Improving Transit Operations Through Three Communities for PVTA and UMASS Transit

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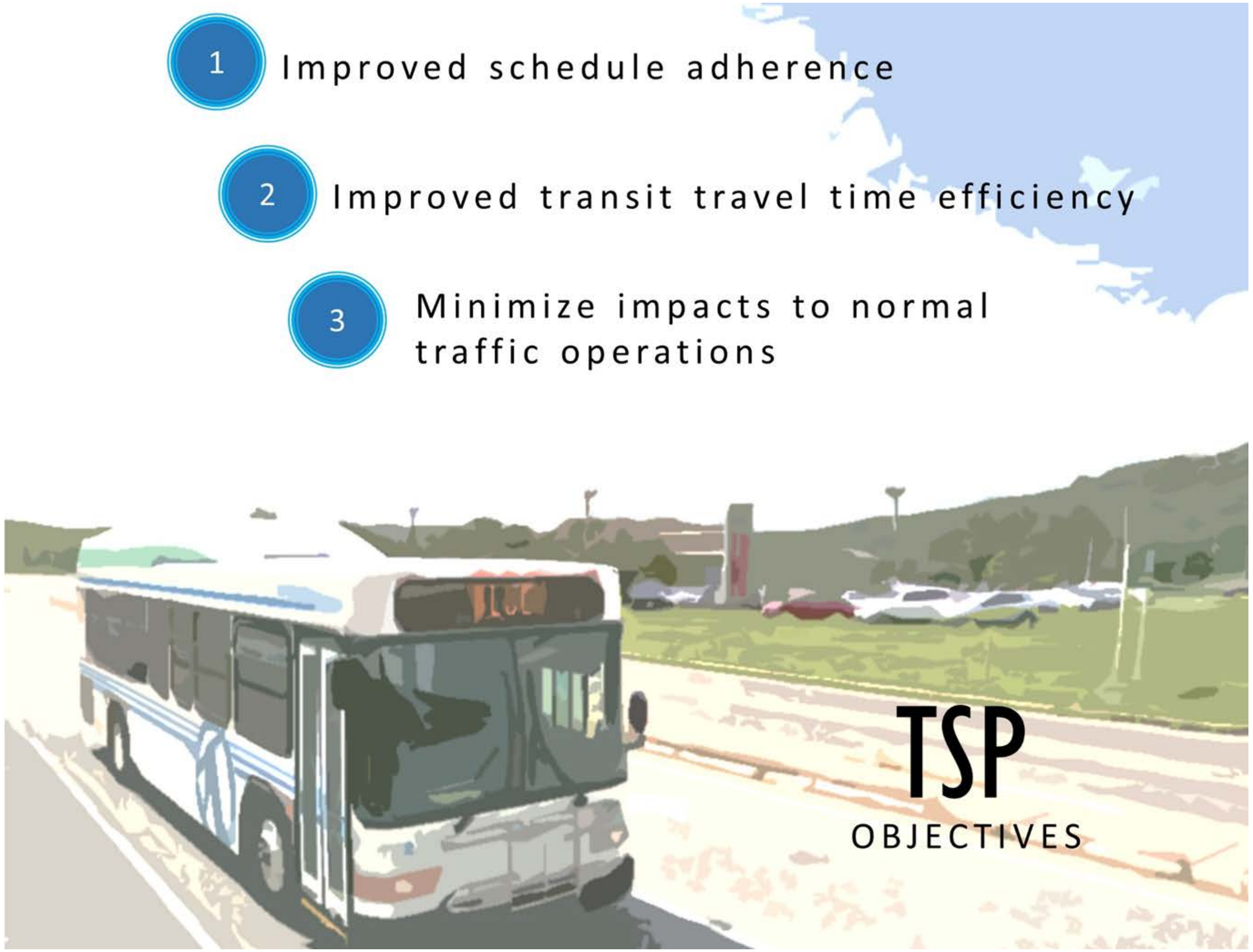
GPI

Engineering | Design | Planning | Construction Management

Typical Project Goals



TSP vs. Pre-Emption

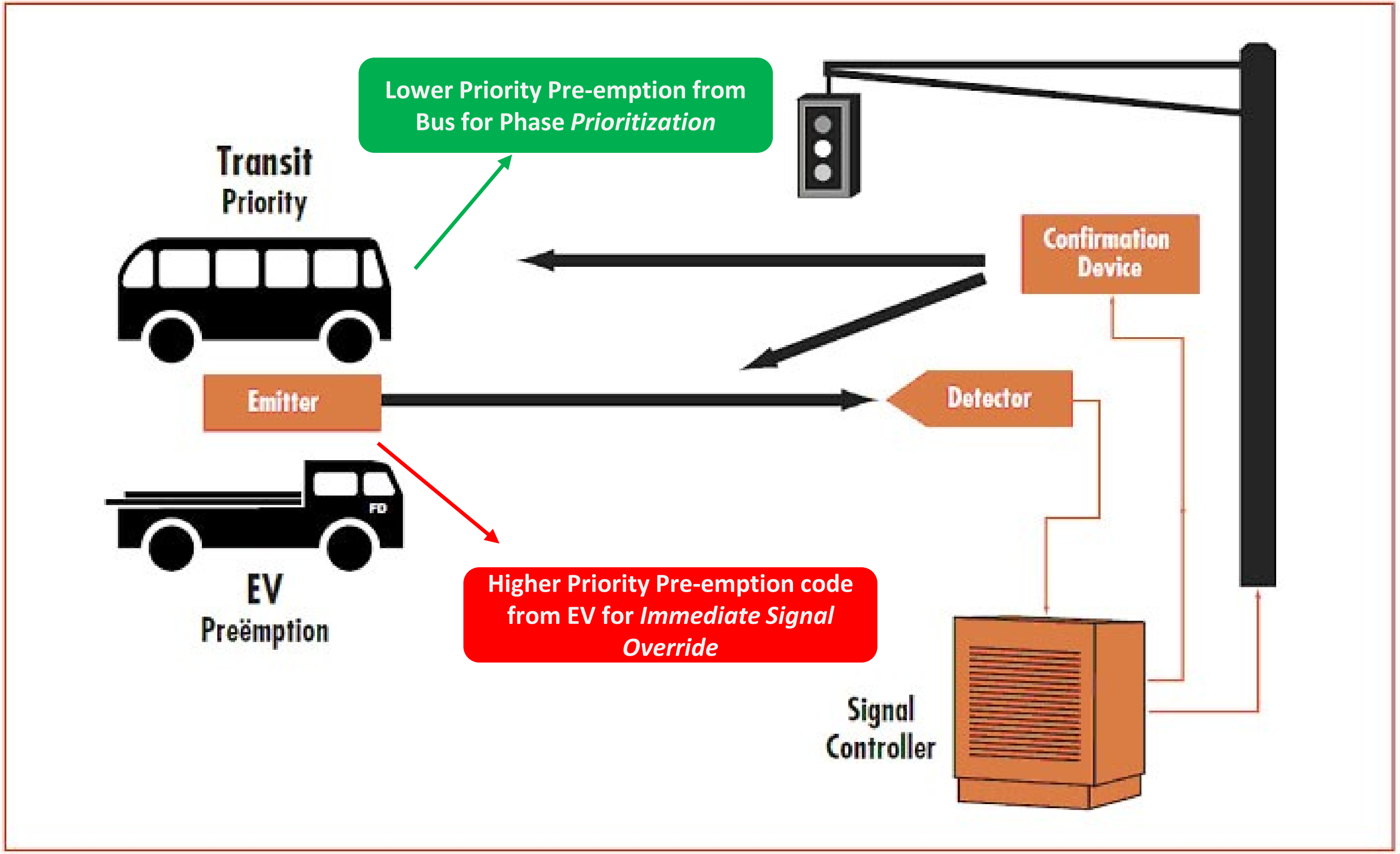


Figure 1: Priority and Preemption Example at Local Intersection Level[2]

According to *Transit Signal Priority: A Planning and Implementation Handbook* TSP is an operational strategy that facilitates the movement of transit vehicles, either buses or streetcars, through traffic signal controlled intersections. *Signal priority should not be confused with signal pre-emption, which while similar (and the terms are often used synonymous), they are in fact different processes.*

Source: Transit Signal Priority: A Planning and Implementation Handbook, May 2005, US DOT

TSP TYPES – Green Extend vs. Early Return

Green Extension

Only effective if bus arrives during Green interval

Early Return to Green

Shortens opposing phases to provide Green sooner

TSP TYPES – Conditional vs Unconditional

Conditional

- TSP Only Activated when pre-established criteria are satisfied
  - Schedule Adherence
  - Ridership Level
  - Specialized Service
  - Less Disruptive to other traffic
- Requires coordination and integration with AVL System or similar

Unconditional

Provides Priority Service any time a priority call is placed

- More disruptive to other traffic
- Could lead to schedule disruption

Requires minimal additional infrastructure

Communication between bus and signal

System Design Process

Planning

↓

Physical Assessment

↓

Engineering (Macro-Simulation)

↓

Modeling (Micro-Simulation)

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Construction Documents

TSP System*

Vehicle ID

Vehicle Recognition

Assessment

Implementation

*Collaboration

Vehicle Detection -AVI Technology

The system consists of three components:

- A coded transmitter mounted to the underside of the vehicle
- An inductive loop in the pavement surface
- Receiver mounted in the traffic control cabinet.

