U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Automated Traffic Signal Performance Measures

Transforming Traffic Signal Management

ITS Washington 2020 Annual Conference

December 9th, 2020

Eddie Curtis, FHWA Office of Operations and Resource Center

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Poll Question

Rate your familiarity with Automated Traffic Signal Performance Measures

- ❑ Today is the first time I've heard the term
- ❑ Introduced to the topic through meetings, conferences, presentations.
- ❑ My organization has explored Implementation
- ❑ ATSPM has been implemented in my organization
- ❑ I'm an active user of ATSPM

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Our Focus

- ❑ Background
- ❑ Data is Transforming Practice
- ❑ Resources to engage

What is High Resolution Data / ATSPM?

Source: Eddie Curtis, FHWA

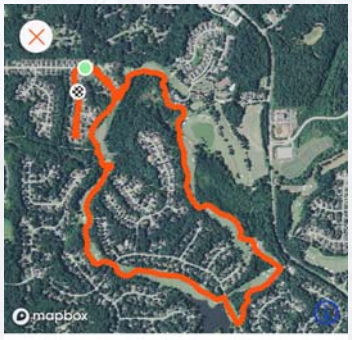
Source: https://en.wikipedia.org/wiki/Stopwatch

Source: https://diy.stackexchange.com/q

What is High Resolution Data / ATSPM?

Source: Eddie Curtis, FHWA

Source: https://mediaonderzoek.nl/7035/7035/

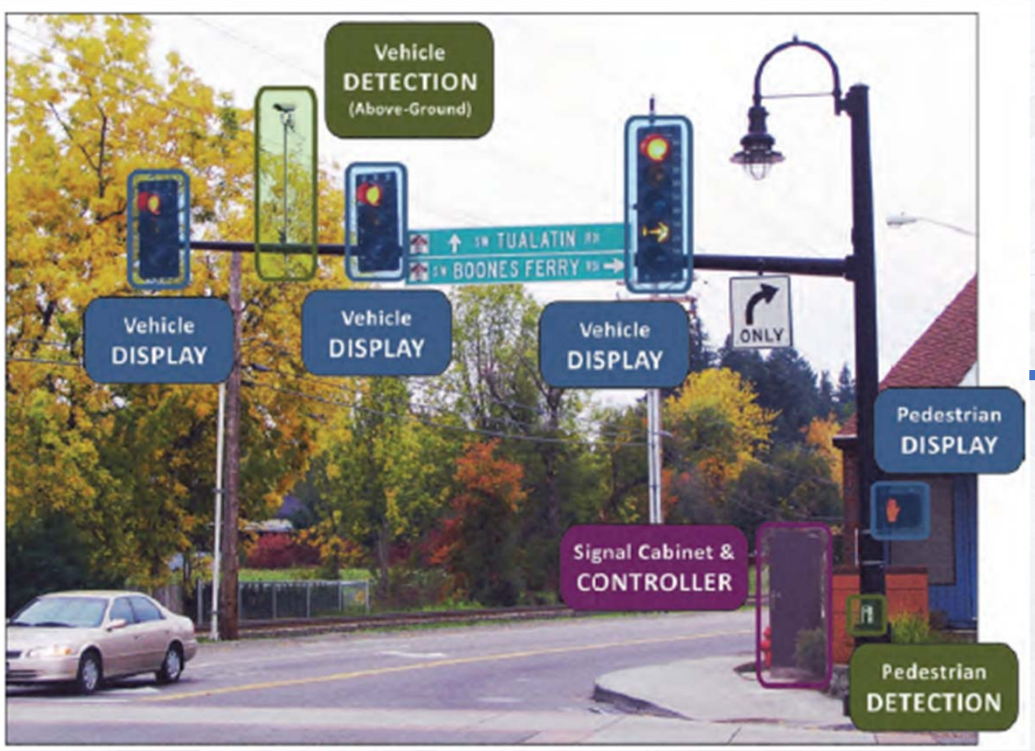


Source: Eddie Curtis, FHWA

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration RESOURCE CENTER

What is High Resolution Data / ATSPM?



Source: Signal Timing Manual Version 2

Source: Signal Timing Manual Version 2

High-Resolution Event Enumerations (Example)

Active Phase Events:

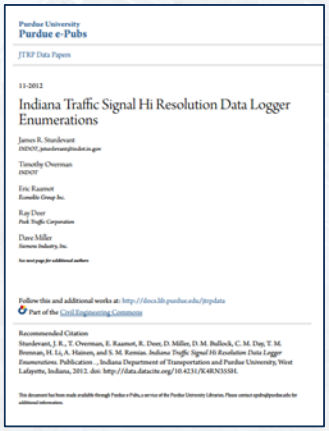
0	Phase On
1	Phase Begin Green
2	Phase Check
3	Phase Min Complete
4	Phase Gap Out
5	Phase Max Out
6	Phase Force Off
7	Phase Green Termination
8	Phase Begin Yellow Clearance
9	Phase End Yellow Clearance
10	Phase Begin Red Clearance
11	Phase End Red Clearance

