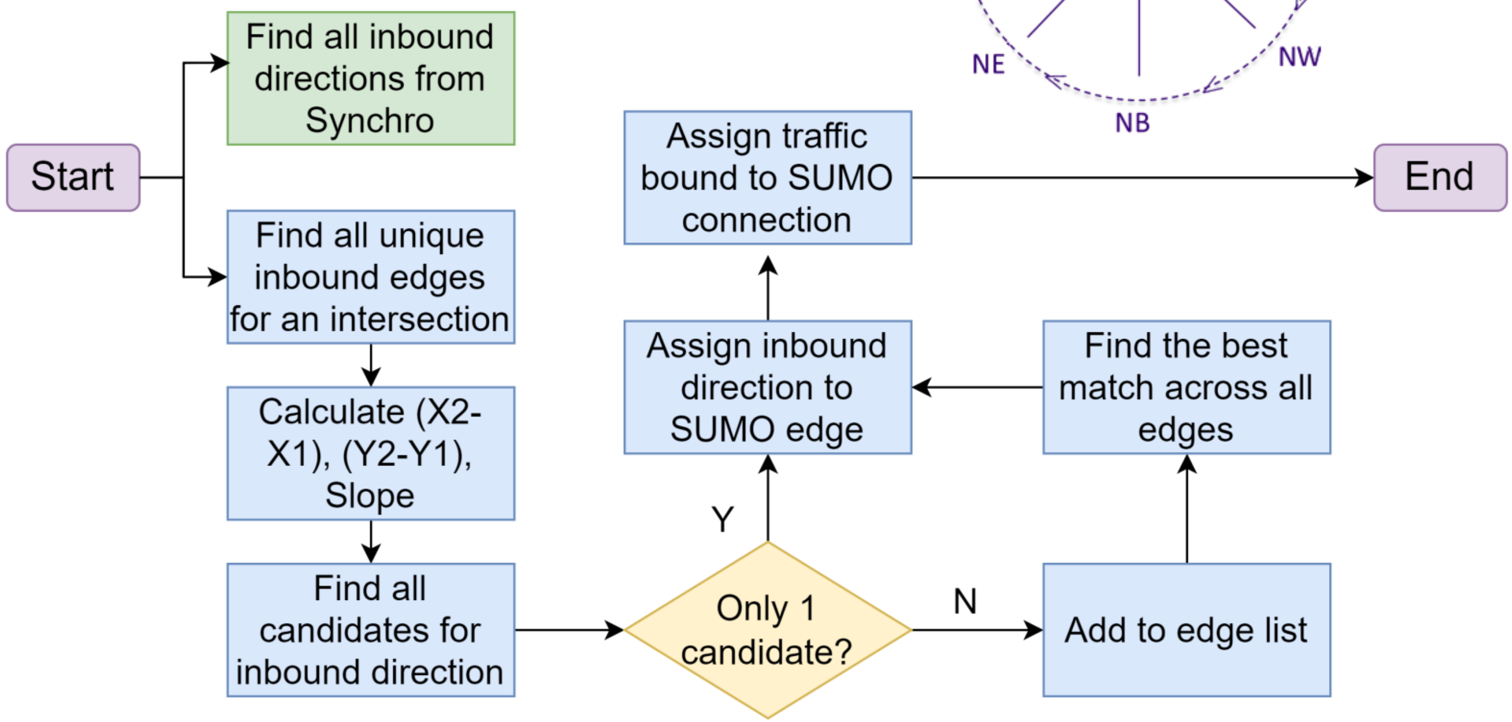
Stage 2: Connection-to-Direction Mapping

- Signal timing rule in SUMO
  - Numbered in a clockwise pattern starting from 0 to 12 o'clock
  - Pedestrian phases is specified after vehicle phases