Advantages

- Installation of loops is similar to standard vehicle loop installation.
- Can provide “check in” and “check out” functionality if additional loop is installed in departure lane.
- Not impacted by weather conditions.
- In pavement loops can also be used to detect traffic and provide actuated signal operations; however, the optimal placement for transit detection may not provide optimal vehicle detection.

Limitations

- Placement of loop detectors is critical.
- May need additional loops cut if existing loop detection is not adequately spaced.
- Requires pavement to be in good condition to cut new loops.
- Loop detectors can be damaged by pavement failures, utility cuts, etc.

Vehicle Detection –**RFID**

The system consists of three components:

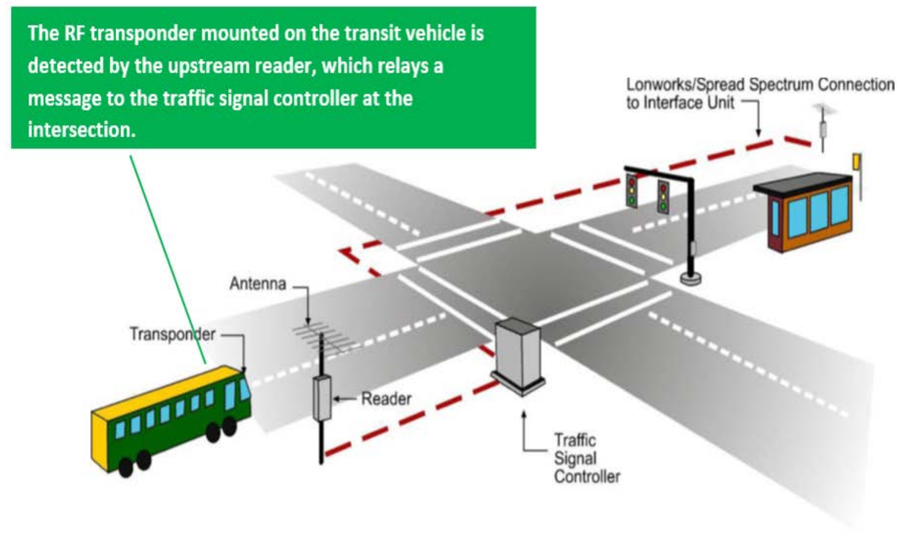
- A vehicle mounted RF transmitter
- A wayside reader
- A priority interface device.

Advantages

- Line of sight and visibility are not required for detection.
- Requires little new equipment on the bus, and per vehicle cost of installing is low.

Limitations

- Equipment required is not easily retrofitted into existing controller equipment cabinets.
- Requires suitable curbside mounting locations upstream of the intersections for the tag readers and communications, power, overhead mount.
- Communications (in most cases conduit and cable) needs to be installed between the curbside monitoring location and the traffic controller.
- Check-in/check-out capabilities can be provided if two wayside detectors (and mast arms) are installed on each side of the intersection.
- This technology is not predictive.



Graphic credit: King County, WA

Vehicle Detection –OPTICAL

The system consists of three components:

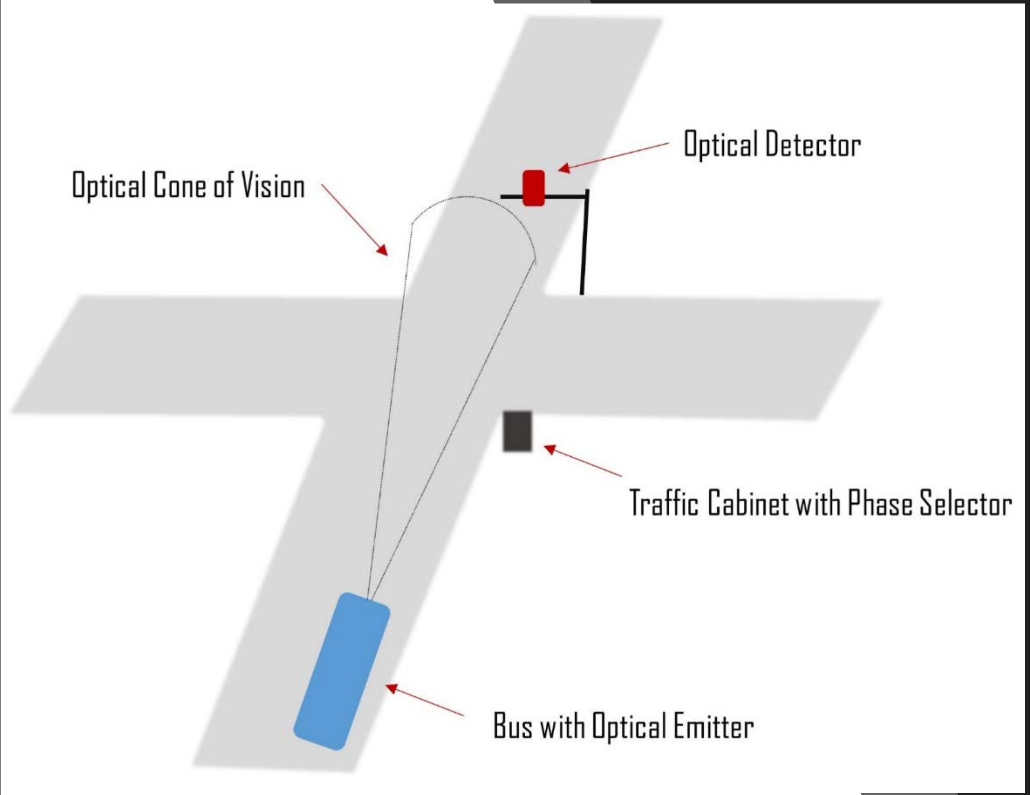
- Emitter mounted on each vehicle
- Receiver mounted at or near the intersection
- Phase selector in the controller cabinet

Advantages

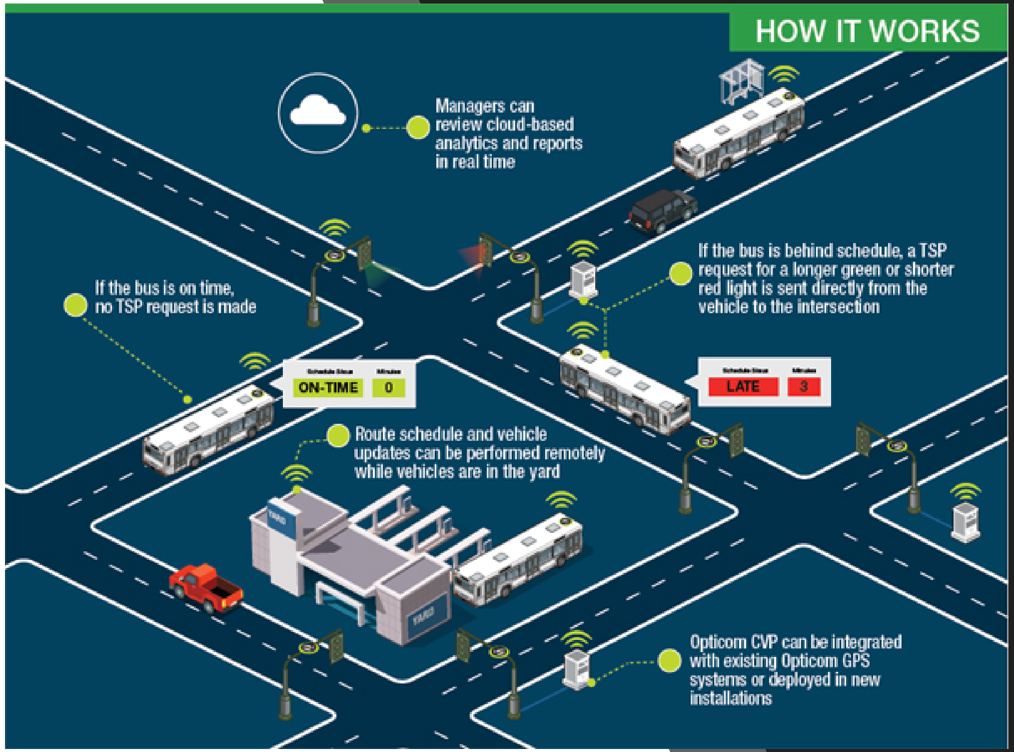
- Can be used simultaneously by both emergency service providers and by transit vehicles Optical receivers may already be installed for Emergency Vehicle pre-emption.
- Emitters and receivers can be coded or uncoded.
- In-cabinet technology can log priority requests and there is little customization of traffic controller cabinets required.
- This technology has been field-tested and is a proven technology.