Detector Events:

81	Detector Off
82	Detector On
83	Detector Restored
84	Detector Fault- Other
85	Detector Fault- Watchdog Fault
86	Detector Fault- Open Loop Fault

Preemption Events:

101	Preempt Advance Warning Input
102	Preempt (Call) Input On
103	Preempt Gate Down Input Received
104	Preempt (Call) Input Off
105	Preempt Entry Started


Purdue University
Purdue e-Pubs

JTRP Data Papers

11-2012

Indiana Traffic Signal Hi Resolution Data Logger Enumerations

James R. Sturdevant
INDOT, jsturdevant@indot.in.gov

Timothy Overman
INDOT

Eric Raamot
Econolite Group Inc.

Ray Dorr
Peek Traffic Corporation

Dave Miller
Siemens Industry, Inc.

See next page for additional authors

Follow this and additional works at: http://docs.lib.purdue.edu/jtrpdata

Part of the Civil Engineering Commons

Recommended Citation

Sturdevant, J. R., T. Overman, E. Raamot, R. Dorr, D. Miller, D. M. Bullock, C. M. Day, T. M. Brennan, H. Li, A. Hamen, and S. M. Remias. *Indiana Traffic Signal Hi Resolution Data Logger Enumerations*. Publication ... Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: http://dx.doi.org/10.4231/K4RN35SH.

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

http://docs.lib.purdue.edu/jtrpdata/3/

Source: Chris Day, Iowa State University

Example High-Resolution Data

Timestamp	Event Code	Event Parameter
6/27/2013 1:29:51.1	10	8
6/27/2013 1:29:51.1	82	5
6/27/2013 1:29:52.2	1	2
6/27/2013 1:29:52.2	1	6
6/27/2013 1:29:52.3	82	2
6/27/2013 1:29:52.8	82	4
6/27/2013 1:29:52.9	81	4
6/27/2013 1:29:53.3	81	6
6/27/2013 1:29:54.5	81	2
6/27/2013 1:30:02.2	8	2
6/27/2013 1:30:02.2	8	6
6/27/2013 1:30:02.2	33	2
6/27/2013 1:30:02.2	33	6
6/27/2013 1:30:02.2	32	2
6/27/2013 1:30:02.2	32	6
6/27/2013 1:30:06.1	10	2
6/27/2013 1:30:06.1	10	6
6/27/2013 1:30:08.1	1	8
6/27/2013 1:30:13.1	32	8
6/27/2013 1:30:15.8	81	5
6/27/2013 1:30:18.5	82	6
6/27/2013 1:30:27.5	81	6
6/27/2013 1:30:30.4	8	8

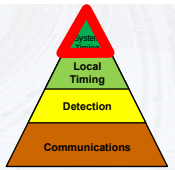
Detector 5 ON

Phase 8 GREEN

Detector 5 OFF

Phase 8 YELLOW

Source: Chris Day, Iowa State University



"Do I Have Most of my Vehicles Arriving on Green?" Coordination Diagram Concept

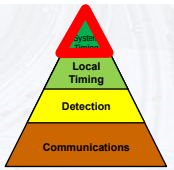
Source: Chris Day, Iowa State University