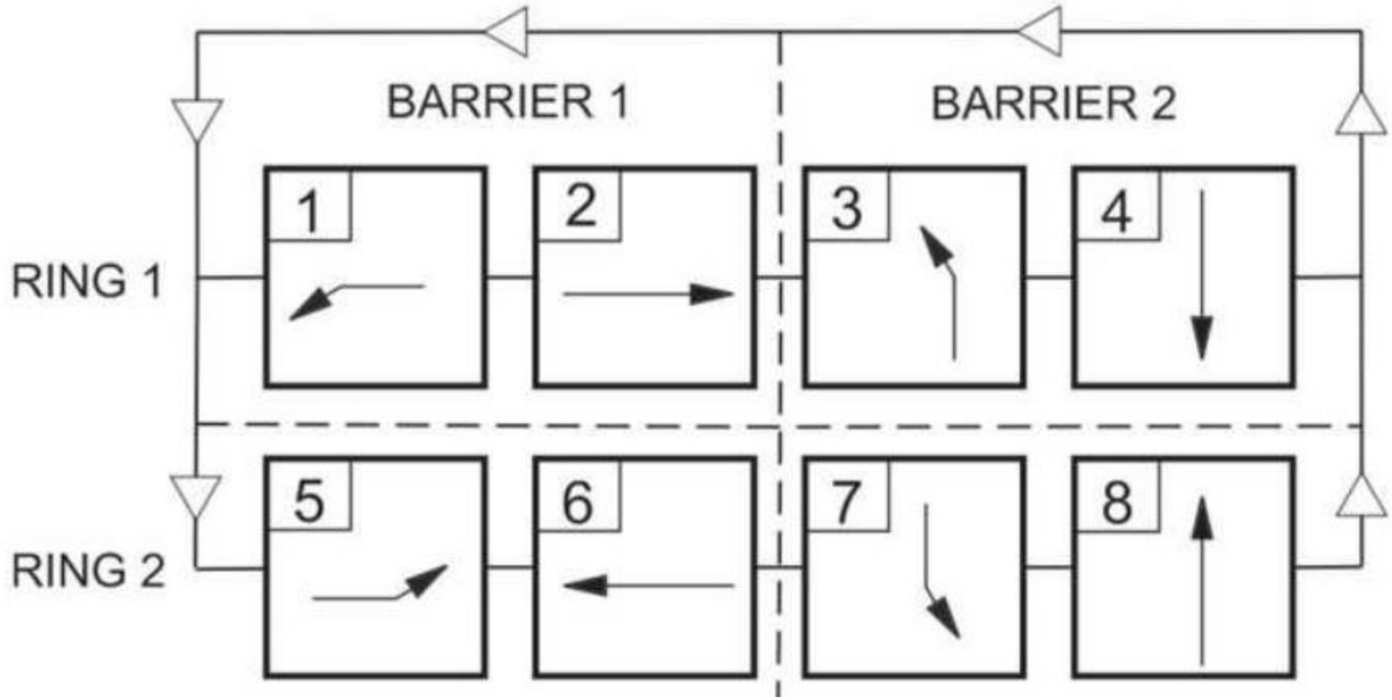
Stage 2: Connection-to-Direction Mapping