Limitations

- Requires direct line of sight between the emitter and detector.
- Latency in receiving requests from optical emitter may occur due to range acquisition
- Higher Installation costs



Vehicle Detection –GPS



Functionally the GPS interface operates similar to the Optical system.

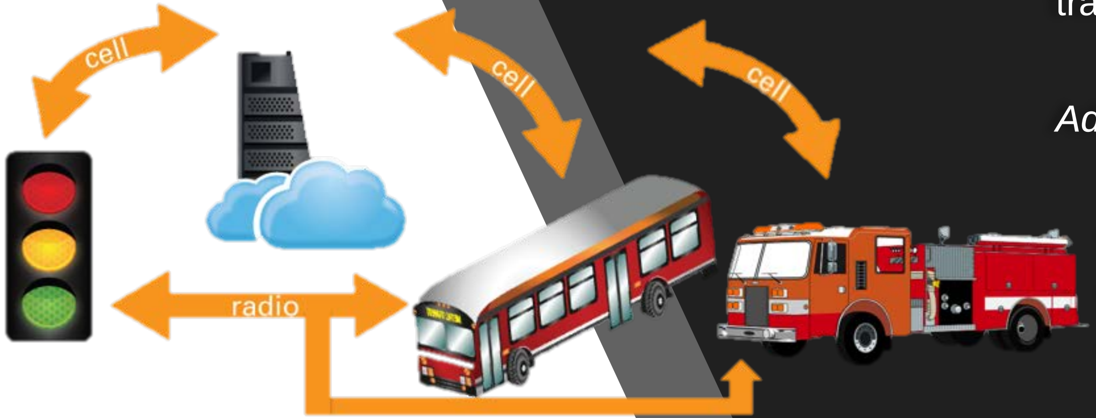
Advantages

- Wireless communications reduce infrastructure costs
- Line of sight and visibility are not required
- Dual Mode (Optical and GPS)
- Check-in/check-out capabilities to allow efficient return to non-TSP operations.
- GPS technology could potentially be integrated into existing AVL.

Limitations

- Existing AVL GPS, may not be compatible with the TSP GPS system.
- GPS system may fail to locate the transit vehicle in some locations due to “urban canyon” effect (where the GPS signal cannot be properly received), which would prevent adequate TSP operations.

Vehicle Detection –WiFi & Cellular



Wi-Fi and Cellular Digital Packet Data (CDPD) wireless communication systems is becoming increasingly popular for ITS applications. The wireless communication system is similar to what is implemented on mobile technology devices. Packets of information are sent via radio waves between the transit vehicle (mobile client) and each intersection (terminal client), both of which are IP addressable. Infrastructure on the bus and in the traffic signal controller cabinet communicates within the available range of the network.

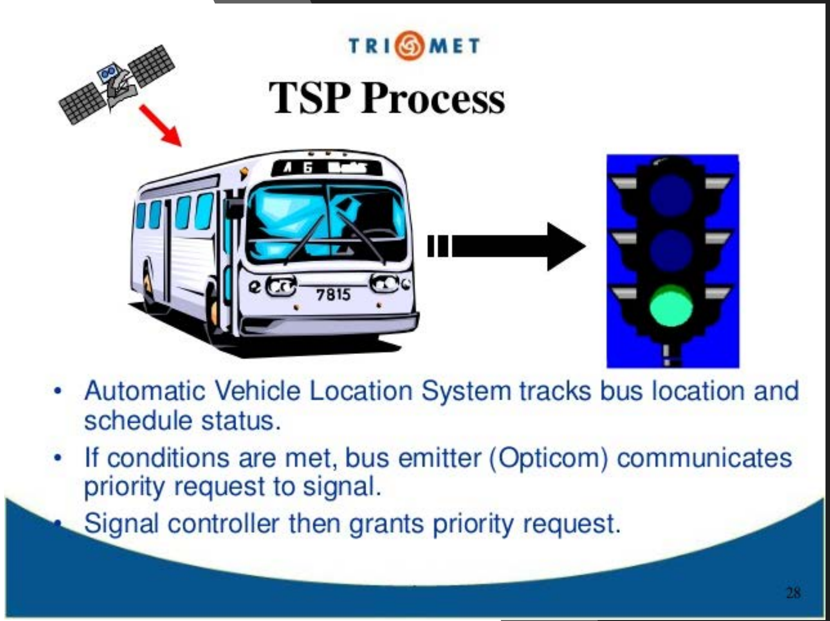
Advantages

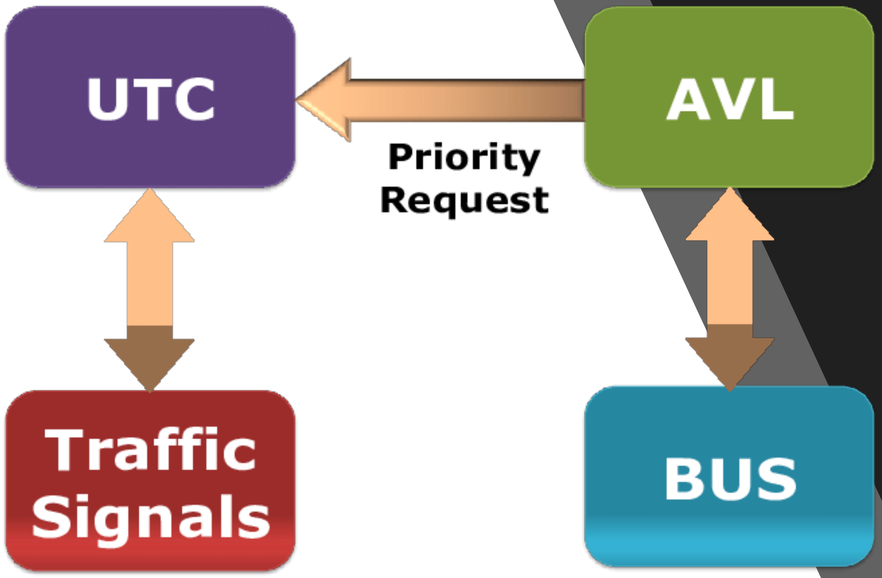
- Effective use of new technology for implementation of NTCIP messages.
- Greater range than many other detection technologies.
- Data flows may be between the vehicle and traffic signal controller, and between the traffic signal controllers using various communications medium available
- Relatively low hardware cost

Limitations

- Initial costs associated with development of specific hardware tailored to meet local traffic signal systems' needs
- Detection range may be limited by the coverage of the network
- May be sensitive to line-of-sight restrictions depending on type of antenna used.

Vehicle Detection –AVL





An AVL (Automatic Vehicle Location) system continually senses or calculates, at intervals, the location of transit buses along the roadway corridor. Bus location can be used in various applications, including schedule adherence monitoring, operational control and incident management through computer-assisted dispatching, real-time customer information, passenger counting, and transit signal priority, etc. Most AVL systems now use GPS to determine vehicle location.