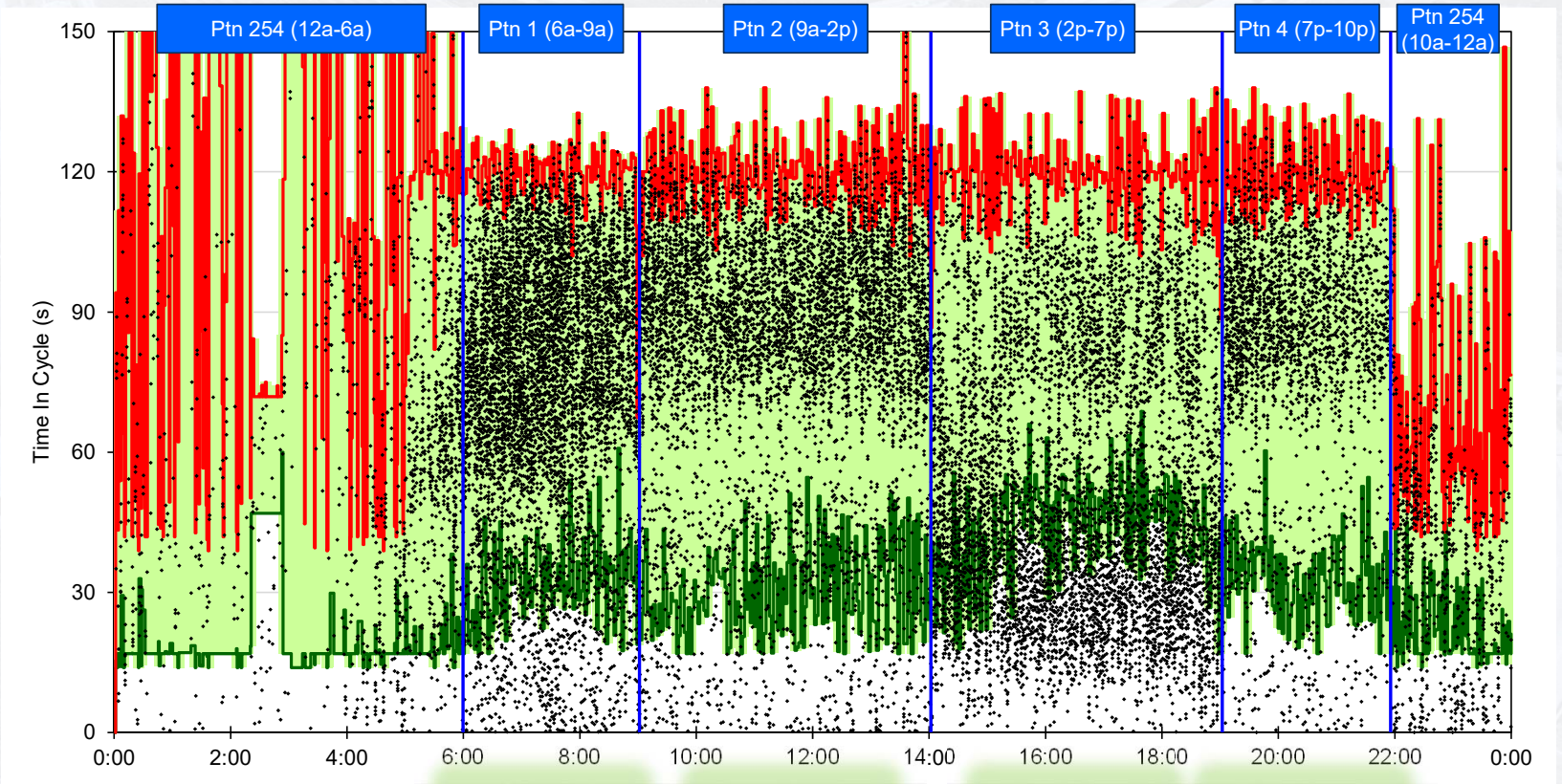
https://www.youtube.com/watch?v=YhrtTuhcjMw

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration RESOURCE CENTER

Coordination Diagram (24 Hours)





88.6% on Green

91.6% on Green

56.6% on Green

91.0% on Green

Day, C.M., D.M. Bullock, H. Li, S.M. Remias, A.M. Hainen, R.S. Freije, A.L. Stevens, J.R. Sturdevant, and T.M. Brennan *Performance Measures for Traffic Signal Systems: An Outcome-Oriented Approach*. West Lafayette, Indiana: Purdue University, 2014.

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

U.S. Department of Transportation
Federal Highway Administration

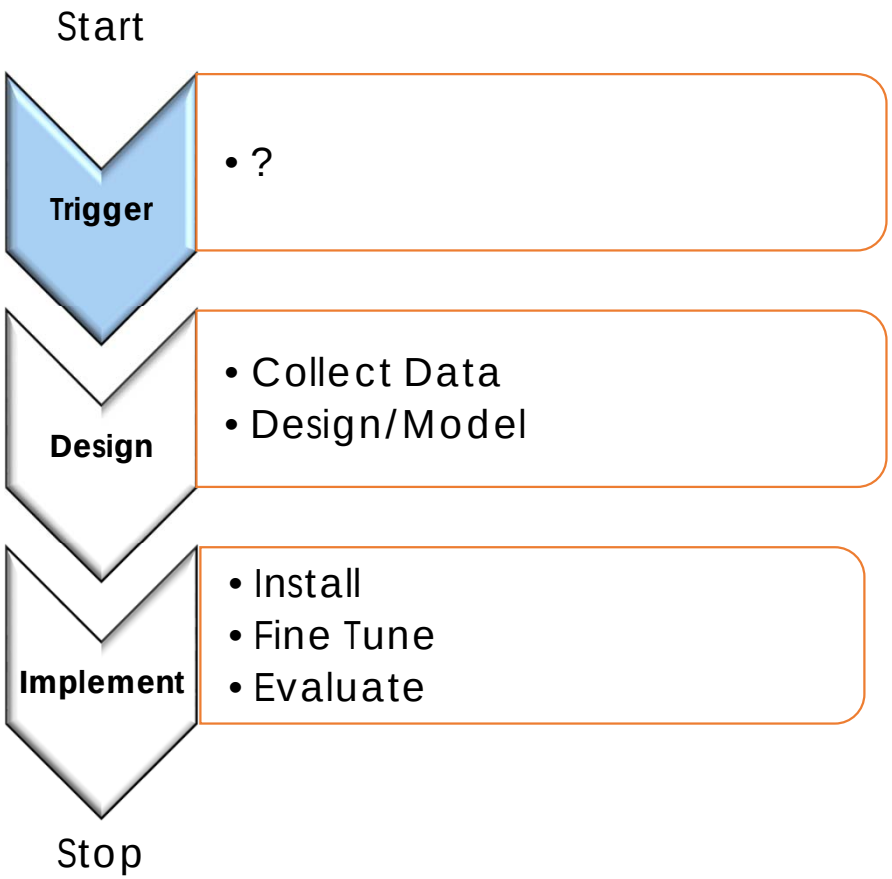
Federal Highway Administration
RESOURCE CENTER