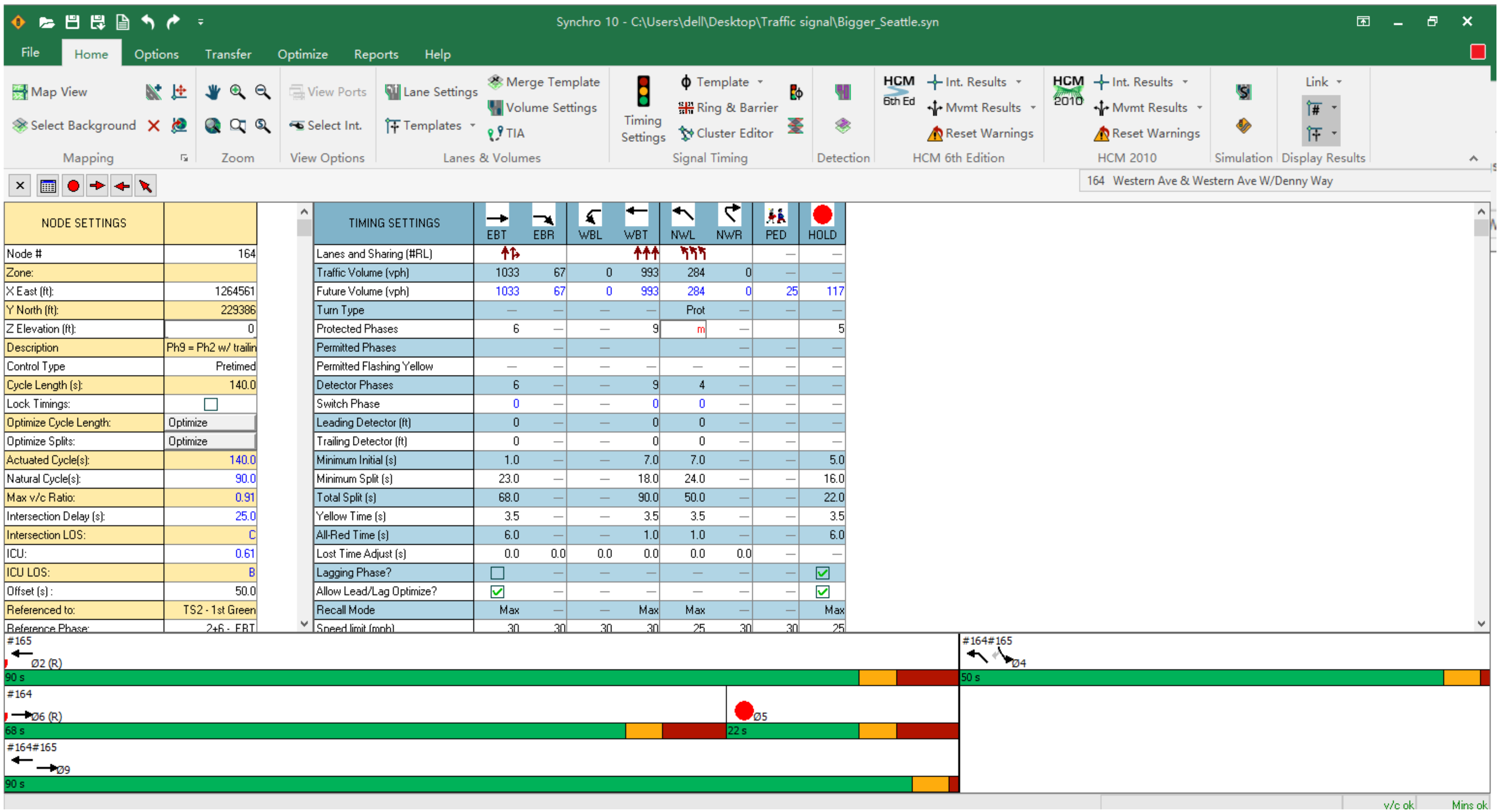
Stage 3: Signal Phase Mapping

> **Ring barrier control**



Stage 3: Signal Phase Mapping

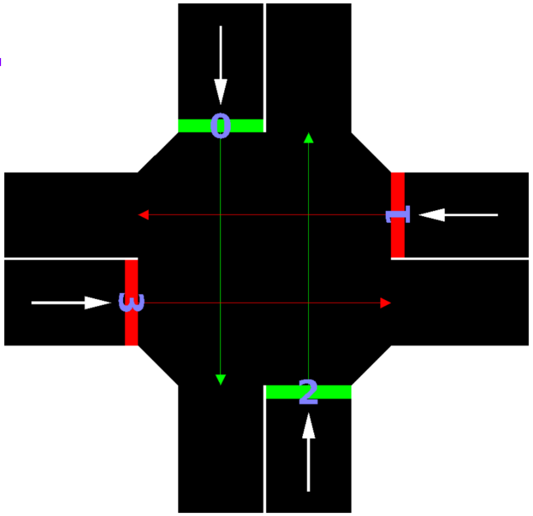
Signal timing setting in Synchro



Stage 3: Signal Phase Mapping

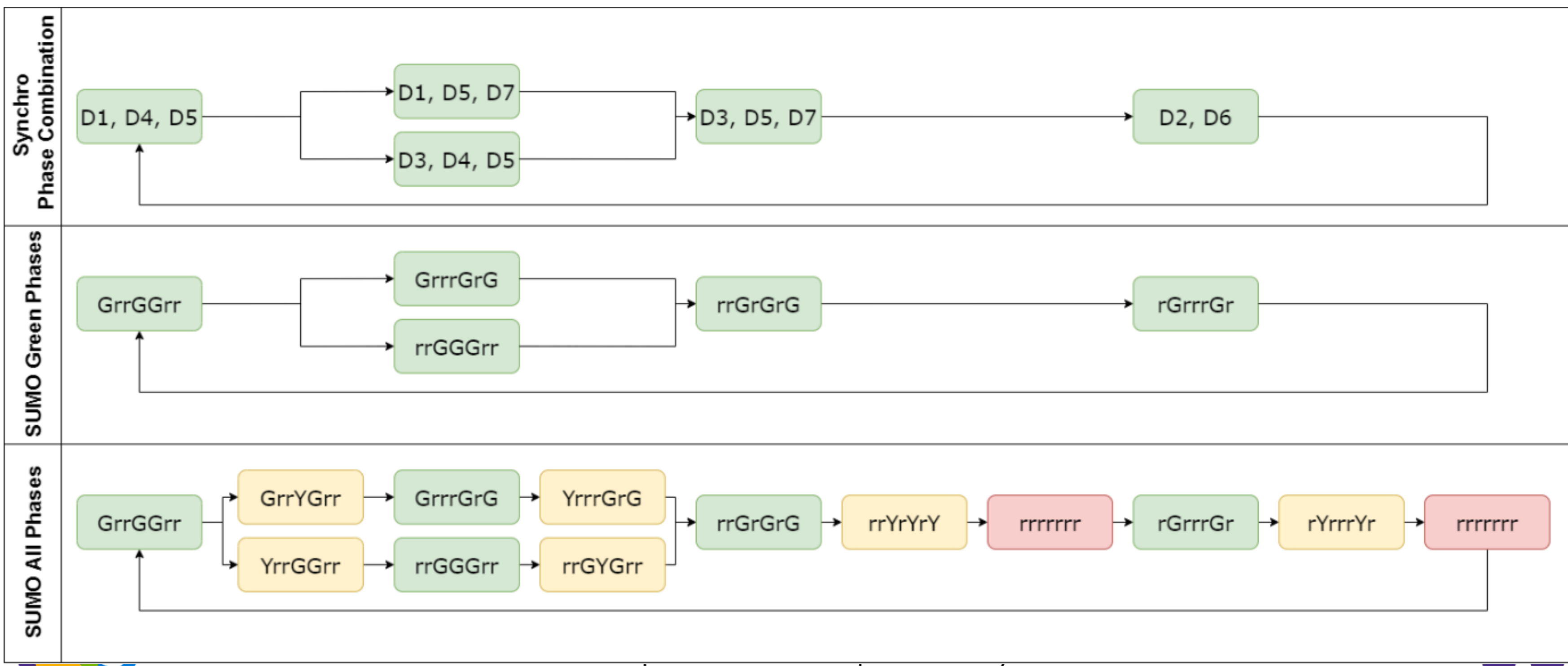
Signal setting in SUMO

```
<tlLogic id="0" programID="my_program" offset="0" type="actuated">
  <param key="max-gap" value="3.0"/>
  <param key="detector-gap" value="2.0"/>
  <param key="passing-time" value="2.0"/>
  <param key="vTypes" value=""/>
  <param key="show-detectors" value="false"/>
  <param key="file" value="NULL"/>
  <param key="freq" value="300"/>

  <phase duration="31" minDur="5" maxDur="45" state="GrGr"/>
  ...
</tlLogic>
```



Stage 3: Signal Phase Mapping

- > **Find phase combination**
- > **Generate states for green phases**
- > **Generate Yellow/Red phases**



Stage 4: Data Revision & Output

- **Logging and Analysis**
  - Logs are generated detailing intersection IDs and causes of issues for further analysis.
- **Validation and Quality Assurance**
  - Validation steps are integrated at each stage to ensure SUMO's signal phases align with those in Synchro.
  - Checking conflict phases
  - Discrepancies are identified, indicating possible misalignments.
- **Manual Revisions**
  - Mismatched intersections necessitate manual revisions to correct misalignments.