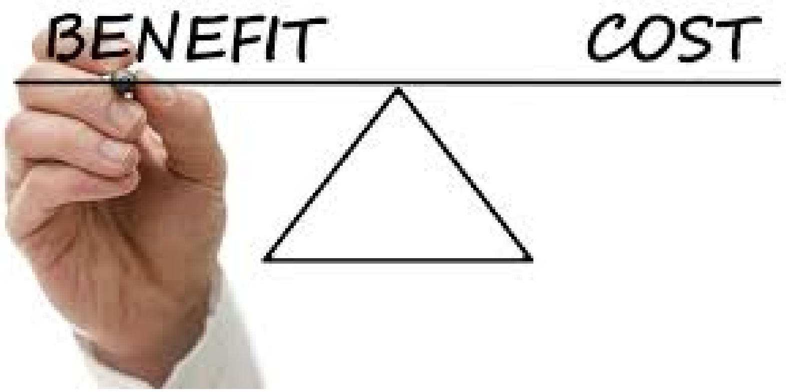
Advantages

- No additional hardware on the transit vehicle if a functional AVL system is already in place.
- Data flows may be directed to the traffic or transit management center.
- Ability to transfer information such as vehicle location, speed, and schedule adherence.
- System provides check-in and check-out capabilities to allow efficient return to non-TSP operation.
- Line of sight and visibility are not required

Limitations

- Latency in receiving requests from buses per their polling rate (communication frequency) Requires real-time communication between Traffic Management Center (signal system) and local traffic signal controller

- Due to the infrastructure investment required for TSP, modeling is critical to understand the costs and benefits.



- **Microsimulation modeling program Aimsun was chosen for simulation, and Synchro was chosen for optimization of signals**

Aimsun

Trafficware

Simulation Process

Create Base Condition Simulation

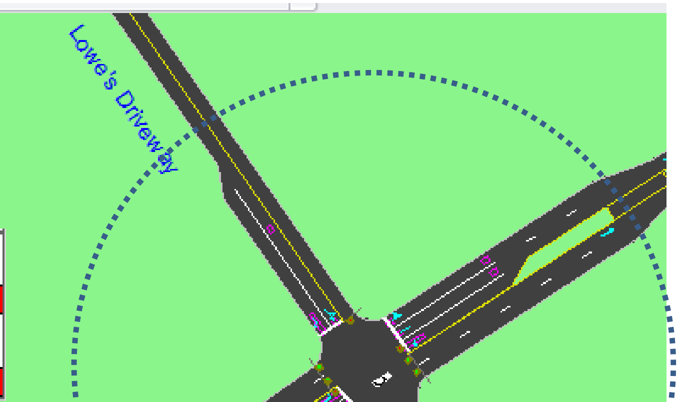
Create Simulation with Optimized Signal Times & TSP

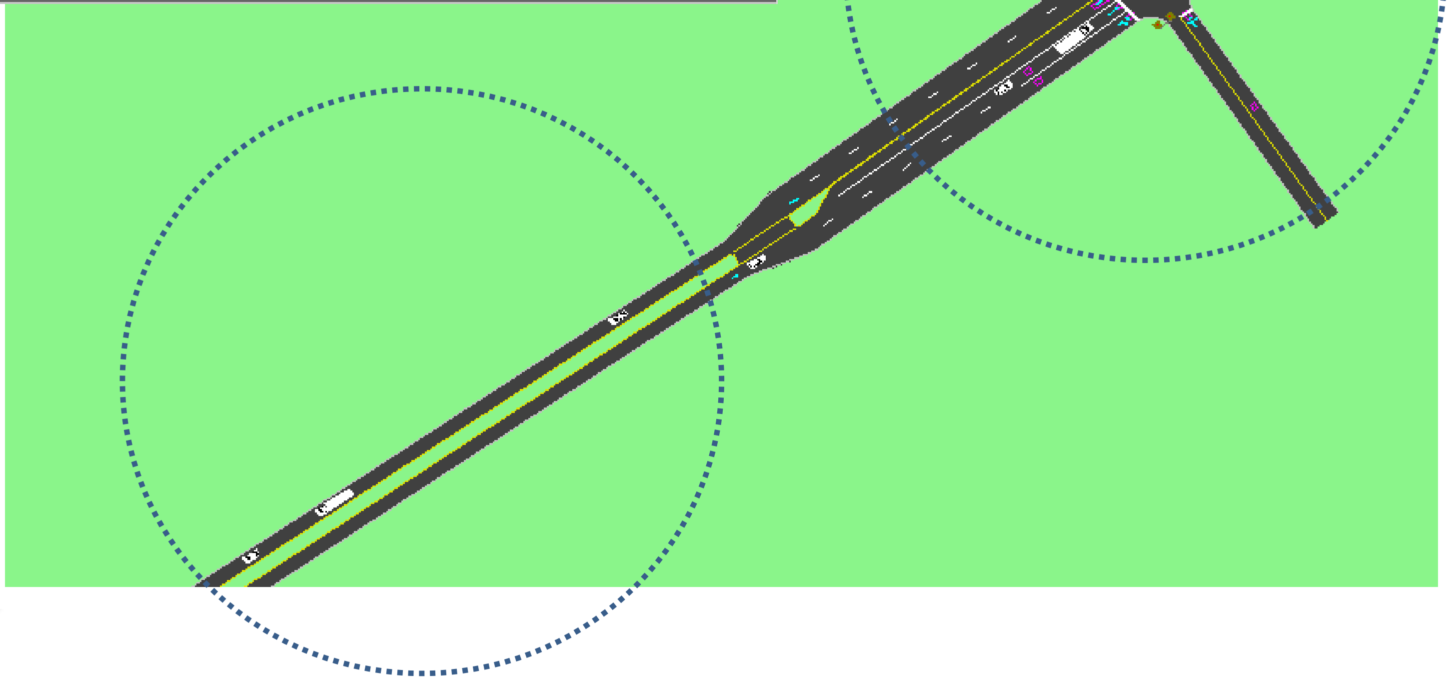
“Turn Off” TSP to Review Impacts

Fine Tune

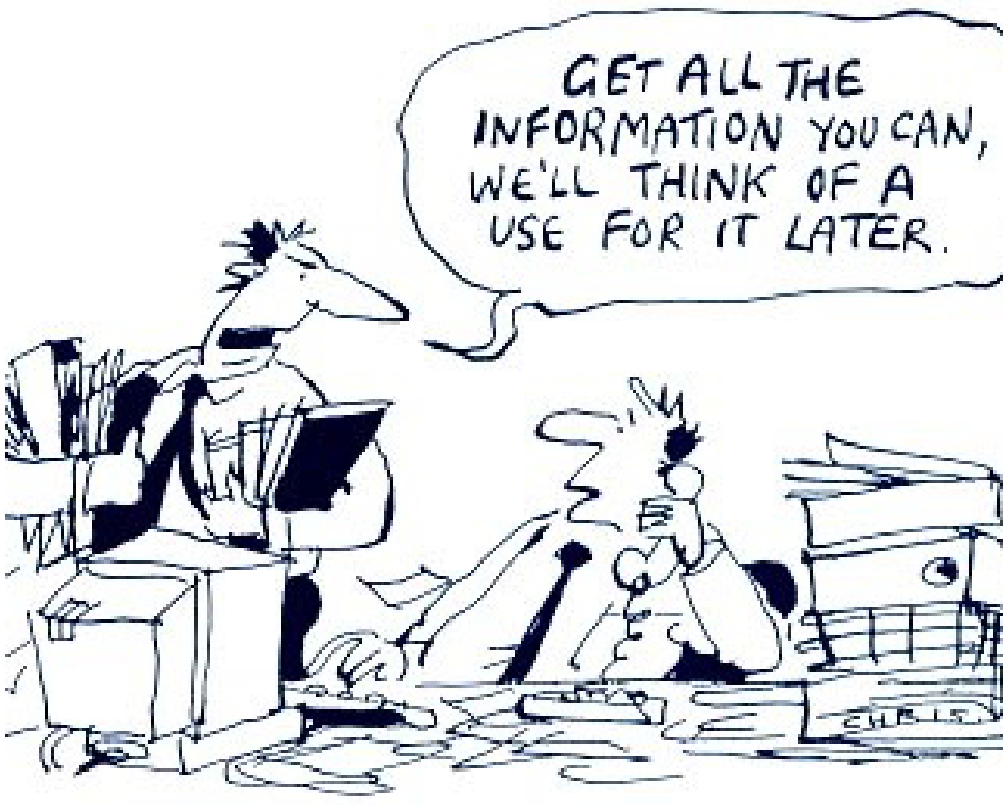
Question:

- **How do we determine the TSP parameters, which TSP features to use and at which intersections?**