Poll Question

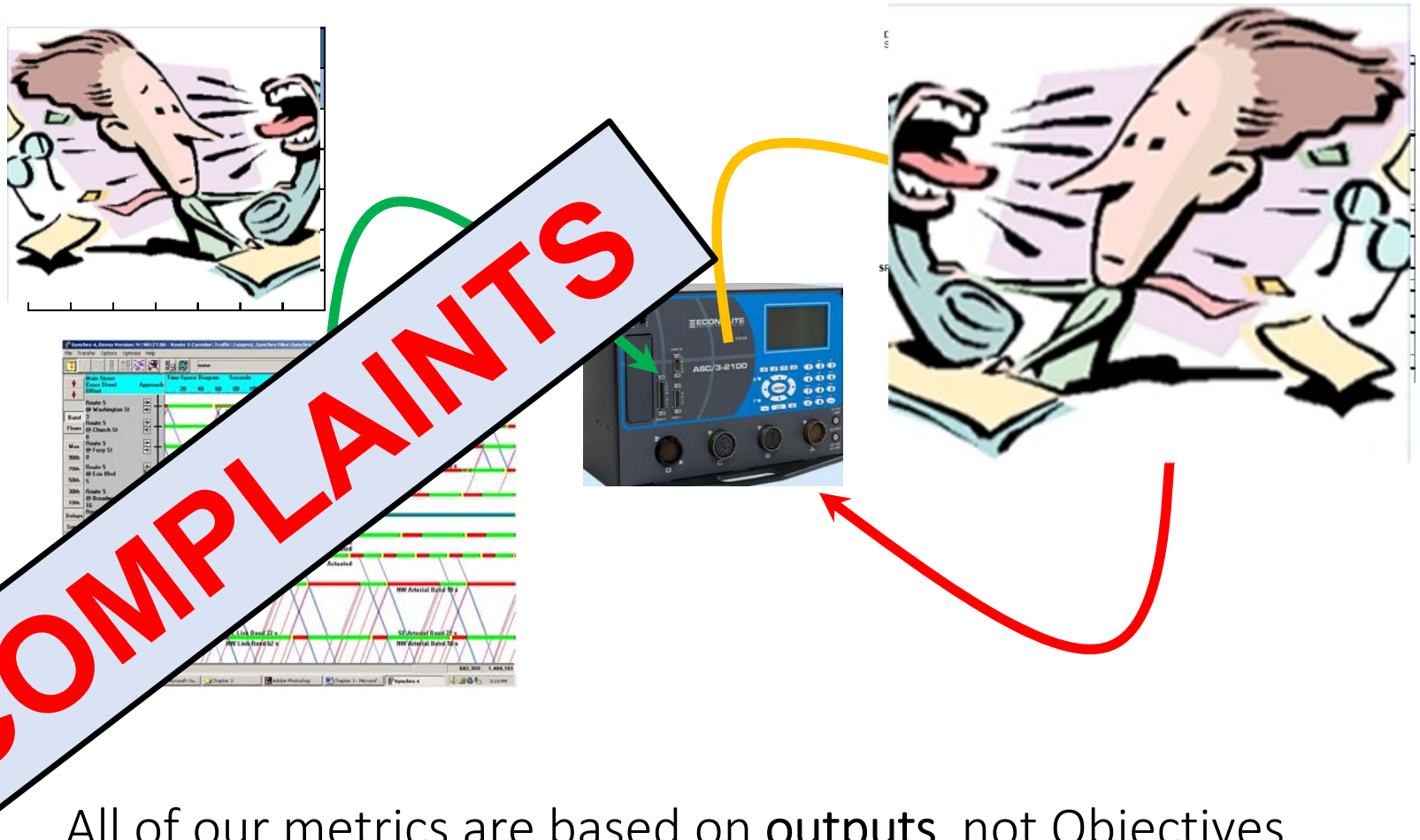
What's the most common trigger for traffic signal retiming

- ❑ Performance monitoring indicates retiming is necessary
- ❑ Annual or Other Scheduled Frequency
- ❑ Complaints
- ❑ Emissions have exceeded a Threshold

Traditional Practice



Traditional Traffic Signal “Operations”