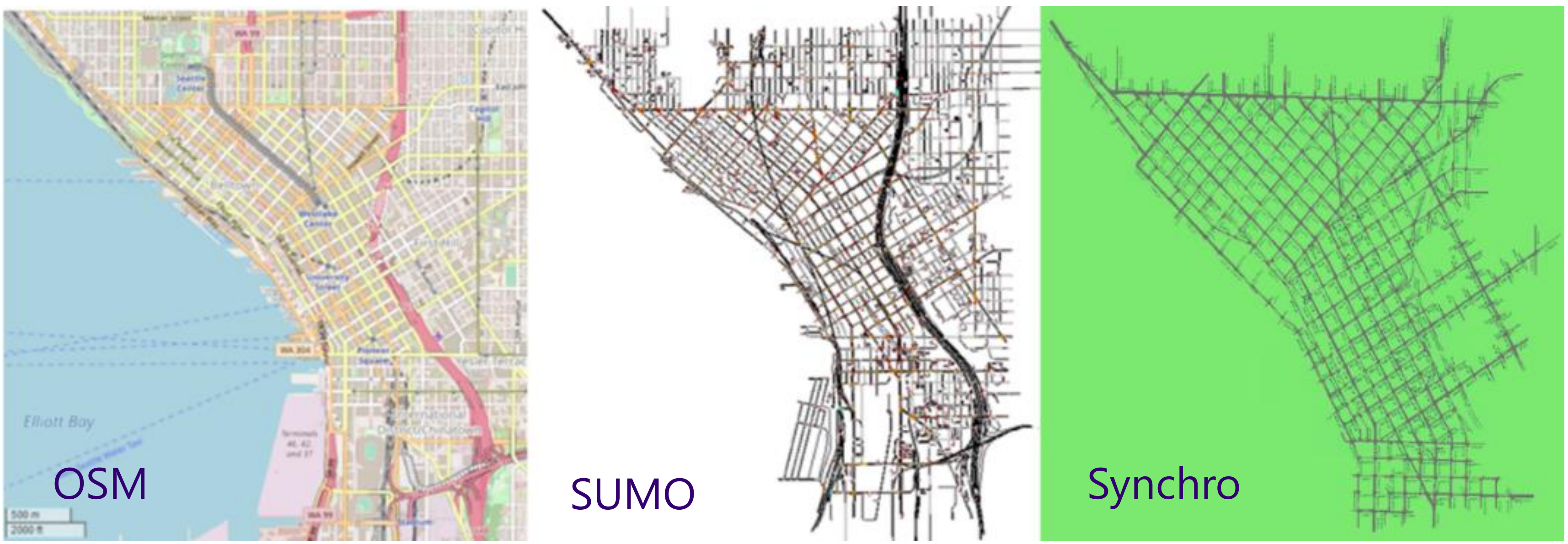
Case Study: SUMO simulations in downtown Seattle