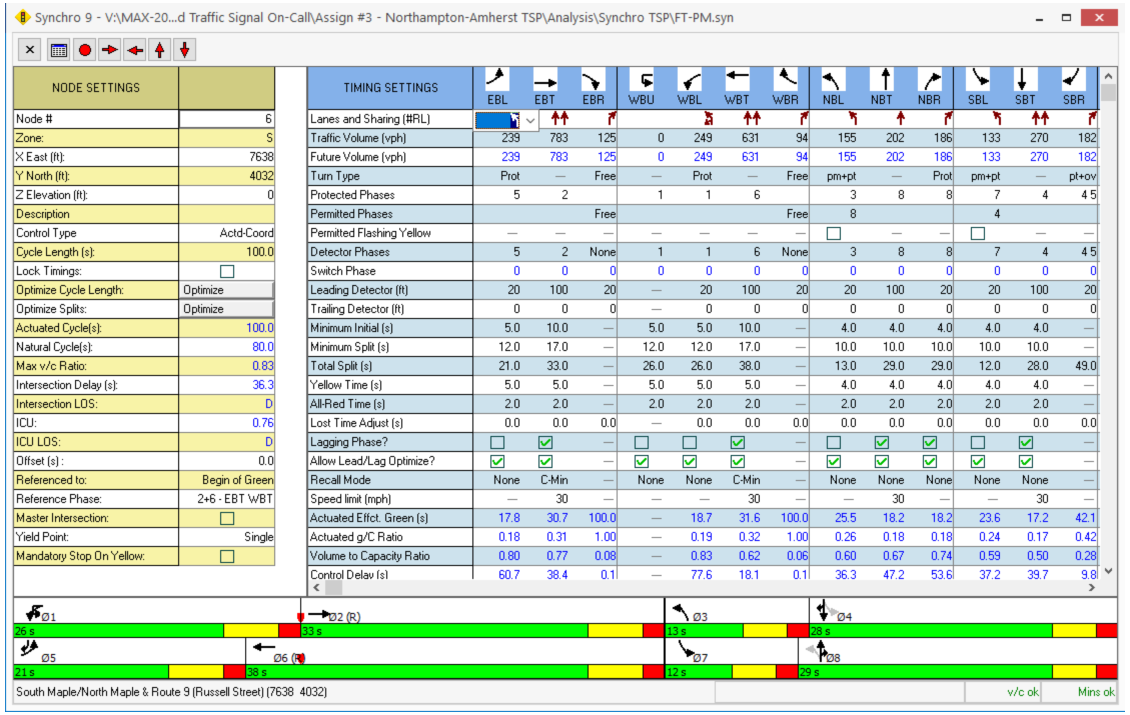
- **For a GPS TSP system, we need to**
  - determine at what distance should TSP be activated
  - which functions should be activated (early return to green, green extension)
  - and for how much time



- **First step is to gather field data including:**
  - Vehicle counts
  - Signal timing
  - Roadway geometry
  - Speeds
  - Car travel time (4 runs in each direction, for 3 peak periods)
  - Bus information (data received from transit agency)
    - *travel times*
    - *frequency*
    - *schedule*
    - *stop locations*
    - *stop type (pull off/stop in lane)*
    - *dwell time at stops*
  - PVTA project is 10 miles long with 24 signalized intersections and many unsignalized intersections
  - Advanced Transit project chose isolated areas, not the whole route (many stretches without signals/major intersections)

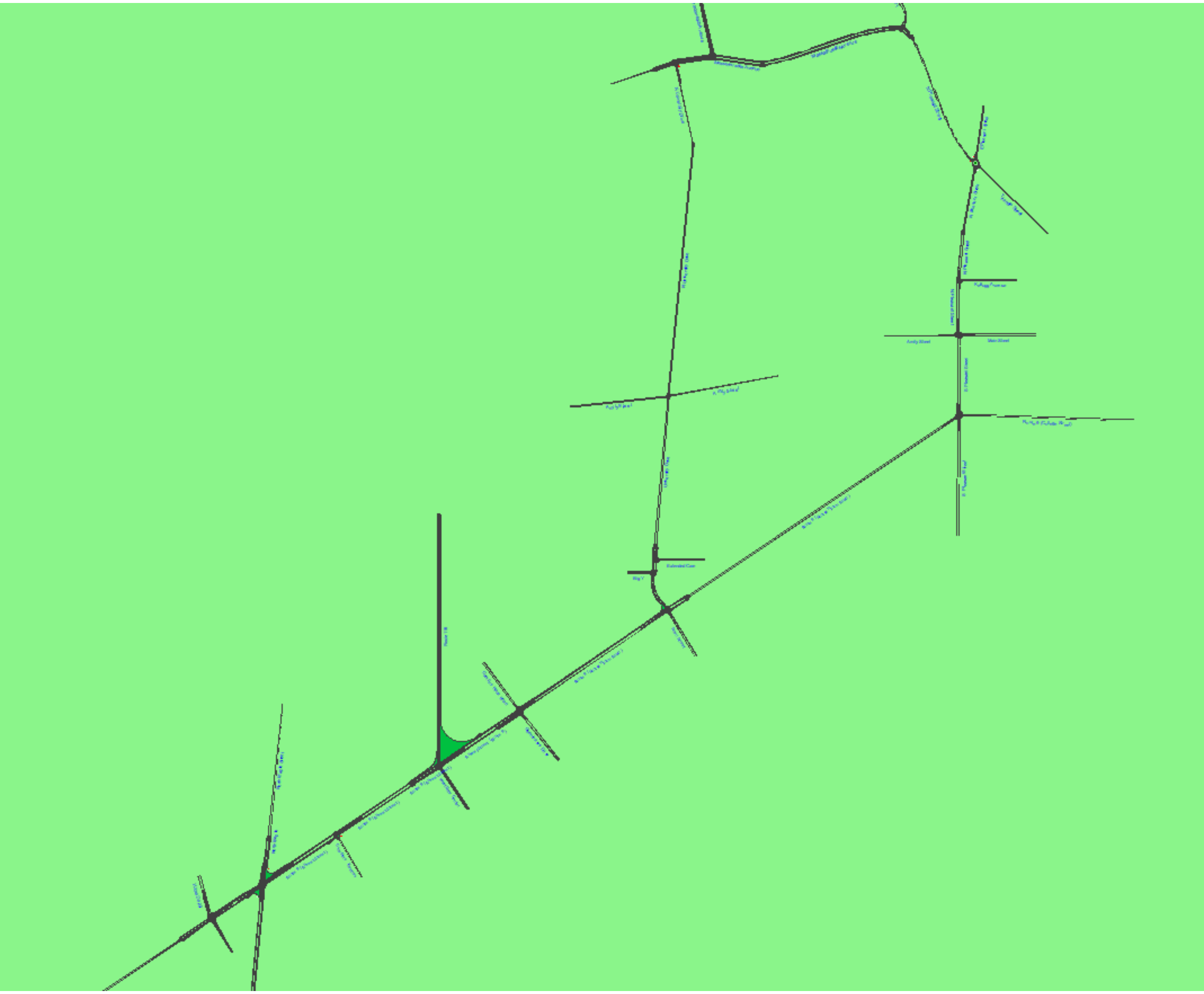
Synchro

- **Base model first built in Synchro**
- **Timings optimized as starting point for TSP timing adjustments**
- <u>Note</u>: Correcting Y/R and Ped times may result in reduced performance



NODE SETTINGS	
Node #	6
Zone:	S
X East (ft):	7638
Y North (ft):	4032
Z Elevation (ft):	0
Description	
Control Type	Actd-Coord
Cycle Length (s):	100.0
Lock Timings:	☐
Optimize Cycle Length:	Optimize
Optimize Splits:	Optimize
Actuated Cycle(s):	100.0
Natural Cycle(s):	80.0
Max v/c Ratio:	0.83
Intersection Delay (s):	36.3
Intersection LOS:	D
ICU:	0.76
ICU LOS:	D
Offset (s) :	0.0
Referenced to:	Begin of Green
Reference Phase:	2+6 - EBT WBT
Master Intersection:	☐
Yield Point:	Single
Mandatory Stop On Yellow:	☐