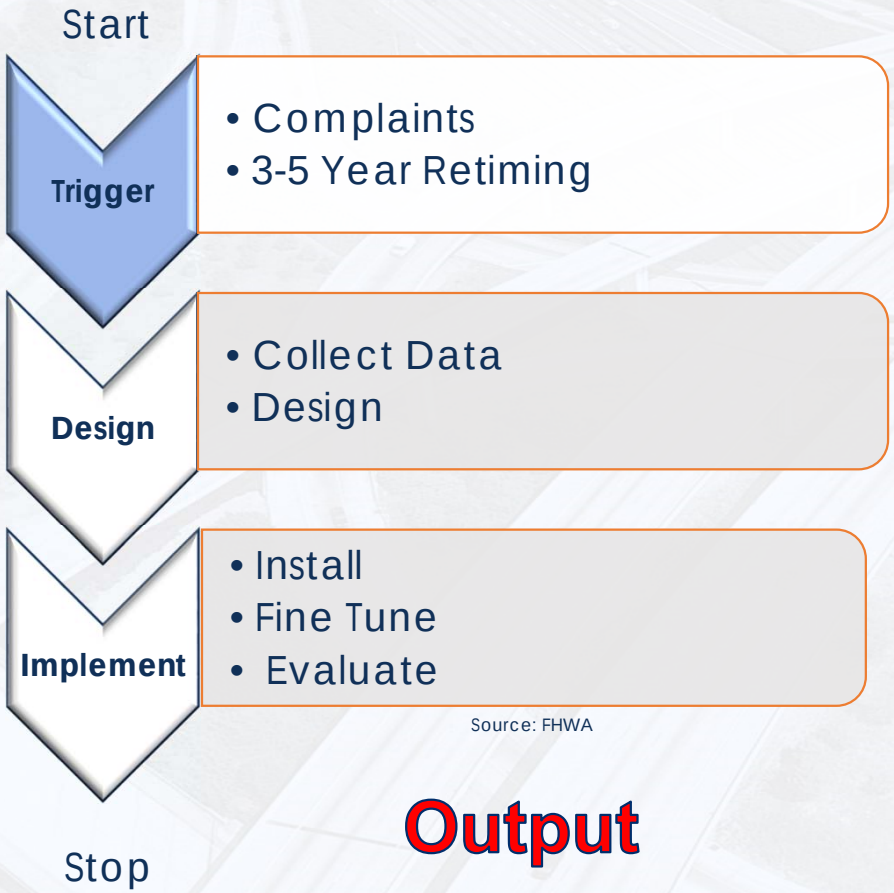
All of our metrics are based on **outputs** not Objectives

Source: INDOT

How is High Resolution Data transforming Traffic Signal Operations?