Original network extracted from OSM

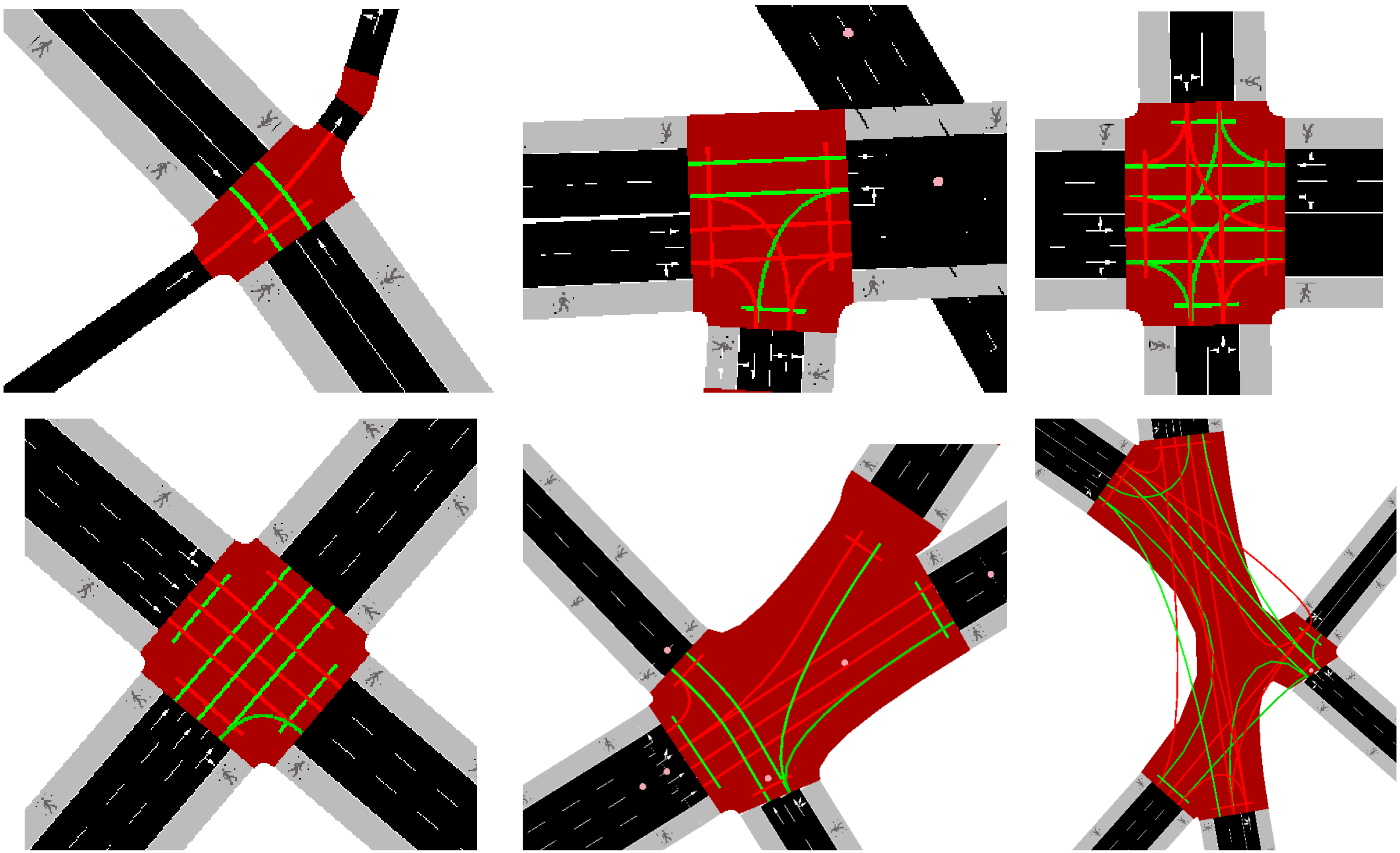
> **Study region**
  - North: Mercer St
  - South: Atlantic St
  - West: Alaskan Way
  - East: 12th Ave

> **Available network feature**
  - Pedestrian lane
  - Bus stop
  - Link light rail
  - TAZ