TIMING SETTINGS	EBL	EBT	EBR	WBU	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lanes and Sharing (#RL)													
Traffic Volume (vph)	239	783	125	0	249	631	94	155	202	186	133	270	182
Future Volume (vph)	239	783	125	0	249	631	94	155	202	186	133	270	182
Turn Type	Prot	—	Free	—	Prot	—	Free	pm+pt	—	Prot	pm+pt	—	pt+ov
Protected Phases	5	2		1	1	6		3	8	8	7	4	4 5
Permitted Phases			Free				Free	8			4		
Permitted Flashing Yellow	—	—	—	—	—	—	—	☐	—	—	☐	—	—
Detector Phases	5	2	None	1	1	6	None	3	8	8	7	4	4 5
Switch Phase	0	0	0	0	0	0	0	0	0	0	0	0	0
Leading Detector (ft)	20	100	20	—	20	100	20	20	100	20	20	100	20
Trailing Detector (ft)	0	0	0	—	0	0	0	0	0	0	0	0	0
Minimum Initial (s)	5.0	10.0	—	5.0	5.0	10.0	—	4.0	4.0	4.0	4.0	4.0	—
Minimum Split (s)	12.0	17.0	—	12.0	12.0	17.0	—	10.0	10.0	10.0	10.0	10.0	—
Total Split (s)	21.0	33.0	—	26.0	26.0	38.0	—	13.0	29.0	29.0	12.0	28.0	49.0
Yellow Time (s)	5.0	5.0	—	5.0	5.0	5.0	—	4.0	4.0	4.0	4.0	4.0	—
All-Red Time (s)	2.0	2.0	—	2.0	2.0	2.0	—	2.0	2.0	2.0	2.0	2.0	—
Lost Time Adjust (s)	0.0	0.0	0.0	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lagging Phase?	☐	☑	—	☐	☐	☑	—	☐	☑	☑	☐	☑	—
Allow Lead/Lag Optimize?	☑	☑	—	☑	☑	☑	—	☑	☑	☑	☑	☑	—
Recall Mode	None	C-Min	—	None	None	C-Min	—	None	None	None	None	None	—
Speed limit (mph)	—	30	—	—	—	30	—	—	30	—	—	30	—
Actuated Effct. Green (s)	17.8	30.7	100.0	—	18.7	31.6	100.0	25.5	18.2	18.2	23.6	17.2	42.1
Actuated g/C Ratio	0.18	0.31	1.00	—	0.19	0.32	1.00	0.26	0.18	0.18	0.24	0.17	0.42
Volume to Capacity Ratio	0.80	0.77	0.08	—	0.83	0.62	0.06	0.60	0.67	0.74	0.59	0.50	0.28
Control Delay (s)	60.7	38.4	0.1	—	77.6	18.1	0.1	36.3	47.2	53.6	37.2	39.7	9.8



Aimsun

- **Aimsun base model built**
  - Model calibrated to travel times
  - Model verified by throughput volumes

PM Peak Hour Vehicle Travel Times

EB to Amherst	id	Observed (s)	Simulated (s)	Diff	%Diff
Bedford Terrace					
Central Rock Gym sign	5950	722.00	726.84	4.84	1%
Maple Street	5951	322.50	321.12	-1.38	0%
South Pleasant St at College Street	5955	877.75	824.13	-53.62	-6%
		1922.25	1872.08	-50.17	-3%

PM Peak Hour B43 Bus Travel Times (by stop #)

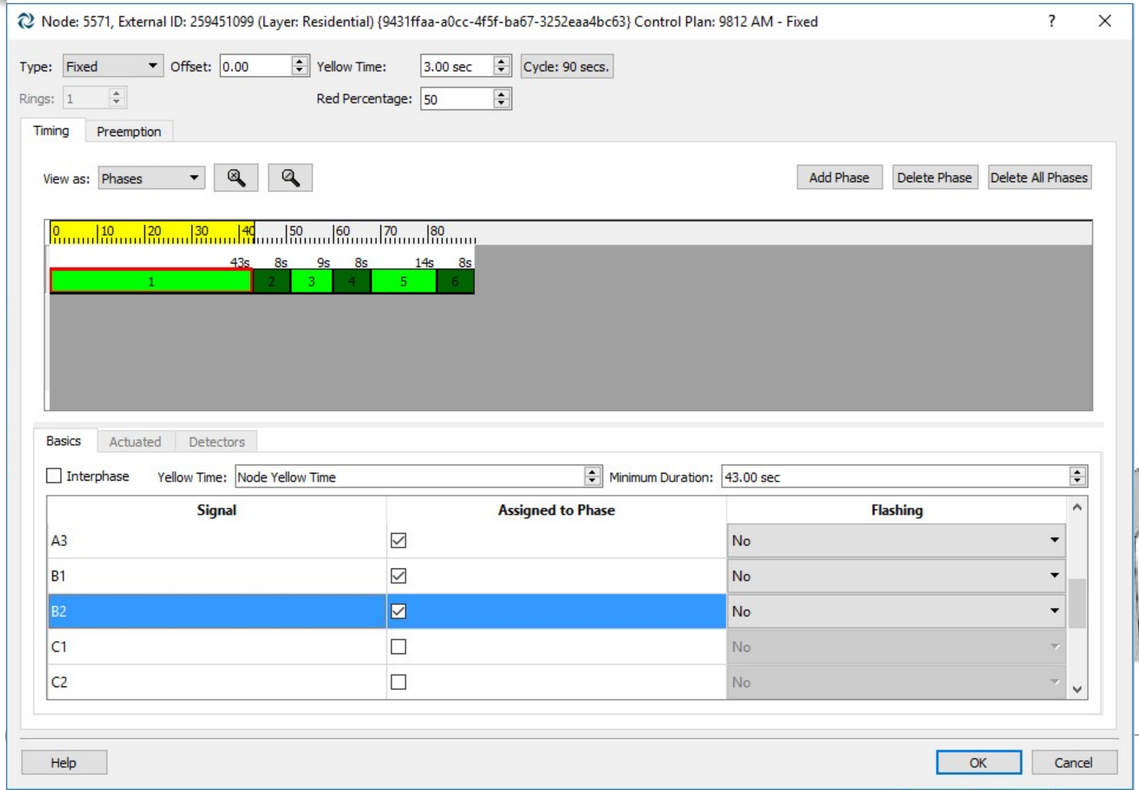
B43 Eastbound (Northampton --> Hadley --> Amherst)					
	id	Observed (s)	Simulated (s)	Diff	%Diff
#261 Academy of Music to #172 Middle Street	6434	749	819	70.23	9%
#172 Middle Street to #140 Hampshire Mall	2183	585	617	32.34	6%
#140 Hampshire Mall to #113 Amherst Common	6438	1246	1336	89.78	7%
		2580	2772	192.36	7%