Source: http://www.dot.state.mn.us/rtmc/ - MnDOT Regional TMC

An Opportunity to Transform the Practice



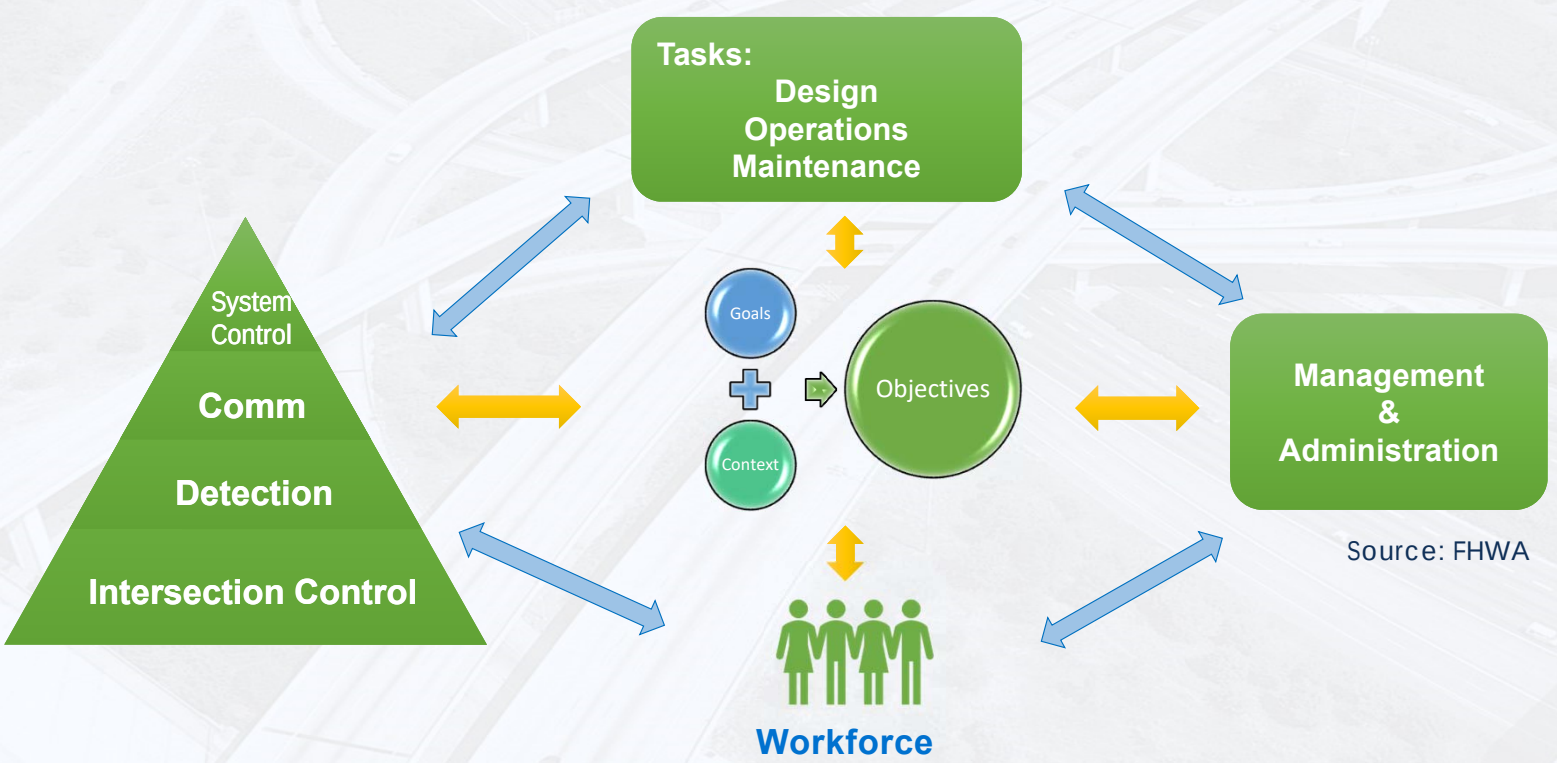
Source: FHWA

Output

Source: FHWA

Outcome

Goals, Context and Objectives can Drive all Areas of a Traffic Signal Program



Source: FHWA

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Goal	Context	Objective / Strategy	Performance Measure
Safety	**Network:** CBD, Urban, Suburban (Linear Arterial, Grid, Interchange)	• Safely Transfer Right of Way	• Yellow and Red Actuations • Arrivals on Red • Ped/Bike Delay
Mobility **Equity**	**User mix:** peds, bike, transit, vehicle, freight **Traffic demand:** Uncongested (Light, moderate, heavy)	• Equitable distribution of Green Time • Smooth flow, • Peds/bike Convenience/Comfort • Transit Efficiency	• Purdue Coord Diagram, • Arrivals on Green/Red • Split Failure, • ped/bicycle delay • vehicle delay • Queue length • Split Monitor • Progression Quality • Travel Time and Average Speed • Priority Details
	Traffic demand: congested	• Throughput • Queue management	• Vehicle Volumes • Queue length • Oversaturation Severity Index

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Poll Question

If the Goal is Equity, What Primary Objective(s) should be Pursued?

- ❑ Equitable distribution of Green Time
- ❑ Smooth flow
- ❑ Peds/bike Convenience/Comfort
- ❑ Transit Efficiency
- ❑ Queue management

Goal	Context	Objective / Strategy	Performance Measure
Safety	**Network:** CBD, Urban, Suburban (Linear Arterial, Grid, Interchange)	• Safely Transfer Right of Way	• Yellow and Red Actuations • Arrivals on Red • Ped/Bike Delay
Mobility **Equity**	**User mix:** peds, bike, transit, vehicle, freight **Traffic demand:** Uncongested (Light, moderate, heavy)	• Equitable distribution of Green Time • Smooth flow, • Peds/bike Convenience/Comfort • Transit Efficiency	• Purdue Coord Diagram, • Arrivals on Green/Red • Split Failure, • ped/bicycle delay • vehicle delay • Queue length • Split Monitor • Progression Quality • Travel Time and Average Speed • Priority Details
	Traffic demand: congested	• Throughput • Queue management	• Vehicle Volumes • Queue length • Oversaturation Severity Index

Goal	Context	Objective / Strategy	Performance Measure
Safety	**Network:** CBD, Urban, Suburban (Linear Arterial, Grid, Interchange)	• Safely Transfer Right of Way	• Yellow and Red Actuations • Arrivals on Red • Ped/Bike Delay
Mobility **Equity**	**User mix:** peds, bike, transit, vehicle, freight **Traffic demand:** Uncongested (Light, moderate, heavy)	• Equitable distribution of Green Time • Smooth flow, • Peds/bike Convenience/Comfort • Transit Efficiency	• Purdue Coord Diagram, • Arrivals on Green/Red • Split Failure, • ped/bicycle delay • vehicle delay • Queue length • Split Monitor • Progression Quality • Travel Time and Average Speed • Priority Details
	Traffic demand: congested	• Throughput • Queue management	• Vehicle Volumes • Queue length • Oversaturation Severity Index

Resources

- Implementation Guidance
- Lessons learned from early implementations
- Connecting objectives/goals to performance measures
- Identifying how to make the best use of SPM