Case study

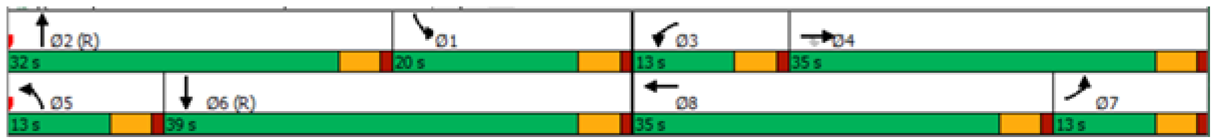


Diverse intersections in Downtown Seattle

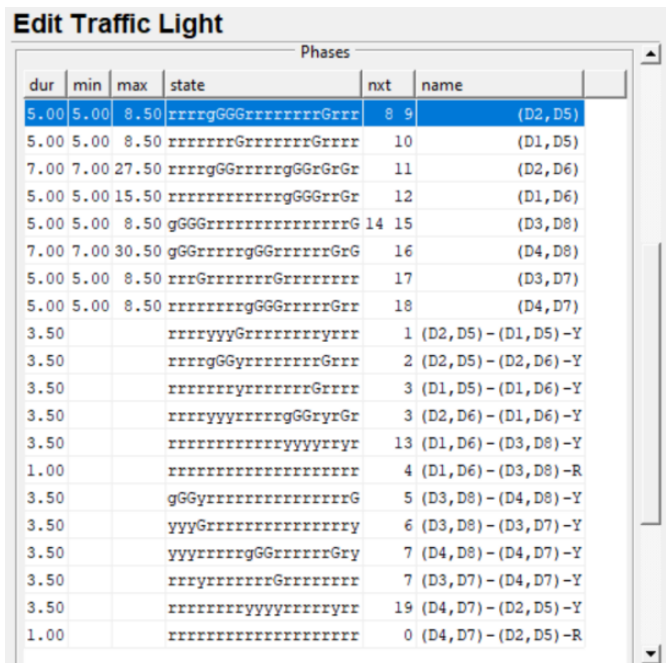


Results

Synchro



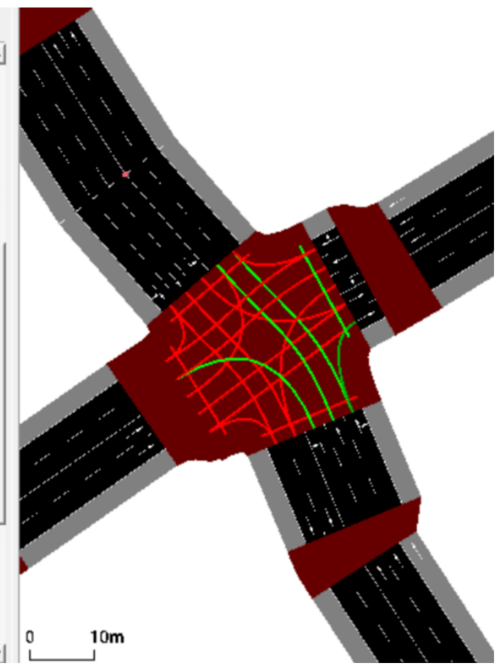
SUMO



Edit Traffic Light

Phases

dur	min	max	state	nxt	name
5.00	5.00	8.50	rrrrgGGrrrrrrrrGrrr	8 9	(D2,D5)
5.00	5.00	8.50	rrrrrrrGrrrrrrrGrrrr	10	(D1,D5)
7.00	7.00	27.50	rrrrgGGrrrrrgGGrGrGr	11	(D2,D6)
5.00	5.00	15.50	rrrrrrrrrrrrgGGGrrGr	12	(D1,D6)
5.00	5.00	8.50	gGGGrrrrrrrrrrrrrrrG	14 15	(D3,D8)
7.00	7.00	30.50	gGGrrrrrgGGrrrrrrGrG	16	(D4,D8)
5.00	5.00	8.50	rrrGrrrrrrrGrrrrrrrr	17	(D3,D7)
5.00	5.00	8.50	rrrrrrrrgGGGrrrrrGrr	18	(D4,D7)
3.50			rrrryyyGrrrrrrrrryrrr	1	(D2,D5)-(D1,D5)-Y
3.50			rrrrgGGyrrrrrrrrrGrrr	2	(D2,D5)-(D2,D6)-Y
3.50			rrrrrrryrrrrrrrrGrrrr	3	(D1,D5)-(D1,D6)-Y
3.50			rrrryyyrrrrrgGGryrGr	3	(D2,D6)-(D1,D6)-Y
3.50			rrrrrrrrrrrryyyyrryr	13	(D1,D6)-(D3,D8)-Y
1.00			rrrrrrrrrrrrrrrrrrrr	4	(D1,D6)-(D3,D8)-R
3.50			gGGyrrrrrrrrrrrrrrrG	5	(D3,D8)-(D4,D8)-Y
3.50			yyyGrrrrrrrrrrrrrrry	6	(D3,D8)-(D3,D7)-Y
3.50			yyyrrrrrgGGrrrrrrGry	7	(D4,D8)-(D4,D7)-Y
3.50			rrryrrrrrrrGrrrrrrrr	7	(D3,D7)-(D4,D7)-Y
3.50			rrrrrrrryyyyrrrrryrr	19	(D4,D7)-(D2,D5)-Y
1.00			rrrrrrrrrrrrrrrrrrrr	0	(D4,D7)-(D2,D5)-R