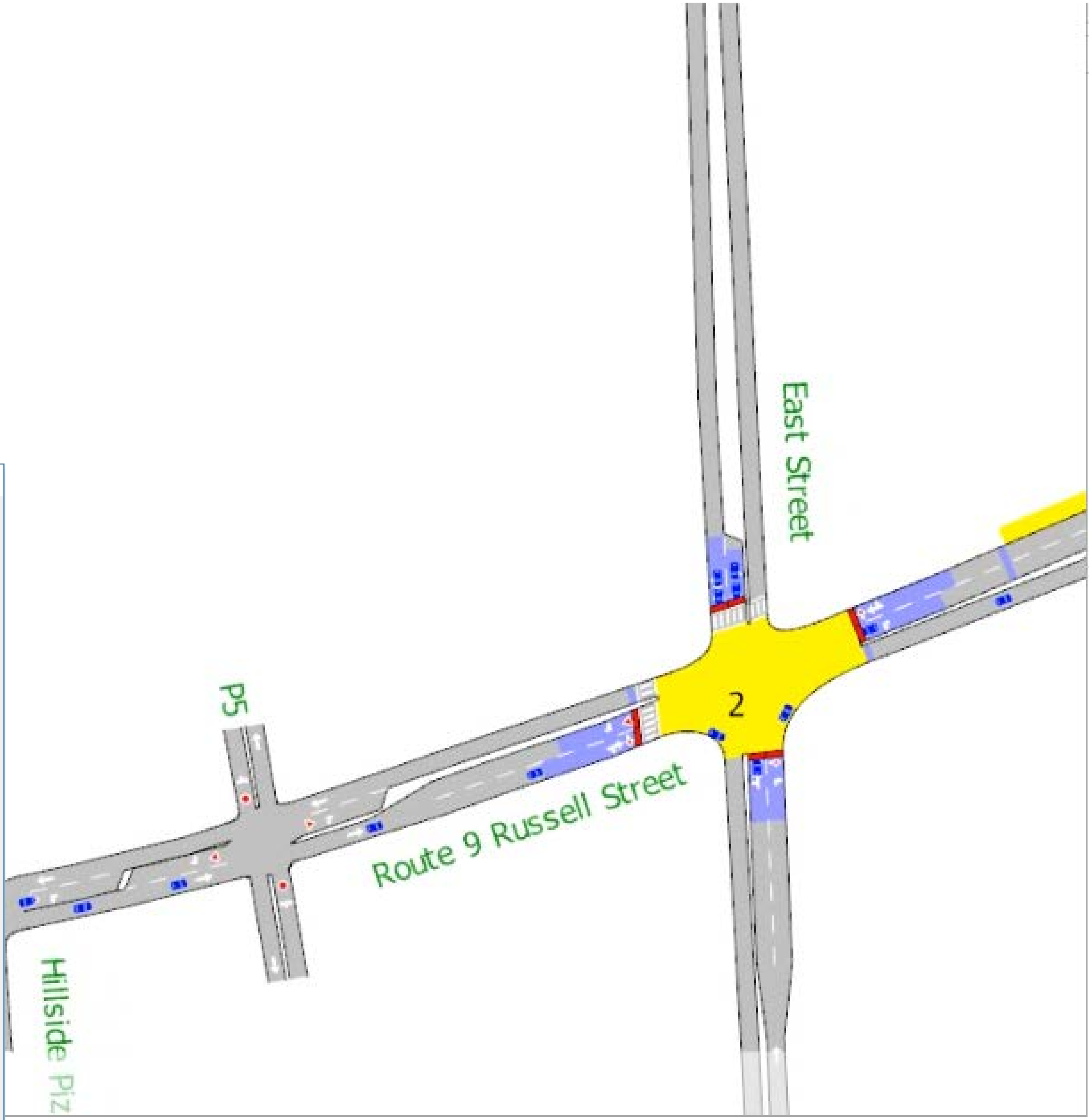
PM Peak Hour Vehicle Flow Comparison

Intersection	Approach	ID	Observed	Simulated	Diff	%Diff	GEH
Rt 9 at Lowe's & Hadley Garden	NB	615	23	23.2	0.2	1%	0.04
	WB	599	827	866	39	5%	1.34
	SB	592	53	54.8	1.8	3%	0.25
	EB	596	891	879.8	-11.2	-1%	0.38
Rt 9 at Home Depot & Mt Farms Mall	NB	636	330	338	8	2%	0.44
	WB	643	898	944.2	46.2	5%	1.52
	SB	639	225	226.8	1.8	1%	0.12
	EB	646	953	932.4	-20.6	-2%	0.67
Rt 9 at Maple Street	NB	650	504	514.8	10.8	2%	0.48
	WB	683	921	938.4	17.4	2%	0.57
	SB	686	542	548.8	6.8	1%	0.29
	EB	694	1096	1073	-23	-2%	0.70
Rt 9 at Cinemark Theater	NB	3065	242	240.4	-1.6	-1%	0.10
	WB	3067	1135	1150.8	15.8	1%	0.47
	EB	3073	1010	989.6	-20.4	-2%	0.65
Rt 9 at Westgate Center Road	NB	3080	166	164.8	-1.2	-1%	0.09
	WB	3102	1082	1047.8	-34.2	-3%	1.05
	SB	3089	456	424.2	-31.8	-7%	1.52
	EB	3096	1186	1182.2	-3.8	0%	0.11
Rt 9 at Greenleaves Drive & Campus Plaza Road	NB	3129	62	61.2	-0.8	-1%	0.10
	WB	3126	1004	976.8	-27.2	-3%	0.86
	SB	3132	306	304.4	-1.6	-1%	0.09
	EB	3123	1032	931.6	-100.4	-10%	3.20
Rt 9 at Snell Street	NB	3161	213	219.4	6.4	3%	0.44
	WB	3164	508	521.2	13.2	3%	0.58
	SB	3170	642	606.8	-35.2	-5%	1.41
	EB	3167	1038	986.8	-51.2	-5%	1.61
University Drive & Big Y & Extended Care	NB	3214	403	382	-21	-5%	1.06
	WB	3226	47	47.8	0.8	2%	0.12
	SB	3228	614	556	-58	-9%	2.40
	EB	3210	291	280.6	-10.4	-4%	0.62

Aimsun

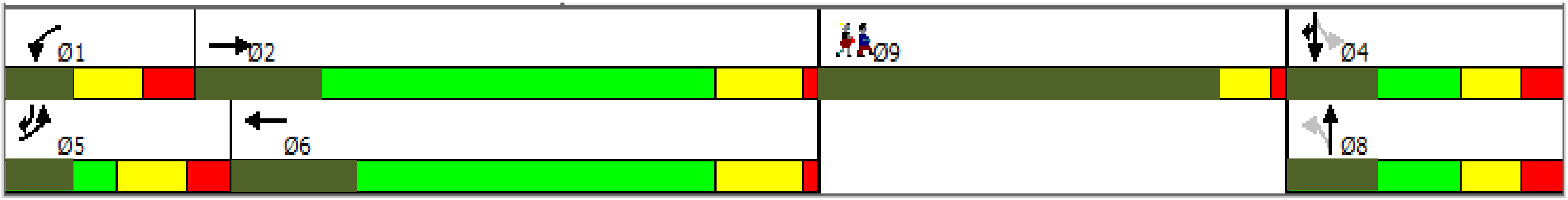
- **Aimsun alternative models built**
  - Optimized signal times were adjusted based on corridor performance, and TSP requirements and operations





Isolated Intersections

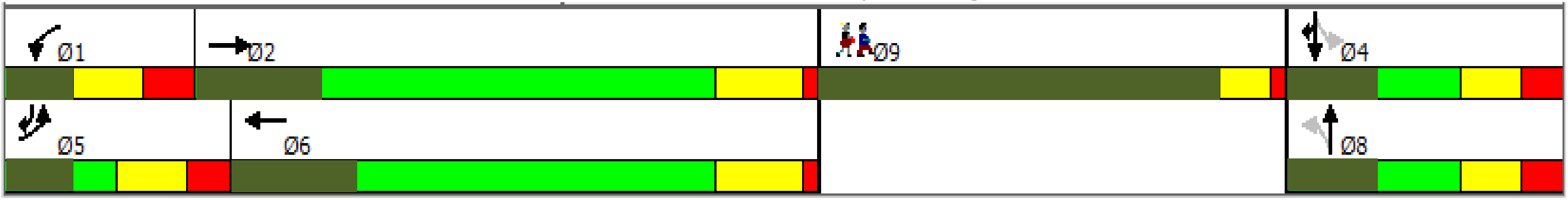
- Green extension can be as long as needed without significantly impacting intersection operations
- Early return can be as long as the “other” phases usable green time (max green time minus min green time)



Coordinated Intersections

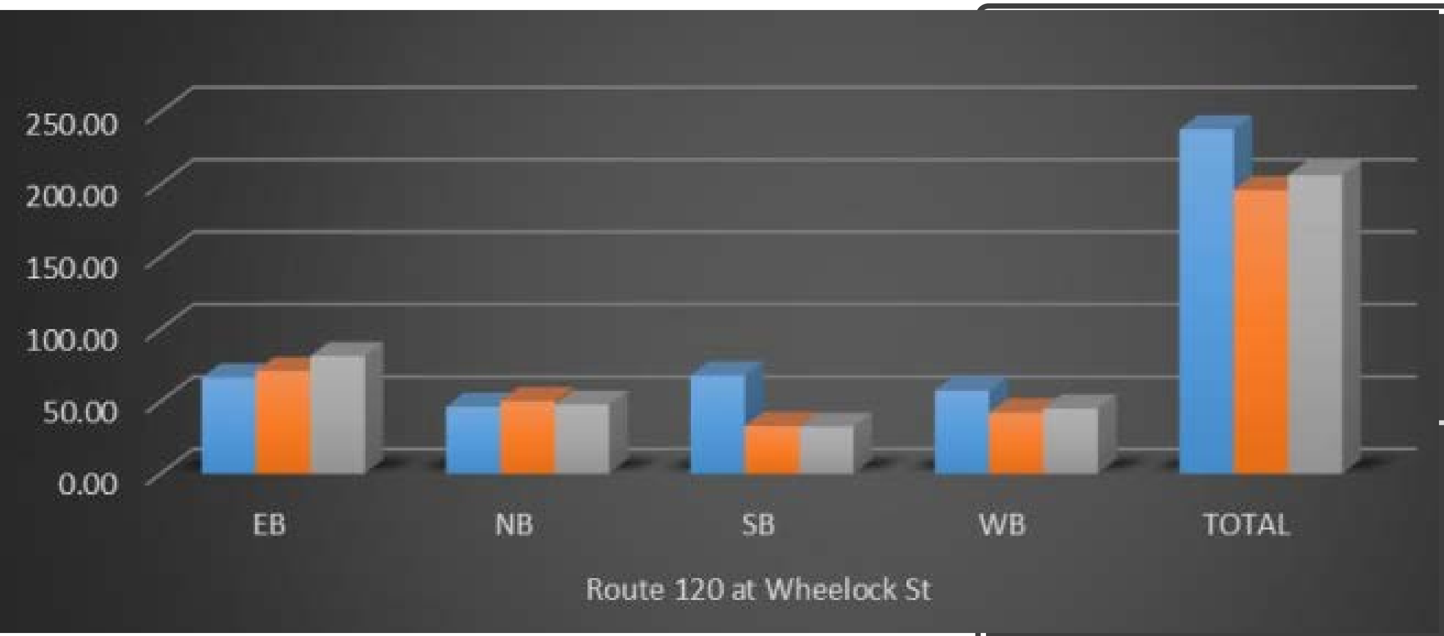
- At coordinated intersections, green extension is limited by the cycle length
- If more time is given to the mainline, it will need to be taken away from the other phases
- Green extension/early return are always used together, whether the bus arrives on the mainline green phase, or another phase (whether green extension is activated first, or early return is activated first)