EXHIBIT 2-2. OBJECTIVE-BASED CATEGORIES FOR SIGNAL PERFORMANCE MEASURES

CATEGORY	OBJECTIVE(S)
1 COMMUNICATION	• Maximize number of connected intersections
2 DETECTION	• Maximize number of functioning detectors
3 INTERSECTION / UNCOORDINATED TIMING	• Minimize delay for transportation system users (e.g., vehicles, bicycles, pedestrians) • Improve safety
4 SYSTEM / COORDINATED TIMING	• Improve progression
5 ADVANCED SYSTEMS AND APPLICATIONS	• Minimize delay for modes with preferential treatment (e.g., rail, emergency vehicles, transit, trucks) • Manage traffic variability

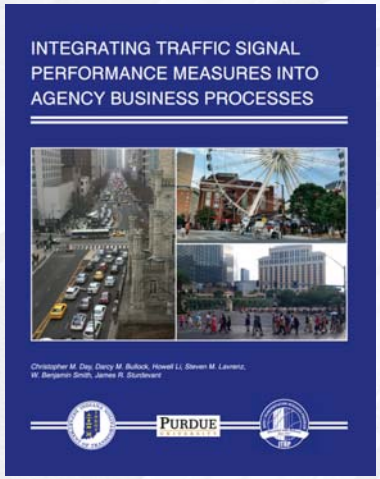
Source: Chris Day, Iowa State University

U.S. Department of Transportation
Federal Highway Administration

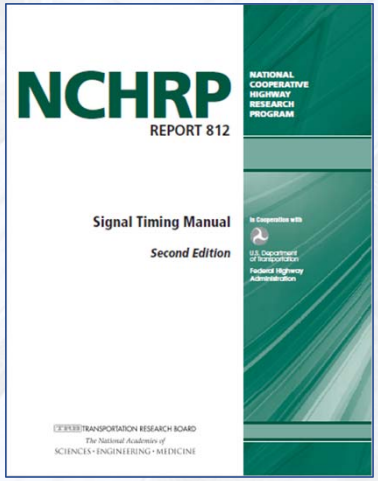
Federal Highway Administration
RESOURCE CENTER

Objectives Driven Traffic Signal Programs & ATSPM

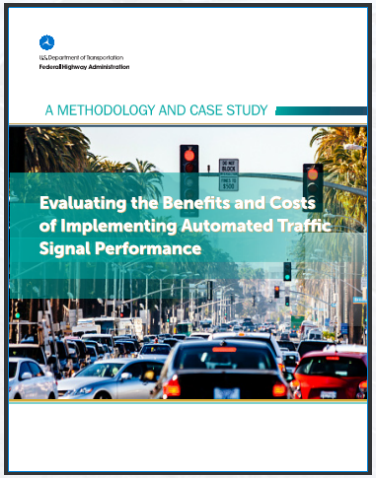
FHWA Arterial Management Website
https://ops.fhwa.dot.gov/arterial_mgmt/