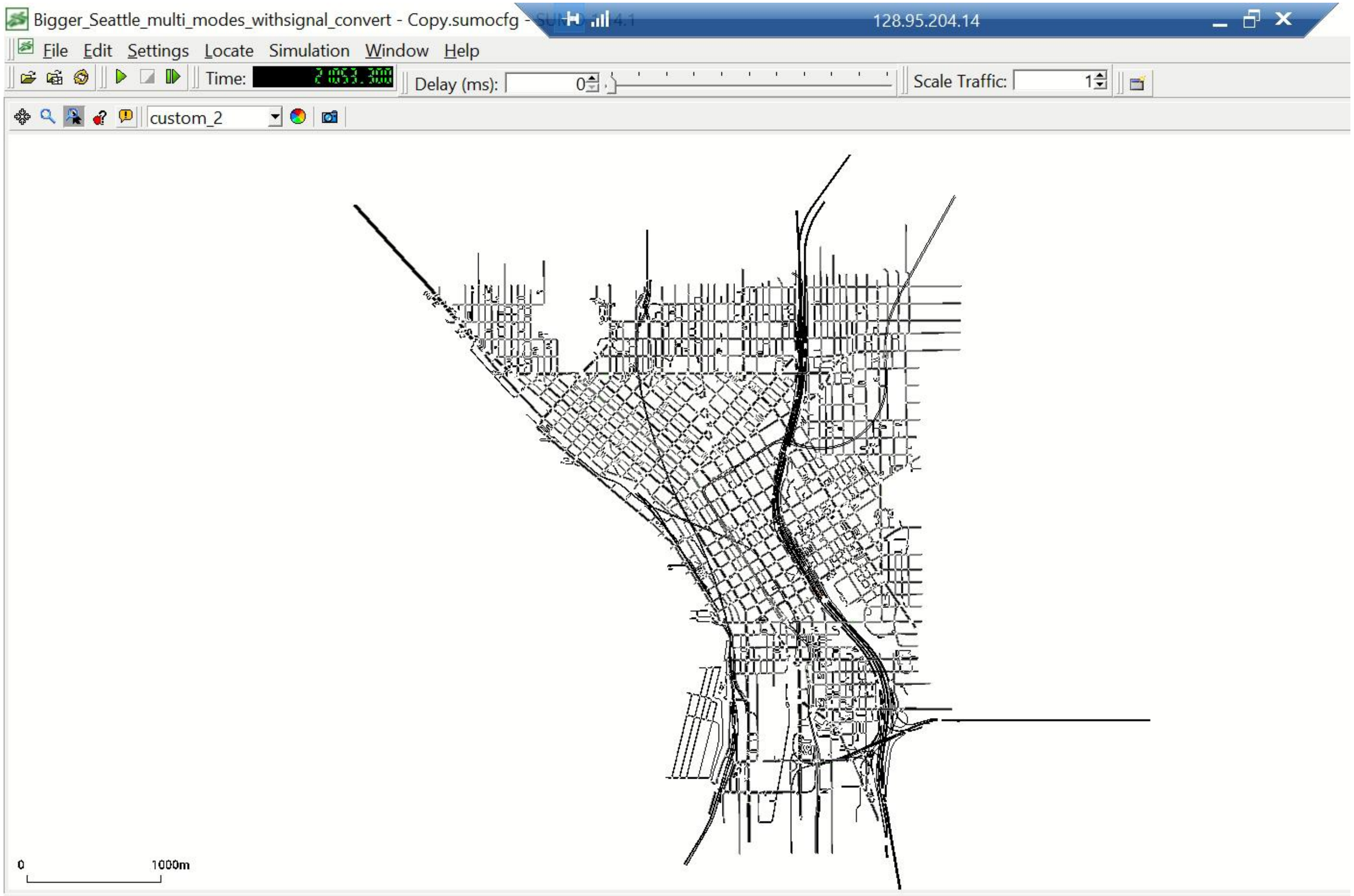
Signal integration results

Scenario	# of Intersections	Successful Converted Intersections	Success Rate
Dearborn Street Arterial	5	5	100%
Downtown Seattle	281	239	85.1%

168 TAZs

39286 edges

Simulation display



Conclusion & Future Step

> **Conclusion**

- Proposed four-stage approach and the integration Process Examined
- Developed a semi-automated pipeline in Python
- Tested on two Synchro models in downtown Seattle with an 85% success rate

> **Future Step**

- Framework Expansion
- Algorithmic Enhancements (for higher accuracy)
- Advanced Features (Coordinated signal control)
- Broader Integration Goals (not just traffic signal)

THANKS!

QUESTIONS & COMMENTS?