120 second fixed cycle length

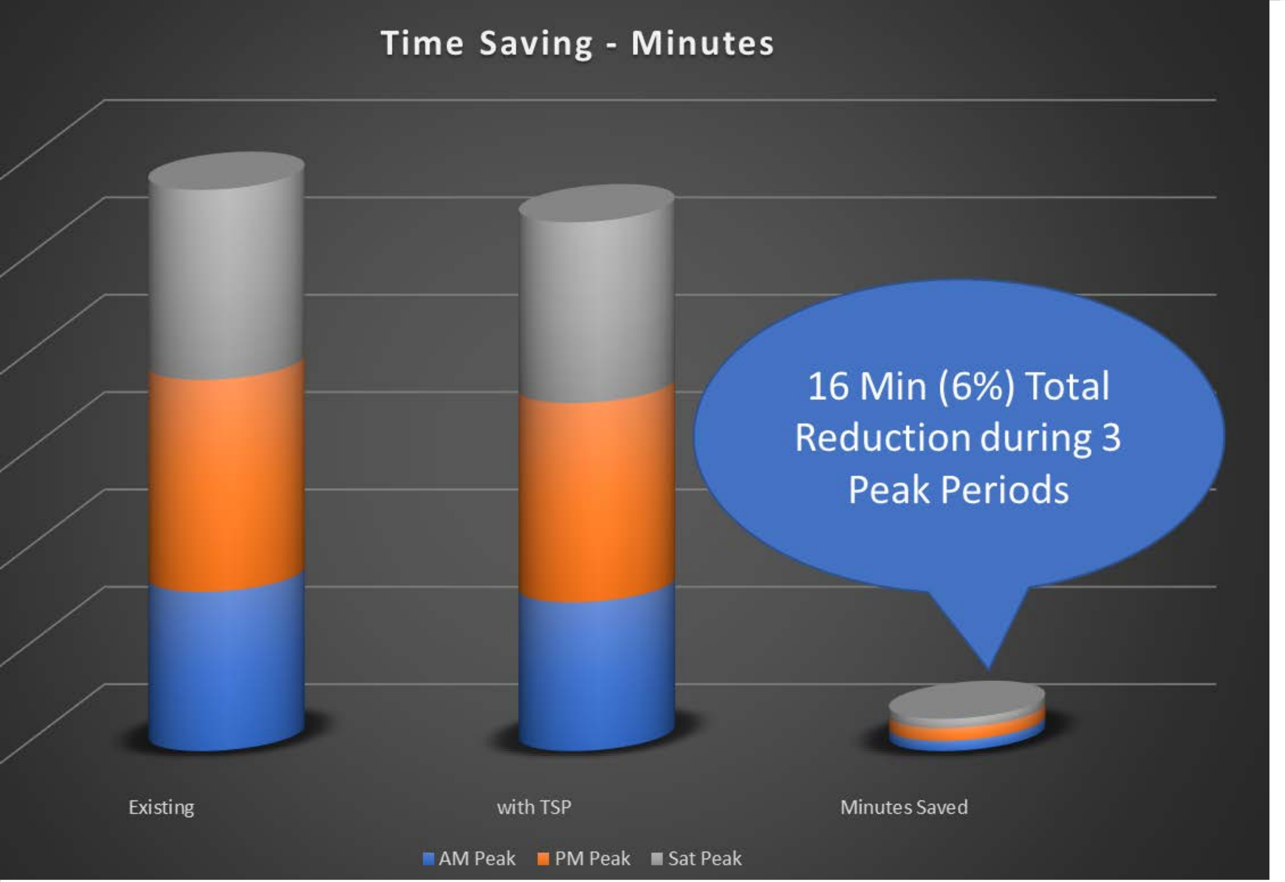


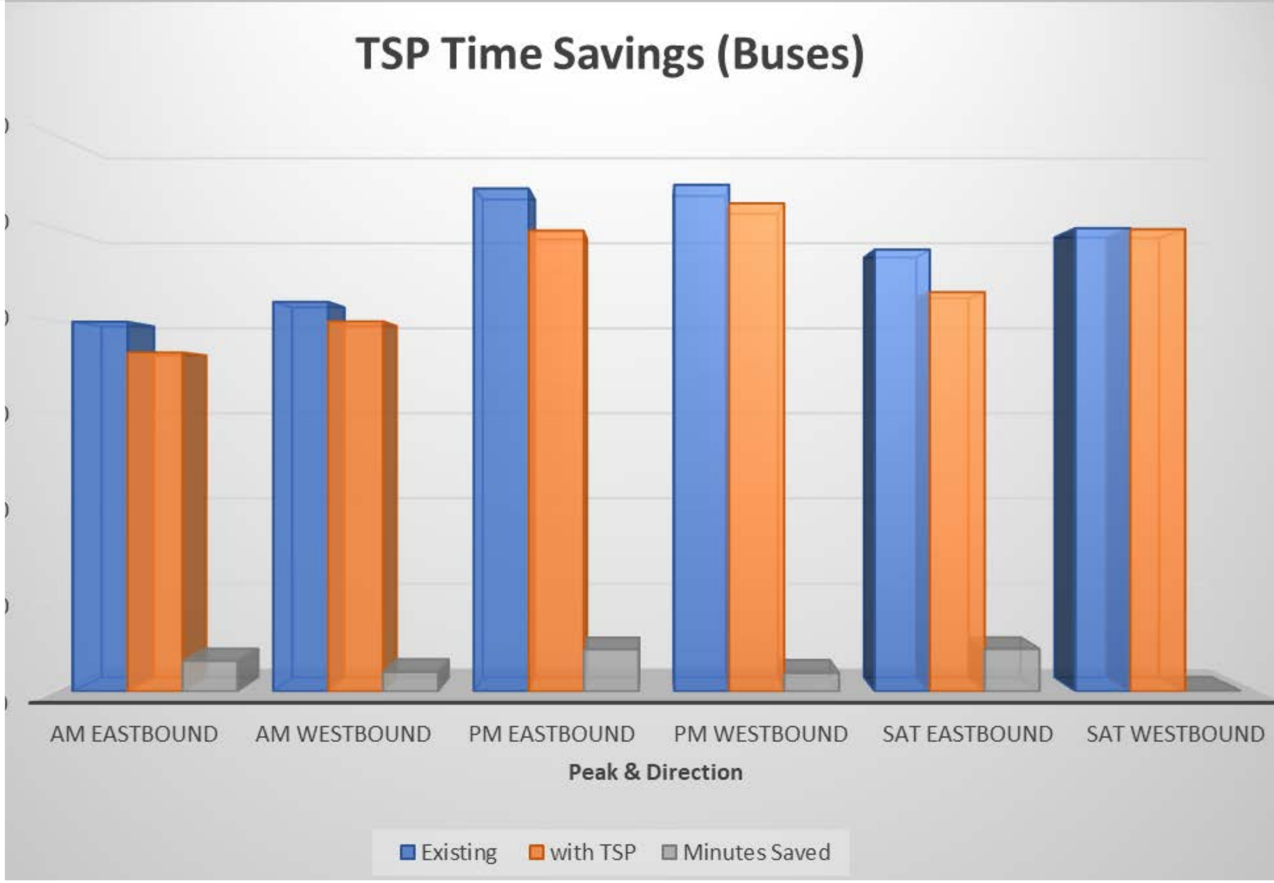
- **From this you can tell that short cycle lengths do not work as well for TSP since they limit how much time you have to shorten/lengthen green time**

Isolated – (V2I) PVTA B43 – TSP and Adaptive Signal Control



Intersection Delay





Travel Time Savings

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