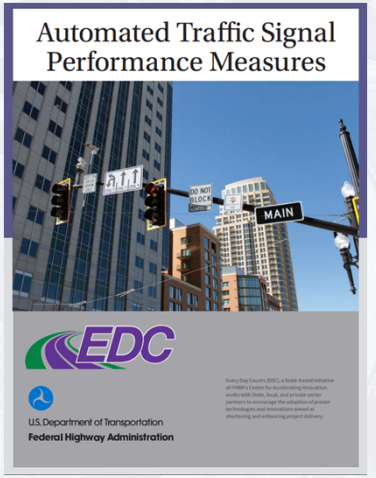
http://tinyurl.com/signalmoe



http://www.trb.org/Publications/Blurbs/173121.aspx



Source: FHWA



Source: FHWA

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

FHWA Training NHI #133122

OST MATRIX - UNCONGESTED

CONTEXT		OBJECTIVES	CONTEXT		STRATEGY	CONTEXT		TACTIC
Uncongested	Typical Conditions	Intersection - Equitable Distribution of Green To provide access equity, **the demand for all phases will be handled equitably** by serving all movements regularly and **not providing preferential treatment** to coordinated movements to the extent that delays and stops of other movements are significantly increased. To do this objective function is to balance delays. Strategies to prevent queue overflow on minor movements may be needed.	Isolated	Light flow	Minimize phase failures			Design passage time and max green to reduce phase failures
				Moderate flow	Reduce wait time			Design passage time and max green to reduce wait time
			In network	Moderate flow	Minimize delay			Webster's Method
								Highway Capacity Manual's Quick Estimation Method
								Critical Movement Analysis
				Mobility > Access	Maximize coordinated split	Some spare capacity at signal		Design minimum split for non-coordinated phases
		Network - Smooth Flow This objective seeks to **provide a green band along an arterial road, in one or both directions**, with the relationship between the intersections arranged so that **once a platoon starts moving it rarely slows or stops**. This may involve holding a platoon at one intersection until it can be released and not operating downstream stops. It may also involve **operating non-coordinated phases at a high degree of saturation** (by using the shortest possible green), with a **constraint of preventing or minimizing phase failures and overflow of turn bays** with limited length, and with **spare time in each cycle generally reverting to the coordinated phases.**	**Design Network Cycle Length**					
			Linear arterial	Predominantly one-way flow	One-way progression	Any intersection spacing		Consensus cycle length
				Two-way flow	Two-way progression	Even intersection spacing		Resonant cycle length
						Uneven intersection spacing	Sufficient left turn phases	Resonant cycle length using average spacing
							Few/no left turn phases	Consensus cycle length
			Grid	One-way streets	Four-way progression	Even intersection spacing		Quarter cycle
			Design Intersection Splits					
			Any network		Progression	Travel to the area more important than travel through the area		Use equitable distribution of green
						Travel through the area more important than travel to the area		Maximize coordinated splits
			Design Offsets					
			Linear arterial	Predominantly one-way flow	One-way progression	Minimal side street turning traffic		Design offsets for first car
						Moderate side street turning traffic		Design offsets for first car with queue clearance
				Two-way flow	Two-way progression	Equal/favorable intersection spacing		Resonant offsets
						Unequal/unfavorable intersection spacing	Sufficient left turn phases	Resonant offsets with lead/lag phasing
			Grid	One-way streets	Four-way progression	Even intersection spacing		Quarter cycle
			Design Phase Sequence					
			Arterials and grids	Signals without left turn phases	Progression			Use default phase sequence (no options)
				Signals with left turn phases	Two- and four-way progression	Excellent bandwidth		Use default phase sequence
						Poor bandwidth		Use lead/lag phasing to maximize bandwidth
	Special Condition	Intersection - Equitable Treatment by Mode	Isolated		*(not covered)*			
		Network - Programmed Stop	In Network		*(not covered)*			
		Many Other Objectives			*(not covered)*			

OST MATRIX - UNCONGESTED

CONTEXT		OBJECTIVES	CONTEXT		STRATEGY	CONTEXT	TACTIC
Congested	Typical Conditions	Intersection - Throughput This objective seeks to **provide a green split** that provides the **maximum throughput** at the stop bar **maintaining a high degree of saturation without causing unacceptable congestion** or delay on the non-coordinated movements. The **non-coordinated** phases would typically be **vehicle actuated** and operated at a **high degree of saturation** (by using the shortest possible green), within a constraint of preventing or minimizing phase failures and overflow of turn bays with limited length, and with spare time in each cycle generally reverting to the coordinated phases.	Inappropriate timing		Fix timing		As needed (meet OST)
			Failed equipment		Fix equipment		As needed (meet functionality)
			Problematic geometry	Storage bay self-block	Mitigate problematic geometry		Short bay method
				Storage bay blocking	Mitigate problematic geometry		Lead/Lag phasing
				Hot spillback and blocking	Mitigate problematic geometry		Phase reservice
			Excess demand		Minimize unused green	Try this first	Aggressive passage times
						Early phase terminations	Variable gap times (with aggressive minimum gap)
						Phase stays green too long	Cap the max greens
					Improve lane flow	Flows inconsistent with lanes	Change lane striping
						Uncoordinated network	Drop out of coordination
						Multilane approaches	Lane-by-lane detection
						Any/all	Think like HCM adjustment factors
		Network - Manage Queues Where there are closely spaced intersections, such as at a diamond interchange or within a tight grid network, and especially when a short block is fed by movements from various phases, **the primary objective is to ensure that queues do not block upstream intersections or movements** (such as occurs when a left turn bay spills over into adjacent lanes, or off turn queues exceed the intersection spacing at a tight diamond interchange). **This often requires constraints on cycle lengths and phase lengths to ensure that a large platoon does not enter a short block** if it must be stored within that block and wait for a subsequent green phase. **It may also involve "gating" a movement, so that a movement is stored at an intersection simply to hold it in a location that has sufficient queuing capacity**, even though other movements at the intersection may not require the green time. **Phase reservice** may also be an effective tool for management of queues, especially for minor movements where queue overflows can cause problems for major movements.	Operational issues from queue spillback	Two-way flow	Gating	Bottleneck intersection(s)	OSTs from Intersection – Throughput
						Upstream of the bottleneck	Cycle/Splits/Offsets for bottleneck queue relief
				Predominately one-way flow	One-way gating	Light Side/Midblock Turns	Last car
						Moderate Side/Midblock Turns	Simultaneous offsets
						Heavy Side/Midblock Turns	Negative offsets
			Safety issues from queue spillback		Prevent unsafe queues		Cycle/Splits/Offsets to serve priority movements
	Special Condition	Intersection - Preferential Distribution of Green			*(not covered)*		
		Network - Priority to Arterial			*(not covered)*		
		Many Other Objectives			*(not covered)*		

U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Recap

- ✓ Background
- ✓ Transforming Practice
- ✓ Resources to engage

Questions?

Eddie Curtis, FHWA
Eddie.Curtis@dot.gov

Source: FHWA